Guidelines for Developing Climate Resilient Buildings

Building Regulators Edition

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Acronyms and Abbreviations

GHG	greenhouse gas
AHJ	Authorities Having Jurisdiction
ICC	Internation Code Council
IPCC	Intergovernmental Panel on Climate Change
FCL	Flood Construction Levels
ISO	International Standards Organization
EU	European Standards
CO2	carbon dioxide
DACCS	direct air carbon dioxide capture and storage
wbLCA	whole-building life cycle assessment
EPDs	Environmental Product Declarations
DALYs	Disability Adjusted Life Years
GWLs	Global Warming Levels
CMIP	Coupled Model Intercomparison Project
RCPs	Representative Concentration Pathways
SSP	Share Socioeconomic Pathways
NBCC	National Building Code of Canada
CWEEDS	Canadian Weather Energy and Engineering Datasets
CWEC	Canadian Weather Year for Energy Calculation
HygDbM	Hygrothermal database of building materials
DVE	Design Value Explorer
TMY	Typical Meteorological Year
AMY	Actual Meteorological Year
EPW	EnergyPlus Weather

Executive Summary & Project Background

The climate is changing and will continue to change until all anthropogenic greenhouse gas emissions balance out to zero and a new planetary climatic equilibrium is reached. This requires a concerted effort to drastically reduce greenhouse gas (GHG) emissions but also necessitates adaptation to the impacts of a changing climate. This document is designed to equip building regulators with the approaches and language to help ensure buildings are adapted to the current and future impacts created by climate change.

The impacts of climate change affect nearly all aspects of human life. Already, climate impacts are causing significant levels of loss and disruption for communities and cities in all regions of Canada. Tremendous levels of adaptation will be required to update our built infrastructure to withstand these new and ever-changing climatic loads. With limited time and financial resources, only joint efforts of adaptation and greenhouse gas (GHG) mitigation, defined herein as climate resilience[1], can create the necessary change to tolerate the effects of climate change. Across Canada, there is already a solid foundation of known solutions. However, the larger obstacle is willingness to accept that changes are necessary and urgent, and that investments in climate resilience are needed. These new requirements challenge traditional decision-making processes and add complexity to building design and management due to the added layer of future uncertainty. This document aims to assist in these matters.

This document is divided into four parts. The first part relates to the need for better language and communication on climate resilience. It introduces definitions and terms, including explanatory text and clarifying examples. This section proposes a definition for a climate resilient building and includes definitions of adaptation, GHG mitigation, trade-offs, and maladaptation. It also provides a framework to understand the different types of climate resilience treatments, such as dynamic and static measures.

The second part relates to the ways that climate change is impacting buildings. An introduction to climate resilience concepts and risk-frameworks is provided in this section. This includes discussions of different approaches to managing risk, and that risk, in the context of infrastructure, can be viewed as a function of exposure and vulnerability. This

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[1] Resilience is commonly associated with and even used interchangeably with the term adaptation. Its origins derive from disaster risk management practices and refers to the ability to recover after extreme events. However, the impacts of climate change affect more than just extreme events and requires broader considerations. The definition of climate resilience as used in this document is conceptually aligned with IPCC (2021) definition of *Climate Resilient Development*: "the process of implementing greenhouse gas mitigation and adaptation measures to support sustainable development". See Section 3.1– Climate Resilient Building.

section also familiarizes the reader with the two main approaches of describing future climates and focuses on how the Global Warming Level represents the latest approach that overcomes some of the limitations of the existing paradigm.

The third part is divided into two sections. The first is relevant to regulators who are also building owners in need of procuring new climate resilient buildings or undertaking deep-climate resilient retrofits on existing buildings. The second section relates to the roles that regulators can play in fostering a building industry that recognizes and accepts the needs for urgent action, including developing a Stretch Code type approach to climate resilience.

Finally, Part 4 provides a curated list of relevant resources for building owners and regulators. It contains lists of current standards and guidelines that have applicability to climate resilient buildings, as well as links to datasets and sources containing adjusted climate variables.

1. Introduction

Buildings are a critical lever for climate resilience because of their potential to reduce greenhouse gas (GHG) emissions and adapt to withstand climate related hazards and extreme weather. This dual role places buildings at the center of climate policy and underscores the importance of enabling the development of climate resilient buildings.

Building regulators in particular play a pivotal role in transforming the building sector as they are responsible for overseeing and ensuring the quality of the building. As organizations with authority require or regulate performance-based criteria, an awareness of necessary climate resilience-related measures and obligations can support planning and decision-making. Many regulators are also building owners who own assets that have exposure to climate change. This report aims to provide the regulator with both direct and indirect information to better actualize climate resilience efforts.

This document is prepared to equip b*uilding regulators*, those organizations that provide regulatory oversight in the building sector, with the language and concepts to assist the building sector in adopting climate resilient practices.

1.1 Audience

This document is intended for building regulators. Building regulators are considered as all those organizations and entities that have roles and responsibilities in the regulation of building professions and the development and/or enforcement of building relevant acts, regulations, statutes, and by-laws. Building regulators may also be building owners, and so this document contains relevant information for the enhancement of owned building assets. Classes of building regulators may include:

- Research organizations that provide input into building codes and standards
- Local authorities (cities, towns, municipalities) and their officers (building officials)
- Governmental departments with mandates involving buildings
- Public Sector Organizations that enforce building related acts

This represents a broad audience, and so the contents of this guideline are provided at a conceptual level. Unique contexts and specifics are left to the better judgments of the regulators, who possess the knowledge to best evaluate the merit of the content of this guide as it best applies to the delivery of their duties.

1.2 Purpose

Climate resilient buildings require a slight modification to the status quo. This guide is designed to increase awareness of these adjustments when dealing with the uncertainties posed by climate change. This guide is organized in four parts:

- Part 1: Language of Climate Resilience
    - Necessary language (e.g. definitions) to effectively communicate the objectives and urgency for climate resilient buildings
- Part 2: Understanding Climate Impacts
    - How buildings experience climate change
    - Necessary concepts for risk-informed decision making
- Part 3.1: Resilience in Action
    - Strategies and approaches to enhance climate resilience on new and existing buildings.
- Part 3.2: A Clear Path
    - Importance of regulatory pressures to create change within the building industry
    - Roles that engineers and other building professionals may play in assisting with delivery of climate resilient buildings.
- Part 4. Resources:
    - New codes, standards, guides, and tools that may be beneficial to advance climate resilient buildings

The field of climate resilience is rapidly evolving. The focus of this document is on foundational principles instead of prescriptive approaches to better enable the reader to understand the concepts, find the best solutions to their unique challenges, and to better tolerate iterations and changes in the domain of climate resilience practices.

1.3 Scope

Buildings have long service lives with many internal renewal cycles. When factoring climate change, changes in the neighbouring built environment, and changes in owners or occupants and their needs, specific contexts always have precedence over generalized recommendations. Both geographical and temporal aspects can have a significant impact on climate resilient building delivery. This highlights the necessity of climate hazard exposure assessments.

The approaches towards delivery of climate resilient buildings must also recognize the different opportunities or challenges that exist for new and existing buildings. New buildings benefit from the ability to design for future climate and environmental loads at the earliest stages and can reference or follow new and emerging climate-updated codes and standards. Existing buildings, by comparison, have the major limitation of not being subject to advancing building codes and may fall outside the purview of Authorities Having Jurisdiction (AHJ).

This guide aims to discuss the influence of time and geography on the impacts of climate resilient buildings for both new and existing buildings. This guide also aims to emphasize the critical role that regulators can play in providing clear market signals and pressures to show the urgency for climate resilient buildings. Failure to provide these regulatory pressures will result in a failure of Justice, Equity, Diversity, and Inclusivity, as equity-denied populations are subject to the greatest vulnerabilities because of climate change.

2. Climate Crisis

The climate is warming and global temperatures will continue to rise until all anthropogenic greenhouse gas emissions balance out to zero. This is known as 'Net-Zero Carbon', and based on current policies and actions, humanity will not meet this objective by 2050 to avoid the worst outcomes of climate change. In addition to redoubling efforts to mitigate GHG emissions, it is also essential that we adapt our new and existing built infrastructure to withstand climate-driven hazards and extreme weather events.

A hotter atmosphere and hydrosphere hold greater amounts of energy. This energy can result in increasingly extreme and variable weather. It can also create new climate hazards that have never occurred previously (e.g. continental levels of wildfire smoke, extreme heat domes in oceanic moderated climates, etc.). These hazards can have both catastrophic direct and indirect effects to the public, the environment, and the economy. Critically, these hazards are not far-off threats but are already here. Efforts to manage these threats are mainly retroactive as preparation for future events that have yet to occur are difficult to justify in current economic decision-making paradigms. This requires extra diligence and courage.

Buildings play a central role in the climate crisis. They are responsible for 13%[2] of Canadian GHG emissions. When considering the impacts of building location on transportation related emissions, the total emissions effects of buildings may be as high as

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[2] https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/climate-plan-overview/healthy-environment-healthy-economy/annex-homes-buildings.html

18% of total Canadian GHG emissions[3]. Buildings can also be a source of refuge from extreme climates and weather. As a result, buildings play a pivotal role in fostering climate resilience.

With the monumental efforts needed to completely decarbonize the economy and the unparalleled levels of retrofits needed to adapt our buildings, it is an understatement to say that urgent action is needed.

The Global Resiliency Dialog states Urgency is the first priority, *the need to respond to the associated impacts of climate change and extreme weather events on buildings and building occupants is more urgent than ever.*
(ICC 2022)

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[3] From ECCC: For 2023: Total Canada GHG emissions: 694 Mt; Passenger Cars in 26.1Mt; Other Passenger, 12.5Mt, Buildings: 82.7 Mt.

Part 1: The Language of Climate Change

Climate change communication has embedded within it the language of probability. Consequently, the actions taken to manage the impacts and risks associated with climate change borrow from the language of probabilities, including terms such as uncertainty, likelihood, and risk. When communicating climate change and risk, it is beneficial to have a common language to avoid misunderstandings and ambiguities. This is perhaps even more pertinent in the rapidly developing field of climate science, climate risk assessment, and climate resilience.

This part of the guide proposes a glossary of terms and context around their use to help foster clarity in communication for climate resilient buildings.

3. The Language of Climate Resilience

Approaches to assessing and designing for climate resilience draw from multiple disciplines, each with their own definitions and technical language. This is overlaid on the existing cultures and languages already in use within the building sector and may create contradictions and misunderstandings. To better understand one another, a common language of climate resilience is needed to avoid misunderstandings and ambiguities. This section proposes several key terms and concepts that are directly relevant to climate resilience for the building sector. Each term was developed following intentions and wording of authoritative source material but supplemented to address multi-disciplinary concepts. The terms also include discussions on the implications, with respect to buildings, as well as interactions and synergies with other terms.

3.1 Climate Resilient Building

What is a climate resilient building? The definition presented here draws on definitions used by the International Code Council (ICC) Global Resilience Dialogue, and the Intergovernmental Panel on Climate Change (IPCC).

This definition presented here seeks to address several critical elements relevant to the building sector. Namely, the need to:

- Recognize that the climate has already changed
- Limit climate hazards to those that can be reasonably expected
- Acknowledge that climatic hazards can have important impacts beyond their direct loads
- Define the period over which adequate performance is required

- Include concepts of static and dynamic resilience
- Avoid maladaptation and negative trade-offs
- Highlight the criticality in mitigating greenhouse gas emissions through life-cycle considerations (embodied and operating carbon)

The definition presented (box below) captures the correlated challenges of greenhouse gas emissions reductions and management of risks associated with climate impacts and is framed contextually for the building sector.

Definition of a **Climate Resilient Building**:
"A building that is adapted to withstand all current and expected future climatic conditions and their effects over the whole service life of the building by minimizing the loss of functionality and enabling timely and efficient recovery of any damages to preserve the intended level of performance while mitigating life-cycle greenhouse gas emissions."

At its simplest, climate resilient buildings must **adapt** to, and **mitigate,** climate change. A building that does neither therefore does not meet this definition of a **climate resilient building**.

For building practitioners, advancing climate-resilient buildings requires deliberate planning and careful consideration, as poorly conceived designs or decisions can lead to unintended and undesirable outcomes. The two undesirable outcomes that we must avoid are maladaptation and trade-offs (see definitions). Within the building sector, consideration of unintended consequences – often brought to light through engagement with a range of experts and equity-deserving groups – can ensure the resilience measures maximize benefits for occupants and the public.

Maladaptation:
Actions that may lead to increased risk of adverse climate-related outcomes, including via increased GHG emissions, increased vulnerability to climate change, or diminished welfare, now or in the future. Maladaptation is usually an unintended consequence.
e.g. 1: A storm water retention pond that overflows and diverts water into a neighbouring building.
e.g. 2: Increased air conditioning use, resulting in increased GHG emissions, without demand reduction efforts.
e.g. 3: The levee effect, whereby the presence of flood protection encourages expansion of flooding into other vulnerable areas.

Trade-off:
A competition between different objectives within a decision situation, where pursuing one objective will diminish achievement of other objective(s). This tension can also be expressed as delivery of resilience measures in one area may compromise the ability to deliver climate resilience measures in another.

e.g. 1: Seismic upgrade requirements with concurrent climate adaptation requirements without a commensurate increase in resources
e.g. 2: A climate resilient office building that sends workers back to their non-climate resilient homes during a disaster. The climate resilient retrofit may assist in protecting the asset but exposes the occupants to harm.

3.2 Adaptation

Adaptation is an element of climate resilient buildings. It is necessary to ensure our buildings and infrastructure can withstand the direct and indirect effects of climate change. Buildings that are not adapted can create economic burdens to the owners, as cumulative damages, extreme events, and potential loss of insurance erode a building's viability. Buildings not adapted can also lead to health burdens for occupants.

Adaptation: "The process of adjustment to actual or expected climate and its effects." [4]

Adaptation measures are a response to the different types of **climate hazards** and their effects.

There are three approaches to adaptation relevant for buildings: **Hardening**, **Robustification**, and **Enhanced Durability (**shown conceptually in Figure 1). Each respond to different frequencies and severities of impacts on buildings and are discussed below. They must also be considered in an appropriate context; the intent of adaptation in buildings is to maintain acceptable levels of reliability.

3.2.1 Hardening

Hardening is an adaptation approach that addresses infrequent but high impact events.[5] These include hazards such as tornadoes and microbursts, flooding, hail, and wildfire.

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[4] IPCC AR6 (2023)

[5] Hardening as described here refers to actions taken with respect to the building. However, in the context of flood risks and watersheds, 'hardening' might infer construction of built infrastructure or paved surfaces that can exacerbate flood risk. Management of flood risks often entails renaturalizing shores or increasing permeability and water absorption at the site level. Take care not to conflate these uses of 'hardening'.

Hardening measures are difficult to quantify in terms of risk and financial costs as their low probability of occurrence makes it difficult to properly describe the magnitude of impacts or, more critically, the possibility of occurrence during the building's lifespan. However, *if* such an event were to occur and the hardening measures cost a fraction of the total cost to replace the building, the results of most cost benefit analysis yield trivial results (e.g. the cost to adapt is overwhelmed by orders of magnitude by the avoided costs to significantly repair or rebuild the building).

Hardening measures are also used to deal with **black swan events**. These are *unknown*, low probability events that have significant impacts. Because they are unknown, the type and magnitude of the effects are impossible to predict. From a static resilience perspective, black swan events can only be managed through design that minimizes negative consequences should some failure be initiated. This is referred to as **fragility avoidance**. Some strategies include design for ductile failure modes or redundancies, compartmentalization to avoid cascading failures, or simplified system designs with few dependencies. Black swan events must also be managed through dynamic resilience measures. Dynamic resilience measures, discussed below, possess a greater capacity to adapt to the unknown nature of black swan events. Both static and dynamic resilience measures have crucial roles to play in managing black swan events

Examples of hardening include wildfire fuel management and building hardening against firebrands, adoption of CSA S520 for extreme wind events, or CSA Z800 for flood risks.

3.2.2 Robustification

Robustification is an adaptation measure that shifts the designed threshold for failure; the intent is to adjust the inflection point on the probability-consequence curve. It is a response to known changes in known environmental loads, or imminently recognizable hazards, typically those used for design (e.g. Table C-2 of the National Building Code of Canada). The intent is to ensure the built system can withstand changes in expected loads and increases in variations created by nonstationary. Examples of robustification include designing for changing snow-loads, avoiding design-condition overheating, or adjusting Flood Construction Levels (FCL).

3.2.3 Enhanced Durability

Enhanced Durability measures are those that are needed to maintain expected service lives of building systems aggravated by frequent, low-impact events. The damages caused by these events can be managed either through increased maintenance schedules or through improved design that enhances durability. Climate hazards that can affect durability include a more acidic atmosphere (higher ppm of CO2), fatigue caused by larger temperature fluctuations, or degradation of plastics caused by elevated temperatures.

Examples of enhanced durability include increased concrete cover depths, promoted enclosure drying capacity to avoid biodeterioration of organics, or increased corrosion resistance of exposed metal fasteners.

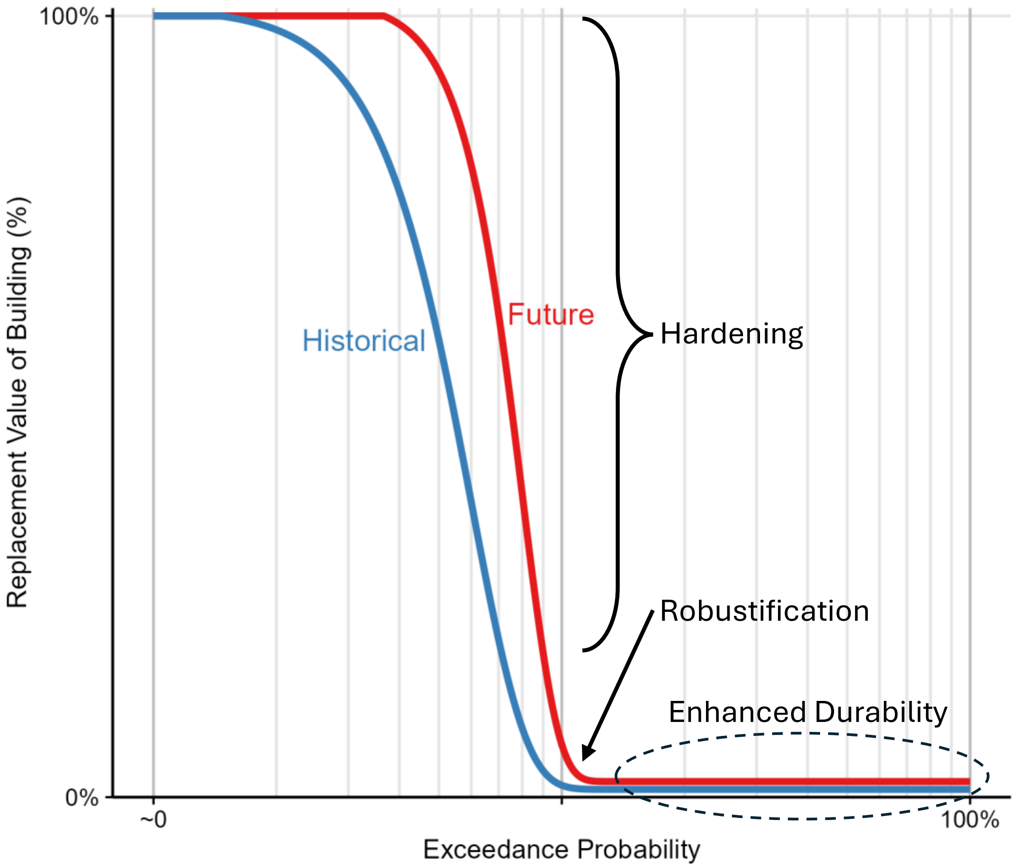

Figure 1 – Conceptual framework for Hardening, Robustification, and Enhanced Durability as a function of Damages and Exceedance Probability for Historical damage curve (blue) and future damage curve (red), assuming worsened future conditions. Damages are clipped to 100% of the replacement value of the building. Probability of exceedance runs from ~0% (e.g. 1-in-infinity return period) to 100%. Note the conceptual framework has logarithmic axes.

3.3 GHG Mitigation

GHG mitigation is a necessary aspect of climate resilience. Successful mitigation reduces future warming and therefore lessens the needs for adaptation. While GHG mitigation effects are experienced in aggregate and over the span of many decades, mitigating is a critical part of resilient buildings as without it, adaptation options are limited, costly, or in some cases, not possible.

GHG mitigation: “Intervention to reduce emissions or enhance the sinks of greenhouse gases.”[6]

GHG mitigation requires managing life cycle carbon flows. Total carbon, embodied carbon, and operating carbon are terms used to describe how the carbon and greenhouse gas emissions are generated at each stage of a building life cycle. Upfront carbon is another term sometimes used to differentiate embodied carbon emissions that occur from cradle-to-gate.

Carbon accounting is the process of tracking, measuring, and quantifying greenhouse gas emissions. There are many standardized processes to support this. The **Greenhouse Gas Protocol** defines Scope 1, 2, and 3 emissions to describe carbon flows. Scope 1 emissions refer to all those direct emissions produced on site (e.g. operational carbon from onsite appliances). Scope 2 emissions are the emissions associated with purchased energy. Last, Scope 3 emissions refer to all other carbon emissions, including embodied emissions. An extended view of Scope 3 emissions also includes the impacts of transportation related emissions for the use of the building.

The International Standards Organization (ISO) and European Standards (EN) (ISO 14040, EN 15804) use different modules to describe the carbon flows for different product life cycles. Figure 2 shows how these terms are inter-related.

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[6] IPCC AR6 (2023)

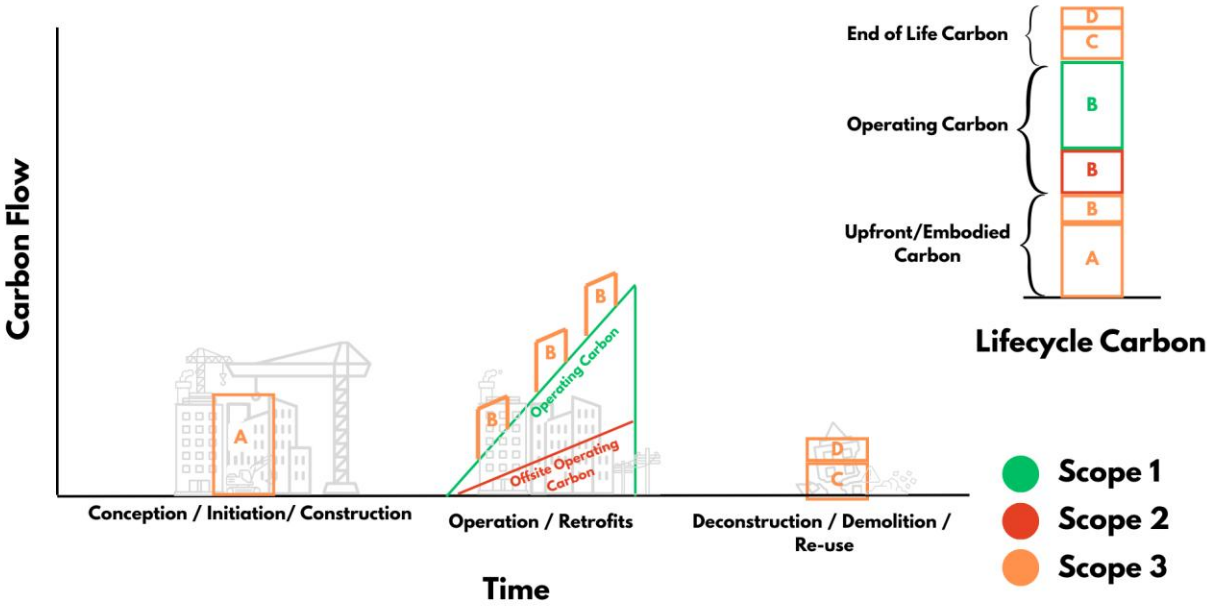

Figure 2 – Comparison of Life Cycle Carbon Terms for Buildings

There are several terms associated with GHG mitigation that are directly relevant for building sector professionals. These terms include "Net-Zero Carbon" or "Carbon Neutrality", "Carbon Sequestration" and "Carbon Removal", and "Carbon Offsets".

3.3.1 Net-Zero or Zero Carbon

Net-Zero Carbon is a term whereby anthropogenic emissions are countered by anthropogenic removals. Net-zero carbon buildings are only possible with **carbon offsets**. A similar term, Zero Carbon Buildings, also requires offsets.

The intent of Net-Zero Carbon buildings is to drastically reduce all embodied and operating carbon and deploy carbon offsets to balance those difficult or impossible to mitigate sources. In practice, Net-Zero Carbon encounters two major challenges. First, offsets are very often not as effective at avoiding GHG emissions as claimed, and according to some studies, worsen climate change (Calel et al. 2021; Naef et al. 2025; Macintosh et al. 2025). Second, that reliance of offsets as an easier solution decreases focus, efforts, and investment in tangible mitigation solutions for the building.

> *"There is a real risk that [carbon offsets] slow progress towards Net Zero or damage other priorities such as climate adaptation and biodiversity" - (UK Climate Change Committee 2022)*

Note: Net-Zero and Zero Carbon Building standards have different definitions and, critically, different underlying assumptions. Some standards may include avoided emissions as offsets, or some methodologies for calculating offsets may not be representative of realistic conditions (e.g. photovoltaics accruing “negative carbon emission” in comparison to a worst-case fossil fuel plant).

3.3.2 Decarbonization and Zero Emissions Buildings

A competing view on building mitigation is Zero Emissions or Decarbonized buildings. This approach differs from Net-Zero carbon in that the objective is not to balance out emissions with offsets, but rather elimination of all Scope 1 emissions. It is also important to understand the fine print, as some decarbonization standards do not require full decarbonization, but only a significant reduction in Scope 1 emissions.

3.3.3 Carbon Offsets

Carbon offsets are reductions in greenhouse gas emissions in one source meant to compensate for emissions that occur elsewhere (see text box for definition).

There are two broad categories of carbon offsets: emissions reductions and carbon removal. Emissions reductions can be further separated into **avoided emissions** or **carbon sequestration**. Avoided emissions represent the gap between a typical (or business-as-usual) action and the emissions that result from an alternative and lower carbon project. Carbon sequestration refers to the transfer of carbon from one sink to another. If the carbon is transferred into a longer lasting or more durable sink, the net effect is to slow the effects of climate change. **Carbon removal** is the active removal of carbon dioxide from the atmosphere. Carbon dioxide removal strategies actively reduce the effects of climate change. However, emerging evidence suggests limited effectiveness in most carbon dioxide removal technologies, including afforestation, direct air capture and sequestration, bioenergy and carbon capture and sequestration.

> Carbon Offset: “The reduction, avoidance or removal of a unit of greenhouse gas (GHG) emissions by one entity, purchased by another entity to counterbalance a unit of GHG emissions by that other entity. Offsets are commonly subject to rules and environmental integrity criteria intended to ensure that offsets achieve their stated mitigation outcome.
>
> *For a Carbon Offset to be reliable, it must include, but not limited to, the (1) avoidance of double counting and leakage, (2) use of appropriate baselines, (3) additionality, and (4) permanence or measures to address impermanence.”*[7]

A critical aspect of carbon offsets is the longevity of storage. For stored carbon to have an impact on the climate, it needs to be removed from the carbon cycle long enough that natural sources and sinks achieve an equilibrium before it is released back into the

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[7] IPCC AR6 (2023)

atmosphere. The carbon cycle lasts in the thousands of years, and buildings, typically lasting less than 100 years, are not durable enough to meaningfully impact the carbon cycle (Brunner et al. 2024). The largest roles that buildings can play in climate mitigation is by ensuring they are designed to have the lowest operating and embodied carbon as possible, but using them as a sequestration strategy has questionable benefits.

Avoided Emissions: The greenhouse gas emission impact of a product (good, or service) relative to the situation where that product or service does not exist.

Note: Avoided emissions do not achieve the ‘additive’ property of a carbon offset, as it is a comparison to a future that does not exist.

Carbon Sequestration: “The process of storing carbon in a carbon pool.”[8] Delayed carbon impacts are only beneficial when moving from a short-lived sink to a longer-lived sink. The sink must still sequester the carbon for a long-enough duration to impact the carbon cycle.

Carbon Removal: “Anthropogenic activities removing carbon dioxide (CO2) from the atmosphere and durably storing it in geological, terrestrial, or ocean reservoirs, or in products. It includes existing and potential anthropogenic enhancement of biological or geochemical CO2 sinks and direct air carbon dioxide capture and storage (DACCS) but excludes natural CO2 uptake not directly caused by human activities.”[9]

3.3.3.1 Note on Life Cycle Carbon Assessments

The field of whole-building life cycle assessments (wbLCA) is underpinned by several ISO standards. This discipline has been active for decades, but the application to buildings is relatively new. Best practice in wbLCA can still create significant errors in models and the efficacy for hitting specific regulatory targets, given the potential for order of magnitude in errors, is concerning. The Environmental Product Declarations (EPDs) are not fit for purpose given their original intent was to verify legitimacy of claims, not as an evaluative process to determine total environmental impacts of a product. A leading wbLCA research states:

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[8] IPCC AR6 (2023)

[9] IPCC AR6 (2023)

> *"However, the literature on building LCAs consists of highly varying results between the studies, even when the assessed buildings are very similar. This makes it doubtful if LCA can actually produce reliable data for supporting policy-making in the building sector" – Antti Säynäjoki et al (2016)*

Another caution is the use of negative carbon estimates. A negative unit of mass is only possible relative to a reference condition. For building sector professionals, it is important to understand these assumptions. For instance, biogenic carbon (carbon deriving from biological organisms) is often assumed to have a negative carbon impact as it represents carbon atoms that are not in the atmosphere. However, this is an artificial comparison that ignores alternate scenarios that may, on the contrary, further sequester carbon (e.g. leave the fields fallow or don't harvest the forest).

Overall, the field of accounting for building emissions at each stage of the lifecycle can be complex. Practitioners and owners should understand their objectives, clearly and transparently represent emissions and mitigation efforts, and where possible act at the building level to reduce embodied and operational carbon.

3.4 Climate Resilience Measures

Climate resilience measures are actions and processes that are designed and implemented to reduce climate vulnerability through combined achievement of adaptation and GHG mitigation objectives. The benefits of GHG mitigation may be a reduction in operating carbon but may also manifest as avoided embodied carbon costs necessary for repair, replacement, or reconstruction of systems damaged by climate hazards.

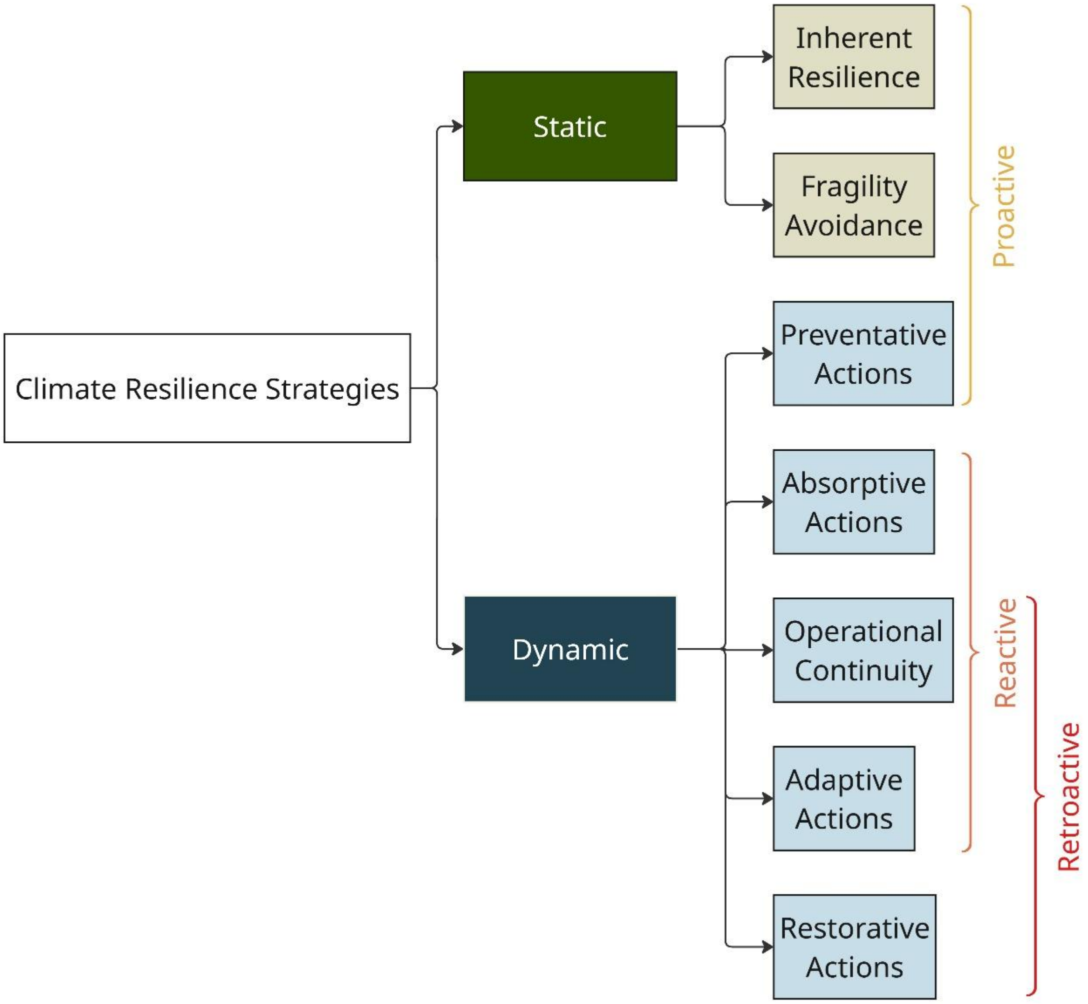

Figure 3 – Climate Resilience Strategies.

Climate strategies can be broadly categorized as either static or dynamic. Each category is further divided into their treatment of the hazard. Static measures are predominantly focused on reducing damages and are proactive, that is, occur before the hazard manifests. Reactive treatments require human intervention to respond during the hazard and its effects. Retroactive treatments require human intervention to manage the aftermath of the event.

There are two classes of climate resilience measures, depending on the requirement of human action: static or dynamic.

3.4.1 Static Resilience Measure

Static resilience measures are fixed or passive systems that achieve their objectives mainly through reduction or preventing damage to the building, its systems, or its functionality.

Generally, static resilience measures take the form of hardening, robustification, or enhanced durability adaptive measures. Their impact on GHG mitigation is by avoiding embodied carbon emissions from needing repair, renewal, or restoration.

Many static resilience measures may also achieve reduced operational carbon emissions through demand reduction or active system efficiency gains (e.g. insulation, solar shades).

3.4.2 Dynamic Resilience Measure

Dynamic resilience measures are those that require active involvement or intervention by humans. These may be preventative, absorptive, adaptive, restorative, or behavioural in nature. The reactive and retroactive dynamic resilience measures also require institutional knowledge transfer and mobilization; what must be done, when, and by whom? The intent is to enable a rapid recovery of building functions through flexible responses depending on the nature and magnitude of the event. Preventative dynamic resilience measures may include climate risk assessments or early warning system, anticipatory changes to building operations, or even changes in inspection/maintenance schedules. Behavioural dynamic resilience measures may include protocols to work in compromised building systems (e.g. how to work without power).

4. Importance of Communication

Climate resilience is a pressing issue at all scales of government and in all corners of the country. Many organizations and institutions are actively working to solve problems. Communication and collaboration across disciplines and sectors is a necessary part to identify effective adaptation solutions and securing support for implementation. Breaking down silos, whether within a company, an organization, or governments is needed at different scales. Sharing information among different groups avoids replication, redundancy, or contradictions, both in terms of policy related action, but also physical climate resilience procurements.

To assist in breaking down silos and fostering greater communication, consider establishing local networking and practice groups within your organization. Reach out to other organizations that share similar challenges and share information either through standing meetings, informal relationship building, or by hosting engaging knowledge sharing sessions. Nominate a team representative to engage with different levels of government or different institutions and provide this person with a clear and explicit mandate, included within their job description, to engage and dialogue with intra- and inter-agency communications. These relationship focused roles are essential to any effort to build resilience.

Some networks include CanAdapt or the PIEVC Practitioner’s network. Engage through professional or practitioner networks, by joining or initiating a climate committee. Small grassroots organizations like the Climate Design Initiative, or informal get-togethers (such as the Victoria League of Resilient Adapters), are an effective way to foster cross-disciplinary discussions, awareness building, and ally networking.

Finally, an essential aspect of good communication is listening. Understand your partners, your audiences, and your clients and the values and objectives they have. Talk to them, on their terms and with language they use, about how approaches to climate adaptation and mitigation can help them achieve their goals. In some cases, it may be better to focus on the direct and indirect benefits of climate resilience without using new terms like adaptation or mitigation. Instead of ‘passive survivability to power outages’, consider ‘energy independence’, or ‘low operating costs.

Part 2: Understanding the Problem

5. The Impacts of Climate Change on Buildings

Climate change affects every aspect of a building, from footings to finials. These impacts may be direct, as in structural damage (impact) caused by extreme wind pressures (hazard), or indirect, such as power outages (impact) from downed power lines caused by a windstorm (hazard). The consequences of these impacts can range from trivial to catastrophic. Yet an often-overlooked aspect is how these impacts affect the building users and occupants.

The assessment of climate impacts on buildings is typically undertaken within a risk management process. This process may include hazard, risk, or vulnerability assessments, each responding to different aspects of uncertainty.

This section first discusses the key concepts necessary to understand climate risks for buildings. It is written to assist a recipient of a climate impact assessment with the knowledge and understanding to parse, interpret, and question the results. It then discusses some of the hazards that may be relevant for buildings, methods to characterize the future (an essential step for assessing future risks), and a brief note on the limitations of the epistemology of risk.

6. Climate Risk Concepts

Risk-informed decision making is the cornerstone of developing climate resilient buildings. The application of risk concepts and structured risk assessments sheds light on hazards and impacts the building may be exposed to through its life cycle. Risk management approaches allow building designers, engineers, and decision-makers to compare alternative courses of action and recognize their consequences and sources of uncertainty. Climate resilience cannot be achieved without using risk-informed methods, and so a basic understanding of risk is needed.

Consider: If climate change was not happening, would any action be required?

This section discusses key principles of risk necessary when conducting, or reviewing, risk assessments on a new or existing building.

6.1 What is Risk?

Risk is a commonly misunderstood concept. The lay and technical definitions can diverge, and an individual's personal experience will influence how they perceive or even define risk. Two people, shown the same data, may draw drastically different conclusions about risk.

ISO 31000 provides a definition of risk:

Risk: The effects of uncertainty (ISO 31000)

This definition indicates that the main effects of risk are not risk itself, but rather how we choose to act on this risk. The ISO definition of risk is derived from consensus-based processes and has remained unchanged even as the field of risk management has evolved. The Society for Risk Analysts, for instance, provides as many as seven different definitions[10] depending on contexts, with the simplest description of risk as a concept including:

Risk (Concept): Risk is the occurrences of some specified consequences of an activity and associated uncertainties (SRA)

Regardless of definition, the core concept of risk is uncertainty. Uncertainty is a factor affecting the future contexts or preferences of possible outcomes wherein decision-makers possess insufficient knowledge (Marchau et al. 2019). Risk management include approaches to better describe these uncertainties in a manner that enables informed decision-making. Some factors create complex situations where even experts and key party decision makers cannot agree. This includes challenges of identifying appropriate models to describe system effects, the appropriate probability distributions to represent key variables, and how to value different outcomes (Marchau et al. 2019). These are all critical elements when dealing with the risks associated with climate change and are known under the term of 'deep uncertainty'.

Regardless of the definitions, climate changes pose threats to buildings and their occupants, and decisions must be made as to how our buildings are to maintain their performance into the future.

6.2 Components of Risk

Before discussing the concepts of risk, a few core concepts must first be discussed. These include

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[10] Aven and Thekdi, *Risk Science*, 2024.

6.2.1 Exposure

"Presence of people, livelihoods, species, or ecosystems, environmental functions, services, resources, infrastructure, or economic, social, or cultural assets in places and settings that could be affected." [11]

Many systems may be exposed to climate hazards. However, the consequences of this exposure may be negligible. On the other hand, some systems may not be exposed directly to the climate but are rather conditional on the functioning of other systems (e.g. interior primary structural elements are protected from the climate through the building enclosure). These types of conditional exposures are a core element of 'cascading risk'.

6.2.2 Consequences

Something that occurs as a result of a given climate impact (e.g. basement damage from flooding, increases in respiratory illness from heat). Consequences may be defined as a specific threshold (e.g. the point at which the cooling system is no longer able to meet a set-point temperature), or as a distribution (the heat strain of occupants as indoor temperatures increase). Consequences can be defined in multiple different metrics as well, from monetary equivalents, Disability Adjusted Life Years (DALYs), or hours of disruption to a given service.

6.2.3 Likelihood

Likelihood is the probability of an event (e.g. a hazard or impact) occurring. It can be defined qualitatively (likely / not likely), semi-quantitatively (likelihood scoring), or quantitatively, in terms of return periods or annual exceedance probabilities.

6.2.3.1 Concerns on Likelihood

The concept of likelihood may be confusing as it can represent either relative odds (event A is more likely than event B) or absolute values (event A is likely). Likelihood is also sometimes treated as a prediction of a singular or specific event, as a defined point on a distribution, which may occur in the future (e.g. an EF2 tornado). However, as the future is unknowable, predictions of occurrence may not produce useful information for decision-makers.

However, likelihoods must not be confused with the changes in probabilities provided by climate data. Climate data provide robust probability distributions as a function of different scenarios which enable comparative assessments. It does not make a prediction as to whether the event will occur but rather describes changes in climatic behaviours that

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[11] ISO 14090: 2019

may provide decision-makers with insights into what steps may be needed to manage future hazards.

A secondary issue with the likelihood concept is that it is not an independent variable. Likelihood and consequences form a continuous distribution (the more extreme the event, the less likely) and are therefore confounded. The selection of a single point on the likelihood-consequence distribution is unable to characterize the non-linear effects created by high-consequence events. This assumption is particularly dangerous in non-linear and poorly quantified systems (limited data points), such as those that define extreme events. This may limit the value of the risk calculations as the focus is applied to a singular event/scenario.

Lastly, many risk assessment methodologies and protocols transform likelihoods and consequences into manageable scoring metrics to permit rapid comparison across multiple hazards. However, when likelihood or consequence scoring is transformed into a scale of 1 – 5, interpreting risk assessment results can be challenging. Studies have shown that human cognition struggles with non-linear or logarithmic values. For instance, the consequence of 5 may be 10,000x worse than the consequence of 4, and that could be misinterpreted when risk scores are generated.

6.2.4 Vulnerability

Vulnerability is the conditional risk if a given hazard were to occur. It is the product of the sensitivity of the system to a hazard and the adaptive capacity to manage potential impacts.

Vulnerability: “Predisposition to be adversely affected.” [12]

When assessing a building for vulnerability, the intent is to ask, “what if”, as opposed to a “how likely”, which is common in climate impact assessments. Implementation of climate resilience measures is unable to affect the likelihood of climate hazards occurring, and so the focus should be placed on reducing those controllable potential impacts as managed through vulnerability.

6.2.5 Adaptive Capacity

“Ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.” [13]

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[12] ISO 14090: 2019

[13] ISO 14090: 2019

6.2.6 Sensitivity

Sensitivity determines the degree to which a system is adversely or beneficially affected by a given climate change exposure. Sensitivity is typically shaped by natural and/or physical attributes of the system.

Many static climate resilience measures are focused on decreasing the sensitivity of systems exposed to climate hazards. Increasing the flood construction level, designing to an EF-2 tornado, or using non-combustible claddings are all examples of measures that decrease the sensitivity to climate hazards (flooding, wildfire, and strong winds).

6.3 Descriptions of Risk

There are two predominant models to describe risk. These form the foundation of many climate risk assessments. The assumptions that are built into the models should be understood to recognize the benefits and limitations of the assessments.

6.3.1 The Triplet Model

One of the more common risk models is the triplet model (Kaplan and Garrick, 1981):

$$Risk = Exposure \times Likelihood \times Consequence$$

It considers that risk is a product of three *independent* concepts:

- The Exposure, or “what can happen”,
- Likelihood: “how likely is it to happen”, or more formally “the chance of a specific outcome occurring where this might be estimated probabilistically”, and
- Consequences: “what are the consequences of it happening”, or more formally, “the impact of the effect on natural and human systems[14]”

This estimation of risk is used in several risk standards and has been applied to a wide range of engineered systems. However, it has some important limitations that may lead to underestimations of risk. The challenge lies mainly in the concept of ‘likelihood’ and its inability to predict future occurrences of hazardous events, especially given the unknown changes to climatic parameters. The likelihood parameter serves mainly to enable comparison between different hazards for resource allocation purposes.

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[14] ISO 14090: 2019

6.3.2 Uncertainty Model of Risk

Newer approaches to risk assessment instead focus more on the effects of uncertainty on the consequences. This description of risk is,

$$Risk = P(A) \times P(C|A)$$

where P(A) is the probability of exposure and P(C|A) is the conditional probability of the consequences given the exposure. This output of risk is a distribution and not a discrete value that could be easily plotted on a risk matrix. However, this definition is particularly useful for buildings as the second term, P(C|A), is also known as *vulnerability*. Since resilience is manifested through the systematic removal of vulnerabilities, this definition is particularly relevant for climate resilient buildings.

Hazard, Vulnerability, and Risk Assessment – What's the difference?

Hazard assessments are technical assessments; it is generally agnostic to the exposed systems and predicated mainly on uncontrollable, environmental factors.

Vulnerability assessments are tactical assessments; they detail the necessary steps to create a response to a potential threat.

Risk assessments are more strategic in nature; they are used to plan the approach to create a desired end-state. Risk assessments find better use in building portfolios where there are greater elements of uncertainty.

7. Climate Hazards

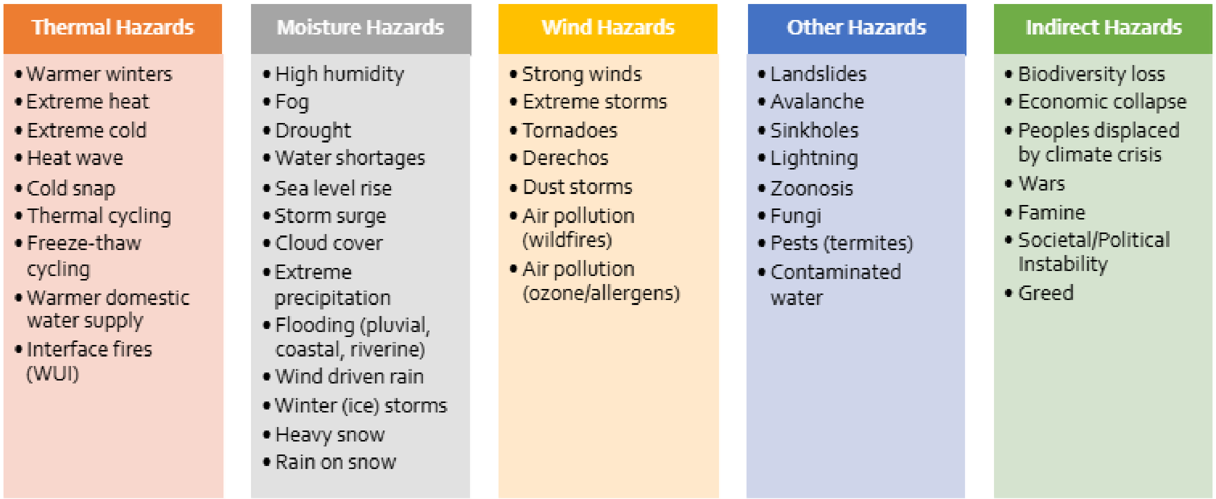
Climate hazards are anything that can cause harm to a building or its occupants. These hazards may be direct or indirect. Direct hazards are those that enter into the parcel/property level and act on the building itself. Generally, these pertain to the thermodynamic properties of the atmosphere or hydrological impacts (e.g. windstorms, extreme heat or cold, flooding) and are termed 'physical hazards. Indirect effects are those events that can impact a building but whose area of impact falls outside of the parcel. This may include effects such as community level flooding that interrupts access to the building, wildfire damaging power transmission lines leading to power outages, or drought that dries up the water reservoir. All the above examples are physical hazards connected to climate change.

Buildings may be exposed to a range of non-climate hazards, including systemic and socioeconomic hazards such as economic disasters, insurance collapse, war, and famine.

Most climate risk assessments for buildings limit their focus to physical hazards that are amplified by or driven by climate change.

Climate hazards may be slow-moving, manifesting over years or decades, known as 'stresses', or they may be rapid and short, known as 'shocks. An extreme rainstorm may occur over the span of tens of minutes leading to localized, surface pluvial flooding, but annual changes in precipitation patterns may lead to fluctuations in ground-water level which could create foundation infiltration leaks. The former is a 'shock', the latter is a 'stress'.

A partial list of a range of climate hazards, grouped by generic environmental factors, is shown in Figure 4.



Thermal Hazards

- Warmer winters
- Extreme heat
- Extreme cold
- Heat wave
- Cold snap
- Thermal cycling
- Freeze-thaw cycling
- Warmer domestic water supply
- Interface fires (WUI)

Moisture Hazards

- High humidity
- Fog
- Drought
- Water shortages
- Sea level rise
- Storm surge
- Cloud cover
- Extreme precipitation
- Flooding (pluvial, coastal, riverine)
- Wind driven rain
- Winter (ice) storms
- Heavy snow
- Rain on snow

Wind Hazards

- Strong winds
- Extreme storms
- Tornadoes
- Derechos
- Dust storms
- Air pollution (wildfires)
- Air pollution (ozone/allergens)

Other Hazards

- Landslides
- Avalanche
- Sinkholes
- Lightning
- Zoonosis
- Fungi
- Pests (termites)
- Contaminated water

Indirect Hazards

- Biodiversity loss
- Economic collapse
- Peoples displaced by climate crisis
- Wars
- Famine
- Societal/Political Instability
- Greed

Figure 4 - List of Climate Hazard by Class

8. Predicting the Future

For professionals and practitioners, developing an understanding of the climate conditions a building may face in the years and decades ahead remains a significant barrier to action. Climate science is a complex field, so this is understandable. Developing awareness about how climate models are generated and how climate data generates projections of future climate conditions can help us overcome that barrier and move forward with adaptation actions.

Climate models described how our climate will change in relation to a series of globally agreed scenarios. The scenarios that are used as inputs in climate models have many sources of uncertainty, from assumptions about technology change to the implementation of global climate policies. Consequently, climate models representing these diverse scenarios project a wide range of future climate values, particularly at long time horizons.

When using climate-adjusted design data, it is important to recognize how the load is changing over time. Commonly, either current or future loads create the governing design condition, but in some cases (e.g. snow loads in the North), mid-century levels may be higher than present or end-century values. Over a system's design life, consider which condition is limiting and design appropriately.

There are two main approaches when it comes to identifying how, and to what conditions, we are designing and planning infrastructure. The first is selecting one or more IPCC climate scenarios and time horizons (e.g. 2050s) and using corresponding climate model data in design. The second is identifying Global Warming Level (GWLs), where a level of climate damages (in terms of global warming levels) is selected based on a reference baseline trajectory. As GWLs directly describe levels of climate impacts, they are a better fit for design decisions. The two approaches are discussed below.

8.1 IPCC Climate Scenarios

Current future projections are limited to the availability of Coupled Model Intercomparison Project (CMIP) scenarios. These are mainly Representative Concentration Pathways (RCPs) from CMIP5 (2014) and Shared Socioeconomic Pathways (SSP) from CMIP6 (2019). These are identified by different levels of climate forcing by the end of the century. Research by Huard and Fyke (2022) suggests that SSP3-4.5 represents a reasonable 'middle of the road' approach by end of century, and SSP5-8.5 represents a worst-case scenario or climate impacts beyond the year 2100. However, proper use of scenarios requires recognition that the climate impacts are continually changing over time and are therefore extremely sensitive to assumed building service lives.

There is also a tendency to avoid using projections that are too far in the future. Near-term projections (e.g. 2050s) do not significantly diverge. A practitioner can select any scenario and not be accused of being 'incorrect'. However, this fear of being wrong is damaging to the design of the buildings, which have service lives that extend well beyond the year 2100.

8.2 Global Warming Levels

Another method to describe possible futures is the GWLs. They directly describe the level of climate impacts, without a need for changing time horizons. They are a more robust and transparent way of quantifying future climate impacts, and it is for this reason that the Climate Resilient Buildings and Core Public Infrastructure CRBCPI report uses GWL to describe possible future climate. Table 1 uses the best available data to map out conservative global warming levels out to the year 2100.

Table 1 – Reference Baseline Global Warming Level by Decade for “Current Policy” scenario using CRBCPI Global Warming Levels[15] (Lepage, Murdock, Barrows, 2025, submitted to J. ASCE Open).

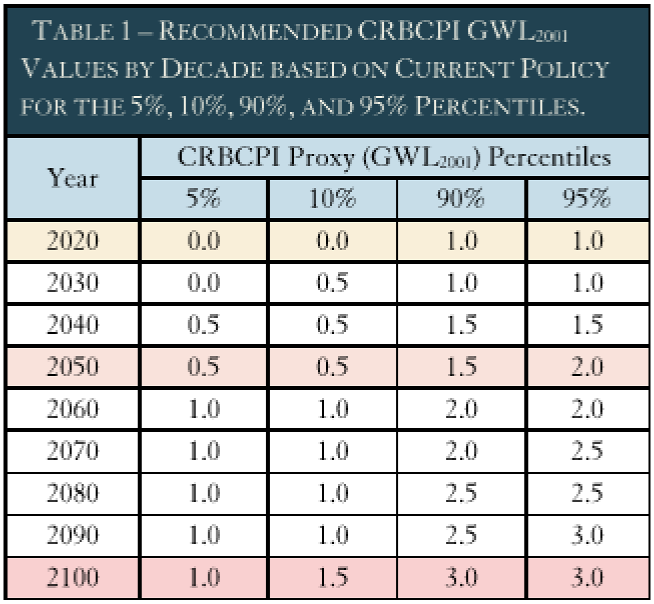


TABLE 1 – RECOMMENDED CRBCPI GWL_{2001} VALUES BY DECADE BASED ON CURRENT POLICY FOR THE 5%, 10%, 90%, AND 95% PERCENTILES.

Year	CRBCPI Proxy (GWL_{2001}) Percentiles			
	5%	10%	90%	95%
2020	0.0	0.0	1.0	1.0
2030	0.0	0.5	1.0	1.0
2040	0.5	0.5	1.5	1.5
2050	0.5	0.5	1.5	2.0
2060	1.0	1.0	2.0	2.0
2070	1.0	1.0	2.0	2.5
2080	1.0	1.0	2.5	2.5
2090	1.0	1.0	2.5	3.0
2100	1.0	1.5	3.0	3.0

9. Part 2 Summary and Key Points

In this section we described different definitions to risk and defined how different concepts and characteristics are part of and related to a building’s current and future climate risk. This included exposure, adaptive capacity, and sensitivity. We also discussed how climate models generate data that can inform our design, and approaches to how we can identify and select data (IPCC climate scenarios, GWL) that can lead us to adaptation solutions.

There are a range of definitions for risk, and different approaches to assessing and managing it. The key point is that the assessment provides us with information about present and future risk, which enables us to move forward with identifying and implementing solutions to ensure the building maintains its full-service life functionality.

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[15] Climes Group Engineering, 2025: Report to Environment and Climate Change Canada, Canadian Centre for Climate Services

Part 3.1: Resilience in Actions – Owners

Building owners seek to preserve the function and lifespan of their buildings. For building regulators who also own and operate buildings, there is an added need beyond protection of the physical asset, but also maintenance of their capacities to fulfill mandates and deliver critical services despite adverse climate conditions. For this segment of the building sector, leadership in climate resilience is both a necessity and an important part of shaping the market through demonstration.

This section discusses approaches that building regulators can take as building owners, for both new and existing buildings.

There are three phases: planning (including pre-planning), climate impact assessments, and implementation. The process of creating resilience for both new and existing buildings is similar, however, the execution and planning for each may differ appreciably. The process is outlined in the Climate Resilient Buildings Flow Chart, shown in Figure 5. Additional tools and references can be found in Part 4: Resources.

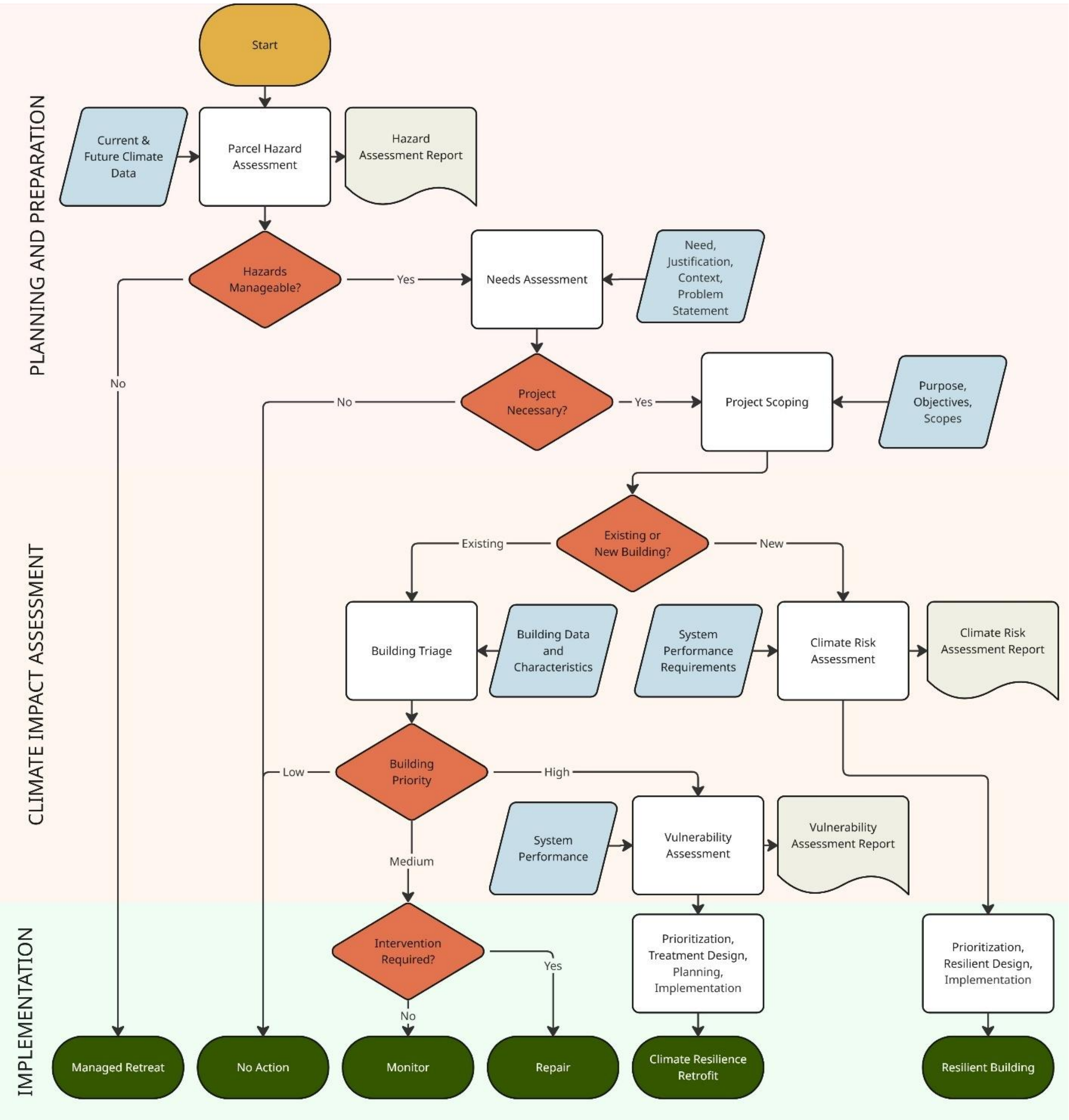

Figure 5 – Resilient Building Flow Chart

9.1 Planning and Preparation

Planning is the most critical part for delivery of a climate resilient building, as it sets the foundation upon which all subsequent decisions are made.

Planning for climate resilience follows three separate steps, with one added step required for existing buildings.

1. Climate Hazard Assessment: evaluation of the probability of different climate hazards occurring at a given parcel.
2. Needs Assessment: evaluation of whether the project can address the needs, given the parcel's exposures.
3. Project Scoping: identification of boundaries and limits, as well as the problem, objectives, and desired outcomes, for the climate impact assessment.
4. Building Triage: identification of and allocation of resources to buildings where assessment and intervention provide the greatest potential value and benefit.

9.1.1 Pre-Planning

Before commencing the planning phase, building owners can establish conditions for success by reflecting on needs and resources for the upcoming project. The project leads should have buy-in from leadership to enable a clear and transparent progression for the project. A leadership team, tasked with ensuring delivery of the project, should have the required levels of expertise or knowledge on hand, or the ability to retain someone to assist as needed, as well as being charged with adequate financial resources to undertake the added assessment efforts. The pre-planning step is also the moment to identify co-benefits and harmonized efforts with existing frameworks, such as combining climate resilience measures with needed asset management plans, capital planning, or procurement policies.

If there are any specific occupant communities that would be using the building and have particular needs, the pre-planning phase is the opportunity to start relationship building with those affected groups. This is the moment to identify any engagement needs. Developing relationships is a long process; provide yourself with plenty of time to enable an organic development as opposed to a forced, or even performative, engagement. Extreme sensitivity and understanding is needed when dialoguing with certain groups, such as First Nations and Indigenous communities.

The pre-planning phase of any climate resilience project can help ensure the project is adequately supported, and on track for success.

9.1.2 Parcel Hazards Assessment

The first step to planning a climate resilient building is to understand the hazards. All major properties should have a climate hazard assessment to identify what threats may occur in the present or in the future. Both direct and indirect climate effects should be considered. This should take place before any discussions on what types of activities or purposes can be delivered with this parcel. It is essential that future climate data are used to inform these surveys. Climate resilience consultants can provide valuable insight into the potential hazards that are relevant for different building types and regions. Engaging with climate scientists and subject matter experts can help identify the range of possible climate hazards.

The key output of the Hazards Assessment is a recognition of the types, magnitudes, and characteristics of the hazards that may occur on the property. Likelihood estimates are not necessary and could even be detrimental should errors or uncertainty be large. The hazards may be prioritized based on potential impacts. An assessment based on potential acceleration of damages as a function of the load can help identify where those hazards can create non-linear damages.

Most importantly, it should be recognized that some climate hazards may be missed. There is a human tendency to focus on confirmation bias and the availability heuristic; we are more easily able to recall recent events. Concerns such as heat waves, flooding, and extreme precipitation are more likely to be identified if such events have occurred recently. For most regions, and because climate is shifting rapidly, there may be climate hazards that have not yet occurred at a building site and are therefore not immediately recognized as part of retrospective “hazard assessment” repertoire for a given geographic location.

9.1.3 Needs Assessment

Once each parcel has identified and prioritized hazards, a needs assessment should be considered to determine if a climate resilience retrofit or new climate resilient building is necessary. The main purpose of this document is to evaluate whether exposure to potential climate risks is necessary to meet the identified needs. If the documented needs can be met through alternate avenues (e.g., municipal service can be provided from a different location), it is worthwhile to investigate these alternatives.

The needs assessment should do the following: specify the owner’s needs, provide any justification for the building use given the awareness of new and developing hazards, provide appropriate context for how these needs may change as the climate warms, and summarize in a problem statement how a new or retrofitted building will address those needs. The needs assessment forms the core part of the reason to undertake a climate impact assessment.

9.2 Project Scoping

If the needs assessment determines that a climate retrofit or a new climate resilient building is necessary, project scoping is the next step to establish the structure of the climate impact assessment.

The project scope must identify the purpose and intentions of why the owner needs a climate assessment for the building. If the reason is to acquire funding, the level of effort is significantly different than if it is to identify vulnerable systems and initiate a comprehensive resilience plan to maintain critical infrastructure.

The objectives of the climate assessment should be clearly stated, as well as the desired outcomes. Scoping and context are essential for defining the limitations of climate assessments. These should include the range of hazards to be considered, areas under review, spatial and temporal resolution and limits of the assessments, any required methodologies to be used, and resources that are available for the impacts assessment.

Once the project scopes are clearly defined, the process diverges for new and existing buildings. Existing buildings already have known systems with known performance to historical climate loads; the level of uncertainty of performance is relatively low. Extrapolation to changing future climates is founded on empirical knowledge. As a result, these assessments usually take the form of a *vulnerability assessment*. New buildings, that have as-yet defined systems, can only be inferred from models and analyses; the levels of uncertainty on exposure and conditional consequences are much greater. Due to these greater levels of uncertainty, *risk assessments* are often more appropriate. We will elaborate on these in the coming sections.

For **new buildings**, the project requirements or performance specifications can be written such that systems are capable of functioning for all identified hazards. This can be characterized by a prospective climate risk assessment. **Existing buildings** require a prior step before progressing to a vulnerability assessment. This step is called *Building Triage*.

9.2.1 Building Triage

Triage is a process that is used when demands greatly exceed available resources. In medical disasters, triage is used to identify those persons who cannot be saved, those that do not require immediate assistance, and those who are in need of immediate intervention. The same principle applies to buildings.

Building owners must determine how to allocate limited resources. Not all buildings can be saved; some may be in areas where no amount of effort can adequately abate climate impacts (e.g., in flood plains, exposed WUI zones). For other buildings, the costs for intervention may be so high that greater benefit may be achieved in redirecting these resources within the owner’s portfolio.

Several dimensions that impact building triage may include:

- Building criticality

- Occupancy type and use
- Facility Condition Index
- Remaining service life
- Exposures and potential magnitudes of climate hazards
- Societal valuation of the building
- Concurrency of renewals for different systems
- Presence of hazardous materials
- Present life-safety concerns or issues

The output of building triage could be categorized into the following possible conditions:

- Non-Viable
  - Buildings located in areas with extreme, unavoidable climate exposures
  - Retrofit costs approaching an unacceptable percentage of replacement value
  - Structural deficiencies incompatible with climate retrofits
  - Building service life cannot be reasonably extended with retrofit efforts
- Priority Intervention
  - Critical infrastructure (hospital, community centers, etc.)
  - Buildings serving vulnerable populations
  - Buildings with current or imminent life-safety issues
  - Systems with near-term concurrency in required renewals for bundling efficiencies
- Scheduled Intervention
  - Buildings with moderate climate exposures and adequate current conditions
  - Opportunities for strategic timing for major system renewals
  - Non-critical facilities with manageable interim risks
- Opportunistic Improvement
  - Buildings with low climate exposures
  - Structure and systems in good working conditions.
  - Current maintenance strategies provide adequate short-term functionality
- Adequate Resilience
  - Buildings with minimal climate exposure or adequate resilience measures
  - Monitor and re-assess

9.3 Climate Impact Assessment

A climate impact assessment is the overarching term for climate risk and vulnerability assessments. Risk and vulnerability have different purposes and levels of uncertainty, driven by different exposure and consequence distributions. The key purpose of a risk or vulnerability assessment is to identify the *questions* that need to be answered to ensure functionality of the building. This is achieved by describing the sources of uncertainty and potential damages that can occur as a result of a hazardous event to the building or its necessary inputs (e.g. connection to the grid, accessibility for users). A climate impact assessment follows the same general principles as are outlined in ISO 31000 and ISO 14090:

1) Scope, Context, Criteria
2) Risk Assessment
    a. Risk Identification
    b. Risk Analysis
    c. Risk Evaluation
3) Risk Treatment
4) Recording and Reporting

A climate impact assessment should recognize and provide sound recommendations to avoid trade-offs and maladaptation. A comprehensive risk assessment should also recognize the limitations of risk management approaches and explicitly state the sources of uncertainty and how these could impact the recommendations. Lastly, robust recommendations should provide a framework to follow through with implementation of the recommendations.

For further information on assessing the quality of a climate impact assessment, see Guidance on Good Practices in Climate Change Risk Assessment (*Guidance on Good Practices in Climate Change Risk Assessment*, n.d.).

9.3.1 New Buildings – Climate Risk Assessment

For buildings that are still in the design phase, it can be difficult to properly assess the uncertainties of exposures and the associated conditional vulnerabilities. Risk, in this form, is best understood as the impacts of the uncertainty of the hazards (intensity, duration, frequency), the responses of the proposed modelled systems, and the effects of system interruption on the operation of the building.

In all instances, it is extremely beneficial to include a climate resilience specialist at the outset, who can help provide risk management strategies to the owners and architects in the conceptualization phase of the project. Incorporating a climate resilience specialist after the design is substantially complete will not result in a successful project. Implementing risk management strategies retroactively may require redesign and be costly both in terms of time and dollars. Climate resilience infuses every aspect of a building and must be embedded in the core design process; consideration of it as an ‘add-on’ or supplementary service will result in partial measures that are vulnerable to ‘value engineering’. Embedding climate resilience requirements in procurement language within RFPs and design contracts can help ensure all involved partners are aware of the importance of these measures.

The key benefit of using a risk assessment framework (versus vulnerability) in new construction is the ability to *significantly avoid* damages in the first place by managing the exposures and minimizing the sensitivity of the proposed systems. Attentive design can work around the climate hazards.

9.3.2 Existing Buildings – Climate Vulnerability Assessment

The earlier climate hazard assessment should have identified the relevant hazards for the parcel. The impacts of these hazards on existing buildings are better able to be analyzed as the performance of the existing systems is known. The reduction in uncertainty of the sensitivity of these systems affords more accurate vulnerability assessments. The key components of the vulnerability assessment are a careful analysis of the exposures and the sensitivities of the existing system to the range of possible climate hazards.

9.4 Implementation

The role of the climate impact assessment is to identify potential current and future problems in the building. **Climate resilience measures** address these problems through proactive resilient design (for new buildings), or design of treatments (for existing buildings).

Identifying resilience measures that address the risks or vulnerabilities through climate impact assessments may be an extensive process. Defining the problem and identifying appropriate solutions will likely require engineering analysis and design. Comparative evaluations between the proposed design solutions should consider trade-offs and maladaptation. Novel solutions may require demonstrations of proof of concepts. These are all necessary steps in the development of resilience measures, but due to their complexity, are left for specialist disciplines in other resources and guidelines (see Section 13 Climate Resilience Resources). This section on implementation discusses the aspects required to transform a candidate resilience measure into reality.

The results of climate impact assessments, vulnerability assessments in particular, can feed into renewal planning and maintenance scheduling. Implementation of climate resilience measures can also be used to address deferred maintenance issues or impending renewals; the main difference is that the renewal will be enhanced to deal with the specific requirements of the identified vulnerabilities.

Consider: If climate change was not happening, would these actions be beneficial? These may constitute "no regret" measures.

9.4.1 Leadership and Commitment

Successful implementation of climate impact assessment recommendations requires leadership and commitment by the organization. Leaders must be identified and tasked with the mandate to fulfill the objectives. Accountability and availability of resources are essential for adaptation actions to be effective An implementation plan is a critical part of delivering the resilience objectives. From ISO 14090-19, it should:

- *Have appropriate levels of organizational capability and resources to deliver climate change adaptation actions;*
- *embed climate change adaptation processes into its policies, strategies and processes, and operational activities;*
- *have a formalized organizational structure identifying roles and responsibilities in implementing climate change adaptation;*
- *have processes to reflect upon experiences gained during the implementation process and update the implementation plan as required;*
- *adapt to new opportunities for improved outputs including scalability of interventions;*
- *engage in timely dialogue with interested parties;*
- *have specified improvement objectives (incremental and/or transformation-based).*

One of the most important functions of project leads is to ensure that the recommended climate resilience measures and design solutions are not cancelled through any value engineering. Because the impacts of climate change are system wide, a change in a proposed system may require a complete re-assessment of the efficacy of the solutions, as well as knock-down or cascading effects on other systems.

9.4.2 Monitoring and Evaluation

Along with the implementation, each resilience plan should include a monitoring and evaluation plan that documents key objectives and projected performance while enabling the asset owner to track effectiveness of actions. For resilience efforts that require longer periods of time or that require consistent input, a monitoring and evaluation plan should include plans to verify the continued deployment and readiness of these efforts. Ongoing monitoring and evaluation programs also support knowledge transfer to the people that need to know what to do to implement (e.g., asset managers, operators) and maintain some of the dynamic resilience measures.

9.5 Note: Selecting Climate Experts

A climate resilience specialist can help navigate trade-offs and prevent maladaptation while providing the data necessary to make climate risk-informed decisions. The expert should have appreciable experience or credentials (e.g. Infrastructure Resilience Professional), documented success in applied projects, published reports (e.g., journals, white papers, or peer-reviewed literature), and/or active participation in committees (e.g., code development committees, climate committees).

As climate impacts cross multiple different building systems, a single discipline company may not be able to recognize improved solutions (e.g. mechanical engineering firms tend to see all climate problems as mechanical problems, for instance). A multi-disciplinary or building science company, those that specialize in understanding buildings as systems of systems, may better recognize the appropriate tools or approaches to achieve holistic solutions. Most importantly, a climate resilience specialist should be able to explain their rationale clearly to multi-disciplinary audiences at varying levels of technical ability.

Finally, look for an expert that has consistently worked towards climate solutions and that shares your commitment to climate action. Local governments and First Nations across Canada have used Social Procurement and Community Benefits models that ensure service providers share connected values in equity, diversity, reconciliation, sustainability, and climate action.

Part 3.2: Resilience in Action – Regulators

The last section described a process that governmental and regulatory bodies can follow to design and implement climate resilience measures for the buildings they own, operate, occupy, and depend upon to deliver services and fulfill their mandates. However, these same bodies have capacity through their procurement capacity and their enforcement and regulatory roles to shape the market and advance climate resilience on a larger scale.

In short, governmental and regulatory bodies can play an important role in guiding the building sector *as a whole* in a direction that better manages climate risk. While laws and regulations can limit the authority and domain of any one municipality, regulators, or government agencies, there are a range of opportunities available to encourage climate action. This section discusses some of the approaches of framing a new normal for climate resilient buildings.

10. Shaping Expectations

For government and regulatory bodies, including AHJ, that oversee and approve permits and drawings, it is possible to simply *expect* that climate change is addressed, for example, as an element of a permitting package.

> *"The standard of reasonable care is evolving with society's increased awareness and understanding of potential climate change impacts. It is reasonable to expect a professional to evaluate those potential impacts and address them in their professional work."*[16]

With the accepted recognition of the urgency to address climate change and the widespread availability of climate change guidance and data, professionals have an enhanced standard of care to respond to it. As such, it is *reasonable* to simply expect that all permitting packages include documents that outline what steps are taken to manage current and future climate impacts. This may be a document that provides future climate data, describes changes in historical hazards, or includes a climate change risk or vulnerability assessment (see earlier sections). It is also reasonable to reject any such packages that do not include such provisions.

Climate data and risk assessment guidance are readily available. For instance, Environment and Climate Change Canada's Climate Services portal (climatedata.ca)

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[16] Lewis, Randy. "Changing Climate, Changing Standard of Care?" AXA XL. January 15, 2019. https://axaxl.com/fast-fast-forward/articles/changing-climate_changing-standard-of-care.

provides the National Building Code of Canada (NBCC)'s Table C-2 data in their Future Values Summaries page. Developers and designers can download the appropriate file and follow the included guidance for their design (see References, Section 4.0 for a list of available data and guidance).

In areas with recognized current hazards (e.g. extreme precipitation, heat, winds), it is also reasonable to expect the designers to respond to requests related to steps taken in design to manage climate hazards over the service life of the building.

For government and regulatory bodies in a position to review or grant permitting on new buildings and retrofits, communicating and collaborating with service providers, designers and professionals how expectations are evolving can improve the standard on climate resilience.

11. Codes, Standards, and Regulations

Building codes and standards necessarily lag evolving industry needs. This is due to the criticality in ensuring that these codes and standards are appropriately developed and framed. Tension arises when the needs are immediate and the code cycles are prolonged. In the context of climate crisis and the building sector, the pace of change manifests in multiple ways: the climate conditions themselves are changing, the practice of climate risk management and designing for resilience is evolving, the availability of data and guidance is expanding, and technology and materials are progressing.

To shape market expectations, Step Code frameworks are an option. These frameworks are beneficial in that they indicate a future end-state and the pathway to achieve it. Laying out the pathway provides regulators an opportunity to ensure policy, codes, and standards are appropriately crafted at interim milestones. For practitioners and professionals in the sector, illustrating that desired end-goal for codes and standards can be helpful to prepare themselves for what to anticipate in the future. This is not necessarily limited to just building codes but could be adopted by 3rd party standards as well.

Make sure that you identify appropriate measures, but avoid GoodHart's Law: "When a measure becomes a target, it ceases to be a good measure"[17]

11.1 Enhanced Standards of Care

Professional associations, such as Engineers and Geoscientists BC, provide their members with practice guidance and advisories to consider the effects of climate change.

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[17] doi:10.1002/(SICI)1234-981X(199707)5:3<305::AID-EURO184>3.0.CO;2-4.

The NBCC is also explicit that considerations for a changing climate are required. As a result, building sector professionals are held to a higher standard of care. Engineers in particular are ready to deliver climate resilient buildings. Professional associations have also made clear that their members are responsible for consideration of climate change (see call-out box).

Engineers and Geoscientists BC: Registrants are expected to keep themselves informed about the changing climate and consider potential impacts on their professional activities

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Registrants have the potential to influence greenhouse gas emissions through their professional activities and are expected to consider the impact of their work on the climate.

"In Principles of Climate Adaptation and Mitigation for Engineers, Engineers Canada cautions that, "Changing climate conditions, particularly weather patterns that deviate from historical climate ranges, may adversely affect the integrity of the design, operation, and management of engineered systems. It is the engineer's duty to take all reasonable measures to ensure that those systems appropriately anticipate the impact of changing climate conditions."[18]

In parallel to the expansion of accessible climate data, risk guidelines, and updated codes, building sector professionals and practitioners have access to a variety of professional development, training and credentialling opportunities.[19] From online webinars to post-graduate programs, practitioners can find and participate in climate-focused training to help them build the skills and competencies[20] needed to participate actively in addressing the climate crisis. Because this training is available, it is reasonable to expect that engineers and other building professionals integrate climate change considerations as part of their design. Intentions to exclude climate effects should be followed with explicit written statements as to why climate change impacts, both direct and indirect, are excluded.

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[18] Lewis, Randy. "Changing Climate, Changing Standard of Care?" AXA XL. January 15, 2019. https://axaxl.com/fast-fast-forward/articles/changing-climate_changing-standard-of-care.

[19] The Infrastructure Resilience Professional (IRP) program is one example of a program designed by and for infrastructure professional and engineers. Infrastructure Resilience Professional (IRP) Credentialling Program – Climate Risk Institute

[20] Climate Action Competency Framework. Climate Action Competency Framework | Royal Roads University

> “Given knowledge of climate change effects in a geographic area as a result of the proliferation of climate-related information and projection models, if the “standard practice” at the time of designing a specific type of infrastructure project is to ignore potential climate-change effects (despite widely available evidence), the standard practice itself may be negligent. Adhering to a deficient standard would be a breach of a design professional’s standard of care" - Patricia Koval, LLP, a partner in Torys’ Corporate Group[21]

11.2 Final Remarks

Government and regulatory bodies can play a pivotal role in steering the building sector toward greater climate resilience by setting expectations and by adopting and enforcing forward-looking codes and standards. For building sector professionals, regulatory bodies are pointing to enhanced standards of care and directing their members to consider and respond to the climate crisis.

By integrating the climate projections into all aspects of the building sector – including as early as design and permitting – government bodies, regulators and practitioners can ensure that new construction and retrofits are better equipped to withstand extreme weather, reduce emissions, and promote sustainability. A comprehensive approach to climate resilient buildings not only safeguards communities, infrastructure and services but will also drive innovation and accountability across the industry. In doing so, regulatory agencies become catalysts for a more adaptive, resilient, and climate-conscious built environment.

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[21] https://www.peo.on.ca/sites/default/files/2021-05/ED-JF2013-PP.pdf

Part 4: Resources

12. Climate Data Sources

Climate scientists have developed multiple climate data sets devised to assist in climate adaptive design. All design and simulations should be using future climate adjusted data as inputs. Should designers have difficulties finding such data sets, the following provide a comprehensive list of data sets, files, and formats that can be used to ensure buildings are, at the very least, designed to withstand anticipated future climate conditions.

- **Future Value Summaries:** ClimateData.ca now offers one-page summaries with future climate-adjusted building design values for over 660 Canadian locations.
- **Canadian Weather Energy and Engineering Datasets (CWEEDS):** Canadian Weather Energy and Engineering Data Sets are quality-checked historical hourly weather records from Canadian stations, used as the basis for building energy simulations and for creating CWEC "typical year" files.
- **Canadian Weather Year For Energy Calculation (CWEC):** A Canadian Weather Year for Energy Calculation file is a standardized dataset that provides hourly weather conditions for a typical (average) year in Canadian locations to support building energy modeling and design.
- **Hygrothermal database of building materials (HygDbM):** The Hygrothermal database of building materials (HygDbM) provides data on the hygrothermal properties of 34 commonly used building materials in Canada to support hygrothermal and energy modeling.
- **Design Value Explorer (DVE):** The Design Value Explorer is a tool for professionals using the National Building Code of Canada or the Canadian Highway Bridge Design Code, offering advisory climate data and projections. Developed with federal partners, it also provides historical climate extremes, though its information is not yet officially included in the codes.
- **Climate Data:** ClimateData.ca addresses this need by providing free, accessible historical and future climate data to support adaptation planning, helping Canadians make informed, confident decisions.
- **Climate Atlas:** The Climate Atlas of Canada is an interactive tool that combines climate science, mapping, and storytelling to make climate change understandable and relevant to Canadians, supporting informed action at all levels. By integrating scientific data with personal stories and Indigenous

knowledge, the Atlas offers accessible, localized insights and continues to evolve to better support education and decision-making.

- **Uncertainty in Climate Projections**: Adapting to a changing climate requires confronting and dealing effectively with a wide range of uncertainties. ClimateData.ca breaks down the three main sources of uncertainty in climate projection.
- **Typical Meteorological Year (TMY) data** is a synthesized weather file that combines long-term historical records into one "average" year, representing typical climate conditions for energy modeling and design.
- **Actual Meteorological Year (AMY)** data is a weather dataset that contains the real, measured hourly conditions for a specific year at a given location, used to analyze building performance under actual climate conditions.
- **EnergyPlus Weather (EPW)** is a standardized weather data format that provides hourly climate information for a location, used in building energy simulations and design software.

13. Climate Resilience Resources

A wide variety of guidelines, references and resources are available to support climate change adaptation and resilience in the building sector. The following set of resources can support planning, design, and implementation of climate resilience measures in practice.

13.1.1 General Resilience

- **Realizing Resilient Buildings in B.C. A toolkit for local governments** (BC Housing, 2024)
- **Climate Change Resilience for Buildings Primer** (RDH Building Science Inc., 2021)
- **Building Sustainability & Resilience Guide** (ASHRAE BC, 2022)
- **Resilient Retrofits Climate Upgrades for Existing Buildings** (Urban Land Institute, 2022)
- **Chapter 9: Buildings** In IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. (IPCC, 2022)
- **Global Building Resilience Guidelines: Guidelines for Resilient Buildings** **(**Global Resiliency Dialogue, 2022)
- **A Practical Guide to Climate-resilient Buildings & Communities** (UNEP, 2021)

- **Incorporating Climate Change Considerations for Project Scoping and Procurement** (ACEC-BC Sustainability and Climate Change Committee, 2024)

13.1.2 Flood Resilience

- **Ahead of the Storm: Developing Flood-Resilience Guidance for Canada's Commercial Real Estate** (Intact Centre on Climate Adaptation, University of Waterloo, 2019)
- **Coastal flood risk assessment guidelines for building and infrastructure design: supporting flood resilience on Canada's coasts** (National Research Council of Canada, 2020)

13.1.3 Resilience Planning and Design

- **Climate Resilience Guidelines for BC Health Facility Planning & Design** (BC Green Care, 2024)
- **Building Design Strategies for Future Climate** (UBC Sustainability Initiative, 2020)
- **Primer: Resilient Buildings Planning Worksheet** (City of Vancouver, 2023)
- **Guidance on Using Future Climate Data for Building Performance Simulation** (ClimateData.ca, n.d.)

13.1.4 Overheating Resilience

- **Climate Resilience Buildings: Guideline for management of overheating risk in residential buildings** (National Resource Council of Canada, 2022)
- **Thermal Resilience Design Guide** (University of Toronto John H. Daniels Faculty of Architecture, 2019)