STANDARDS RESEARCH

Climate Adaptation and Resilience in Commercial Real Estate

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Authors

Alanna Komisar, MEng, BASc, CEM, Mantle Developments

Michael Chen, MGA, BA, Mantle Developments

Ryan Zizzo, MASc, LEED AP ND, Mantle Developments

Project Advisory Panel

Bala Gnanam, BOMA Canada

Claudia Verno, JLL

Darryl Neate, REALPAC

Hazel Sutton, JLL

Michael Brooks, REALPAC

Peter Kennedy, Aon

Victoria Papp, BOMA Canada

Jennifer Teague, CSA Group

Priya Patel, CSA Group

Scott Grant, CSA Group (Project Manager)

Vanessa Mitchell, CSA Group

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Glossary

This glossary is derived from *Changing Climate, Changing Communities* [1], unless otherwise stated.

Adaptation: Any initiative or action in response to actual or projected climate change impacts that reduces the effects of climate change on built, natural and social systems.

Adaptive capacity: The ability of built, natural and social systems to adjust to climate change (including climate variability and extremes), moderate potential damages, take advantage of opportunities or cope with the consequences.

Climate: The weather of a place averaged over a period of time, often 30 years. Climate information includes the statistical weather information that tells us about normal weather, as well as the range of weather extremes for a location.

Climate adaptation: A process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm, or exploit beneficial opportunities. In some natural systems, human intervention can facilitate adjustment to an expected climate and its effects [2].

Climate change: Changes in long-term weather patterns caused by natural phenomena and human activities that alter the chemical composition of the atmosphere through the buildup of greenhouse gases, which trap heat and reflect it back to the earth's surface.

Climate change mitigation: A human intervention to reduce emissions or enhance the sinks of greenhouse gases [2].

Climate exposure: The presence of people, livelihoods, species or ecosystems in places and settings that may be affected by climate change [2].

Climate projections: Projections of the response of the climate system to emissions or concentration scenarios of greenhouse gases and aerosols. Climate projections are subject to uncertainty, as they depend upon the climate change or emission scenarios used, which are based on assumptions concerning future socioeconomic and technological developments that may or may not be realized.

Consequence: Something that occurs as a result of a given climate impact, such as basement damage from flooding, increases in respiratory illnesses from heat or damage to buildings.

Exposure: The presence of people, livelihoods, species or ecosystems in places and settings that may be affected by climate change.

Extreme weather event: A meteorological event that is rare at a specific place and time of year, such as an intense storm, tornado, hailstorm, flood or heat wave, and is beyond the normal range of activity. An extreme weather event would normally occur very rarely or fall into the 10th percentile of probability.

Global Real Estate Sustainability Benchmark (GRESB): A mission-driven and investor-led organization that provides actionable and transparent environmental, social and governance (ESG) data to financial markets [3].

Hazard: A biophysical event, such as drought, rain or wind, that could cause potential impacts.

Impacts: The effects of existing or forecast changes in climate on built, natural and human systems, including on lives, livelihoods, human health, ecosystems, economies, societies, cultures, services and infrastructure. There is a distinction between “potential” impacts of climate change, which may occur without considering adaptation, and “residual” impacts, which would occur after adaptation.

Likelihood: The probability of an event, such as a hazard or impact, occurring.

Operational resilience: The essential ability of an operation to respond to, and absorb the effects of, shocks and stresses, and to recover as rapidly as possible to normal capacity and efficiency [4].

Physical risks: Risks from a climatic event. Physical climate risks are either acute or chronic. Acute risks are specific events such as floods, extreme precipitation and wildfires. Chronic risks are longer term changes, such as droughts, rising temperatures and humidity levels, sea-level rise, precipitation changes over time, the expansion of tropical pests and diseases into temperate zones, and an accelerating loss of biodiversity [2].

Representative Concentration Pathways: A greenhouse gas concentration trajectory adopted by the UN’s Intergovernmental Panel on Climate Change (IPCC).

Resilience: The capacity of a system, community or society exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure.

Resilience (infrastructure): The ability to absorb, adapt to, or rapidly recover from, a potentially disruptive event [5].

Risk: The combination of the likelihood of an event occurring and its negative consequences. Risk can be expressed as a function where risk = likelihood × consequence. In this case, “likelihood” refers to the probability of a projected impact occurring, and “consequence” refers to the known or estimated outcomes of a particular climate change impact.

Risk assessment: Assesses the vulnerabilities, exposure and climate change hazards and their likelihoods and consequences. Risk assessment is one of the key stages of risk management.

Risk management: A systematic approach to selecting the best course of action in uncertain situations by identifying, assessing, acting on, and communicating risk issues.

Sensitivity: Measures the degree to which the community will be affected when exposed to a climate-related impact. Sensitivity reflects the ability of a given system or jurisdiction to function normally when an impact occurs.

Transitional risk: Transitional risks are business-related risks that follow societal and economic shifts toward a low-carbon and more climate-friendly future. These risks can include policy and regulatory risks, technological risks, market risks, reputational risks and legal risks. These risks are interconnected and often top of mind for investors, as they attempt to navigate an increasingly aggressive low-carbon agenda that can create capital and operational consequences for their assets [3].

Taskforce on Climate-Related Financial Disclosures (TCFD): The TCFD is a framework to help public companies and other organizations more effectively disclose climate-related risks and opportunities through their existing reporting processes [6].

Vulnerability: The degree to which a system or jurisdiction is susceptible to harm arising from climate change impacts. It is a function of a community's sensitivity to climate change and its capacity to adapt to climate change impacts.

Weather: The day-to-day state of the atmosphere, and its short-term variation in minutes to weeks.

Wildland-urban interface (WUI): The WUI is the zone of transition between unoccupied land and human development. It is the line, area or zone where structures and other human development meet or intermingle with undeveloped wildland or vegetative fuels [7].

Executive Summary

The increasing frequency and severity of devastating climate events requires an urgent reassessment of climate risk and adoption of climate adaptation measures, including for the commercial real estate (CRE) sector.

Climate-related disruptions to the CRE sector are projected to rise, resulting in major asset losses and significant social impacts.

For example, following the 2013 floods in Alberta, more than 150,000 people could not access their office space in downtown Calgary for approximately two weeks. This disruption translated to the loss of approximately 5.1 million work hours and $500 million dollars in GDP [8]. These estimates do not include other related costs, such as the impact on local real estate investments, the cost of damages, potential lawsuits, insurance ratings, credit ratings, and the distress caused to disrupted tenants and the broader community.

The CRE sector is determined to address these risks through climate adaptation planning. This is motivated by many factors, including business continuity, support of tenants, protection of future and current investments and long-term value, and alignment with environmental, social and governance (ESG) disclosure frameworks and evolving best practice.

Extensive resources exist to support climate adaptation for municipalities, communities and critical infrastructure. Yet, there remains little comprehensive technical content addressing adaptation specifically for the CRE sector in Canada.

This report aims to help fill that gap. It includes a literature review of available resources, a gap analysis, and recommendations on how to support climate adaptation and resilience for CRE. A summary of those recommendations are listed below:

- Consider the development of a CRE-specific toolkit to support climate adaptation and resilience planning. Toolkits should highlight relevant climate data, and include resources for both asset-based and capabilities-based approaches, such as climate risk assessments and hazard-specific guidelines.
- Develop and share resources to address barriers and support enabling factors. These resources can include guidelines for business case creation, opportunities for adaptation and mitigation co-benefits, and relevant disclosure frameworks.
- Conduct further research on the identified gaps. This study was limited to a desktop literature review, so additional gaps may be filled by interviewing risk practitioners, academics, researchers, CRE organizations, builders, trades and tenants. Getting wide representation from different communities across Canada and internationally would provide further insight.

"Climate change has contributed to a significant rise in asset damages and operational downtime, with the 10 most damaging events in recent Canadian history attributed to extreme weather events."

1 Introduction

Over the past four decades, the costs in damages from climate related events have been steeply increasing. Between 1983 and 2008, the average catastrophic insurable losses in Canada were $400 million annually. From 2009 to 2013, this figure more than quadrupled. Most recent figures show that from 2014 to 2020 the amount rose to nearly $2 billion annually [9].

In a global context, the United Nations Framework Convention on Climate Change (UNFCCC) reported that within the next 50 years, approximately US$35 trillion in global real estate assets are expected to be exposed to climate risk [10].

Climate change has contributed to a significant rise in asset damages and operational downtime, with the 10 most damaging events in recent Canadian history attributed to extreme weather events [11]. This underscores the urgency to identify climate risks and adopt climate adaptation measures to help mitigate the impacts of increasing frequency and severity of climate events.

The Government of Canada is leading the Climate-Resilient Building and Core Public Infrastructure Initiative to support climate adaptation in Canada. One of its many pillars is to support climate adaptation revisions to Canadian building and infrastructure codes and standards. Commercial real estate (CRE) is covered under Part 3 buildings of the National Building Code of Canada (NBC), which is primarily focused on new construction.

However, Canada's CRE sector also requires clear guidance on how to protect existing assets and incorporate climate adaptation and resilience strategies into their overall operations. This is especially important since the life of modern commercial buildings is roughly 60 years [12]. Most CRE buildings were designed and constructed using past climate data, and may not be well-equipped to deal with current and future climate risks.

To help protect existing assets and operations against future climate events, new climate adaptation and resilience strategies must be considered. This includes updating resources such as guidelines, codes and standards that consider climate risks for both new construction and retrofits, and for overall operations.

To support the CRE sector, the objectives of this study are to identify and review:

- Guidance, frameworks, protocols, tools, academic publications, industry publications and other essential resources for conducting climate-risk assessments
- Best practices for climate resilience measures for the CRE sector
- Existing codes and standards in Canada and abroad that are relevant to climate resilience in CRE
- Potential opportunities where standardization could support climate resilience in CRE

2 Methods

This study was conducted as a desktop literature review. Content specifically related to climate adaptation in the CRE sector was sparse, so general resources on infrastructure climate adaptation were included. When conducting a deeper analysis on climate-risk assessments, the study used reputable sources from academia, industry and other standards associations.

Variations of search terms such as adaptation, resilience, buildings, commercial real estate, hazards, physical risks, risk management and vulnerability assessments were used to find resources about climate adaptation and CRE. For the purpose of this study, CRE was defined as property intended to generate profit for either capital gains or rental income, and was considered synonymous with the terms "commercial buildings" and "commercial assets" [13].

The research heavily focused on a Canadian context, but international markets, including British, European and American markets, were also examined. In total, 130 potential resources were identified and sorted, with the most relevant content reviewed. This included written and published content from the following sources:

- Commercial real estate organizations, including developers, asset managers, investors and real estate associations
- Governments of various levels, including municipal, provincial, and national governments
- Peer-reviewed literature
- Resilience and risk management practitioners working in the field
- Non-governmental and intergovernmental organizations

3 Literature Review

3.1 Existing Guidance and Resources

There are many codes, standards, guidelines and reporting frameworks relevant to climate adaptation for CRE.

The Government of Canada has ongoing initiatives to incorporate considerations for climate adaptation into building codes [14]. Existing and upcoming standards from a variety of sources address some elements of climate adaptation and resilience. These include the International Organization for Standardization (ISO), ASTM International, British Standards Institution (BSI), Canadian Standards Association (CSA), American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE), and FM Global.

Guidelines related to climate adaptation for CRE have been released from sources such as the Building Owners and Managers Association (BOMA), the Intact Centre on Climate Adaptation (ICCA), Engineers Canada with the Institute of Catastrophic Loss Reduction (ICLR), the Urban Land Institute (ULI), and some municipalities such as the City of Boston. The rise of frameworks such as the Task Force on Climate-Related Financial Disclosures (TCFD) has also added to the number of relevant resources.

3.1.1 Codes

Canadian building codes impact new construction and deep retrofit projects, but often do not apply to older buildings. In a presentation delivered by the ULI in July 2022 [15], a forest fire expert expressed concerns for buildings in their jurisdiction constructed before 2010. Since fire resilience guidance and codes were only ratified in 2010, buildings constructed prior to this had increased wildfire risk.

Under the NBC, the CRE sector aligns with guidance categorized for Part 3 buildings[1].

1 Part 3 buildings are buildings classified as Group A, B or F-1, which exceed 600 m^2 in building area or exceed three stories in building height and have major occupancies. It also includes Group C (residential), Group D (office/service), Group E (retail) and Group F-2, F-3 (medium- and high-hazard industrial) buildings.

Applicable codes for the CRE sector include the NBC, the National Energy Code for Buildings (NECB) and the National Fire Code (NFC), all of which are updated on a five-year cycle. Statistical climate factors such as long-term averages, temperature extremes, rain volume and intensity, and maximum wind gusts are revaluated in each cycle.

Building codes reflect the minimum acceptable design the construction industry must meet. However, there are code-based tools to support even higher performance. The National Master Specification (NMS) is a framework developed by the National Research Council of Canada (NRC) to support construction specifications. Though the NMS is not a code, it offers guidance to specification writers on sustainable and resilient practices relating to the NBC. In the 2022–2024 version of the NMS, over 300 updates were included to support developers in creating net-zero and resilient buildings [16]. Although there is no "resilient and net-zero building" code or standard for Canada, the NMS provides a framework for specification writers to develop adaptation and resilience criteria as project requirements aligned with the NBC.

While the NBC, NECB and NFC set out minimum national criteria for buildings, building to these codes does not guarantee that a site has been constructed to safeguard against all climate hazards. Some provincial and municipal jurisdictions will adjust for local circumstances [17], for example, using more stringent approaches where needed. And despite ongoing updates to national climate data from the federal government, jurisdictions may also need to incorporate local climate data, such as local rainfall levels, to determine their own specific climate hazards [18].

International bodies such as the European Union [19] and the United States [20] are also launching initiatives to update the climate data that informs the development of codes. Additionally, the US Federal Emergency Management Agency (FEMA) has set a priority to update America's flood maps [20].

3.1.2 Standards

There is a growing body of standards for climate adaptation and climate-related hazards. Standards have been a mechanism of choice for infrastructure-related climate adaptation strategies. The literature review revealed several standards that focus on climate impact, vulnerabilities and risk assessments. These are shown in Table 1. Table 2 explores standards on implementation support.

These tables highlight the resources for climate adaptation with applicable guidance for CRE buildings, but many resources are directed at a broader audience and for public infrastructure.

Table 1: Standards Relevant to Climate Impact, Vulnerability, and Risk Assessments

Standard	Standard Title	Description
ISO 14090 [21]	Adaptation to climate change – Principles, requirements and guidelines	This international standard specifies principles, requirements, and guidelines for adaptation to climate change. Its scope is described as "the integration of adaptation within or across organizations, understanding impacts and uncertainties and how these can be used to inform decisions. "This document is applicable to any organization, regardless of size, type and nature, e.g. local, regional, international, business units, conglomerates, industrial sectors and natural resource management units. This document can support the development of sector-, aspect- or element-specific climate change adaptation standards."
ISO 14091 [22]	Adaptation to climate change – Guidelines on vulnerability, impacts and risk assessment	An assessment-specific guideline for infrastructure and building-related projects. Though classified as a standard, this document provides guidelines for assessing climate risk and addressing vulnerabilities.

Standard	Standard Title	Description
ISO 14092 [23]	Adaptation to climate change – Requirements and guidance on adaptation planning for local governments and communities	More relevant to governments and communities, but can offer some context when engaging in stakeholder-related activities.
BS 8631 [24]	Adaptation to climate change – Using adaptation pathways for decision making	This is a standard that supports climate-related scenario planning using pathway analysis.
ASTM E3032 [25]	Standard Guide for Climate Resiliency and Planning	The guide states that its "primary purpose is to reduce negative economic impacts associated with extreme weather. This guide presents a generalized, systematic approach to voluntary assessment and risk management of extreme climate related events and conditions."
ASTM WK62996 [26]	New Guide for Property Resilience Assessment	This standard guide is currently under development. The guide will describe the process of conducting a property resilience assessment, including identifying which climate-related natural hazards may affect a building and how to enhance its performance. The standard is broken into three phases – understanding the hazards, understanding the vulnerabilities, and incorporating adaptation measures.
ISO 31000 [27]	Risk management	This common risk management standard framework is not specifically for climate change. However, it is discussed in the PIEVC protocol (Section 3.1.3), a widely adopted climate resilience framework developed by Engineers Canada and the ICLR. It is also used to comply with Infrastructure Canada's Climate Lens Framework.

Table 2: Standards for Climate Adaptation Measure Implementation and Supporting Analysis

Standard	Standard Title	Description
ISO 14090 [21]	Guideline on Durability in Buildings	This standard identifies practices to increase the durability of buildings. Though not explicitly for climate change, there is a section that discusses its impacts on durability and addresses the degradation of building materials. Practices from this standard may be used to address building degradation for chronic climate risks.
ASHRAE 90.1 [29]	Energy Standard for Buildings Except Low-Rise Residential Buildings	This is a widely referenced energy standard for commercial buildings. Elements are incorporated into Canadian energy codes and voluntary programs such as LEED.
FM Global Data Sheets [30]	Property Loss Prevention Data Sheets: 9-19 Wildland Fire 9-18 Prevention of Freeze Ups 1-40 Flood 1-28 Wind Design	These standards were created by the insurance company FM Global. They provide guidance for climate hazards, including extreme weather events. These documents are specifically meant for industrial and commercial real estate. Asset-level guidance is also provided for several critical systems, such as, boilers and mechanical equipment.

3.1.3 Guidelines, Toolkits and Frameworks

Support for climate adaptation and resilience is often presented in the form of technical guidelines, toolkits and frameworks. In early research conducted by BOMA, it was shown that technical guidelines were frequently used to address climate risks, as many factors are site specific, including the building and business owners' specific tolerance to risk [4]. It was determined that overly prescriptive guidance can create a false sense of security and lead to blind spots if deeper analysis at the site level is not conducted. The reasoning was that a key resource on best practices cannot replace conducting a thorough risk analysis of the site to identify a potential solution [4]. Even the climate adaptation standard ISO 14091 refers to itself as a guideline within the document [22].

There are many guidance documents that focus on climate risk assessments [23] [31] [32] [33] [34], but they have a focus on either general infrastructure projects or public infrastructure, rather than CRE and buildings. International resources for general climate risk assessments were identified, but there was little specifically for CRE. These resources and guidelines include from the EU [31], Australia [35], New Zealand [36], Southern Africa [37] and the US [38]. A conference paper from Australia noted that as of 2018, no specific tools for climate risk assessments in CRE have been identified [28].

The most relevant technical guidelines for CRE have been identified in Table 3. Almost all of them were released in mid-2018 or later.

Toolkits (or toolboxes) were a common way to provide guidelines and templates to begin climate adaptation and resilience assessments and planning. A particular advantage of a toolkit is that resources are constantly emerging and can be added. Though science-based technical guidance often moves slowly, the definition of best practice is constantly being updated as new information, technologies, tools and climate data emerge. Some existing toolkits are identified in Table 4. Though most of these toolkits are meant for a broad audience, some of them provide offerings specific to CRE buildings. Each toolkit provides a combination of resources, such as technical guides, reports, backgrounders, case studies and templates. The study did not reveal a toolkit specifically for the Canadian CRE sector.

As of December 2022, there was a greater abundance of resources for municipal governments and critical infrastructure, than for CRE. As such, the CRE sector has adopted flexible frameworks for their climate risk assessments. The most widely recognized and adopted is the Canadian framework developed by Engineers Canada and Natural Resources Canada (NRCan) [33] called the Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol. The Protocol was assumed by the Institute of Catastrophic Loss Reduction (ICLR), the Climate Risk Institute (CRI) and the Deutsche Gesellschafts fur Internationale Zusammenarbeit (GIZ) in 2020.

The PIEVC Protocol was initially developed for public infrastructure, such as municipal wastewater systems, but their website highlights cases where it has been applied to commercial buildings. PIEVC training is accessible to Canadians through courses and webinars offered by the CRI and supported by federal programs [49]. The PIEVC Protocol began development in 2005 and was first released in 2012, with numerous revisions since its initial edition. The PIEVC Protocol has been used extensively in commercial real estate applications, as well as projects across Canada, Costa Rica, Honduras, Brazil, Vietnam and the Nile Basin [50].

3.1.4 Voluntary Frameworks

Voluntary reporting frameworks have supported a broader discussion about achieving "better than code" performance in CRE. Although the focus has been on climate mitigation through energy efficiency, similar voluntary action may be achievable to increase climate resilience against physical risks. Although building-level credit systems for resilience, such as RELi, are available, greater traction has been established by commercial climate-related and ESG reporting. Some sources [4] argue that scorecard-type systems like RELi can lead to false climate-risk reduction, and further gathering of evidence is required beyond these scorecards.

Table 3: Guidelines Specifically for Commercial Real Estate

Document Names	Author & Contributors	Organization Types	Description
Resilience in the Commercial Real Estate Industry (Canada) [4]	BOMA Canada (CRCI[2], University of Toronto, Southern Harbour Consulting, HIDI Group, Zurich Insurance, GDI Ainsworth, Studio Intersek)	Academic institution, resilience and adaptation practitioners, CRE association, insurance, engineering and consulting firms	Offers practical guidance for operations managers. Connects data collection practices for operational management and efficiency, with corporate portfolio risk management for climate change and other trends.
2019 BOMA Resilience Guide (Canada) [39]	BOMA Canada	CRE association, with contributions from the CRE industry	This guide helps building owners and managers consider resilience and the potential risks imposed by extreme events.
Ahead of The Storm: Developing Flood-Resilience Guidance for Canada's Commercial Real Estate (Canada) [40]	Intact Centre on Climate Adaptation, The University of Waterloo REALPAC[3] , BOMA Canada	Research centre, academic institution, CRE association, real estate corporation	This report provides guidelines on improving flood resilience for commercial buildings.
Climate Resilience Strategies for Buildings in New York State (US) [41]	State University of New York at Buffalo, New York State Energy Research and Development Authority	Academic institution and state government	This report uses specific information from strategy documents to provide more general descriptions of climate resilience strategies.
Building Resilience in Boston (US) [42]	City of Boston, Boston Society of Architects, Linnean Solutions, Built Environment Coalition, The Resilient Design Institute	Municipal government, architectural society, resilience practitioners, research institutions	The scope of this report includes a review of national and international programs, initiatives and activities related to improving the resilience of existing buildings.
Resilient Retrofits: Climate Upgrades for Existing Buildings [43]	Urban Land Institute	CRE association	This report presents the real estate sector with information about preparing existing buildings for climate risks, including extreme temperatures, floods, storms and high winds, earthquakes, drought and wildfires.
REALPAC Climate Risk Assessment Backgrounder (Canada) [44]	REALPAC	CRE organization	This provides a background on climate risk assessments for commercial real estate organizations.

2 Centre for Resilience of Critical Infrastructure

3 Real Property Association of Canada

Table 4: Climate Resilience and Adaptation Toolkits

Title	Organization Type	Audience
US Climate Resilience Toolkit [38]	Federal government	All infrastructure
The Cost of Doing Nothing Toolbox by ICLEI[4] [45]	Non-profit	Canadian municipalities
City of Boston's Climate Resilience Toolkit [46]	Municipal government	Buildings in Boston
FM Global Natural Hazard Toolkit [47]	Insurance company	Industrial and commercial real estate
FCM[5] Resources [48]	Non-profit	Canadian municipalities

ESG reporting has been a mechanism to help corporations establish their climate-related baselines and determine a course of action to address physical climate risk. Disclosure of climate-related risks is an important part of ESG reporting. Frameworks such as the TCFD and the Global Real Estate Sustainability Benchmark (GRESB) can disclose climate risks and uncover opportunities to address these risks.

These frameworks describe two forms of risk – transitional and physical. The content available for CRE to address climate risk has historically emphasized transitional risks (business, societal and economic shifts to a low carbon-future) and climate mitigation strategies. Strategies to address the physical risks from climate-related hazards are less understood.

As of December 2022, frameworks like the TCFD and GRESB have been widely adopted in Canada, but remain voluntary. This may soon change. In April 2022, the United Kingdom (UK) became the first country to introduce mandatory climate disclosure in financial reporting for public entities, and some larger private financial institutions and investors [51]. The UK's mandatory disclosure framework is in alignment with established frameworks such as the TCFD.

Other countries, such as Japan, New Zealand and Switzerland, anticipate making similar climate-related financial disclosures mandatory for some organizations by 2025 [52]. Some North American real estate corporations have been encouraged to align with the TCFD and mitigate their own transitional risk, especially if they have UK-based divisions or partners [53]. Discussions are ongoing on whether Canada will follow [54].

The TCFD is one of many levers that encourages the CRE sector to consider physical risk reporting, and supports discussions on climate resilience and adaptation. Climate resilience methodologies and solutions have been rooted in risk management, with climate hazards a focal point for risk managers and operations managers. The growing presence of ESG reporting, however, now allows a broader diversity of stakeholders, such as investors and dedicated climate change specialists, to use a common language and framework when discussing climate resilience and adaptation.

The rise of ESG reporting and, more specifically, disclosure frameworks, have influenced the release of numerous reports on climate risk for CRE. These reports are typically high-level and have a focus on transitional risk and climate mitigation activities. Technical guidance on climate adaptation, on the other hand, remains sparse, particularly with respect to CRE-specific and peer-reviewed content written by physical risk practitioners. Practitioner-developed content that is also peer reviewed is more frequently written for a broader audience and public infrastructure. While guidance for CRE is beginning to emerge, it may not be peer

4 International Council for Environmental Initiatives

5 Federation of Canadian Municipalities

"Resilience reflects how the operation of a system could fail safely, absorb adverse impacts and enable efficient recovery."

reviewed or vetted by academics, as CRE guidance is generally not held to the same publishing standards. This can create confusion in the marketplace.

Some members of the CRE sector have voiced frustration over a perceived lack of consistent methodologies by climate adaptation practitioners, even in widely adopted frameworks [53] [44]. Practitioners point out that the process is non-linear, iterative and dependent on the site. In addition, tolerance to risk by a building owner or tenant is subjective and relies on individual judgement [33] [4].

3.1.5 Climate Data Sources

Identifying relevant climate hazards depends on the availability of climate data. Some of the primary sources of information to consider for a site can be found from the following public resources:

- Canadian natural hazard data can be accessed through NRCan. This data can be pulled from the federal government's open data portal [55].
- Jurisdictional climate assessments may offer an overview of hazards that a site should consider. Often these are found at the provincial level. Climate risk assessments need to be done at a site level to assess their vulnerabilities, but a provincial study may offer initial insight on which hazards to consider.
- Flood mapping in Canada is usually managed by the provinces, but sometimes by local authorities. For example, in Ontario, flood maps are managed by local conservation authorities [56].

As responsibilities for flood mapping are distributed across jurisdictions, data quality, access and usability can vary tremendously between provinces. Flood mapping guidelines from the federal government exist, but it is unclear if they are enforced [57].

3.2 Definitions and Approaches

3.2.1 Adaptation and Resilience Definitions

Though the words "adaptation" and "resilience" are often discussed interchangeably and share some overlap, the two terms are not entirely synonymous. These definitions often vary by source to align with their specific context. Table 5 highlights various definitions of "adaptation" in a climate context. Across the definitions, the recurring theme is that adaptation focuses on moderating harm, sheltering negative impacts and exploiting beneficial opportunities. In the context of the CRE sector, the goal of adaptation is avoiding harm to the core building components to help protect the system.

In contrast, the definitions of "resilience" discuss how a system would cope, absorb and recover from hazards in a changing environment. Rather than avoiding harm, resilience considers how a system can recover, and considers that it may even fail. Resilience reflects how the operation of a system could fail safely, absorb adverse impacts and enable efficient recovery [4].

It is notable that ISO does not refer to its 14090 in terms of resilience, but rather climate adaptation. Of the existing ISO series, resilience is only discussed in an organizational context.

Table 5: Definitions of Adaptation

Document Names	Author & Contributors
UNEP/IPCC [2]	"Adaptation in ecological systems includes autonomous adjustments through ecological and evolutionary processes. In human systems, adaptation can be anticipatory or reactive, as well as incremental and/or transformational. **The latter changes the fundamental attributes of a social-ecological system in anticipation of climate change and its impacts.** Adaptation is subject to hard and soft limits."
CRCI (UofT)	Not defined in document.
ISO [23]	"The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to **moderate or avoid harm or exploit beneficial capabilities.** In natural systems, human intervention can facilitate adjustment to expected climate and its effects."
PIEVC [33]	"Adaptation is an adjustment in natural or human systems in response to actual or expected climatic changes, which **moderates harm or exploits beneficial opportunities."**

Table 6: Definitions of Resilience

Document Names	Author & Contributors
UNEP/IPCC [2]	"The capacity of social, economic, and environmental systems to **cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function,** identity and structure. Resilience is a positive attribute when it maintains capacity for adaptation, learning and/or transformation."
CRCI (UofT) – (Operational Resilience) [4]	"The essential ability of an **operation to respond to and absorb the effects** of shocks and stresses and to recover as rapidly as possible to normal capacity and efficiency."
ISO – (Organizational Resilience) [58]	"The ability of an organization to **absorb and adapt** to a changing environment."
PIEVC [33]	"Resilience is defined as the **ability of a system,** community or society exposed to hazards to resist, **absorb, accommodate to and recover from** the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions."

3.2.2 Approaches to Climate Adaptation and Resilience

There are two primary peer-reviewed approaches for climate adaptation and resilience in buildings and infrastructure. The first is an asset-based approach and the second is a systems-based approach, often called a capacity-based approach [5]. The literature refers to the intent of a capacity-based approach as operational resilience. The two approaches – asset-based and capacity-based – are not necessarily independent of one another.

3.2.2.1 Asset-Based Approaches

An asset-based approach to climate risk evaluates the infrastructure as the sum of its parts to withstand a climate event. The building or infrastructure is broken down into components. Each component has a threshold for withstanding each relevant climate risk, after which it fails. The infrastructure's tolerance to a climate threat is determined as the sum of its components' abilities to stay within its threshold. Risk treatments are applied to expand the threshold of different components.

When creating a loss scenario for a business case for climate adaptation, an asset-based approach prioritizes calculating damages to specific assets and the cost to replace them [5].

Asset-based approaches are more aligned with the definition of climate adaptation than resilience, and do not necessarily include an evaluation of the system's recovery.

3.2.2.2 Capacity-Based Approaches

Capacity-based approaches to climate risk evaluate a business's operational capacity and business continuity in response to climate events. Capacity-based approaches are systems-based approaches. They are built on the premise that any event that could render a building inoperable for any period would jeopardize the commercial purpose of the building [4].

When communicating the damages caused by a climate event, a capacity-based approach will calculate losses in the form of downtime and identify the strategies needed for the operation's recovery. With this approach, risk treatments prioritize assets that support business continuity, with these strategies often referred to as operational resilience.

3.2.3 Climate Hazards and Risk

The effectiveness of a resilient infrastructure or enterprise depends upon its ability to anticipate, absorb, adapt to and rapidly recover from a potentially disruptive event or "hazard" [59]. Hazards are different from risks – hazards refer to the sources of disruption, while risks refer to the severity and likelihood of disruption.

Climate hazards can be classified into two categories – acute shocks and chronic stressors [39]. Acute shocks represent shorter duration events such as floods, ice storms, extreme precipitation, wildfires, hurricanes and storm surges. Chronic stressors are more gradual occurrences that take place over several years, such as droughts, sea-level rise, changing precipitation patterns, average temperature increase and ocean acidification.

Resilience and adaptation strategies can take an all-hazard approach by including both climate and non-climate risks, such as terrorism, arson, pandemics and extreme weather events. Climate hazards are defined by the World Bank as risks specifically influenced by hydro-meteorological or oceanographic variables [60]. This report specifically focuses on the climate hazards resulting from anthropogenic climate change, that is, the long-term shifts in temperatures and weather patterns driven by human activity, primarily the burning of fossil fuels [61]. Though hazards such as earthquakes and volcanoes qualify as climate hazards under the World Bank definition, this study focuses on the climate hazards more directly related to the climate crisis.

Some hazards are more confidently correlated to climate change than others. The hazards most directly linked to anthropogenic climate change are extreme heat and extreme cold [62]. However, one hazard can influence others. For example, extreme heat is likely to increase the risk of forest fires and droughts, and the severity and number of climate hazards is expected to rise as human-made greenhouse gas emissions increase [62].

3.3 Resilience & Adaptation Planning

Many strategies exist to improve infrastructure resilience. Though infrastructure protection, fortification and hardening are key strategies, other effective solutions are available. They include a combination of planning, early warning systems, redundant systems for critical loads and systems that can fail safely, followed by an agile recovery to full operations.

CRE buildings support and maintain operations for owners, operators and tenants, whether serving as offices, distribution centres, retail locations or for mixed use. If a building cannot sustainably support a tenant's operations, the operator may risk losing the tenant and creating a vacancy, especially if a tenant's operation cannot recover. Furthermore, the liability for a tenant's losses can fall on the building owner, operator, construction engineers, contractors, municipality or any other parties involved [63]. To avoid liability and reduce risk for their own business continuity, owners and operators should support operational resilience and asset climate adaptation by creating a comprehensive resilience plan.

Resilience plans are usually unique to each site, as they include specific information related to a given location (e.g., transportation considerations) and jurisdiction. These plans require analysis and an understanding of the following [4]:

- The risks inherent to the site
- The infrastructure needs of the tenants, compared with the capacity of the facility and supporting infrastructure
- The tolerances to shock and stress of the tenant operations, compared with the response and recovery capabilities of the facility
- The residual vulnerabilities that need to be secured
- A defendable analysis that shock and stress scenarios will play out as expected

A key constraint for any resilience plan is that the measures designed to help mitigate climate risks cannot inhibit the function of the tenant's operation.

3.4 Climate Vulnerability, Impact and Risk Assessments

Site evaluations are conducted to identify hazards, understand their past and future frequency, and determine their consequences. For physical climate risk, these site screenings are called climate risk assessments (CRAs) [64]. CRAs can be part of larger location risk assessments (LRAs), which include hazards not attributed to anthropogenic climate change, such as fires, explosions, arson, earthquakes and terrorism. LRAs are also called hazard identification risk assessments (HIRAs) [65].

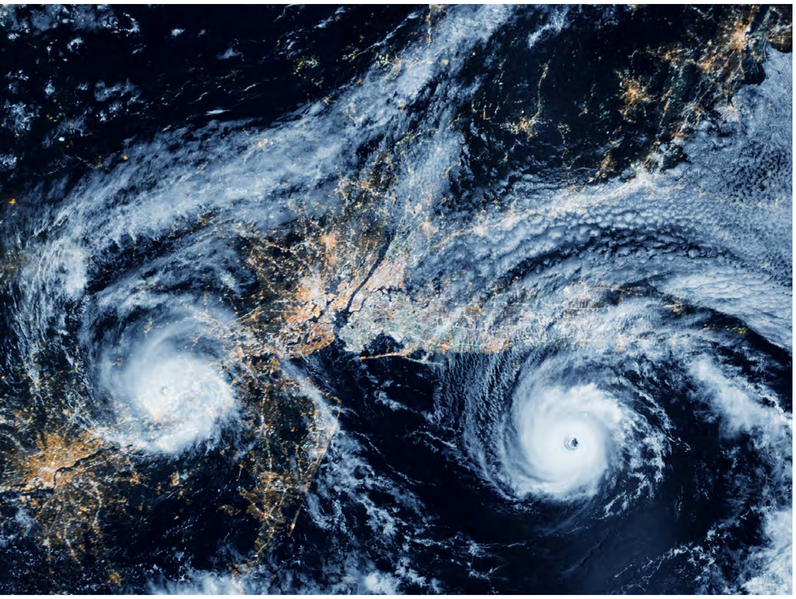
CRAs may include analysis of how the site and the tenant's operation will absorb the risk, evaluating the hazard's impact to the site and the site's vulnerabilities. While the Government of Canada recommends vulnerability assessments for CRAs [32], some European sources do not include either "impact" or "vulnerability" when defining CRAs [31]. Assessments that explicitly consider the building's ability to absorb risk include climate vulnerability assessments (CVAs) [33], climate change impact and vulnerability assessments (CCIVs) [66] and vulnerability risk assessments (VRAs) [67].

For example, under some European definitions of CRAs, if a hypothetical commercial building was located in a flood plain, a CRA would determine that there is a flooding hazard, that floods happen with a moderate frequency, and the consequences could be severe or even catastrophic.

If this same example was reviewed under a CVA, CCIV or VRA, it would consider whether the building has a sump-pump, a robust and well-staffed maintenance plan, critical systems and assets that are stored above grade, an electrical room that is below grade, and back-up energy generation.

All of the frameworks for climate risk, impact and vulnerability assessments include similar stages, which can be generalized to the following:

- Understand the hazards
- Understand the site and its context
- Assess the risks
- Discuss the impact of these hazards, the impacts and the site's vulnerabilities



"Hazards should include both chronic stressors, such as increased average temperatures and ocean acidification, and acute shock incidents, such as floods, wildfires and hurricanes."

After progressing through these stages, the resilience plan's project team should have identified which vulnerabilities to prioritize. The vulnerabilities can then be addressed by determining potential solutions through selected climate adaptation measures.

3.4.1 Understanding the Hazards

The CRE sector should work with a climate risk specialist to identify the hazards. Hazards should include both chronic stressors, such as increased average temperatures and ocean acidification, and acute shock incidents, such as floods, wildfires and hurricanes. Climate hazards are identified according to both the region and the specific site location. Even within the same region, climate hazards may vary.

CRAs can be conducted by federal, provincial and municipal governments within the site's jurisdiction. Risk assessments from local governments can be used as an initial step to identify relevant hazards and their frequencies, using geographic, weather and satellite data sources. Historical information such as insurance claims, articles and interviews with building staff and community members can also offer insight, as can on-site information such as flood lines on buildings.

3.4.2 Understanding the Site and its Context

The site will inform and impact the risk threshold for its systems and assets. It is impossible for a site to have no risk, even after adaptation measures have been implemented. Stakeholders must determine the level of residual risk that is acceptable for the operation.

The context of a site can impact its risk profile of a site, including physical, socioeconomic, regulatory and network factors [4].

- Physical factors include local geological conditions such as soil composition, local vegetation and weather. These may have positive or negative implications on how the site adapts to potential hazards.
- Socioeconomic factors include economic, cultural and social characteristics of surrounding communities. A climate resilience plan could incorporate elements that support the surrounding community's foreseeable risk.
- Regulatory factors such as zoning may create constraints for the site, when developing and incorporating solutions.
- Network factors include how the site connects to utility networks such as water, natural gas, electricity, district thermal and telecommunications. Other network factors include roads and public transit systems for users to arrive and leave the site.

A comprehensive stakeholder process is essential to fully establishing the context of the site, extending beyond hazard-specific specialists, to include tenants, owners-occupiers and operations managers. The stakeholder process can even extend to community residents or nearby business owners, some of whom may actually have had more interactions with the site than current occupants of a CRE building. A broad stakeholder process can help identify various important site components and processes.

3.4.3 Assessing the Risks

Hazards are screened in the context of the site investigated to establish the risk. The analysis can take several different forms. Approaches are more frequently top-down, but bottom-up approaches may be appropriate under certain contexts. Analyses are semi-quantitative and include narrative-based descriptions of each hazard, the factors that lead to the risk, and existing circumstances.

Within the study, the evaluation of each risk follows the same method and scoring in the analysis [31]. Although there are different approaches to conducting risk analysis, it is important that the analysis is conducted consistently within the study. A widely adopted tool identified was a risk-screening matrix. Other evidence-based tools exist, such as threat spectrums [5], but are less common in the literature.

3.4.4 Understanding the Site's Vulnerabilities

An understanding of the site and context can be established by considering how the site for each building will respond to specific climate hazards. The vulnerability assessment evaluates how a specific site is expected to cope with past and potential future adverse climate events. Environment and Climate Change Canada (ECCC) defines climate change vulnerability by the following factors [22] [32]:

- Sensitivity: the degree to which a system or sector is adversely affected by climate-related stimuli
- Exposure: the receptors (e.g., people, livelihoods, species, and ecosystems) that may be affected
- Adaptive capacity: the degree to which an organization or jurisdiction has the financial, human or technical resources to adapt to climate change impacts

There are many tools to assess the risks, impacts and vulnerability of a site. Some examples of evidence-based methodologies selected from leading resources are presented in the following sections.

3.4.5 Tools for Climate Vulnerability, Impact and Risk Assessments

3.4.5.1 Tools for Asset-Based Approaches

3.4.5.1.1 Risk Screening Matrix

Hazards are assessed using a scoring framework that maps their likelihood and consequence. A popular tool to assess hazard risk is a screening matrix or risk matrix [23] [50]. Many versions of screening matrices exist, and methods can be adapted to specific situations.

Stakeholders are involved to assess potential likelihoods and consequences, which are often subjective and dependent on expert opinion and experience. These tools can be used to prioritize adaptation measures.

3.4.5.2 Tools for Capacity-Based Approaches

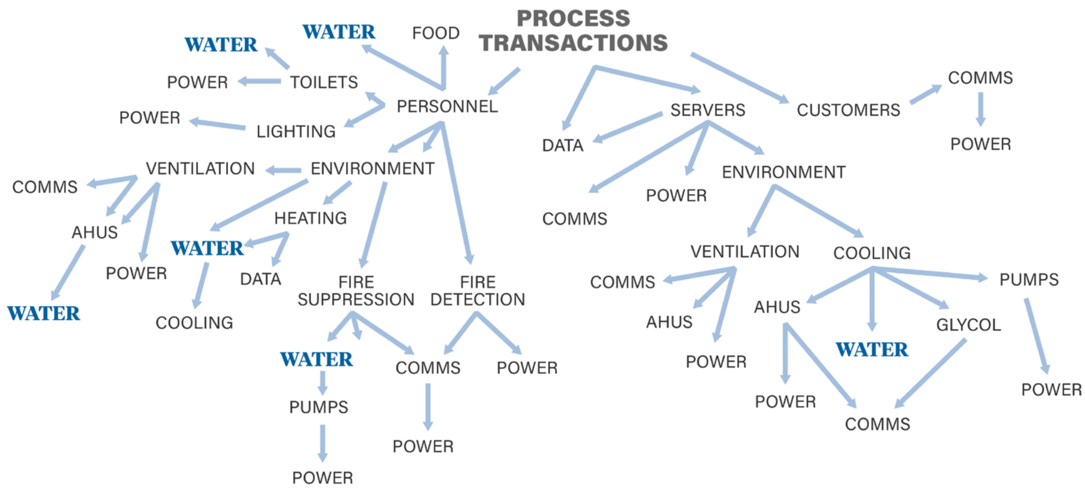
3.4.5.2.1 Dependency Mapping, Impact Chain Analysis and Causal Chain Analysis

CRCI recommends a process called dependency mapping, where anything that a tenant's operation may require to function are identified and mapped [4]. See Figure 1 for example. This is used to conduct further analysis on what is essential and how it may react to climate shocks. ISO 14091 [23] recommends conducting additional analysis using a screening tool to better understand contributing factors that may increase direct and indirect impacts of a hazard. This is also known as an impact chain analysis [23]. Both the dependency map and the impact chain analysis can employ another evaluation tool called a causal chain analysis (also called a root-cause analysis), which identifies the root causes and vulnerabilities within the system [68].

3.4.5.2.2 Incident Sequencing

Scenario planning provides a method for exploring the impact of risk on an operation, adding temporal dimension to the analysis to support business cases where operational downtime is a key metric. See Figure 2 for example. One scenario planning method recommended by CRCI is called incident sequencing, where the impact of an exposure is visualized using narrative-based approach. Estimates are created for the

Figure 1: Dependency Map for a Data Processing Operation. Reproduced with permission from South Harbour Consulting [4].



Dependency network for a firm with core mission requiring data processing

impact on critical systems, estimated downtime, and the time it takes to restore the operation to its "minimum operating capacity," where it functions at its lowest level.

In this scenario, response strategies are deployed to get the operation to a point where the business is neither gaining nor losing money. This is called the "minimum sustainable capacity." Finally, strategies are identified to return to "full operating capacity," back to business-as-usual. In this methodology, when solutions are identified, the reduction of the downtime during the reaction, response and recovery phases are measured and used to construct the business case.

3.4.5.2.3 Critical Load Analysis

Critical load analysis considers the loads required to maintain essential operations, particularly for utilities such as heating, cooling, telecommunications and water. For example, a grocer's critical load may include maintaining emergency lighting, access to a point of sale and ensuring chilled merchandise stays cool (Figure 3). Operations managers can use commissioning studies to better understand their mechanical loads [4] and ensure mechanical equipment works as designed. Clarifying a building's critical loads helps to size redundant and backup systems. For example, it can be used to determine if a generator is sufficient to meet essential operations.

3.5 Climate Risk Mitigation Measures and Supporting Factors

3.5.1 Best Practices to Address Climate Hazards

The literature review revealed that information on climate adaptation measures tended to focus on individual hazards. As such, the discussion has been organized around the climate hazards posing the most potential economic damage to the CRE sector.

Table 7 includes a summary of major climate hazards, with a description of their effects on CRE, the key building systems affected, and best practices to minimize damages. Note that this table should not be interpreted as an exhaustive list of climate hazards and measures.

As demonstrated in Table 7, there is a significant amount of guidance on the adverse effects of climate hazards on CRE, as well as general recommendations on strategies to minimize damages. The Canadian literature reviewed for this study mainly focuses on acute risks caused by extreme events. These include, for example, catastrophic floods, extreme precipitation, high winds, snow and ice storms, heat waves and wildfires. In contrast, there is little guidance on chronic stressors, which develop over the longer term.

Figure 2: Incident Sequencing Diagram. Reproduced with permission from South Harbour Consulting [4].

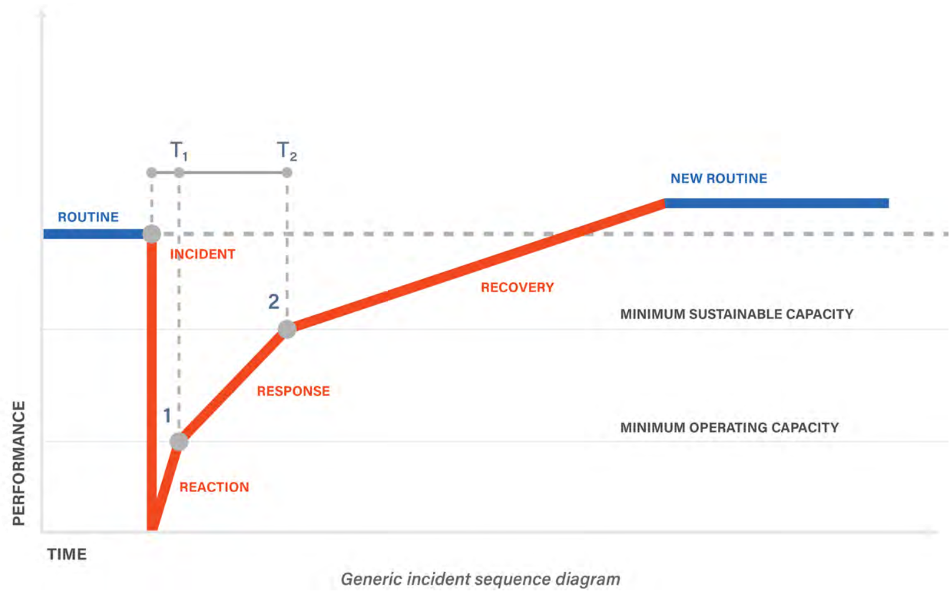
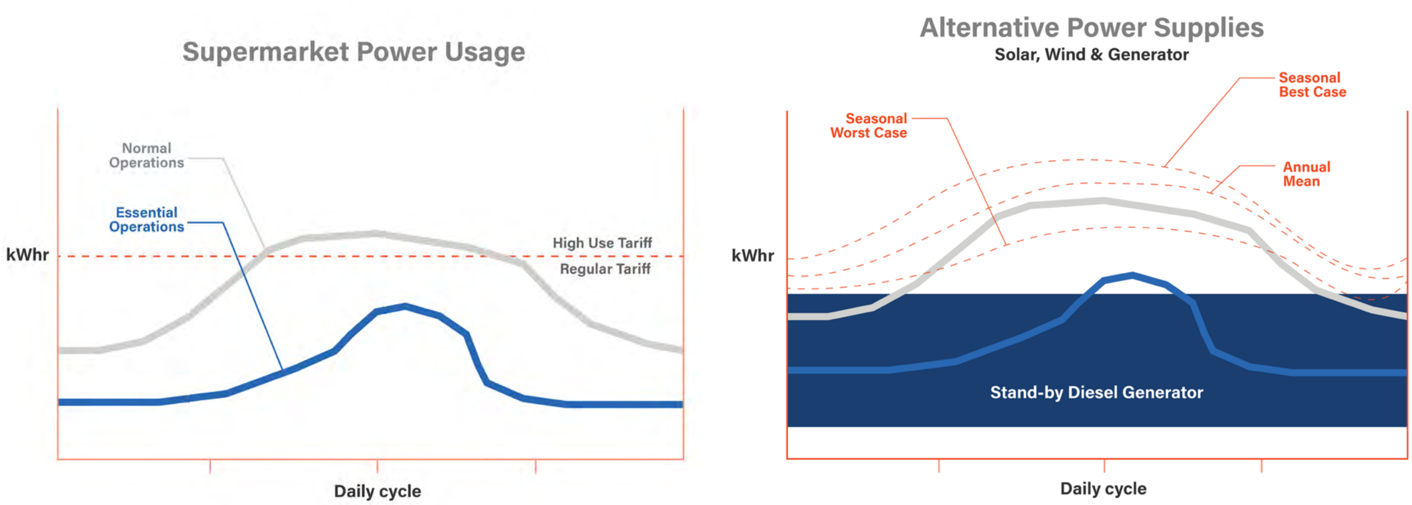


Figure 3: Sizing Backup Systems for Critical Loads. Reproduced with permission from South Harbour Consulting [5].



Most climate adaptation literature focuses on sharing best practices for limiting damages against specific hazards, especially flooding and wildfires. However, due to the geographic constraints of many climate hazards, guidance and best practices may vary across regions. Solutions can also vary by region, dependent on available supply chains, procedures, products and resources to address climate hazards.

Documents for CRE rarely provide regionally specific guidance. Existing resources place a strong emphasis on preparing for a climate disaster, but offer less guidance on best practices during and after the event. There are many guidelines which recommend establishing "emergency plans and procedures," but do not elaborate on key steps or considerations, even at a high level.

Table 7: Collected Best Practices for Addressing Climate Shocks [39] [41] [44] [69] [70] [71]

Hazard	Impact	Affected Building Systems	Best Practices
Flooding	**Description:** ▪ Flooding is one of the most widespread and expensive hazards across Canada. ▪ Coastal flooding is caused by the inundation of land areas along the coast by seawater. ▪ Fluvial flooding refers to river flooding. ▪ Pluvial flooding refers to flooding from an extreme rainfall event, independent of an overflowing water body. ▪ Different types of flooding take place in specific geographies and result in different forms of damages. As a result, they may call for different forms of responses. **Examples of damages:** ▪ Damage to structures ▪ Undermining of building foundations ▪ Water contamination ▪ Water supply disruption ▪ Clogging of sanitation networks and sewer backup ▪ In extreme cases, danger to life of occupants ▪ Discontinuity of use	▪ Electric ▪ Plumbing ▪ Foundations ▪ Wall units	**Assessment & Planning:** ▪ Conduct local flood risk assessment to determine the minimum capacity of rain to flood entry points. ▪ Have necessary plans, procedures and proper training in place. These may include emergency plans, practice drills, emergency funds, tenant communication channels, and emergency operations centre, emergency contact information and insurance documentation. ▪ Procure and regularly inspect critical supplies and equipment. These may include reusable sandbags, submersible sump pumps, portable generators, fuel, portable lights, extension cords, air dryers, air moisture sensors, dehumidifiers, protective clothing, two-way radios, batteries and medical supplies. ▪ Conduct assessment on utility networks. **Retrofits:** ▪ Elevate and flood-proof critical equipment. ▪ Protect server rooms, and high-voltage and telecommunications pull rooms. ▪ Isolate electrical units. ▪ Upgrade electrical panels with WIFI-enabled breakers. ▪ Consider emergency lighting, elevator water sensors, backwater valves on storm and sanitary water pipes, and hazardous materials storage. ▪ Install sump pumps and manage a regular servicing schedule. ▪ Increase permeable surfaces in landscaping. ▪ Install flood barriers near entry points.

Hazard	Impact	Affected Building Systems	Best Practices
Wildfire	**Description:** ▪ Wildfires can be devastating for entire communities, causing extensive and irreversible damage to commercial infrastructure. ▪ Wildfires often result in widespread land devaluation, due to burn and smoke damage to entire regions. **Examples:** ▪ Building damage and losses ▪ Smoke damage in wall units ▪ Risk of explosion if near gas or water supplies	▪ Windows ▪ Insulation ▪ Roofing ▪ Foundations ▪ Building materials	**Assessment & Planning:** ▪ Conduct short-term wildfire assessment to determine possible risks. ▪ Create a building response plan in the event of nearby wildfires to minimize adverse effects on air quality. ▪ Assess the location in relation to the Woodland Urban Interface. **Retrofits:** ▪ Retrofit with fire-resistant materials for roofing, siding, windows, etc. ▪ Ensure that potential flammable materials and fuel loads, such as wooden crates, propane tanks or vegetation, are not in direct contact with the building. ▪ Retrofit on-site emergency water supply.
Extreme Cold	**Description:** ▪ If not insulated properly, extreme cold can have immediate and lasting effects on several building operations. **Examples:** ▪ Domestic hot water and sprinkler system failure ▪ Mechanical system failure and thermal cycling ▪ Pipes bursting	▪ Power supply ▪ Heating and cooling systems ▪ Windows ▪ Insulation ▪ Roofing ▪ Plumbing	**Assessment and Planning:** ▪ Assess the exposure of utility components. ▪ Perform assessment of utility networks. **Retrofits:** ▪ Retrofit walls and roofing with better insulation and high-performance glazing. ▪ Install backup energy generation.
Extreme Heat	**Description:** ▪ Extreme heat can place significant stress on power grids, due to heavy use of air conditioning units. ▪ Extreme heat increases the risk of spontaneous fires developing in densely populated communities. **Examples:** ▪ Increased wear of building materials ▪ Decreased occupier comfort ▪ Increased energy consumption for cooling ▪ Malfunction of information technology (IT) and heating, ventilation and air conditioning (HVAC) equipment.	▪ Windows ▪ Insulation ▪ Roofing ▪ Heating and cooling systems	**Assessment and Planning:** ▪ Perform a short-term risk assessment. ▪ Stress test HVAC systems to determine threshold and duration of operation. **Retrofits:** ▪ Retrofit walls and roofing to reduce heat penetration and limit heat absorption. ▪ Implement passive solar design. ▪ Install backup energy generation. ▪ Engage in demand-side management activities to reduce critical loads. ▪ Add cooling features like pools and splash pads on the premise.

Hazard	Impact	Affected Building Systems	Best Practices
Extreme Wind, Hurricanes and Tornadoes	**Description:** ▪ Wind, hurricanes and tornadoes can increase loads on roofs and facades. **Examples:** ▪ High winds can cause significant damage to building facades and windows, as well as critical life-supporting systems like water infrastructure and energy services.	▪ Windows ▪ Electric ▪ Facade	**Assessment and Planning:** ▪ Perform a short-term assessment to determine wind and hurricane risk. **Retrofits:** ▪ Install impact-resistant glass. ▪ Implement on-site backup power capacity to help run essential services.

3.5.2 Integrated Design Processes and Integrated Project Delivery

One method to incorporate climate adaptation measures to a site is through integrated design processes (IDP) or its formal project delivery method, Integrated Project Delivery (IPD) [4]. Integrated design is a comprehensive, holistic approach to design that brings together specialties that are otherwise considered separately. In IDP, different members of the building process, such as engineers, architects, contractors and customers, work together, and may also include climate risk generalists, hazard-specific specialists and solution providers.

In the early stages of IDP project development, a collaborative group design session, called a "design charrette," brings together various specialists to provide input and find synergies. IDP is already widely used to enhance project sustainability, but is not as widely used to address climate adaptation. Some developers are starting to adopt these practices, for example, the Lendlease Christus Spohn Hospital project in Texas [72].

3.5.3 Business Case Guidance

Business cases for the implementation of climate adaptation measures are generally created by assessing the potential losses with and without the introduction of adaptation measures, set against the cost of the adaptation measures, to create a cost-benefit ratio.

A challenge for the CRE sector is the gap between the expectation of financial incentives for improving climate adaptation, and the actual, immediate financial benefits that are realized by developers or owners. There is evidence that physical climate risk is not being adequately accounted for in financial valuation, despite the recognition that these risks are present and significant. In a survey by ULI of real estate investment managers across the United States, asset managers still showed significant interest in climate impact areas like coastal cities at risk to ocean rise [73]. In addition, where real estate investment trusts (REITs) were surveyed, many voiced frustrations that investment in asset-level resilience strategies did not lead to clear and consistent reductions in insurance premiums, nor that tenants would be willing to pay more for, or even prefer, a more resilient building [73]. These studies show that there are currently insufficient financial incentives for implementing climate adaptation strategies in CRE.

There is considerable interest in creating direct and short-term financial incentives for implementing resilience strategies. The ICCA has published the guide "Factoring Climate Risk into Financial Valuation," which outlines various financial valuation methods for measuring climate risk, such as ratio analysis, economic value added, and discounted cash flow [74]. Globally, insurance companies are also trying to accurately quantify climate risk in financial valuation. For example, FM Global has published many articles outlining climate risk and adaptation in floods and wildfires but have not publicly revealed how adaptation efforts impact insurance premiums [30]. Ultimately, this leads to more confusion from developers, who may be unclear which resilience measures will have the most impact on lowering insurance premiums.

In a separate survey, some sources shared concerns about disclosing physical risk, as it may impact future capital allocation and insurance premiums. Clearly, insurance for climate risk is an area that is still under significant development, due to uncertainty around the non-linear evolution of climate change and its impacts [71].

Cost-benefit analysis for climate risk is still an emerging field. In Canada, the NRC has completed a comprehensive cost-benefit analysis of storm drainage and flood control infrastructure [75], However, additional research on cost-benefit analyses for other climate hazards should be conducted. On a global level, some organizations have published comprehensive cost-benefit analyses on climate risk. Aktion Deutschland Hilft, a German charitable organization, published a report which analyzes previous case studies to assess the efficiency of various disaster risk-reduction efforts [76]. In Canada, approaches for cost-benefit ratios are taught through CRI courses as part of the Building Regional Adaptation Capacity and Expertise (BRACE) program [50], an initiative launched by the federal government.

3.5.4 Combined Climate Mitigation and Adaptation Initiatives

Both climate adaptation and climate mitigation[6] are critical for addressing long-term challenges. In some cases, climate mitigation action can also contribute to climate adaptation. For example, building to a passive house standard can lengthen the time a tenant can shelter in place if they lose power, due to the increased envelope performance. However, in other cases, the introduction of mitigation measures may decrease resilience. For example, a shading device can reduce heating loads, but when located in a tornado zone can represent an additional hazard if not properly engineered.

A research paper describing the 2002 consolidation of the Goldman Sachs (GS) corporate headquarters in New York noted that by implementing sustainability measures, such as improved energy efficiency and more flexible office spaces, GS was able to withstand physical and operational shocks much better than other firms [77]. For example, during the 2008 recession, when GS converted to a bank holding company and required separate spaces for compliance units, GS could easily handle the new space requirements [77]. GS was also able to withstand Hurricane Sandy much better than others, thanks to its sustainability measures allowing more people to work remotely and its improved adaptive capacity [77].

A potential opportunity for CRE is to conduct retrofits that both enhance a building's ability to both mitigate and adapt to climate change [78]. The GS research paper suggests three pillars for a resilient retrofit. These include:

1. Infrastructure hardening, such as seismic, wind and flood-resistant retrofits
2. Resource conservation, such as water and energy efficiency measures
3. Back-up energy supply using distributed energy resources

When constructing business cases for resource conservation, and back-up energy supply in particular, the climate mitigation and adaptation co-benefits can be used to strengthen the site owner's business case.

3.5.5 Characterizing Non-Monetary Benefits

Resilience-related resources for CRE focus heavily on mitigating physical damages to limit financial losses arising from climate hazards. However, there are many non-monetary considerations for climate resilience that are understudied, particularly within the CRE sector.

Resilience measures that are not generally associated with financial values, such as human-centric considerations, are often not captured by financial models for climate resilience. Legal or social factors such as health and population displacement often deal with human well-being and can be difficult to quantify at a large scale. Environmental impacts such as erosion, impacts on the natural environment, including flora and fauna, water quality, energy footprint and GHG emissions are other considerations. Estimating the

6 Climate mitigation is a form of sustainability.

There may not be a single standardized process that is universally appropriate. Resources generally provide technical guidance and foundational information so that users can apply as appropriate to their site."

monetary equivalent of intangible benefits can be challenging, but should be considered in discussions regarding cost-benefit analysis of resilience measures.

A potential tool to conduct non-monetary analysis is a multi-criteria analysis (MCA), which compares the intangible costs and benefits to those of potential alternatives, which can be weighted based on stakeholder input [75]. To assist with an MCA, the shadow cost of intangible benefits can be "estimated based on monetary values assigned to tangible costs, or through the use of a weighted scoring method for each of the monetized and non-monetized costs [75]."

4 Discussion and Gap Analysis

4.1 Definitions and Assumptions Vary

Guidelines and standards were difficult to compare, as the sequencing, framing, definitions and assumptions often varied.

For example, CRCI's guidance [4], designed for CRE, provides a capacity-based approach and uses the definition of "operational resilience" to guide their document, prioritizing recovery of a tenant's operation. In comparison, ISO 14901 focuses on climate adaptation, providing guidelines on related vulnerability, impacts and risk assessment. PIEVC begins with an asset-based approach using a risk-screening matrix, although more capabilities-based approaches can be added to later stages of the analysis.

All of these sources of information have been vetted by climate experts and reviewed by peers as valid frameworks and guides to reduce physical climate risk. However, climate resilience and adaptation plans are specific to each organization, and are often even specific to the site. There may not be a single standardized process that is universally appropriate. Resources generally provide technical guidance and foundational information so that users can apply as appropriate to their site.

4.2 Guidelines, Toolkits and Frameworks Are Preferred

Flexible resources such as guidelines, toolkits and frameworks are often preferred over prescriptive standards. Still, there appears to be a gap in the market for simplified resources enabling consistency and comparability between climate resilience plans and climate risk assessments.

While there is demand from the CRE sector for more standardization and prescriptive resources, there were no documents offering rigid guidance. This may be because prescriptive guidance is not appropriate for climate adaptation and resilience strategies, due to variabilities in sites and stakeholder risk tolerance.

If a standard were to be created, it would likely follow the format of ISO 14901, which reads more like a guideline. Guidance documents are preferable to prescriptive standards, since every situation is unique, and the intent and the circumstances of the risk assessment can impact methodology.

As discussed in Section 3, there are many approaches appropriate for assessing risk. Differences in tools result from varying perspectives, site contexts, and the non-linear and iterative nature of risk assessments and resilience planning. Value-based judgments are often required throughout risk management.

This field is constantly progressing, so accepted best practices will evolve and may be jurisdictionally specific. Despite variations, any approach or tool selected must be evidence-based, defensible and repeatable.

4.3 Reporting Through Disclosure Can Be Standardized

Variations in reporting can be a source of frustration for the CRE sector. The analysis and measures can differ at similar sites under the same portfolio due to variation in applied approaches, tools, scoring criteria, data availability, the strategic importance of the site, and the individual conducting the analysis [44]. While different approaches for an analysis may be valid, a standardized approach to reporting and disclosure can help the CRE better understand variations between sites.

Ideally, relevant information on the data sources, methodology sources, data integrity, assumptions, methods and scoring criteria should be disclosed in a consistent format. A consistent reporting format can enhance the ability to understand the site's risk, vulnerabilities and proposed solutions. Practitioners may also provide a rationale on why certain methods were selected and deemed appropriate. The CRE-sector may benefit from a format that complements reporting requirements for pre-existing disclosure frameworks like the TCFD and GRESB.

4.4 Collaborative Guidance in the CRE Sector is Limited

Resilience resources are often directed towards municipal governments rather than CRE. CRE-specific content that focuses on physical risk most often provides a high-level overview for contextualizing TCFD and GRESB reporting. Though high-level content on physical climate risks is abundant, granular technical guidance specifically for CRE is limited. More content for CRE may exist, but it is possible that it is privately funded and kept internal, in contrast to the guidance for municipalities, which is publicly available.

Documents for climate resilience and adaptation are not always consistent between authors, and this is no exception for CRE. In fact, documents that were supported by both climate resilience and adaptation subject matter experts, and members of CRE organizations, were difficult to identify. The contributions from climate resilience and adaptation subject matter experts are particularly important to include in the development of future resources for CRE.

4.5 Available CRE Guidance is Ontario-Centric

Though adaptation and resilience resources for community and public infrastructure often have a national scope, CRE-related resources are more limited. Available reports on resilience for Canadian CRE are skewed towards Ontario, specifically Toronto. Many major research organizations such as the ICLR, ICCA, CRIC and CRI are based in Ontario. Ontario also has the largest percentage of the Canadian population and of CRE floorspace in Canada.[7] However, to fully understand Canada's CRE sector, additional insight on other markets would be beneficial, especially for other urban centres with high concentrations of commercial buildings, such as Vancouver.

4.6 Flood Mapping Has Data Gaps

Data gaps still exist, particularly for flood mapping. Flood mapping is managed by the provinces and sometimes by local conservation authorities. Certain data sets may be more available to some sites than others, making availability of data varied and inconsistent across the country. In Ontario, a single county can have four different sets of flood maps from different conservation authorities. which are not necessarily reporting their data with the same rate, format and level of detail. Private organizations could create digital platforms that amalgamate the flood data from conservation authorities, but this would not

7 As of 2021, 39% of office space in Canada is in Ontario [92].

address inconsistencies in how it is made available to the public.

In comparison, the US federal government has a unified flood mapping tool that is managed by the Federal Emergency Management Agency (FEMA) Flood Map Service Centre (MSC). The Canadian federal or provincial governments may consider enforcing or incentivizing a unified approach to sharing flood mapping data with the public.

4.7 Information on Chronic Risk Is Lacking

Guidance for addressing acute climate shocks is abundant, unlike guidance for chronic climate stressors. Any guidance created for CRE should address both acute shock and long-term impacts from chronic stressors. The limited information to address these chronic stressors is in alignment with CSA 478:19, *Durability in Buildings* [28]. As information on chronic climate risk develops, CSA 478:19 should be updated.

4.8 Guidance for Disaster Management and Recovery Is Insufficient

There is an abundance of guidance on how to mitigate climate risk, but less guidance on what to do during extreme weather events and how to recover. Additional guidance on tools such as incident sequencing can help plan for how a site will react to an extreme weather event, and help establish pathways for its recovery.

4.9 Mitigation and Adaptation Should Be Unified

More guidance for the Canadian CRE sector is required to bring together climate adaptation and climate mitigation. Such guidance can highlight co-benefits and synergies, which strengthen business cases and justify investments. This is particularly relevant as Canada tries to achieve its net-zero emissions objectives, since the building sector anticipates a need for deep retrofits to meet these targets.

4.10 Monitoring and Evaluation Guidance Is Limited

With many resilience planning activities, ongoing monitoring and evaluation is suggested. However, guidance and support on how to do this was limited.

5 Recommendations

The following recommendations are designed to address the gaps identified in section 4.

5.1 Create a CRE-Specific Toolkit

There are multiple vetted approaches for climate adaption and resilience planning. A CRE-specific toolkit would enable flexibility for a CRE organization's resilience and adaptation objectives. The toolkit should address resources for both asset-based and capabilities-based approaches. It could point to the most relevant publicly available data, as well as hazard-specific guidelines, so CRE organizations have the resources to address the climate hazards relevant to their sites.

5.2 Provide Additional Guidance for Specific Areas

Some areas where the CRE sector would benefit from additional guidance include the following:

- **Existing buildings in Canada:** Existing buildings have the greatest vulnerabilities to climate hazards, as they were constructed under outdated building standards and climate scenarios. New guidance on existing buildings should focus on retrofits. As information on chronic stressors develops, guidance may be better suited for the existing CSA 478:19, *Durability for Buildings.* Creation of a new section for new construction and major retrofits should be considered, and should reference Canada's National Master Specification.
- **Co-benefits:** The development of energy efficiency and back-up generation measures that simultaneously support climate adaptation and mitigation are particularly valuable. It is recommended to highlight opportunities where adaptation and mitigation measures align, and where increased performance of building envelopes can support sheltering in place. In addition, energy codes and standards officials should be consulted to determine current systems can respond to expected future temperatures. Commissioning and retro-commissioning of buildings can help optimize performance and minimize energy demand, while ensuring systems can respond to extreme heat and cold. Although some municipal standards require commissioning, it is not currently required in Canada's National Energy Code. The mandatory five-year review period for codes and

standards provides an opportunity to align with changing climate conditions and knowledge.

- **Business cases:** Best practices and establishing the "cost of doing nothing" can support business cases for resilience measures. It is recommended to create a standardized document, which can include different approaches for cost-benefit ratios. Further research is required to consolidate best practices for a business case, and may recommend the exclusion of insurance premiums, since these are dependent on the underwriting of different insurance providers.
- **Tenant engagement:** It is recommended to develop tenant engagement strategies related to resilient operations, maintenance and emergency response planning. These strategies should reinforce the important role and responsibilities of the tenant during an emergency.
- **Climate risk financial disclosure:** Regulators are mandating climate risk reporting, including the TCFD for some companies in certain countries. Though this was still voluntary in Canada as of December 2022, climate risk reporting would be beneficial for Canadian CRE and may soon become a requirement. Clear guidance on reporting physical risk in alignment with disclosure frameworks would support the uptake of climate risk reporting.
- **Integrated project delivery:** Integrated design can be a powerful contract and procurement tool to identify effective solutions across different disciplines, contexts, dependencies and hazards. The CRE sector may consider using this contract method to enable climate resilient design.

5.3 Conduct Further Research on Identified Gaps

The landscape for adaptation and resilience resources is evolving quickly, but there are limitations to conducting research as a literature review, and more stakeholders should be interviewed to help fill the identified information gaps. These could include climate risk practitioners, academics, research groups, members of the CRE sector, builders, developers, trades and tenants.

Some of the identified gaps include:

- Climate adaptation and resilience resources for CRE beyond Ontario. Resources were lacking for CRE in other jurisdictions such as Vancouver, Montreal, Calgary and Edmonton.
- Chronic climate stressors. This information should also be updated in CSA 478:19, *Durability in Buildings*.
- Data-related gaps. Further research should be done to understand if the issues with climate data, particularly flood mapping, has more to do with availability, accessibility or usability.
- Information on post-disaster recovery.
- Information on monitoring and evaluation of resilience and adaptation programming.

6 Conclusions

To address the increased frequency and severity of extreme weather events, the CRE sector must assess its existing and future climate risks and vulnerabilities. In response, this study conducted a scan for relevant climate adaptation and resilience guidance, frameworks, protocols, tools, publications and other resources – from jurisdictions in Canada and around the world.

The two key areas of focus were conducting climate risk assessments and identifying measures to improve climate resilience for the Canadian CRE sector. Following the jurisdictional scan, key gaps in CRE resilience were identified, and opportunities for standardization to support climate adaptation measures were highlighted.

After exploring domestic and international resources, some of the key findings were as follows:

- Flexible resources are needed to address the unique circumstances of buildings, rather than a prescriptive or one-size-fits-all approach.
- Adaptation and resilience resources are often delivered in the form of guidelines, frameworks or as a toolkit, which enables context-specific tools to be selected. Still, CRE-specific tools are needed to address the unique considerations for this sector.
- Canada's CRE sector requires a unified approach that addresses the distinct climate risks to specific sites and their operations.

Climate change will continue to present risks to the CRE sector. Further research, guidelines and tools that build on existing and evolving climate data, and that apply to multiple jurisdictions, will serve to benefit the CRE sector and beyond.

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