Climate Risk Elements for Buildings

UBC Sustainability Scholars

OPEN Technologies

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Written by Teresa Amiama, MEL Candidate

Prepared for Daniel Eden, GRID Product Manager, Vancouver, OPEN Technologies

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This report was produced as part of the UBC Sustainability Scholars Program, a partnership between the University of British Columbia and various local governments and organisations in support of providing graduate students with opportunities to do applied research on projects that advance sustainability across the region.

This project was conducted under the mentorship of OPEN Technologies staff. The opinions and recommendations in this report and any errors are those of the author and do not necessarily reflect the views of OPEN Technologies or the University of British Columbia.

Land Acknowledgement

The land on which the work/research for UBC Sustainability Scholars Program's internship was completed is the unceded territory of the Coast Salish Peoples, including the territories of the xwməθkwəy̓əm (Musqueam), Skwxwú7mesh (Squamish), Stó:lō and Səl̓ílwətaʔ/Selilwitulh (Tsleil-Waututh) Nations.

"Future climate is partly determined by the magnitude of future emissions of greenhouse gases, aerosols and other natural and man-made natural and man-made forcings. These forcings are external to the climate system, but modify how it behaves. Future climate is shaped by the Earth's response to those forcings, along with internal variability inherent in the climate system. A range of assumptions about the magnitude and pace of future emissions helps scientists develop different emission scenarios, upon which climate model projections are based. Different climate models, meanwhile, provide alternative representations of the Earth's response to those forcings, and of natural climate variability. Together, ensembles of models, simulating the response to a range of different scenarios, map out a range of possible futures, and help us understand these uncertainties."

Intergovernmental Panel of Climate Change (IPCC)
Fifth Assessment Report (AR5)

Context

This project is part of the University of British Columbia's (UBC) Sustainability Scholars Program, a paid internship program for graduate students focused on environmental research topics. Sustainability Scholars is run by UBC's Sustainability Hub; they work with local partners to "work on applied research projects that advance sustainability across the region" (University of British Columbia, 2022).

> "Energy benchmarking can be an internal process, measuring your building's performance against its own past performance or against other buildings in your portfolio, or it can be an external process, comparing your building to similar buildings outside your organization."
>
> (Government of Canada, 2020)

OPEN Technologies (OPEN), this project's partner organization, is a software company based in Vancouver, BC. "OPEN software tools help the people shaping our cities to make pro-climate decisions with confidence" (OPEN Technologies, 2022). OPEN's flagship product is GRID, a building energy benchmarking software that helps jurisdictions run disclosure programs by providing the data and visuals to understand energy consumption patterns.

The objective of this project was to conduct research to get a better understanding of datasets, data sources and the accessibility of climate risk data, and to provide a set of recommendations to try to include climate risk data into GRID.

Scope of Work

The mandate for this internship was to conduct primary and secondary research of climate risk data at a building level. OPEN provided the following questions as guidelines:

1. What are the **key climate risk datasets** and data points that are available at a building level? (flood risk, fire risk, walk score, etc.)
2. How important are those points to various **stakeholders**? (regulators, financial institutions, building owners, insurance providers, etc.)
3. What are the **existing gaps in climate risk data**, and what is required to ensure these gaps are addressed?

Primary and Secondary Research

Secondary research predominantly consisted of internet searches. Included in the review were downloadable datasets, reports, online tools, reporting frameworks, and articles. A list of useful resources is included in

Appendix B – List of Resources.

The primary research consisted of 9 interviews with industry stakeholders representing regulators, financial institutions, consultants, property managers, public institutions, and non-profit organizations. A summary of the interviewees can be found in Table 1 below and the interview notes have been included in Appendix C – Interview Summaries.

Limitations

The findings in this report should be considered a first phase of research, as it was not exhaustive. The largest barrier to complete the research comprehensively was lack of time due to the part-time nature of the internship over only three months.

As such, the research focused mostly on British Columbia (BC) and Canada-wide resources, rather than on other provinces, USA or global resources.

Terminology

This section will cover the definition of terms to:

1. establish a basis on which to communicate ideas, and
2. to ensure uniformity and understanding by different readers.

All terms and their definitions will be viewed through the lens of sustainability and environmental science.

Mitigation, Adaptation, and Risk

Mitigation, Adaptation and Risk are different concepts that may be related to one another.

Mitigation – an attempt to minimize or limit negative impacts by taking action.

> *"Our efforts to limit climate change by reducing greenhouse gases."*
>
> (City of Vancouver, 2022)

Adaptation – a change to conform to and coexist with a new situation.

> *"Creation of proactive plans that take advantage of opportunities and prepare for impacts by understanding what climate we are likely to experience in the future."*
>
> (City of Vancouver, 2022)

Risk – an external force that threatens the safety / security of something or someone.

It is important to remember that sometimes a measure can be both mitigative and adaptative, others can be one and not the other. For example, a seismic upgrade in a building only provides adaptation in the event of an earthquake, as it cannot mitigate the chances or intensity of an earthquake occurring. On the other hand, replacing a natural gas furnace with an electric heat pump in BC, where electricity is generated by low GHG emission hydroelectricity, provides both mitigation of greenhouse gases, and adaptation to potentially higher temperatures by also providing cooling.

"The result from the interaction "Creation of proactive plans that take advantage of opportunities and prepare for impacts by understanding what climate we are likely to experience in the future." of climate-related hazards (including hazardous events and trends) with the vulnerability and exposure of human and natural systems."

(Swanson, Murphy, Temmer, & Scaletta, 2021)

Resilience:

"The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to transform 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 through risk management."

(Swanson, Murphy, Temmer, & Scaletta, 2021)

Overall, mitigation and adaptation are responses to the risk caused by climate change to eliminate damages and increase resilience.

Climate Change - The Basics

The climate is changing.

Due to our industrial activity, which releases CO_2 and other gases with global warming potential into the atmosphere, the greenhouse effect that naturally protects and enables life on earth is intensifying. This increases the planet's mean air temperature, resulting in extreme (more frequent and more intense) weather events around the world. Environmental scientists use complex global climate models (GCM's) and historical data to calculate different climate forecasts based on a series of emission scenarios. The Intergovernmental Panel on Climate Change (IPCC) has established the most used scenarios called Representative

Concentration Pathways (RCP's). An RCP of 2.6 represents a low emissions pathway, whereas an RCP of 8.5 represents a continued growth in emissions pathway. Figure 2 summarizes this information.

It is within our power to mitigate the effects of climate change, but we must also adapt our society and infrastructure to the changes that are already happening and will continue to occur for decades to come.

Historical climate data is no longer representative of future climate, and we cannot use it for making decisions about designs that will remain part of our buildings for decades (and hopefully more) to come.

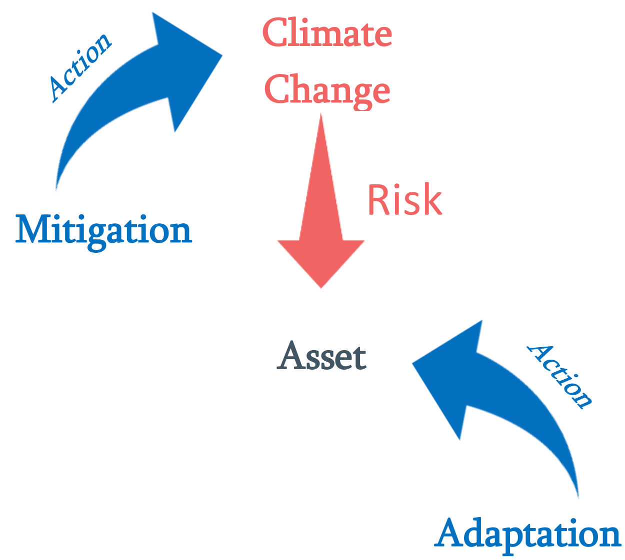


Figure 1. Relationship between Risk, Mitigation and Adaptation

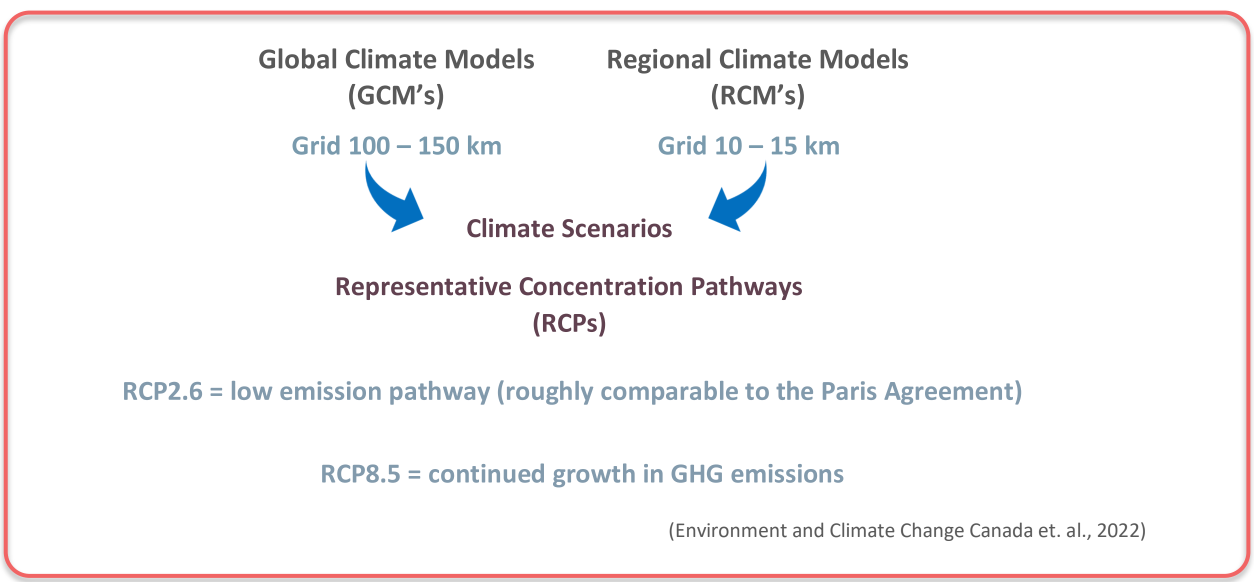


Figure 2. Climate Change Scenarios

Variables

A **variable** is a type of climate data such as temperature, precipitation, and sea-level change (Environment and Climate Change Canada et. al., 2022). Variables can be specific, such as mean temperature, wet Days >= 20 mm, and cooling degree days (CDD).

This project considered the following climate change variables:

- Temperature (extreme heat or cold events)
- Precipitation (extreme rain, snow, or drought)
- Wildfires
- Air Quality (smoke from wildfires)
- Sea Levels Rise (coastal flooding)
- Inland Flooding
- Heat Island Effect
- Landslide Events
- Windstorms

Other variables that would have been interesting to include, but were not:

- EV Readiness
- HVAC Systems Readiness
- Walking Score
- Transit Score
- Electrification and Electrical Readiness
- Community Preparedness

To assess the true resilience at a building level social variables should be investigated also. A building's location and history, the surrounding infrastructure and community greatly impact the occupants of a building. This topic, however, was beyond the scope of this project.

Findings

The research findings are a combination of datasets, reports, tools, and products that were identified as relevant and useful to OPEN's goals of integrating climate risk elements into energy benchmarking.

Stakeholders

As part of primary research, nine (9) interviews were conducted between June 2 and June 30, 2022, to address the following question:

- How important are key climate risk data points such as flood risk, fire risk, walk score, etc. to various **stakeholders**? (regulators, financial institutions, building owners, insurance providers, etc.)

A sample of different stakeholders were included; however, insurance providers were not interviewed at this research phase (although it would be strongly recommended to consult them in future interviews).

Appendix C – Interview Summaries includes the interview take-aways for all interviews conducted in this project.

Table 1. List of Interviewees

#	Stakeholder Type	Date	Company	Tole
1	Property Manager	June 2	Choice REIT	Senior Director, Sustainability
2	Non-Profit	June 3	BC Housing	Senior Manager, Technical Research & Education
3	Property Manager	June 8	QuadReal Property Group	National Health and Safety Manager
4	Non-Profit	June 13	BC Housing	Sustainability & Resiliency Director
5	Consultant	June 15	RDH	Principal, Senior Project Engineer
6	Regulator	June 16	City of Vancouver	Climate Change Adaptation and Sustainability Planner
7	Public Institution	June 16	Vancouver Coastal Health	Manager Climate Risk & Resilience
8	Financial Institution	June 30	HSBC	Senior Sustainable Finance Manager
9	Financial Institution	June 30	Vancity	Climate + Sustainability, Senior Leadership

Property Managers & Owners

Choice REIT and QuadReal

Property management companies have been publishing ESG (Environment, Social, Governance) Reports for a few years now. The improvement in reporting standards and industry expectations for quality have driven some consulting services to become established in certain markets. For instance, Choice REIT use GRESB and Munich RE to do their climate risk assessment. There are also emerging companies such as the Australian XDI Systems and American Moody's, who have acquired 247, that can similarly provide climate data reporting to clients.

Property managers use consultants to make divestment and acquisition decisions. This means divesting liabilities from their portfolios and acquiring properties only after a risk assessment has been completed with favourable results.

Climate risk assessment is critical to property managers because it identifies liabilities in their portfolios. It is important to note that there might not aligning interest with all stakeholders in a building's lifecycle. Namely, the builders might have different motivating factors than the property managers, and occupants of the building.

One key difference in how builders are motivated to create resilient buildings is if the project is a Build-and-Leave or a Build-and-Manage/Operate. If a builder will be involved in the design and construction of the building, but will not operate/manage the building, then understanding climate risk is not of importance to them since they will not be exposed to it. Conversely, if a builder will be operating/managing the building post-construction, then climate risk management is of importance to them.

What does a property manager need to know?

- How much money is at risk? – i.e.: how much property value is at risk due to climate risks?
- Insurance coverage? What is included vs not included?
    - If 2022 is covered, what is the increased risk in the future? – choose time frame (2030? 2050?)
- Once baseline risk and insurance coverage are established, how do they change as the climate changes?
- Which climate variables present a risk to our assets (i.e., flooding, fire, heat) and to what degree (low, medium, high risk)?
- What is being done (by owners/managers/the city) to mitigate the risk?
    - Insurance is considered a "mitigation" measure by property managers[1].

What does a property manager need from their data provider?

- Data sources must be reputable and robust
- Service provider must have reliable technical support to ensure timely solutions/troubleshooting of any issues that arise.

[1] In this case, "mitigation" does not meet the definition stated in the terminology section as an action to minimize/eliminate a threat/risk. It is in fact an adaptation, an action reacting to that threat/risk to be financially resilient.

Number of At-Risk Assets from Flooding(1)

	50-year flood	Floor area(2) (sq. ft.)	100-year flood	Floor area(2) (sq. ft.)	200-year flood	Floor area(2) (sq. ft.)	500-year flood	Floor area(2) (sq. ft.)
DRM(3)	3	4,000,000	1	400,000	-	-	1	37,000
MPCT.UN(4)	-	-	1	61,000	-	-	-	-
D.UN	-	-	1	78,000	-	-	1	228,000
DIR.UN	1	86,000	13	1,900,000	17	2,400,000	14	2,600,000

(1) Assets that may be classified under more than one category by default are not duplicated in the figures in the other time categories. Changes from 2020 are the result of acquisitions or dispositions of assets since the previous reporting year. As of September 30, 2021.
(2) Floor area square footage is based on Gross Leasable Area (GLA).
(3) Includes Dream Unlimited's Canadian Income Properties, Arapahoe Basin, Willows in Saskatoon and Zibi at 100% of GLA as of September 30, 2021.
(4) MPCT.UN assets managed by D.UN were included in this assessment at 100% of GLA.

Figure 3. Excerpt from Choice REIT's ESG 2021 Report – Example of reporting type on flooding risk to their portfolio

Key Problem: Property managers must hire consultants to do any level of risk analysis and it could be an expensive service. Property managers/owners with smaller portfolios may not have the resources to retain the services of the larger consulting services listed above.

How can OPEN Help: There is an opportunity for OPEN to work property managers and owners on their climate risk reporting as a local software company.

- OPEN could be a data provider (temperature extremes, precipitation, etc.) for companies to use as a basis for their building-specific analysis to calculate/analyze their climate risk.
- Cross-reference the building's location with OPEN's climate risk variable mapping, to create a climate risk scorecard. This tool could be the first step before engaging with a consultant for a more in-depth assessment.
- OPEN could also build a tool to help the managers approximate the risk by asking a set of questions.

In future interviews with property managers/owners understanding which datasets their consultants are drawing information from would be useful to build the scorecard and questionnaire tools.

Financial Institutions

HSBC and Vancity

A main issue became evident rather quickly in both interviews with financial institutions: we were not speaking to the staff that is directly involved with risk assessment work. This problem limited the amount of actionable information we acquired during our conversations. One recommendation is to reach out, obtain the contacts of the risk assessment teams, and include one or two people from each organization in the next round of interviews.

Both institutions have clear GHG emissions targets and timelines for when to meet those targets, such as "Net Zero by 2050." Therefore, the client's GHG emissions are an important factor.

Their main interest is to identify threats to their ability to reach the Net-Zero targets. Most of the work is done internally, however, some outsourcing to companies like Manifest has been done to help achieve these targets.

Some of the identified gaps to ensure good outcomes are:

- Supply chain issues
- Workforce issues
- Lack of understanding
- Lack of motivation across building owners

One of the strategies that a financial institution can use is to provide tools for their clients to understand how their business is performing. For instance, Vancity is launching a business emissions calculator for operating business loans.

Key Problem: Lack of understanding and lack of motivation across building owners are two factors identified as threats to meeting emissions targets.

How can OPEN Help: OPEN can work with financial organizations to help them gather, analyze, summarize, and visualize client emissions data per industry, type of building, business size, location, etc. This tool can be overlapped with a climate risk layer that can inform and spread awareness of how climate change might impact future business liabilities.

Climate risks:
Task Force on Climate-related Financial Disclosures (TCFD) report.

As a pioneer of values-based banking and a financial force for change, Vancity has long recognized the need for urgent action on climate change and we are dedicated to supporting the transition to a net-zero economy. This commitment is embedded in our commitments to climate action and our 2021–2023 Business Plan. This work is guided by a triple focus:

- Working with members and communities to reduce emissions, including our own financed emissions
- Working with members, communities, governments and other stakeholders to drive a just climate transition that leaves no one behind
- Mitigating risks and realizing business opportunities entailed in our work to achieve emissions reductions and drive a just transition

Governance

Board oversight
Elected by and accountable to our members, Vancity's Board of Directors is responsible for setting strategic direction and overseeing a strong risk culture. The Board has established as one of its five strategic goals in the May 2021–April 2022 Board calendar year to govern the Climate Risks Framework that management is developing. The framework will allow us to understand climate risks based on scenario development in conjunction with external stakeholders. The Board oversees progress against the five commitments to climate action, set in 2020, via quarterly reports from management.

Figure 4. Excerpt from Vancity's 2021 ESG Annual Report

Additionally, since lenders do not have direct access to the buildings themselves, they could start asking owners to provide the information for (or results of) a climate risk assessment as a requirement in loan applications. This is where OPEN can provide services: either to owners as climate data providers and building data collection hub, or to the lenders as collaborators to develop data processing tools.

Public Institutions and Non-Profits

Vancouver Coastal Health and BC Housing

Public institutions and non-profits have data about their buildings. There are existing tools[2] and frameworks for risk assessment, but there are gaps such as:

[2] BC Housing might share a Building Vulnerability Assessment Tool

- Indicators and parameters (indoor air quality and temperature, flood protection, etc.) for new facilities
- Threshold analysis for existing facilities
    - Building code at the time of design
    - Major climate events since construction
    - Building features that allow for building's resilience

There is a lack of trained personnel to collect data and monitor conditions of new and existing buildings. Public institutions need effective tools to support those who are leading initiatives to improve conditions. People such as building managers and maintenance personnel could help gather data and keep it up to date. They could even help develop the tools by beta testing applications.

Overheating is a major concern for healthcare and vulnerable population buildings. Understanding real building data would help with this issue. Cataloguing cooling capacity of buildings has become a priority to the organizations responsible for their safe operation.

Since insurance brokers do not always have the ability to determine risks, a tool to measure and compare risks between various buildings would be useful to these organizations. They would welcome the development of a climate risk scorecard to benchmark vulnerabilities amongst buildings to help with prioritization. Privacy and security are paramount for healthcare environments; therefore, public disclosure of assessment results will not be possible.

The Vancouver Coastal Health Authority has developed a Story Map to visualize community health and climate change, focusing on community vulnerability to high temperatures, wildfire smoke, flooding, and ground-level ozone. This map is not interactive – does not allow for zoom in/out, grid selection or extents.

Key Problem: Gaps in existing buildings data and lack of resources to get that data. Also, people may not feel motivation to act due to gradual nature of climate change, which creates a reactive mindset instead of a proactive one.

How can OPEN Help: OPEN has a great opportunity with public institutions and non-profits to create interactive visualization tools and provide centralization of data. By collaborating with the organization, OPEN could:

- Create cloud-based surveys for the organization's building technologists to upload the buildings' attributes, drawings/records, and maintenance schedules to monitor, analyze and risk assess their portfolios systematically.
- Cross-reference the building's location with OPEN's climate risk variable mapping, to create a climate risk scorecard – cataloguing cooling capacity. This tool could be the first step before engaging with a consultant for a more in-depth assessment.
- Build upon the VCH's Story Map to create functional mapping of community vulnerabilities.

Regulators

City of Vancouver

The City of Vancouver is doing a great job of collecting data; however, the work by different departments is siloed and collaboration is a challenge. They key challenge is how to mainstream climate risk into their processes so that there is better understanding between action and consequence of their programs/policies. The climate adaptation/resilience department and the buildings department would benefit from linking or joining datasets to enhance communication, collaboration, and efficacy of team initiatives.

An example of the great work that the City has been doing is a dynamic and high-quality urban heat island effect map developed internally, which is not publicly available. The map is ESRI- based and the data is collected by volunteers on bikes that carry a sensor through a pre-determined route. This project allows the City to know where the hot-spots are, but not what kind of buildings there are within those high-risk areas. Gathering this building-level data would allow them to develop aid, for instance, financing programs targeting grants for heat pumps for buildings in those high-risk areas. Other municipalities are interested in replicating this project.

For larger sites, the City is asking builders to fill in resilience worksheets to collect data at a building level, but there are still a lot of questions that need answering, such as: how does outdoor temperature translate into indoor temperature?

For flooding, the City has data, but it is sensitive due to liability issues; thus, publicly available data is not granular on purpose.

Key Problem: Siloed departments inhibit collaboration and prevent understanding of policies' impact.

How can OPEN Help: Design tool to bridge the gap in communication amongst departments:

- OPEN could create a centralized database for information to be stored and analyzed by location - building on existing tools like the City's heat map and the builder's resilience worksheet.

Consultants

RDH Building Science Inc.

RDH is working with the Provincial government on two (2) projects to advance climate risk and resilience of buildings at the policy level. They are:

1. Working with the BC Government Climate Action Secretariat (CAS) to develop minimum standards for climate resilience of new and existing projects (i.e.: adaptation and mitigation strategies list).
2. Developing a guidebook on how to complete a climate hazard scan, then a risk assessment, and finally design (i.e.: a list of steps to be taken with portfolio). This guidebook references the PIEVC Program, a protocol that systematically reviews historical climate information and projects the nature, severity and probability of future climate changes and events.

Although an overall risk score would not be useful, a broken-down score would. This tool could be found useful as it would provide a hazard/risk assessment as a basis for recommendations.

Data Sources

Data sources are the datasets and related information that can be used to perform analysis. During this study several datasets were analyzed and the 5 most applicable are presented in the following section.

Datasets

Climatedata.ca - Link – Historic and projected data

Climatedata.ca is the most comprehensive database for climate data in Canada that was found for different temperature, precipitation and other variables. The website includes data on:

Temperature

- Hottest Day
- Mean Temperature
- Minimum Temperature
- Maximum Temperature
- Days with Tmin <- 15C

Precipitation

- Wet Days >= 1 mm
- Wet Days >= 10 mm
- Wet Days >= 20 mm
- Maximum 1-Day Total Precipitation
- Maximum Number of Consecutive 18C Dry Days

Other Variables

- Relative Sea-Level Change
- Frost Days
- Freeze-Thaw Cycles
- Cooling Degree Days
- Tropical Nights (Days with Tmin > 18C)

It also includes station data on:

- Intensity Duration Frequency (IDF) curves, pertaining to "short-duration rainfall intensity, often used for flood forecasting and urban drainage design" (Environment and Climate Change Canada et. al., 2022)
- Climate Normals which "describe the average climate conditions of a particular location over a 30-year period" (Environment and Climate Change Canada et. al., 2022).

Data can be searched for by location, by variable and by sector, and can be downloaded in a tabular (csv or NetCDF) file which includes location data (i.e.: longitude and latitude). The site also functions as a visualization tool by providing graphical and gridded representations of the data.

Example of search by Location: Prince George, BC

Summary and Location: This section summarizes the information pertinent to the selected location. It also includes a map which highlights the grid.

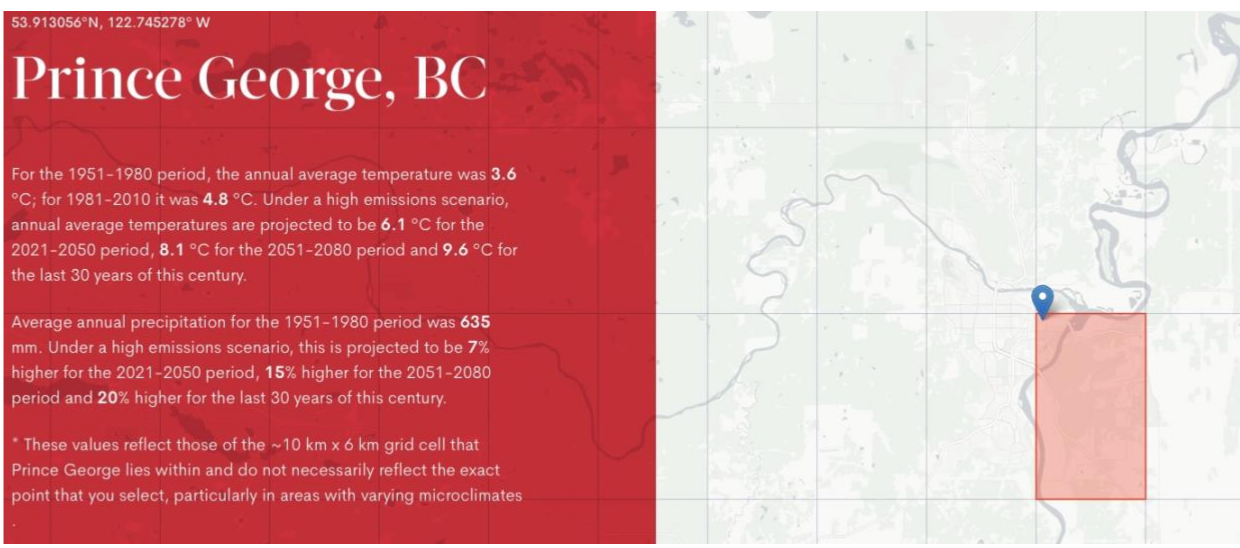


Figure 5. ClimateData.ca Screenshot - Search by Location

Temperature Variables (historical data and three different RCP's): This section provides a dropdown menu to select the target variable (e.g.: hottest day), a definition, and a reason of why it is important to consider it.

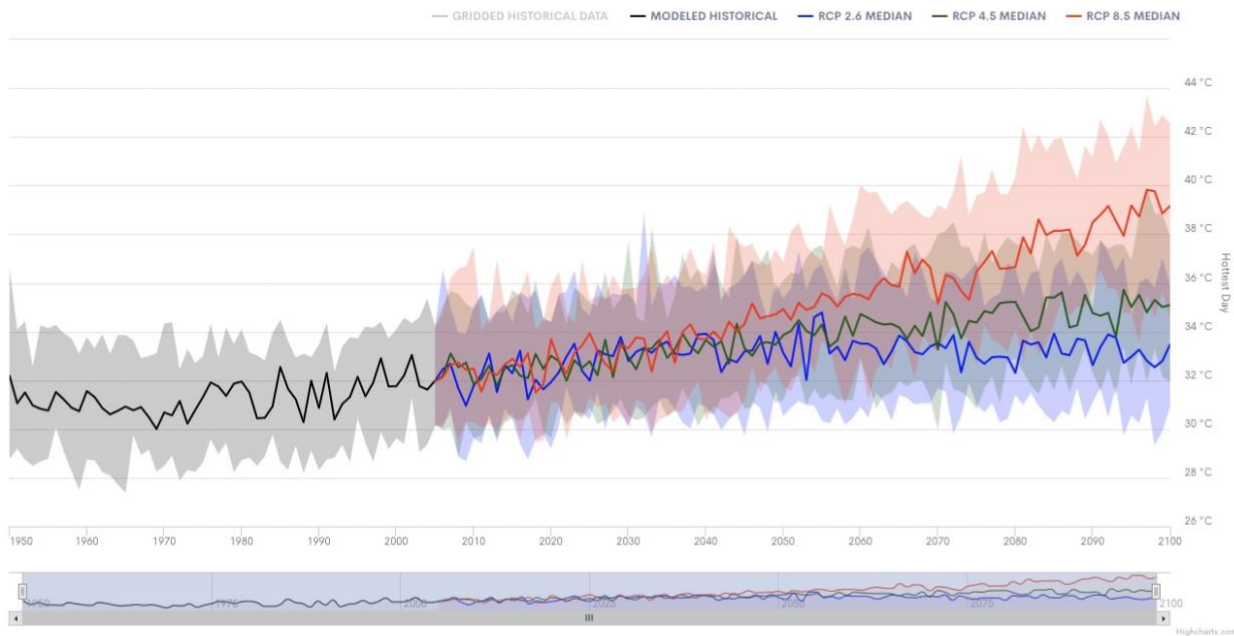


Figure 6. ClimateData.ca Screenshot - Temperature Graph (historical and projected data)

Precipitation Variables and **Other Variables** (historical data and three different RCP's): Similarly, these sections also provide a dropdown menu to select the variable, a description and graph.

Alternatively, the data can be viewed on a map (gridded), by variable, time period and RCP.

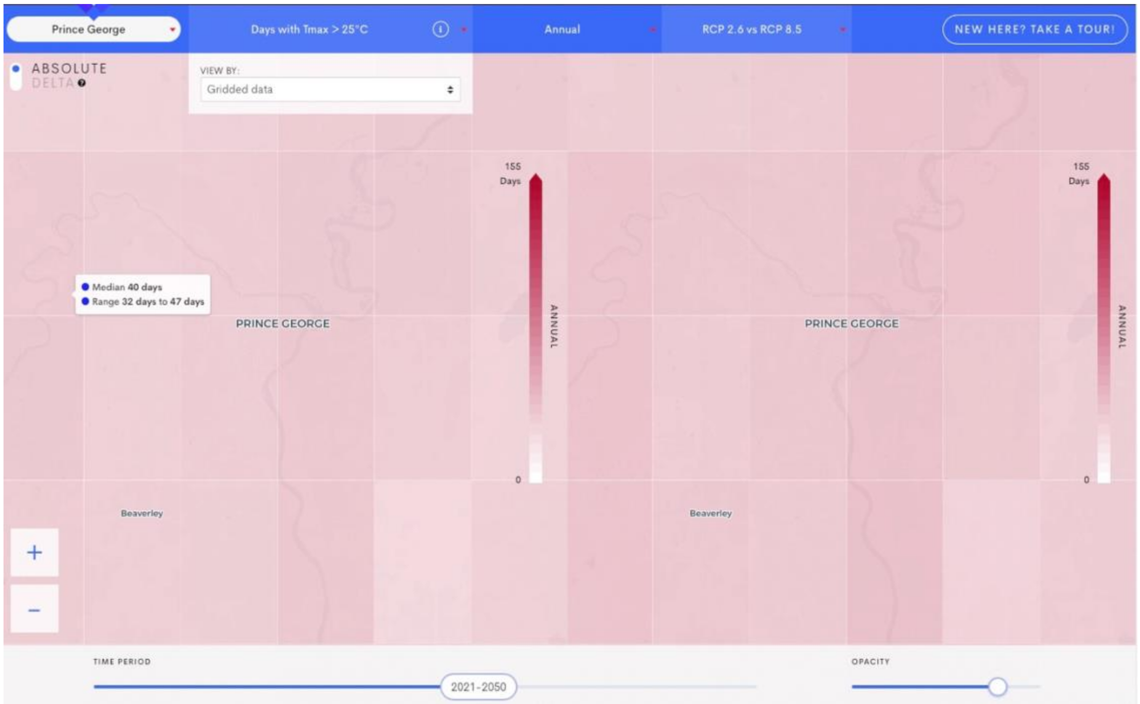


Figure 7. ClimateData.ca Screenshot - Side-by-Side Views of RCP 2.6 and 8.5 - Gridded data

Tabular data can be downloaded directly from the website by selecting the frequency (annual, monthly, seasonal or daily), target variable, location, and file format.

x	y	STATION_NAME	CLIMATE_IDENTIFIER	ID	LOCAL_DATE	PROVINCE_CODE	LOCAL_YEAR	LOCAL_MONTH	LOCAL_DAY	MEAN_TEMPERATURE	M	MAX_TEMPERATURE
-123.18388888888900	49.19472222222200	VANCOUVER INTL A	1108395	1108395.2013.6.13	2013-06-13 00:00:00	BC	2013	6	13	14.1		19.3
-123.18388888888900	49.19472222222200	VANCOUVER INTL A	1108395	1108395.2013.6.14	2013-06-14 00:00:00	BC	2013	6	14	14.9		18.3
-123.18388888888900	49.19472222222200	VANCOUVER INTL A	1108395	1108395.2013.6.15	2013-06-15 00:00:00	BC	2013	6	15	13.9		19.9
-123.18388888888900	49.19472222222200	VANCOUVER INTL A	1108395	1108395.2013.6.16	2013-06-16 00:00:00	BC	2013	6	16	17.8		22.4
-123.18388888888900	49.19472222222200	VANCOUVER INTL A	1108395	1108395.2013.6.17	2013-06-17 00:00:00	BC	2013	6	17	18.5		22.8
-123.18388888888900	49.19472222222200	VANCOUVER INTL A	1108395	1108395.2013.6.18	2013-06-18 00:00:00	BC	2013	6	18	16.5		19.9
-123.18388888888900	49.19472222222200	VANCOUVER INTL A	1108395	1108395.2013.6.20	2013-06-20 00:00:00	BC	2013	6	20	14.2		15.9
-123.18388888888900	49.19472222222200	VANCOUVER INTL A	1108395	1108395.2013.6.21	2013-06-21 00:00:00	BC	2013	6	21	15.9		20
-123.18388888888900	49.19472222222200	VANCOUVER INTL A	1108395	1108395.2013.6.22	2013-06-22 00:00:00	BC	2013	6	22	17.9		22
-123.18388888888900	49.19472222222200	VANCOUVER INTL A	1108395	1108395.2013.6.24	2013-06-24 00:00:00	BC	2013	6	24	16.2		18
-123.18388888888900	49.19472222222200	VANCOUVER INTL A	1108395	1108395.2013.6.25	2013-06-25 00:00:00	BC	2013	6	25	16.7		19.7
-123.18388888888900	49.19472222222200	VANCOUVER INTL A	1108395	1108395.2013.6.26	2013-06-26 00:00:00	BC	2013	6	26	17.3		20.6
-123.18388888888900	49.19472222222200	VANCOUVER INTL A	1108395	1108395.2013.6.27	2013-06-27 00:00:00	BC	2013	6	27	17.8		20.1
-123.18388888888900	49.19472222222200	VANCOUVER INTL A	1108395	1108395.2013.6.28	2013-06-28 00:00:00	BC	2013	6	28	17.8		20.4
-123.18388888888900	49.19472222222200	VANCOUVER INTL A	1108395	1108395.2013.6.29	2013-06-29 00:00:00	BC	2013	6	29	20.5		24.4

Figure 8. ClimateData.ca – Partial Screenshot of Downloaded Tabular Data for Vancouver International Airport

Intergovernmental Panel on Climate Change – Link – Raw Data

Similarly to climatedata.ca, the IPCC provides downloadable datasets for several variables based on their global climate models. The Data Distribution Centre (DDC) is the hub where all datasets are stored and available for download within the IPCC website. Most of the datasets appear to have global coverage and be part of larger reports such as the example in Figure 10 and Figure 9.

SROCC_SPM4_PanelB_RCPs

longitude	latitude	year_85	year_26	diff
-177.3667	28.2167	2069.0	2099.0	2.0
-176.6317	51.8633	2049.0	2057.0	1.0
-175.1667	-21.1333	2027.0	2030.0	1.0
-171.75	-13.8167	2010.0	2014.0	1.0
-171.7183	-2.81	2030.0	2029.0	1.0
-170.6833	-14.2833	2010.0	2015.0	1.0
-169.53	16.7383	2050.0	2059.0	1.0
-166.537	53.88	2043.0	2046.0	1.0
-166.2883	23.8683	2033.0	2037.0	1.0
-165.43	64.5	2101.0	2101.0	2.0
-160.5017	55.3367	2063.0	2087.0	2.0
-159.775	-21.2067	2062.0	2082.0	2.0
-159.35	21.9667	2040.0	2045.0	1.0
-158.0533	-8.9767	2045.0	2049.0	1.0
-157.8667	21.3067	2023.0	2023.0	1.0
-157.8	21.4333	2023.0	2022.0	1.0
-157.4717	1.9817	2024.0	2026.0	1.0
-156.4667	20.9	2026.0	2026.0	1.0
-155.0667	19.7333	2037.0	2042.0	1.0
-152.5117	57.7317	2067.0	2091.0	2.0
-151.7199	59.4405	2077.0	2101.0	2.0
-149.89	61.2383	2058.0	2079.0	2.0
-149.5667	-17.525	2048.0	2055.0	1.0
-149.4267	60.12	2073.0	2101.0	2.0
-148.5267	70.4	2081.0	2101.0	2.0
-146.3617	61.125	2077.0	2101.0	2.0
-145.7533	60.5583	2077.0	2101.0	2.0
-139.7334	59.5485	2083.0	2101.0	2.0
-135.3417	57.0517	2075.0	2101.0	2.0
-135.327	59.45	2086.0	2101.0	2.0
-134.9533	-23.125	2023.0	2021.0	1.0

Figure 10. IPCC Data Download Example – AR6 SROCC Data for Figure SPM.4: Extreme Sea Level Events

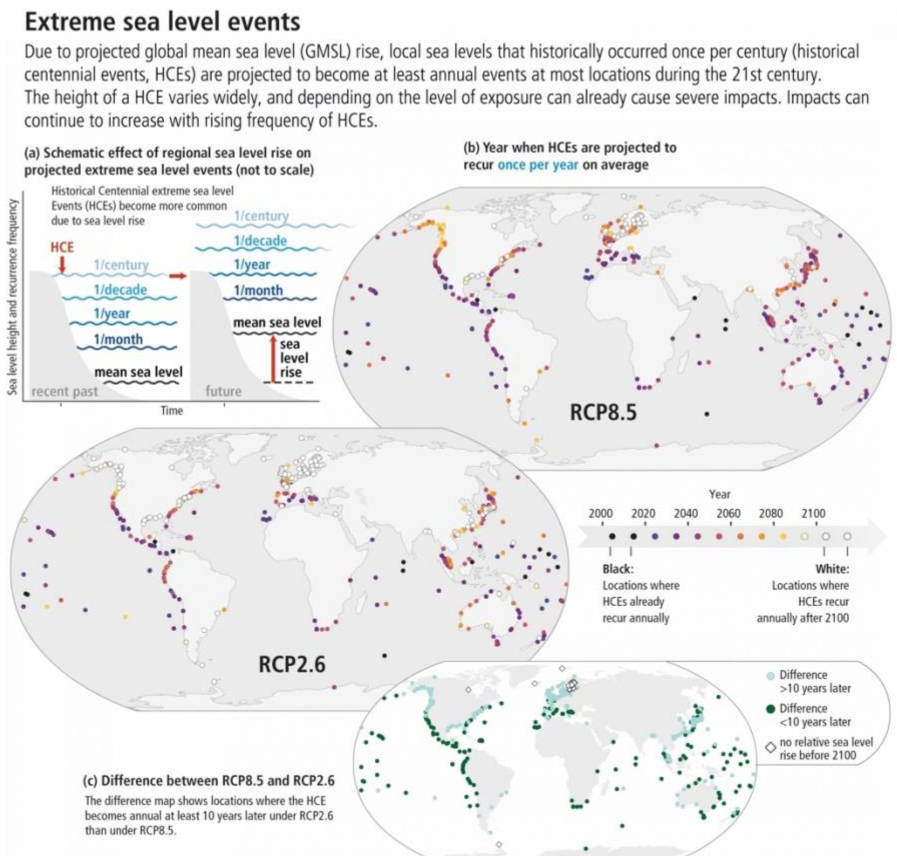


Figure 10. IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC) - Figure SPM.4: The effect of regional sea level rise on extreme sea level events at coastal locations (IPCC, 2019)

Library of Climate Data, Government of Canada - Link – Various

The Library of Climate Data is a "collection of links to climate datasets, tools, guidance and related resources" by various governmental entities, professional and international organizations (Government of Canada, n.d.). There are search filters that help navigate the over 400 links on various climate and environment resources.

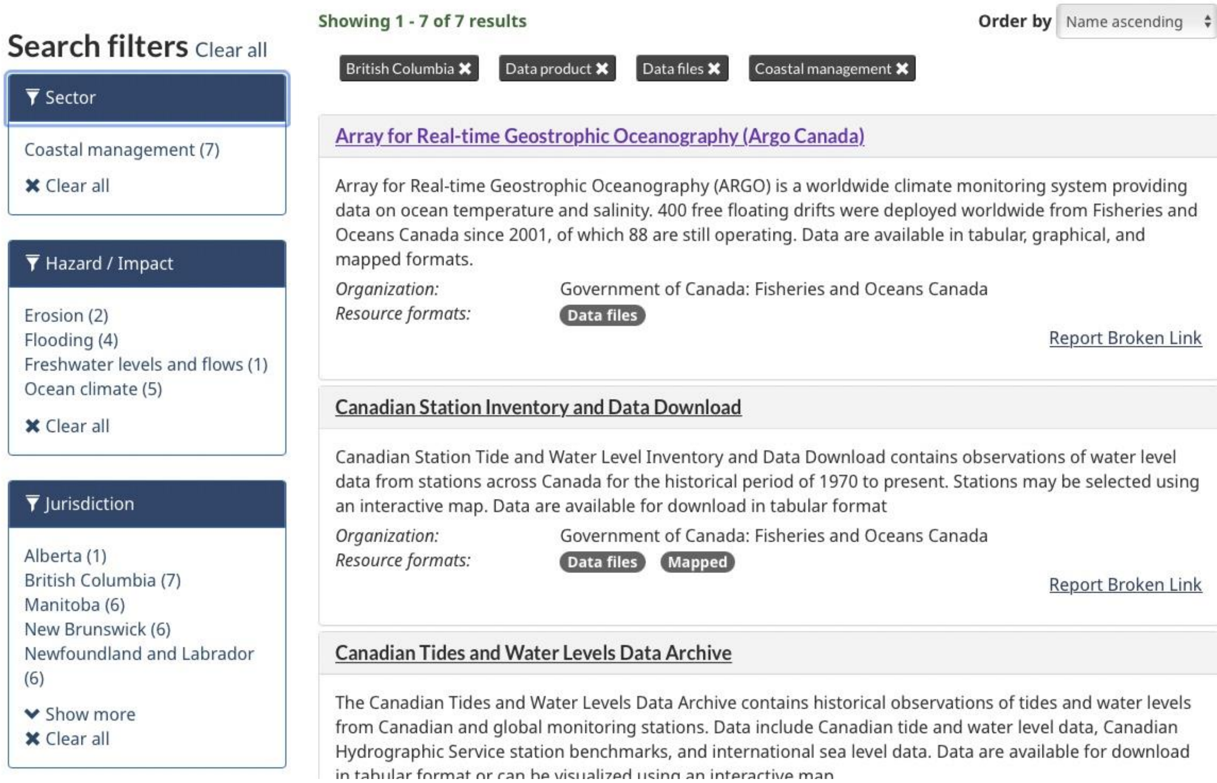


Figure 11. Library of Climate Data - Example of using filters for British Columbia, Datasets, and Coastal data

BC Government Datasets – Link

The BC Government Datasets website contains the Data Catalogue, the hub for thousands of provincially managed datasets. The site is easily searchable via key words and provides downloadable data in tabular form as well as visualization for geographical reference. For some datasets the website links to iMapBC, a provincial service to explore digital map layers for British Columbia.

Figure 13 is an example of the Data Catalogue's searchable data: The Provincial Strategic Threat Analysis (PSTA) analyzes and maps potential wildfire threats to integrate hazard and risk to communities, infrastructure and natural resources. The example below shows the Head Fire Intensity (90th percentile) data layer. This data can be found here. Similarly, Figure 12 provides the floodplain boundaries for a 200-year event and the data can be found here.

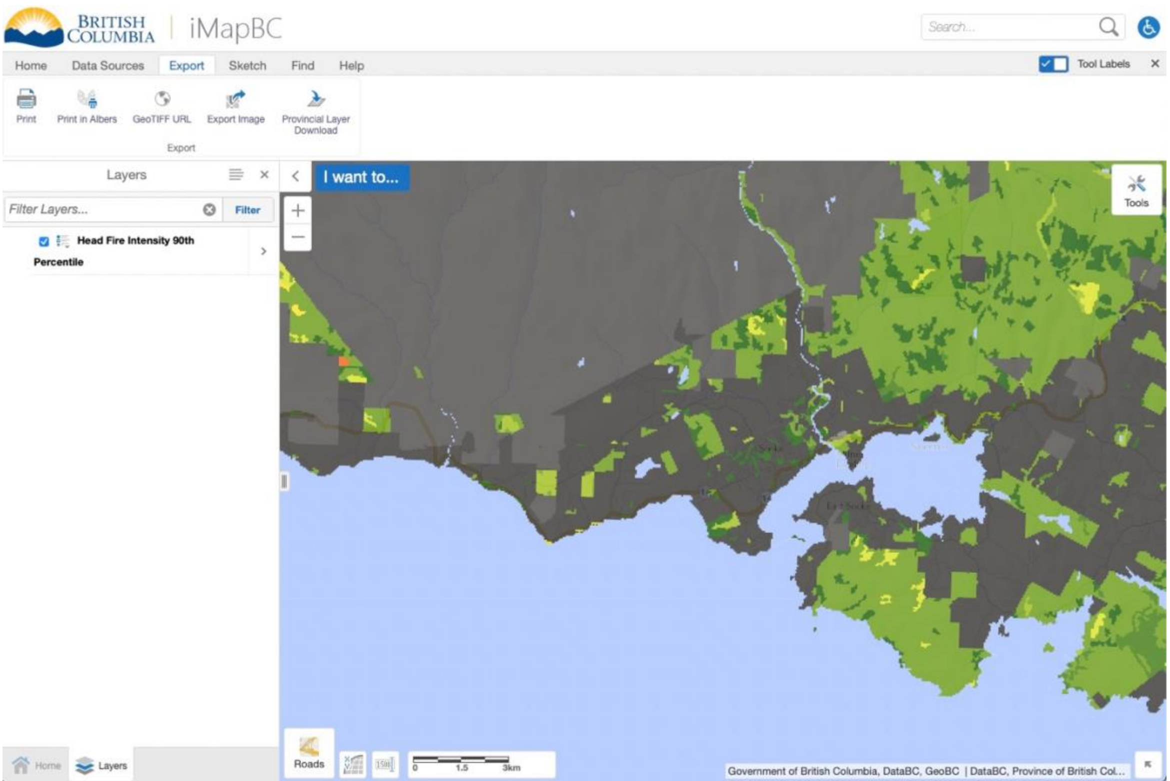


Figure 13. BC Data Catalogue - BC Wildfire PSTA Head Fire Intensity - iMapBC Visualization

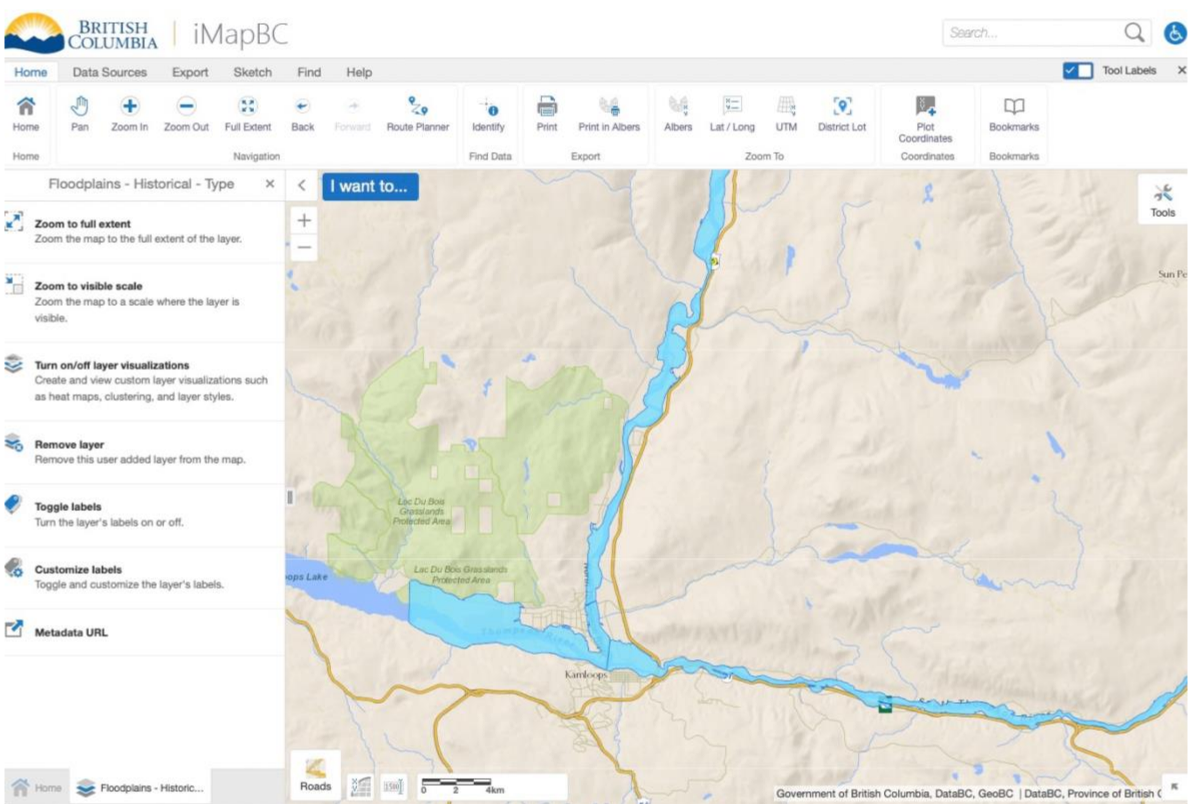


Figure 12. BC Data Catalogue - Mapped Floodplains in BC (Historical) – iMapBC Visualization

Level of Confidence in Data by Variable

The following is an assessment of the quality and level of confidence in the datasets per variable as found per the research.

Table 2. Risk Variable Data Summary

Risk Variable	Quality of Data	Global / National / Provincial / Municipal Data Source	Historical Data	Projected (future) Data	Location Data	Multiple Sources	Easily Downloadable Data	Global vs. Local Variable (See note 6)	Notes	Dataset Links
Temperature	High	All	Yes	Yes	Yes	Yes	Yes	Global	Data projections sourced from statistically downscaled global and regional models from the IPCC.	Climatedata.ca
Precipitation	High	All	Yes	Yes	Yes	Yes	Yes	Global	Data projections sourced from statistically downscaled global and regional models from the IPCC.	Climatedata.ca
Fire	High	Provincial	Yes	No	Yes	No	Yes	Local	-	BC Wildfire PSTA Head Fire Intensity
Air Quality	Low	Provincial / Municipal	n/a	n/a	n/a	Yes	n/a	Global	See note 1 below.	n/a
Flooding - Coastal	Medium	All	Yes	Yes	Yes	Yes	Yes	Global	-	Climatedata.ca
Flooding - Inland	Low	Provincial / Municipal	Yes	Yes	Yes	Yes	See note 5	Global / Local	See notes 2, 3 and 4 below.	Mapped Floodplains in BC (Historical) And Climatedata.ca (IDF Curves)
Heat Island Effect	Low	Municipal	Yes	No	Yes	Yes	No	Local	Data may not be publicly available. See note 2 below.	n/a
Landslides	Low	Provincial	Yes	No	Yes	No	No	Local	-	n/a
Windstorms	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Global	Could not find reliable windstorm data.	n/a

Note 1: Air quality is affected by multiple factors such as industrialization, traffic intensity, topography, wind patterns, weather patterns, and season of the year. Although some of the aforementioned factors can have local or regional effects, smoke from wildfires can travel long distances affecting the air quality of areas well outside of the wildfire's impacted area. Therefore, all buildings should be prepared to manage poor air quality, even if only seasonally, regardless of location.
Note 2: Datasets do not have 100% area coverage (significant data gaps exist).
Note 3: Datasets have low precision.
Note 4: Data consists of short-term forecasts for select watersheds, and/or floodplain data.
Note 5: Downloadability of data is not consistent across sources.
Note 6: A Global variable refers to one that is mostly influenced by global or long-range regional climate patterns; a local variable refers to one that is mostly influence by local topography and infrastructure/landscapes.

Variables such as temperature, precipitation, coastal flooding, and fire, can be reported on with the existing datasets highlighted in the Datasets section. Air quality may not be a significant variable to include in the assessment; understanding the building's mechanical systems and infiltration rate to manage indoor air quality may be more important instead.

Inland flooding data is available, however:

- only select watersheds are covered in the provincial datasets, and
- the municipal records have low precision (deliberately).

The heat island effect requires a relatively precise and up-to-date grid to be useful. Some municipalities have mapped it and more will follow suit, but at this point only larger urban centres, such as City of Vancouver, have data on this variable.

This research round did not find enough good quality/relevant data on landslides and windstorms.

Reports

The following reports were useful as background information and for reference during the project's secondary research phase. Links to all resources are listed in Appendix C.

IPCC's Sixth Assessment Report – Climate Change 2022: Impacts, Adaptation and Vulnerability - Link

- Global and regional impacts of climate change on communities
- Assessment on vulnerabilities and the capacities and limits of the natural world and human societies to adapt to climate change

2020 Climate-Resilient Buildings and Core Public Infrastructure - Link

- Provided background to understand how the Canadian Government models climate projections and summarizes their findings.

Climate Projections for Metro Vancouver - Link

- Projections at a regional Level – suitable level of granularity

Task Force on Climate-related Financial Disclosures – 2021 Status Report - Link

- Recommendations on Disclosure Frameworks (Table ES2)

- Key Findings (from a Preparer and User Perspective (Table ES4)

Advancing the Climate Resilience of Canadian Infrastructure: A review of literature to inform the way forward - Link

- Provided understanding of the federal government's climate hazards, impacts, and resilience options (Table 2 as shown below in Figure 14)

Infrastructure type	Climate hazard	Examples of infrastructure impacts	Examples of resilience options
Buildings	Heat	• Increased indoor air temperature and reliance on cooling systems • Accelerated ageing of building materials	• Upgrade ventilation systems and install window shades • Install thermally reflective material for the roof and facades of buildings
	Changing precipitation patterns	• Increased risk of flooded structures • Roof collapse from heavier snow loads on roofs	• Install backwater valves, sump pumps; redesignate no-build areas in high-risk flood zones • Retrofit at-risk structures to a higher standard and monitor/ remove snow accumulation
	Seasonal temperature changes	• Foundation and building damage from changes in freeze/thaw patterns and drying of soils	• Select concrete mixture aggregates that perform better in freeze–thaw cycles
	Permafrost degradation	• Subsidence and buckling can damage foundations • Loss of strength in building	• Improve ventilation and adjustable structural posts • Best design practices for foundations
	Storm surges	• Erosion compromises the integrity of foundations • Increased corrosion of metals	• Protective structures/dikes/ seawalls • Metal product components with enhanced resistance to corrosion
	High winds	• Loss of roof sheathing • Windborne debris can shatter windows and damage exteriors and facades	• Reinforce roofs/hurricane straps and additional fasteners • Install impact-resistant glass

Figure 14. Examples of Climate Hazards, Impacts, and Resilience options for Buildings

Standards

According to Infrastructure Canada, the Climate-Resilient and Core Public Infrastructure Initiative is in phase 2. This work is being conducted by the National Research Council of Canada (NRC) to "integrate climate resilience into building and infrastructure design, guides, and codes" (Government of Canada, 2022). This initiative is addressing updates to guidelines, and a new standard on durability in buildings, as well as a new guideline on basement flood protection and risk reduction.

Data Tools

The researched data tools are varied in type and accuracy. Listed below are the most relevant online tools.

Weather Data Visualization Tools

The following data visualization tools were analyzed and found to be a useful reference for the development of OPEN's own tools.

Environment Canada

The Canadian Government has several climate-related viewing tools. The best two tools cover the variables temperature and precipitation and have slightly different presentations.

Tool 1: CMIP6 Climate Scenarios
This tool is based on GCM's from the IPCC Assessment Report (AR6).

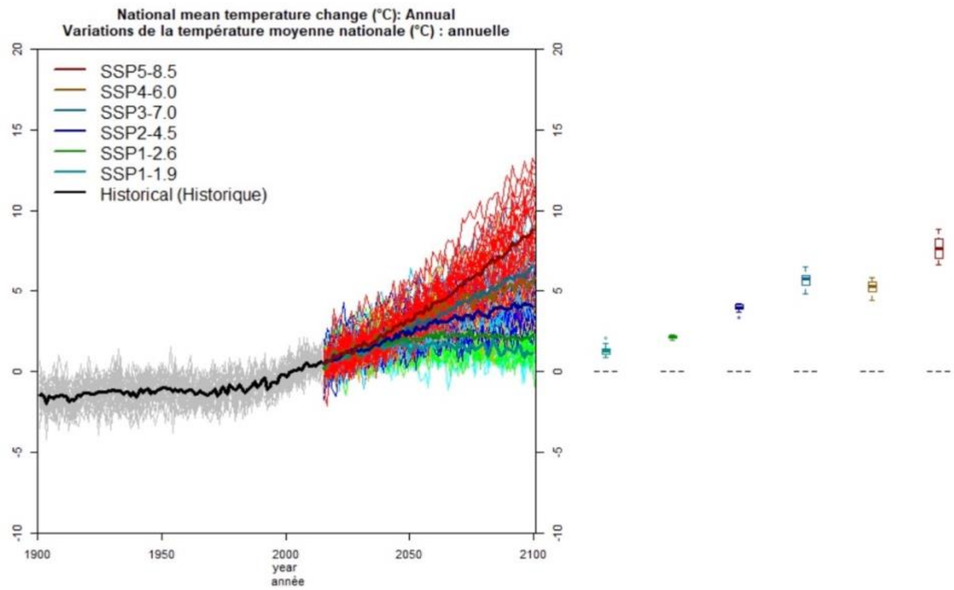
The data is presented by Shared Socio-Economic Pathway (SSP) scenarios, the latest iteration and most comprehensive of scenarios used for the IPCC 6th Assessment Report (overview). The SSP's focus on human development factors such as:

- Population
- Education
- Urbanization
- Gross Domestic Product (GPD)
- Economic Grown
- Rate of Technological Developments
- Greenhouse Gases (GHG) and Aerosol Emissions
- Energy Supply and Demand
- Land-Use Changes
- Etc.

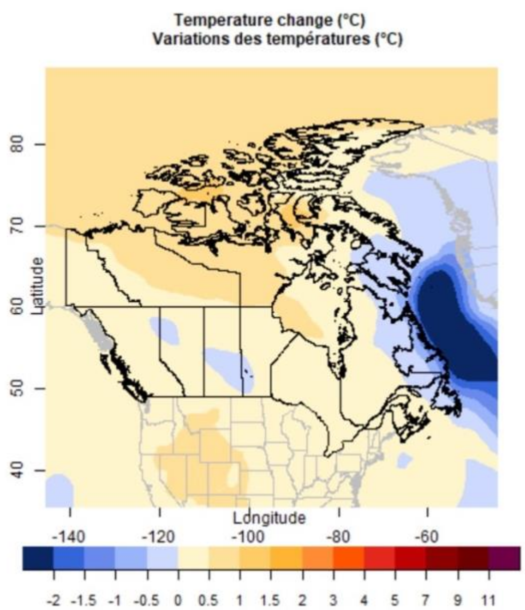
There are five SSP's; SSP1 reflects a gradual path to sustainability (low challenges to mitigation and adaptation), whereas SSP5 reflects the production of rapid technological progress and development of human capital as the path to sustainability development (high challenges to mitigation, low challenges to adaptation).

The website offers time series, map and tabular visualizations for Temperature (K) and Precipitation (%) variables for the period 1900 to 2100 for all SSP's in 20-year increments. The data can be downloaded as PNG graph or a NetCDF file.

Graph View – All SSP's + Historical Data



Map View – 5th percentile – SSP1-1.9



Tabular View – SSP1-1.9

Regions	SSP1-1.9 25th percentile	SSP1-1.9 50th percentile	SSP1-1.9 75th percentile
Canada	0.71	1.19	1.60
Alberta	0.54	0.73	1.12
British Columbia	0.45	0.70	1.03
Manitoba	0.64	1.11	1.39
New Brunswick	0.48	1.12	1.50
Newfoundland & Labrador	0.44	0.99	1.46
Northwest Territories	0.81	1.21	1.66
Nova Scotia	0.48	1.03	1.32
Nunavut	0.95	1.59	2.02
Ontario	0.48	1.10	1.52
Prince Edward Island	0.40	1.06	1.44
Quebec	0.55	1.08	1.57
Saskatchewan	0.73	0.91	1.20
Yukon Territory	0.51	0.86	1.22

Figure 15. CMIP6 Climate Scenarios by Environment Canada for the variable Temperature, annual means from 2021-2040

Finally, there is gridded data, a multi-model ensemble (or for each individual model) of CMI6 that can be downloaded as a NetCDF file for each SSP scenario or historical data.

Tool 2: Climate Data Viewer
The data in the Climate Data Viewer includes three emission scenarios

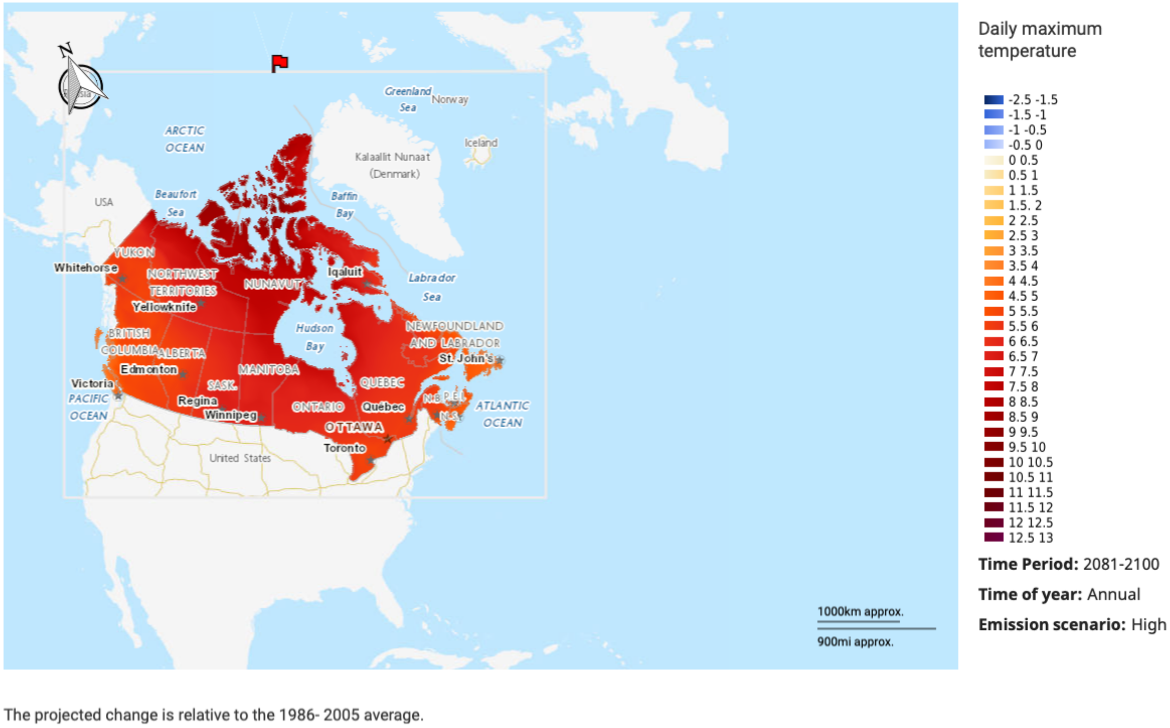


Figure 16. Environment Canada Climate Data Viewer - High Resolution Future Climate Simulation (downloadable image)

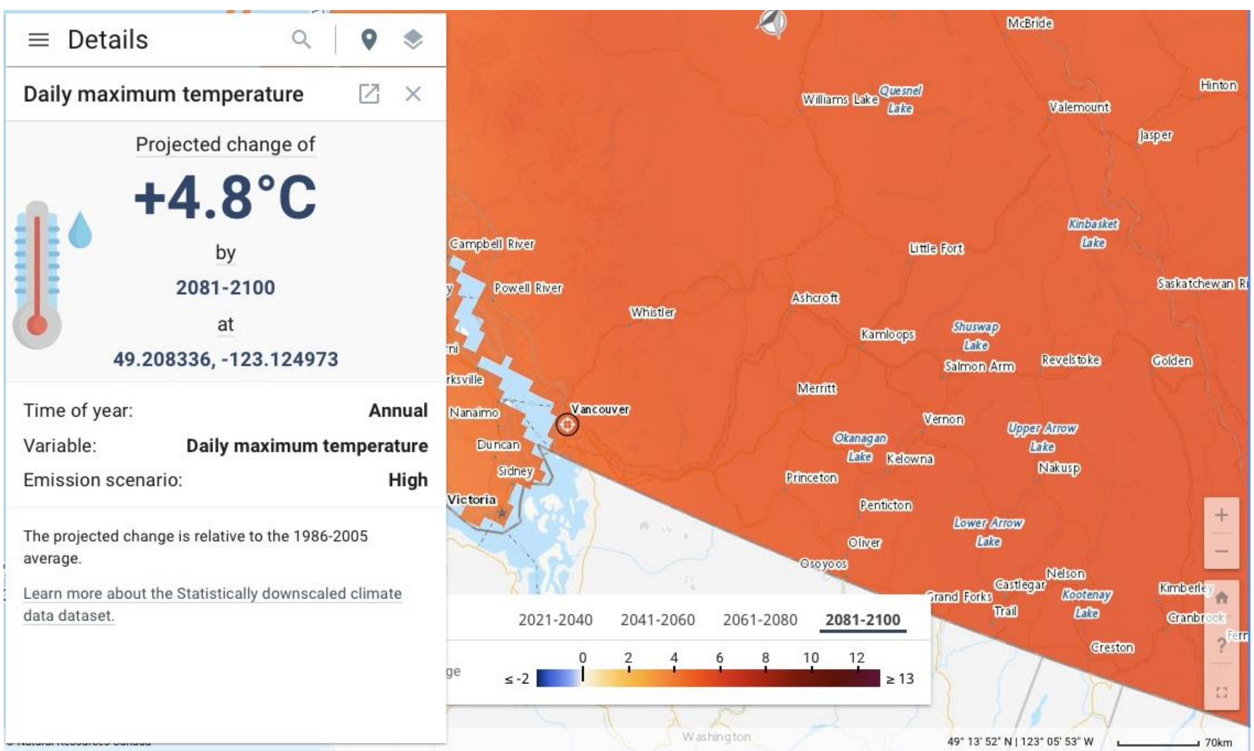


Figure 17. Environment Canada Climate Data Viewer - Specific Geographic Location

iMapBC

iMapBC is a web-based mapping (html) provincial service that allows for the viewing and analysis of BC's geographic datasets in the BC Geographic Warehouse, upload of map data and export of results.

PICS - Visualizing BCs Wildfire Threat

The Pacific Institute for Climate Solutions (PICS) is conducting research via the Wildfire and Carbon project on forestry management's impact wildfire threat and wildfire emissions. The data for this project is not readily downloadable from the PICS website, but could be requested by reaching out to the organization since they are based on BC Wildfire Service data.

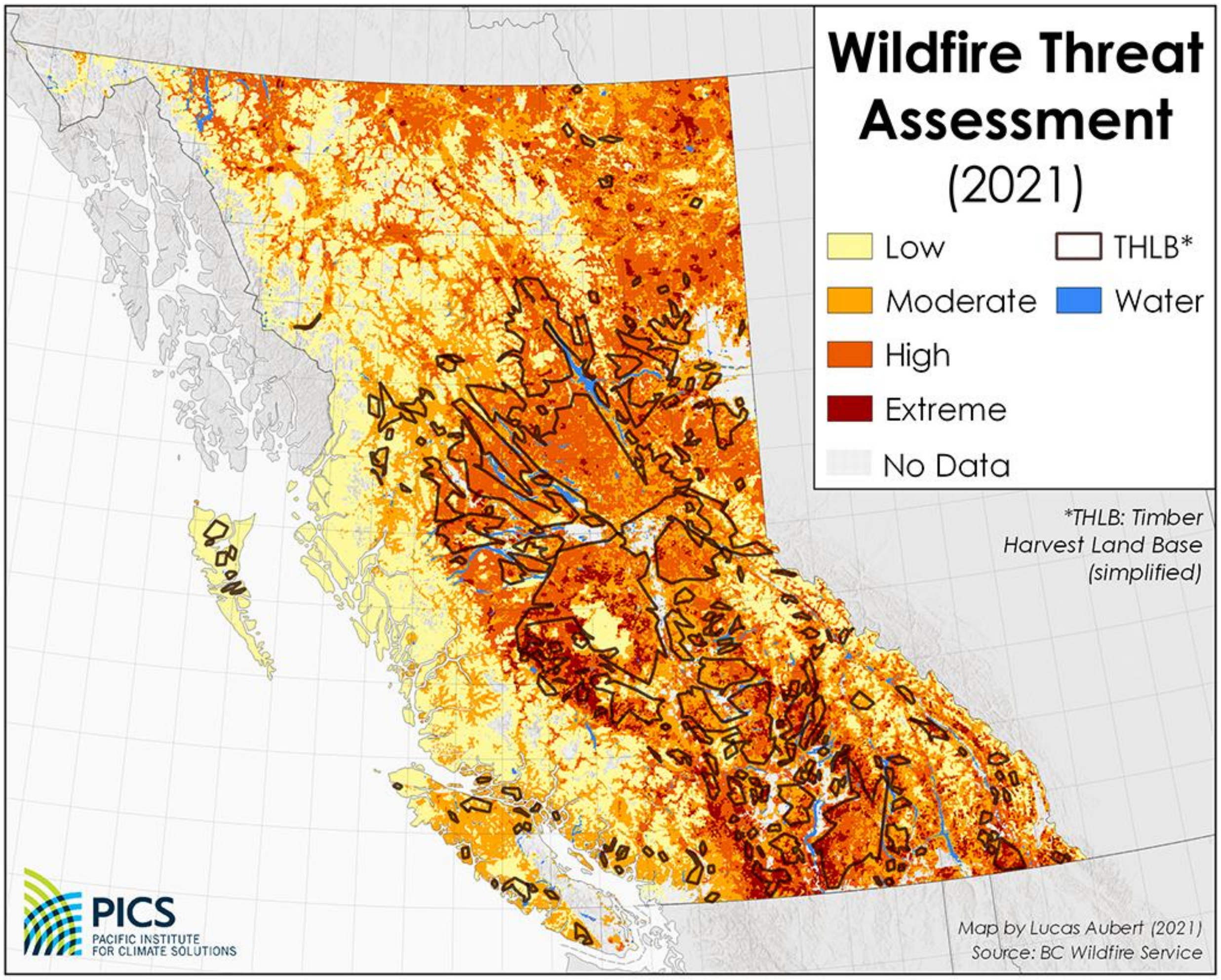


Figure 18. PICS BC Wildfire Visualization

Risk Analysis Tools

Moody's DataHub – Link – is a paid service with the following qualities:

- Cloud-based platform
- Centralized datasets
- Proprietary analysis and models
- Deliver data in variety of formats

MOODY'S ESG SOLUTIONS

Moody's ESG Solutions is a trusted ESG and climate data provider that empowers organizations to make better, more sustainable decisions. The group provides forward-looking, location-specific and globally comparable climate data to support investors, banks, insurers and companies in pinpointing and managing their climate-related risks. Leveraging decades of domain expertise and best-in-class risk models and analytics, the group delivers transparent data-driven ESG insights – including ESG Scores and Sustainability Ratings – to serve every ESG objective across sustainability investing and risk management within the global equity and credit markets.

RISK DATA SUITE (RDS)

RDS is a family of solutions offering ratings and related information on corporate, financial institutions, sovereigns, structured finance and public finance (US Municipals). The solutions provide you access to current and historical data sets allowing for detail risk exposure analysis and improve data integrity.

Figure 19. Moody's DataHub Datasets on Climate Change

Figure 19 is a screenshot of Moody's datasets on climate change. Moody's ESG Solutions is based on company formerly known as Four Twenty-Seven Inc. which was acquired by the Moody's Corporation in 2019.

XDI Systems – Link – Cross Dependency Initiative provides reporting services with multiple levels and types of reports including freemium and paid services. XDI also developed Climate Risk Engines that calculate the cost of physical climate risk and are used for TCFD reporting.

- Online Asset Analysis
- Asset Adaptation Planning
- Online Spatial Analysis
- Supply Chain Risk

XDI Systems is a good example of a company providing climate risk reporting services. OPEN could provide similar services with higher quality assurance standards and more accurate results in the Canadian market.

Cross Dependency Analytics

Bespoke algorithms are used to find the critical infrastructure required to run each asset – including power, communications, water and access. Cumulative upstream risk is added to the risk profile of each asset being analysed.

Asset Specific Archetypes

Asset specific information gives deeper insight into how an asset will perform in certain conditions, when it is likely to fail and why. XDI Platform analyses climate hazards against representative assets ("archetypes") which are tailored to mimic a real asset at the same location and embedded in the Climate Risk Engines.

A single archetype is defined by up to 100 pieces of information which include type, location, age, replacement cost, design specifications, major component parts (elements), construction materials, and capacities. Factors like floor height, construction materials, height of electrical components and wind ratings will all impact an assets performance under extreme weather stress.

Figure 20. XDI Systems Screenshot - Approach Overview

Mitigation/Adaptation Strategies

BC Housing has developed the Mobilizing Building Adaptation and Resilience (MBAR) program to build knowledge and capacity amongst its partners and the public. Among other tools, the MBAR program published a set of nine (9) Design Discussion Primers that provide high-level guidance for design and operations strategies; Appendix D includes the 9 primer documents. The MBAR primers list mitigation measures for different risks, including:

- Air Quality
- Chronic Stressors
- Fires at the Urban Interface
- Flood Events
- Heat Waves
- Power Outages and Emergencies
- Seismic Events
- Severe Storms
- Wildfires

OPEN could collaborate with municipalities, housing organizations, consultants, inspectors, and building owners to develop the risk assessments tools required to plan and execute mitigation and adaptation strategies. Collecting the building data in the list below is a good starting point to start this process:

- Existing HVAC Systems/Age
  - Heating and cooling capacity – Is the building capable to maintaining thermal comfort?

  - Ventilation capacity and type – Does the building meet ventilation standards?
  - type of equipment – What is the maintenance type and schedule necessary?
  - Age – When is replacement anticipated?
- Envelope Construction/ Roof Type/Age
  - Assembly type and condition – Is the envelope able to effectively withstand exposure to weather?
  - Performance – What R-values and U-values do the walls, roof and windows have? Are they sufficient to maintain thermal comfort within the building?
- Passive Cooling Strategies
  - Building form and orientation – Does the building have favourable form and orientation to optimize daylighting and solar load to support passive thermal comfort and minimize mechanical requirements?
- Indoor Air Quality
  - Controls – Does the building have sensors to monitor indoor air quality?
- Infiltration
  - Air tightness – Was an air tightness test ever performed to confirm perforations through envelope have been sealed properly?
- Other Resilience Design Features (included by architects/engineers in original design/construction of building)
  - Flooding protection features – such as berms/barriers/elevated entrances/location of mechanical rooms/etc.?
  - On-site renewable energy generation?
  - Back-up equipment on-site?
  - Etc.

Conclusion

The following are the key findings of the research project:

1. Climate risk assessments must remain private. Public disclosure of the results would not be possible due to liability concerns.
2. Temperature, precipitation, and fire variables have readily available, high-quality data.
   - Could be reported on immediately
   - A scorecard could be useful to clients
3. Inland flooding, heat island effect, landslides, and windstorms have inconsistent, low-grade or not publicly available data.
   - Could be a research project on their own
4. Additional interviews of financial institution and insurance company’s representatives are needed – this step is key to understanding financial risk and liability of clients/stakeholders.
   - Could be a research project on their own
5. Most stakeholders do not have the detailed, high-quality data required to establish resilience in their building portfolios. This data includes the current condition of the passive and active systems that affect a building’s ability to mitigate and adapt to climate change.

6. All stakeholders recognized that collecting this information in an accessible, centralized, reliable, secure, and interactive platform would be beneficial for their organizations.
7. Most stakeholders also recognized that benchmarking climate risk could aid in their efforts to prioritize maintenance, create policies, and target incentives to address major concerns such as overheating during heat wave events and indoor air quality during wildfire season.

OPEN could collaborate with building owners, property managers and financial institutions to create interactive database hubs that aggregate and visualize online data (public + private sourcing) by:

- Creating cloud-based surveys for the organization's building technologists to upload the buildings' attributes, drawings/records, and maintenance schedules to monitor, analyze and risk assess their portfolios systematically.
- Cross-referencing the building's location with OPEN's climate risk variable mapping, to create a climate risk scorecard – cataloguing cooling capacity and other resilience features. This tool could be the first step before engaging with a consultant for a more in-depth assessment.
- Building upon existing tools such as VCH's Story Map and the City of Vancouver's heat map to create functional mapping of community vulnerabilities.

OPEN is uniquely positioned to foster collaboration amongst stakeholders and create the tools required to bridge gaps, as well as assure high-quality data, reliability, and security - adding value to our society by helping public and private organizations optimize resources and increase resilience to climate risks elements of our building infrastructure.

Appendices

Appendix A - References

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Appendix B – List of Resources

Summary of useful resources mentioned in this report.

Datasets

- Climatedata.ca
- IPCC DDC
- Library of Climate Resources
- BC Government Datasets
- BC Fire Service – Historic Points and Boundaries

Tools

- Environment Canada – CMIP6 Climate Scenarios - Visualization tool
- Environment Canada - Climate Data Viewer
- iMapBC – Web-based tool to view Digital Map Layers for British Columbia
- PICS - Visualizing BCs Wildfire Threat
- Moody's Data Hub - Moody's ESG Solutions (formerly known as Four Twenty Seven)
- XDI Systems Cross Dependency Initiative

Reports (pdf files have been saved to OPEN's Drive)

- 2020 Climate-Resilient Buildings and Core Public Infrastructure
- Advancing the Climate Resilience of Canadian Infrastructure: A Review of Literature to Inform the Way Forward
- Coastal Flood Risk Assessment Guidelines for Building and Infrastructure Design
- Weathering the Storm: Developing a Canadian Standard for Flood-Resilient Existing Communities
- Climate Projections for Metro Vancouver
- Task Force on Climate-related Financial Disclosures – 2021 Status Report
- Dream Group Companies 2020-2021 Sustainability Report
- Vancity Annual Report

Other Links

- PIEVC Program
- VCH Story Map
- Climate Resilient Buildings and Core Public Infrastructure Initiative

Appendix C – Interview Summaries

Omitted

Appendix D – MBAR Climate Strategies

#	Title
D1	Air Quality
D2	Chronic Stressors
D3	Fire
D4	Flood Events
D5	Heat Waves
D6	Power Outages Emergencies
D7	Seismic Events
D8	Severe Storms
D9	Wildfires

AIR QUALITY

Risks to Buildings, Occupant Safety & Environment

- Decreased outdoor and indoor air quality due to allergens (e.g. pollen)
- Risk of building-related and non-specific building-related illness
- Electrical system overload due to increased energy usage associated with ventilation and air conditioning systems
- Potential utility service interruption due to increased energy usage

Design Strategies

Strategy	Cost	Impact	Alignment
Select a minimum of double-paned tempered window and frames with an air barrier seal to provide greater air quality protection	$$	**	
Include mesh debris screens for gutters, eaves and vents to reduce accumulation of allergens	$	*	
Include mesh screens into operable windows to prevent and insects pests from entering occupied areas	$	***	
Ensure the building air intake is away from local sources of outdoor air pollution	$	***	
Exceed industry standards for ventilation to keep indoor air pollutants and carbon dioxide levels low. Consider including a carbon dioxide monitor to monitor ventilation needs	$$	***	
Use demand-controlled ventilation based on carbon dioxide levels to reduce the introduction of outdoor air beyond required air flow rates	$	**	
Ensure HVAC systems are HEPA ready and/or procure portable HEPA filters with carbon filters to be used during wildfire smoke events	$	**	
Use the highest rated filter possible in HVAC systems (minimum MERV 13, and ideally HEPA) in areas with poor local air quality, such as areas with high traffic, rail, port, or industrial activity	$$	***	
Activated carbon filters can be incorporated into HVAC systems in areas with poor local air quality to reduce exposure to outdoor gaseous contaminants (e.g. VOCs)	$$	**	
Consider ventilation systems that reduce humidity and prevent allergens, such as dust mites, mould, and pollen	$	**	
Include cooling in HVAC design to allow windows to be closed under conditions of poor air quality"	$$	***	
Connect cooling and ventilation systems in refuge areas to a source of back-up power	$$	**	
Ensure backup power to critical systems and areas to prevent system overload during high use of mechanical ventilation/cooling (i.e. when air quality is poor)	$$	*	
Eliminate infiltration of air from the parking garage into the building using air barriers and ventilation	$$	***	
Ensure sufficient ventilation in cooking areas to reduce particulate matter exposure	$	**	
Further reduce indoor particulate matter levels in small rooms for extreme air quality events, such as a building amenity space, through use of air cleaners equipped with high-efficiency particle air (HEPA) filters or electrostatic precipitators (EP)	$$	***	
Place equipment and furniture with air circulation, temperature control, and pollutant removal functions of the HVAC systems in mind	$	**	
Use building materials and furnishings that are low in volatile organic compounds	$	***	

Sources of airborne contaminants from both inside and outside a building can have a serious impact on indoor air quality. Outdoor sources of contaminants include major roads, rail yards, industry, fireplaces and wildfire smoke events, while indoor sources of contaminants include off-gassing from building materials and furnishings, cooking, moisture, mould and pests. As the climate changes, climate scientists expect to see an increase in the number of wildfire smoke events and in the levels of summer ozone overall. Exposure to these contaminants have been linked to a number of short-term health effects such as fatigue, headaches, eye, nose and throat irritation, and impacts on cognitive function. Long-term health effects include respiratory diseases, cardiovascular disease and cancer. Emerging research shows association of poor air quality with birth outcomes, diabetes, obesity, mental health outcomes, cognitive development and cognitive decline. However, several measures can be taken to reduce exposure to poor air quality and improve occupant health and well-being.

Operations Strategies

Strategy	Cost	Impact	Alignment
Create a schedule to inspect, maintain and regularly replace high-efficiency air filtration media for all outdoor air building ventilation systems	$	*	Fire at the Urban Interface
Improve access to local outdoor air quality data by installing displays in common areas of the building	$$	*	Fire at the Urban Interface
Close building openings to temporarily reduce the intake of outdoor air during extreme events, including forest fires	$	***	Fire at the Urban Interface
Keep relative humidity below 60% to control dust mites	$	**	
Develop a whole-building strategy to manage moisture and mould by reducing wet or damp areas, standing water, and condensation (minimizing attraction for mosquitos and other insects)	$	***	
Integrate indoor air quality concerns into purchasing decisions (e.g. building materials and furniture)	$	*	

Power Outages · Heat Waves · Fire at the Urban Interface · Severe Storms · Seismic Events

Relative Cost/ Cost Premium		
Low	Medium	High
$	$$	$$$

Relative Impact		
Low	Medium	High
*	**	***

Community Benefits

Consider the following strategies to help improve the resilience of the community overall:

- Educate building managers and occupants on measures to prevent exposure to and reduce impact of allergens, extreme air quality events, and traffic-related air pollution
- Provide refuge areas with excellent air filtration to create safe and healthy spaces for vulnerable community members during periods of extreme air quality advisories

Potential Design Conflicts

Take care and ensure resilient strategies do not exacerbate vulnerability and other risks

- Passive ventilation strategies that rely on natural air flow to cool and ventilate a building may exacerbate indoor air quality issues during times of poor air quality (e.g. forest fire smoke). Ensure buildings have back-up cooling and ventilation systems that allow for mechanical ventilation when necessary.

Additional Resources

- US Environmental Protection Agency: *Fundamentals of Indoor Air Quality in Buildings.*
- US Environmental Protection Agency: *Indoor airPLUS Program for Builders.*
- US Environmental Protection Agency: (2013) *Moisture Control Guidance for Building Design, Construction and Maintenance.*
- US Environmental Protection Agency: *Best Practices for Reducing Near-Road Pollution Exposure at Schools.*
- US Environmental Protection Agency: (2016) *Recommendations for Constructing Roadside Vegetation Barriers to Improve Near-Road Air Quality.*
- US Environmental Protection Agency: (2001) *Building Radon Out: A Step-by-Step Guide On How to Build Radon-Resistant Homes.*

CHRONIC STRESSORS

Climate change driven chronic stressors include freeze-thaw cycles, wind-driven rain, wetting and drying, frost penetration, wind-driven abrasive materials, atmospheric chemical deposition on materials, and broad spectrum solar radiation and ultraviolet (UV) radiation.

Risks to Buildings, Occupant Safety & Environment

- Premature and accelerated deterioration of concrete, pavement, building facades. Concrete is especially subject to deterioration caused by absorption of moisture and thermal expansion and contraction resulting in fractures and spalling.
- Uncontrolled moisture accumulation in structural materials can reduce the structural integrity of building components through mechanical, chemical and biological degradation.
- Roof ice damming, increased rain penetration and moisture absorption, efflorescence and surface leaching concerns
- Increased decay processess, specifically for wood products
- Changes in hydraulic conductivity, unconfined compressive strength, and longitudinal resonant frequency of the structural performance of cement-treated soils.

Site Strategies

Strategy	Cost	Impact	Alignment
Ensure proper site drainage so that water, rain, and snowmelt is prevented from entering the building. This can be achieved through increased soil infiltration, decreased impervious surfaces, and grey infrastructure such as retention tanks	$$	***	
Reduce water infiltration directly adjacent to the buildings foundation, especially if a below grade structure is present. Apply moisture and vapour barriers to below grade concrete to prevent moisture problems	$$	***	
Use permeable paving materials and grade the site away from structures to improve overall rainwater infiltration capacity of the site, reducing water and moisture inundation to buildings	$	**	

Design Strategies

Strategy	Cost	Impact	Alignment
Use concrete mixes with reduced water content to minimize risk of structural degradation from changes in freeze-thaw cycles	$	**	
Avoid mass and barrier exterior wall designs and select pressure-moderated rain screen walls to shed water at the face with back up drainage. For high-rise buildings, consider pressure equalized rain screen walls for exterior walls	$$	**	
Include flood vents to allow floodwater to escape and ensure all materials installed below the DFE are water and moisture resistant	$	**	
Design the envelope to prevent weather elements from entering the structure and becoming trapped inside the walls. Ensure wall assemblies are designed to resist penetration of moisture through vapour and moisture barriers, and that the dew or condensation point does not lie within the dry portion of the wall assembly	$$	***	
Perform air sealing, high performance insulation, and attic venting to eliminate the escape of heat from conditioned areas which can result in ice dams	$$	***	

As some of BC's regions become warmer and wetter, interior and exterior moisture will become an increasing threat to buildings. In BC's northern latitudes, warmer winters may lead to more frequent freeze-thaw cycles, while regions with milder winter climates could see freeze-thaw cycles decline. These changes are expected to result in higher rates of weathering of building material, as well as general moisture damage. Concrete buildings are particularly vulnerable to weathering impacts that can compromise their durability and resilience over time. As a result, it is important to ensure building envelopes and enclosures are able to resist these changes and prevent moisture from entering the structure.

Design Strategies

Strategy	Cost	Impact	Alignment
Consider the drying potential of both cladding and the wall sheathing/framing and cavities and back venting introduced for drainage purposes	$	*	
Avoid constructing with wet materials throughout the construction process. Ensure all products that will be contained within the building envelope are dry before being sealed in place	$	***	
Ensure placement of dehumidification and exhaust ventilation fans in moisture-rich interior environments, such as bathrooms or basements where moisture may be prevalent	$	***	
Optimize the HVAC system to ensure the indoor air condensation point is low enough to prevent building on cold surfaces and moisture absorption	$	***	
Maintain relatively low moisture levels in conditioned spaces. Protect building systems from getting wet from the interior and allow them to dry toward the outdoors	$	***	
Ensure air is well distributed and the HVAC system can provide sufficient air changes per hour to prevent humidity accumulation	$	**	
Use concrete mixes with reduced water content to minimize risk of structural degradation from changes in freeze-thaw cycles	$	**	

Operations Strategies

Strategy	Cost	Impact	Alignment
Inspect regularly for signs of moisture damage, waterproofing performance, and proper drainage around the building	$	***	
Inspect plumbing and water conveyance systems to ensure they are free of leaks or symptoms of future leaks	$	***	
Application and maintenance of proper drainage systems (i.e. gutters or other diversion methods) to ensure rainwater runoff is controlled and diverted away from the building	$$	***	
Develop a maintenance plan to maintain the permeable and impermeable surfaces that contribute to water diversion	$	**	

Severe Storms Heat Waves Flood Events

Relative Cost/ Cost Premium		
Low	Medium	High
$	$$	$$$

Relative Impact		
Low	Medium	High
*	**	***

Additional Resources

- European Commission. (2017). Science for Environment Policy Future Brief: Noise abatement approaches
- Hong Kong Environmental Protection Department. Environmental Noise Mitigation Measures
- Toronto Public Health. (2017) How Loud is Too Loud? Health Impacts of Environmental Noise in Toronto
- Engineering Services City of Vancouver. City of Vancouver Noise Control Manual
- Moisture Control Guidance for Building Design, Construction and Maintenance.

FIRES AT THE URBAN INTERFACE

Risks to Buildings, Occupant Safety & Environment

- Damage to, or destruction of buildings
- Utility service interruption
- Potential loss of property and personal assets
- Decreased outdoor and indoor air quality and associated risk to human health
- Risk of human injury or loss of life through exposure to fire, smoke, and/or decreased air quality

Site Strategies

Strategy	Cost	Impact	Alignment
Identify prevailing wind direction and airshed characteristics to determine direction of potential fires	$	***	
Conduct a full risk assessment, considering fuel types, building location relative to slope, and the nature of the structure	$$	***	
Maintain 10m setback from all combustible materials to create a natural firebreak. Increase this setback for structures or vegetation closest to the forest interface	$	***	
Install outdoor water fixtures connected to a gravity-fed source in a location easily accessible to building occupants	$	***	

Design Strategies

Strategy	Cost	Impact	Alignment
Include mesh debris screens in gutters, eaves and vents to reduce accumulation of flammable vegetation and limit exposed areas from sparks and embers	$	*	
Install a chimney spark arrestor to reduce release of sparks and embers to surrounding areas	$	*	
Select higher performance fire-retardant or -resistant siding materials (e.g. stucco, metal siding, brick, concrete and fibre cement, log or heavy timbers)	$$	***	
Select fire-retardant roofing materials, such as metal, asphalt, clay and composite rubber tiles with Class A, B or C ratings – avoid green roofs for buildings at the wildland-urban interface	$$	***	
Use double-paned tempered windows and frames with an air barrier seal to provide greater air quality protection and heat resistance	$$	**	
Ensure building and garage entry doors are fire-rated and sealed with an air barrier	$	**	
Install high-efficiency air filtration media (MERV 11 or higher) for all outdoor air building ventilation systems to improve indoor air quality	$$	***	
Install air cleaners equipped with highest-efficiency particle air (HEPA) filters and activated carbon filters in refuge areas (e.g. amenity spaces)	$$$	***	
Make use of demand-controlled ventilation based on CO2 levels to reduce the introduction of outdoor air beyond required air flow rates.	$$$	**	
Install mechanical systems such as air source heat pumps that allow for cooling during fire events	$$	***	
Design a common building area to act as a cooling room or clean air refuge	$	***	
Connect cooling and ventilation systems in refuge areas to a source of back-up power.	$$	**	
Ensure a minimum of 72 hours of fuel storage for power to refuge area and key services, including building pumps, fans, emergency lighting, and security systems	$$	***	
Design building entry and exits that can be operated manually	$	***	

Power Outages & Emergencies · Air Quality · Flood Events · Severe Storms · Seismic Events · Heat Waves

Relative Cost/ Cost Premium		
Low	Medium	High
$	$$	$$$

Relative Impact		
Low	Medium	High
*	**	***

An interface fire is an unplanned fire with the potential to threaten building safety. Risks occur when the close combustion of natural fuels (e.g. trees, grasses and shrubs) spread to human-made structures. Wildfires at the urban interface are more complex as a result of the compounding fuel sources presented by combustible building and other materials. At the wildland-urban interface, fires can start either as wildfires and spread to adjacent structures, or as "urban" fires that ignite vegetation and spread through the wilderness. Interface fires are projected to increase in severity and magnitude as a result of climate change, and can in turn lead to air quality advisories across the province.

Operations Strategies

Strategy	Cost	Impact	Alignment
Trees should be set back 10m from all buildings or any combustible materials upon mature canopy growth	$	***	
Plant fire-resistant vegetation with moist, supple leaves and low sap or resin production	$	*	
Ensure planting groups are a minimum of 6m apart, and trees are a minimum 3m apart	$	*	
Prune lower branches within 6' (1.8m) of ground for trees taller than 18' (5.5m)	$	*	
Regularly mow lawn areas and check roof gutters to remove flammable vegetation	$	*	
Inspect, maintain and replace high-efficiency air filtration media for all outdoor air building ventilation systems	$	**	
Close building openings to temporarily reduce the intake of outdoor air during extreme events	$	***	
Plan, rehearse, and identify procedures necessary to maintain a successful refuge area (e.g. testing equipment, checking shelf life of stored provisions)	$	*	
Provide occupant education on refuge areas, evacuation measures, exit locations, etc.	$	***	
Educate building maintenance staff in firefighting/resistance measures to help delay need to evacuate (e.g. operating sprinklers, wetting down surfaces, removing flammables)	$	***	
Provide sufficient personal protective equipment for building occupants, (e.g. N95 masks or N95 respirators) to minimize exposure to particulate matter	$	**	
Ensure personal cooling devices are available to building occupants (e.g. cooling blankets)	$	*	
Ensure there is adequate means for people who don't have cars to evacuate the vicinity (e.g. public transportation or a carpool-evacuation plan)	$	*	
Ensure alternate access routes are available and known to building occupants	$	**	

Community Benefits

Consider the following strategies to help improve the resilience of the community overall:

- Provide access to local outdoor air quality data and indoor CO2 levels via occupant displays
- Design amenity rooms to act as cooling centres/clean air refuge areas for at-risk community members (e.g. seniors) and a central location for emergency support and services
- Ensure refuge areas and common spaces are designed to foster social connection, mental health, and overall cultural safety
- Ensure building connection to community fire response plans (e.g. notification systems)

Potential Design Conflicts

Take care and ensure resilient strategies do no exacerbate vulnerability and other risks

- Vegetation setbacks may eliminate benefits associated with trees for shading and heat island reduction
- Consider the durability of siding materials to withstand storms, freeze/thaw and seismic events
- Consider the impact of roofing materials on the heat island effect
- Passive ventilation strategies that rely on natural air flow to cool and ventilate a building may exacerbate indoor air quality issues during times of poor air quality (e.g. forest fire smoke). Ensure buildings have back-up cooling and ventilation systems that allow for mechanical ventilation when necessary.

Additional Resources

- BC Air Quality, Current Air Quality Data Map – Air Quality Health Index
- FireSmart Your Property
- FireSmart Homeowner's Manual

FLOOD EVENTS

Risks to Buildings, Occupant Safety & Environment

- Damage to, or destruction of buildings caused by coastal or inland flooding
- Weakened foundations and structural integrity from flooding and increase runoff
- Utility service interruption, including sewage systems
- Loss of property and personal assets due to water damage or contamination from sewage, soil and mud
- Increased coastal salt spray and salinization of soils

Site Strategies

Strategy	Cost	Impact	Alignment
Avoid sites in projected zones of coastal, estuarine and riverine floodplains, and areas vulnerable to groundwater, stormwater/overland (aka pluvial) flood hazards	$	***	
Review available flood hazard information available from the province or local municipality to identify relevant flood risks and develop knowledge of historical flood events for the site	$	***	
Assess the criticality of buildings and identify infrastructure that is required (e.g. ability of building and surrounding infrastructure to accommodate a 5, 10, 50 year flood depending on building type or occupancy)	$	***	
Include scour protection for shoreline developments, such as riprap aprons, blanket and gravel toppings, or filter fabric or floodwalls	$$$	***	
Incorporate landscape features such as berms to provide natural barriers, and wetlands and swales with native plants to buffer wave energy and absorb and redirect water on-site	$$	***	
Use permeable paving materials and grade away from structures to improve overall rainwater infiltration capacity of the site, reducing the pressure on sewer systems	$$	**	
Abide by the established design flood elevation (DFE) / flood construction level based on the future floodplain extent, and limit programming uses below this level in to parking, building access and minor storage	$$	***	
Where necessary, infill sites to raise the land, or elevate the building using stilts, foundation walls, or other water resistant structures to ensure habitable spaces and mechanical and electrical equipment are above the established DFE	$$$	***	

Design Strategies

Strategy	Cost	Impact	Alignment
Where necessary, select higher performance, water-resistant building materials to reduce damage to building structure, envelope and interior finishes within the DFE	$$	**	
Install watertight shields for windows and doors, reinforce walls to withstand the pressures from floodwaters, and include removable barriers or flood proof doors or gates at all entrances below the DFE	$$	**	
Ensure key services (e.g. electrical rooms, back-up power) are located on higher floors at low/no risk of flooding	$$	***	
Ensure elevator controls are placed to avoid flooded areas and inspect elevators after a flood. Ensure hydraulic elevators' machine rooms are located above the ground floor to prevent flooding, and install locking systems (e.g. float switch systems) to prevent elevator cabs from descending below lowest floor or base flood level	$$	***	
Protect electrical equipment with waterproof enclosures	$$	***	
If necessary, include flood vents (permanent openings in foundation walls) to allow floodwater to escape	$$	**	
Use sealants and membranes to reduce seepage of floodwaters through walls. In high risk areas, it may be better to allow basements to flood if foundation walls are not capable of withstanding hydrostatic, buoyancy forces	$$	*	
Install sump pumps at the lowest point of the floor, with backup power supply and regular testing (low rise)	$	*	
Design site storm water conveyance away from structures for increased volumes and flows	$$	*	
Install check valves or backwater valves in third pipe, storm and sanitary sewer lines and permanently seal any floor drains that are not in use	$	*	
Ensure downspouts are directed to rock pits and away from backfill zones and rainwater volumes are not directly conveyed to the storm sewer systems, except where stormwater systems are designed to accommodate flows	$	***	

Flooding events can originate from either slow or sudden inundation of water from extreme rainfall events, or seasonal snow and glacial melt. Flooding along coastal areas can also be caused by storm surges and high tides associated with sea level rise. Increased flows of water poses a challenge to infiltration and drainage infrastructure, including permeable ground and storm water sewer systems. Both slow and fast moving slood events pose threats to building, infrastructure and human health. The frequency and severity of flooding events are projected to escalate with climate change as storm events increase and sea levels continue to rise along most of BC's coast.

Operations Strategies

Strategy	Cost	Impact	Alignment
Procure and install temporary flood barriers at entrances to prevent flood waters from entering the building. Provide entry and exit points over barriers	$$	**	
Develop regular maintenance schedule for sewer valves	$	**	
Develop emergency management plan to address potential elevator failures.	$	*	
Implement or connect to an emergency notification system to share details about sudden flooding events, evacuation plans, and steps occupants can follow (ICI buildings)	$	**	
Inspect and maintain sump pump systems and electrical circuit breakers, and ensure systems are labelled to indicate their zone of control.	$	*	
Following occupancy and after major storm events, inspect hardscape and contributing drainage areas. Conduct any needed repairs or stabilization. Replace or repair any necessary pavement surface areas that are degenerating or spalling	$	**	
Inspect and remove accumulated sediment in pre-treatment cells and inflow points (ICI buildings)	$	**	
Check vegetation and green infrastructure for evidence of excessive ponding or concentrated flows. Take remedial action where necessary	$	*	
Add reinforcement planting to maintain desired the vegetation density. Stabilize the contributing drainage area to prevent erosion	$$	*	
Check for clogging or slow-draining soil media, a crust formed on the top layer, inappropriate soil media, or other causes of insufficient filtering time, and restore proper filtration characteristics (except in backfill zone)	$	**	
Identify the appropriate insurance package to prepare for high risk flooding events	$$	**	

Severe Storms   Seismic Events   Chronic Stressors

Relative Cost/ Cost Premium		
Low	Medium	High
$	$$	$$$

Relative Impact		
Low	Medium	High
*	**	***

Community Benefits

Consider the following strategies to help improve the resilience of the community overall:

- Install native vegetation and green infrastructure (rain gardens, infiltration swales, green roofs, rainwater harvesting, daylighted streams and constructed wetlands) to improve water detention, conveyance, and ground permeability
- To mitigate the impacts of riverine flooding, use flood proofing design and elevated structures to reduce the volume of debris scattered during flooding events, reducing the chances for contamination and destruction of surrounding areas
- Coordinate efforts to establish a continuous physical barrier to floodwater inundation, such as structural barriers harmonised across multiple developments, to better protect the surrounding area
- Ensure building connection to community fire response plans (e.g. notification systems)
- Design the building so that it can act as a shelter for those displaced during flood events
- Provide occupant education on refuge areas, evacuation measures, exit locations, etc.

Additional Resources

- FEMA Design Guide for Improving Critical Facility Safety from Flooding and High Winds
- City of Vancouver Citywide Integrated Rainwater Management Plan, Volume II - Best Management Practice Toolkit
- City of Vancouver Flood-Proofing Policies
- Credit Valley Conservation Technical Guidelines for Floodproofing
- CSA Z800-18 Basement Flood Protection Guideline

HEAT WAVE

Risks to Buildings, Occupant Safety & Environment

- Overheating beyond typical comfort conditions
- Electrical system overload due to increased energy usage associated with ventilation and air conditioning systems
- Potential utility service interruption due to increased energy usage
- Decreased lighting and communications connectivity
- Risk of heat exhaustion or loss of life due to overheating, dehydration or hyperthermia
- Decreased outdoor and indoor air quality due to smog and associated risk to human health

Site Strategies

Strategy	Cost	Impact	Alignment
Identify and incorporate opportunities for cross ventilation during floorplan development to increase air flow without dependence on mechanical systems	$$	***	
Reduce parking areas and/or add shading or vegetation to reduce the heat island effect	$$	**	

Design Strategies

Strategy	Cost	Impact	Alignment
Conduct simulations to explore the thermal performance of individual suites and the building as a whole, focusing on window to wall ratio, window to floor area ratio, window thermal performance and solar heat gain coefficient, wall thermal performance, airtightness, shading, natural ventilation, stack effect and solar orientation	$$	***	
Use the latest climatic data for the modelling of thermal performance of the building and individual units	$	*	
Increase thermal mass performance of horizontal and vertical surfaces through the inclusion of exposed concrete floor slabs, exposed brick walls, natural stone tile; avoid carpeting and suspended ceilings	$$$	***	
Take advantage of thermal masses to allow for night-purging of heat from passive gains	$$	***	
Identify facades with highest potention for solar heat gains and optimize glazing accordingly (e.g. reduce ratio of glazing).	$	***	
Design horizontal and vertical external shading and external operable screens to reduce incoming solar heat gains along south, east, and west façades	$$$	***	
Use high performance insulation and glazing, including higher solar heat gain coefficient fenestration, and low-e coatings to reduce the rate of heat transfer through building structures, and reduce heating and cooling loads	$$	***	
Include operable windows throughout floorplan layout and common corridors to assist cross ventilation and night-purging of internal heat	$	**	
Incorporate operable windows in common corridors wherever security concerns do not pose a risk	$	**	
Locate amenity spaces in a north-facing area with operable windows (and high ceilings) to act as a cooling refuge area. Design for additional cooling capacity, connect to back-up power, and finish floors with exposed concrete or natural tile	$$	***	
Place deciduous vegetation along south, east and west façades to reduce solar heat gains	$	**	
Install outdoor water fixtures connected to a gravity-fed source in a location easily accessible to building occupants	$	**	
Use high albedo or "cool" roofing materials or vegetated roof systems to reduce internal heat gains	$	**	
Use light-coloured building materials to reduce envelope surface temperatures	$	*	
Include passive and mixed-mode ventilation strategies to cool internal spaces without dependence on active cooling systems	$$$	***	
Investigate opportunities to use solar energy technologies to power cooling systems or chillers	$$$	**	

Heat waves are prolonged periods of abnormally hot weather that are often paired with high humidity in maritime climates such as the Pacific Northwest. What is considered a heat wave depends on the degree to which temperature exceed the normal temperature range for the area and season. Heat waves can be particularly intense in urban environments, as the number of heat-absorbing structures and buildings can act to increase overall temperature in what is known as the urban heat island effect. Heat waves are projected to increase in frequency and intensity as a result of climate change, and are projected to have adverse impacts on human health and well-being as risks of overheating increase. Building designers and operators should consider a range of strategies to reduce impacts to health and comfort of building occupants.

Design Strategies

Strategy	Cost	Impact	Alignment
Use high-efficiency lighting, equipment and appliances to reduce internal heat gains	$	*	
Place equipment and furniture with air circulation and temperature control in mind	$	**	

Operations Strategies

Strategy	Cost	Impact	Alignment
Ensure a minimum of 72 hours of fuel storage (natural gas) for power to refuge area and key services, including building pumps, fans, emergency lighting, and security systems	$$	***	
Establish operations and maintenance procedures and building management systems (BMS) to determine the level of cooling required in extreme heat events	$	**	
Ensure common areas' operable windows are opened at night to allow for circulation	$	*	
Educate occupants on practices to keep cool, including closing windows after noon and opening them at night	$	**	
Ensure building operators and occupants understand how to use thermal mass to mitigate temperature swings and optmize comfort	$	**	
Develop training programs to help staff to be able to identify symptoms of heat stress and associated health complications	$	**	

Power Outages
Air Quality
Fire at the Urban Interface
Severe Storms
Seismic Events

Relative Cost/ Cost Premium		
Low	Medium	High
$	$$	$$$

Relative Impact		
Low	Medium	High
*	**	***

Community Benefits

Consider the following strategies to help improve the resilience of the community overall:

- Provide a resilient potable water supply in site design to allow for universally accessible drinking water
- Design amenity rooms to act as cooling centres/refuge areas for at-risk community members (e.g. seniors) and a central location for emergency support and services
- Ensure refuge areas are designed to foster social connection, mental health, and overall cultural safety
- Increase tree canopies to help lower local temperatures and provide shading for community members
- Include public information in building common areas to educate on the common symptoms of health impacts from extreme heat
- Incorporate graywater recycling and rainwater cisterns for irrigation and plant drought tolerant species to conserve water during heat waves

Potential Design Conflicts

Take care and ensure resilient strategies do no exacerbate vulnerability and other risks

- Passive ventilation strategies that help cool buildings with fresh outdoor air can conflict with strategies used to reduce the impact of poor air air quality advisories. Ensure buildings have back-up cooling and ventilation systems that allow for mechanical ventilation when necessary.
- Increasing the thermal performance of vertical and horizontal surfaces through the use of concrete floor slabs may pose a risk to seismic resilience overall. Ensure concrete structures are appropriately designed to withstand seismic events.
- Ensure any vegetation used to shade building interiors are planted with fire risk in mind.

Additional Resources

- City of Vancouver. (2014) Extreme Heat Cool Buildings: A Review of Alternatives to Traditional Air Conditioning
- Government of British Columbia. Current Air Quality Data Map – Air Quality Health Index.
- Bureau de normalisation du Québec. Reducing the Urban Heat Island Effect

INTEGRAL GROUP

BC HOUSING RESEARCH CENTRE

POWER OUTAGES & EMERGENCIES

Risks to Buildings, Occupant Safety & Environment

- Reduced functionality of building heating & cooling systems compromises indoor thermal comfort
- Access to potable water and sanitary services cannot be guaranteed
- Decreased lighting and communications connectivity
- Decreased indoor air quality and associated risk to human health due to lack of ventilation, increased humidity, condensation, and mould
- Medical equipment may be inoperable, and medication requiring refrigeration may be threatened
- Vulnerable populations without extensive support networks may become temporarily homeless
- Carbon monoxide poisoning

Design Strategies

Strategy	Cost	Impact	Alignment
Provide natural lighting and operable windows in common areas, corridors, and stairwells	$	**	
Finish floors with exposed concrete or natural tile for added cooling during extreme heat events (thermal mass)	$	*	
Include passive and mixed-mode ventilation strategies to cool internal spaces without dependence on active cooling systems	$$	**	
Design mechanical and ventilation systems for both central control and/or on a per unit basis	$	**	
Consider the use of high energy efficiency or 'regenerative' elevators in building design	$$$	*	
Ensure building entry and exits can be operated manually	$	***	
Identify the appropriate size, form, and location of back-up power. Consider on-site renewable energy systems as a way to decentralize the building's energy supply	$	***	
Identify a building's critical load and necessary duration of back-up power. Ensure a minimum of 72 hours energy storage/backup energy is provided for critical systems, as well as water booster pumps, sump pumps, alarms and secury equipment, outlets for phone charging and medical equipment, wireless/telecomm services, lighting, refrigeration, and bathrooms.	$$$	***	
Integrate solar PV into shading devices and connect to ventilation and other critical systems	$$$	**	
Designate one or more easily accessible amenity rooms as refuge areas in a north-facing area of the building. Design the refuge area for additional cooling capacity/fans and operable windows.	$$	***	
Consider unit designs that allow for refuge within a home (e.g. one room that is resilient to extreme events)	$$	***	
Provide high efficiency (e.g. LED) emergency lighting in highly trafficked areas, and solar power lighting where possible	$	**	
Introduce rainwater or grey water harvesting as a source of non-potable water	$$$	***	
Install outdoor water fixtures connected to a gravity-fed source in a location easily accessible to building occupants	$	**	

Additional Resources

- Minimum Backup Power Guidelines for MURBs
- Enterprise Green Communities' Strategies for Multifamily Building Resilience
- Designing for ZNE and Passive Survivability
- Urban Green Council, Baby it's Cold Inside
- Enhancing the Livability and Resilience of Multi-Unit Residential Buildings (MURBs), MURB Design Guide

A building's power supply may be interrupted for a number of reasons. Windstorms may knock out above-ground power lines, and heavy ice or snow may damage or break power lines. High demand for cooling during heat waves may overwhelm the grid, and flooding may down power lines or flood critical infrastructure such as transformer stations. As most buildings rely on active mechanical equipment to maintain appropriate ventilation rates and interior temperatures, power outages can have dramatic consequences. When paired with thermally inefficient enclosures, interior spaces can overheat due to solar gains and ventilation can become ineffective. Buildings with low thermal resilience become unsafe for occupants during power outages. Changes in climate expected for BC include extreme events and conditions, which may threaten energy supply to buildings and neighbourhoods.

Operations Strategies

Strategy	Cost	Impact	Alignment
Plan, rehearse, and identify necessary procedures (e.g. testing equipment, checking shelf life of stored provisions)	$	***	Fire, Air Quality, Flood, Severe Storms, Seismic, Heat Waves
Provide an emergency kit, including a backup lithium ion battery, food supplies, flashlights, medical supplies, an emergency radio, sources of entertainment, blankets, and other supplies	$$	***	Fire, Air Quality, Flood, Severe Storms, Seismic, Heat Waves
Establish a maintenance schedule for emergency power systems	$	**	Fire, Air Quality, Flood, Severe Storms, Seismic, Heat Waves
Design or connect to a building emergency communication system (e.g. SMS) with a back-up in the building (e.g. bulletin board in Refuge Area)	$	**	Fire, Air Quality, Flood, Severe Storms, Seismic, Heat Waves
Establish operations and maintenance procedures and building management systems (BMS) to include information about resources available to occupants during extended power outages	$	**	Fire, Air Quality, Flood, Severe Storms, Seismic, Heat Waves
Create an emergency management manual identifying key information and contacts. Develop procedures for temporary storage of sewage and waste	$	***	Fire, Air Quality, Flood, Severe Storms, Seismic, Heat Waves

Flood Events · Heat Waves · Fire at the Urban Interface · Severe Storms · Seismic Events · Air Quality

Relative Cost/ Cost Premium		
Low	Medium	High
$	$$	$$$

Relative Impact		
Low	Medium	High
*	**	***

Community Benefits

Consider the following strategies to help improve the resilience of the community overall:

- Provide a resilient potable water supply in site design to allow for universally accessible drinking water
- Design amenity rooms to act as refuge areas for at-risk community members (e.g. seniors) and a central location for emergency support and services
- Ensure refuge areas are designed to foster social connection, mental health, and overall cultural safety
- Build community connectivity through preparedness and other events (e.g. movie nights, block parties)
- Provide occupant education on refuge areas, evacuation measures, exit locations, etc. in multiple languages according to building occupancy
- Designate building or community members with first aid or other experience as emergency coordinators
- Ensure building and community members have access to key information and contact details
- Engage residents in a process of neighbour check-ins to address risks of isolation
- Conduct a sensitivity analysis for occupant demographics to identify key needs and critical services

Potential Design Conflicts

Take care and ensure resilient strategies do no exacerbate vulnerability and other risks

- Passive ventilation strategies that rely on natural air flow to cool and ventilate a building may exacerbate indoor air quality issues during times of poor air quality (e.g. forest fire smoke).

SEISMIC EVENTS

Risks to Buildings, Occupant Safety & Environment

- Full or partial building collapse causing loss of life and irreparable damage to the building
- Access to utility services including power, potable water and sanitary services cannot be guaranteed
- Life safety and injury risks from structural failure, falling objects, and/or breaking glass
- Entry to buildings or communities may be compromised due to structural integrity concerns or physical barriers
- Vulnerable populations without extensive support networks may become temporarily homeless

Site Strategies

Strategy	Cost	Impact	Alignment
Select non-hillside or stable slope sites and avoid cut and fill building sites to reduce risk from landslide and mudslides	$	***	
Construct channels, drainage systems, retention structures, and deflection walls	$$	***	

Design Strategies

Strategy	Cost	Impact	Alignment
Place walls, braced frames, or moment frames in a symmetric and regular layout and allow them to be continuous up the height of the structure.	$$	***	
Avoid the design of 'soft stories' that are more vulnerable to collapse (large, engineered buildings)	$$	***	
Include sheer walls, braced frames, moment resisting frames and diaphragms, and base isolation into building design (large, engineered buildings)	$$$	***	
Make use of energy dissipating devices, such as visco-elastic dampers, elastomeric dampers, and hysteretic-loop dampers (large, engineered buildings)	$$	***	
Brace any non-structral components as needed (large, engineered buildings)	$$	***	
Bolt the sill plate of houses to the foundation to prevent the building shaking off of its foundation (low rise, wood-frame)	$	***	
Include the risk of aftershocks into design thresholds	$	**	
Ensure pipe joints and bracing are reinforced to eliminate breakage and leaks in seismic event	$	***	
Allow for natural daylighting in corridors and stairwells to enable vital areas to be usable during a power outage	$	*	
Include luminescent strips to provide safety in dark spaces	$	*	
Identify a building's critical load and necessary duration of back-up power. Ensure a minimum of 72 hours energy storage/backup energy is provided for critical systems, as well as water booster pumps, sump pumps, alarms and secury equipment, outlets for phone charging and medical equipment, wireless/telecomm services, lighting, refrigeration, and bathrooms	$$$	***	
Consider an automatic transfer switch (ATS) to smoothly and safely switch to emergency power – alternatively, install a permanent exterior manual transfer switch to improve accessibility	$$	**	
Provide extensive emergency lighting in highly trafficked areas. For lower-cost options, consider solar-powered outdoor lighting or battery-powered LED lighting	$	*	
Ensure resilient access to potable water by including water taps or fountains that operate on City water pressure alone	$	**	
Include rainwater storage tanks or rain barrels to maintain an on-site supply of non-potable water	$	**	
Consider on-site renewable energy opportunities to decentralize the building's energy supply	$$	**	

B.C. is considered a high-risk earthquake zone due to the active faults in the Pacific Northwest, including the Cascadia Subduction Zone. This risk presents an enormous challenge to building design, as earthquakes can reveal building deficiencies that lead to poor seismic performance. Building codes have been updated to include seismic considerations but do not guarantee a building's resilience during seismic events. Codes are focused on protecting the lives of occupants as opposed to on earthquake resilience and recovery. In the event of a major quake this can result in significant damage to the building structure, architectural components and facades, mechanical, electrical and plumbing equipment and other building contents. There are opportunities to improve building seismic recovery and resilience over and above what is required by code.

Operations Strategies

Strategy	Cost	Impact	Alignment
Establish maintenance schedule for emergency power systems	$	***	Power Outages & Emergencies
Introduce a process for rapid damage assessment of buildings after earthquake and alert people whether they can re-enter given risk of aftershocks	$	***	
Design or connect to a building emergency communication system (e.g. SMS) with a back-up in the building (e.g. bulletin board in Refuge Area)	$	**	
Establish operations and maintenance procedures and building management systems (BMS) to include information about resources available to occupants during extended power outages	$	**	Power Outages & Emergencies
Allow common building spaces, such as amenity rooms to act as refuge with backup power and basic survival supplies including 72 hours of fuel storage for power to refuge area plus building pumps, fans, emergency lighting and security systems	$$	***	Power Outages & Emergencies

Severe Storms | Chronic Stressors | Flood Events | Power Outages & Emergencies

Relative Cost/ Cost Premium

Low	Medium	High
$	$$	$$$

Relative Impact

Low	Medium	High
*	**	***

Community Benefits

Consider the following strategies to help improve the resilience of the community overall:

- Provide a resilient potable water supply in site design to allow for universally accessible drinking water after seismic events
- In larger mid-rise to high-rise buildings, designate amenity rooms as refuge areas that can act as a central location for community emergency support and services
- Provide occupant education on refuge areas, evacuation measures, exit locations, etc. in multiple languages according to building occupancy
- Designate building or community members with first aid or other experience as emergency coordinators
- Ensure building and community members have access to key information and contact details

Potential Design Conflicts

Take care and ensure resilient strategies do no exacerbate vulnerability and other risks

- Ensure structure and envelope design also take energy performance into consideration.

Additional Resources

- The Resilience-based Earthquake Design Initiative (REDi™) Rating System
- Minimum Backup Power Guidelines for MURBs
- Enterprise Green Communities' Strategies for Multifamily Building Resilience
- Enhancing the Livability and Resilience of Multi-Unit Residential Buildings (MURBs), MURB Design Guide

SEVERE STORMS

Risks to Buildings, Occupant Safety & Environment

- Loss of structural integrity due to increased moisture and compromised drainage
- Greater strain on building material fixtures, claddings and fasteners
- Potential utility service interruption due to increased energy usage
- Impact damage (mostly roofs, guttering, windows) and subsequent rain/moisture penetration
- Decreased indoor air quality and associated risk to human health due to increased humidity, condensation, mould

Site Strategies

Strategy	Cost	Impact	Alignment
Make use of past tree fall/structural damage incidents to find common elements and identify high risk situations	$	**	
Identify potential objects, structures, apartments that may be threatened by severe storms (e.g. wires, trees, telephone poles, shutters, HVAC)	$	***	
Plan and site the building to avoid wind tunnel effects	$	***	
Increase use of greenery that is resilient to storm surges (where applicable)	$	***	

Design Strategies

Strategy	Cost	Impact	Alignment
Mitigate increased wind load by aerodynamically efficient structures to reduce deflection and resonance, including curved corners, minimized eave overhangs, dynamic stabilisation systems, and better foundation design. For Part 9 buildings, ensure continuous vertical load path in the structure	$$	***	
Design roof structures to withstand extreme winds by selecting a hip roofs (for houses), hurricane ties, roof-to-wall connectors, and/or plywood sheathing	$$	***	
Ensure roof materials are adequately fixed and roof assemblies are braced and securely connected to walls. Make use of stiffer structural framework sealants to reduce flexure in storms	$$	***	
Consider increased snow loads in building design in areas forecasting heavier snowfalls	$$	*	
Select impact-resistant building materials, external claddings and glazing where continous load path may be insufficient to protect the structure	$$	***	
Avoid mass and barrier exterior wall designs that provide poor performance related to moisture protection	$	**	
Use pressure-moderated rainscreen walls to shed water at the face with back-up drainage. For high-rise buildings, consider pressure-equalized rainscreen walls for exterior walls	$$	***	
Ensure envelope components, such as vapour permeable air barriers, allow for drainage and two-way drying via ventilation, evaporation or diffusion, paying special attention to details and junctions.	$$	***	
During upgrades to existing buildings, provide continuous insulation outboard of the structure to reduce potential for condensation inside of cavities by elevating cavity surface temperatures above the dew point of the indoor air	$$	***	
Ensure façades are able to deflect increasing precipitation loads via overhangs and recessed windows. Consider potential hail damage to roofing, siding and windows	$$	***	
Ensure backup power for 72 hours is available for critical systems and areas (ICI)	$$$	***	
Design common building areas (e.g. amenity rooms) to act as refuge areas	$	***	
Provide energy efficient emergency lighting in highly trafficked areas	$	**	
Install outdoor water fixtures capable of operating on water pressure (i.e. without electricity) in a location easily accessible to building occupants	$	***	

Severe weather – thunderstorms, hail, blizzards, ice storms, high winds or heavy rains – can occur without warning in any season. These events often lead to loss of utility services, including storm and sanitary management and energy supply. Storms can also present problems to building enclosure systems designed to keep moisture outside of buildings and interior spaces sheltered. Ensuring structures can withstand anticipated future conditions should be prioritized over designing for peak conditions of past storm events. In many areas of BC, increasingly warmer temperatures will make more moisture available for storm systems, resulting in higher rates of precipitation overall, and more frequent, severe and prolonged storm events. Several design and operations strategies can be used to mitigate the impact of these events.

Design Strategies

Strategy	Cost	Impact	Alignment
Ensure renewable energy systems (e.g solar PV) are designed to withstand extreme wind or precipitation	$$	***	
Explore opportunities for the use of low-tech, adaptive heating/cooling strategies (e.g. earth tubes, geo-exchange, cross-ventilation, PV, wind) that can operate during storm events	$$	***	

Operations Strategies

Strategy	Cost	Impact	Alignment
Establish a maintenance schedule for structural fixings to ensure they do not become worn, loosened, corroded or warped from previous storm events	$	***	
Inspect building regularly for signs of moisture damage, waterproofing performance and proper drainage around building	$	***	
Identify and remove debris that may prevent emergency vehicle access	$	**	

Power Outages & Emergencies
Chronic Stressors
Flood Events
Seismic Events
Fire at the Urban Interface
Heat Waves

Relative Cost/ Cost Premium

Low	Medium	High
$	$$	$$$

Relative Impact

Low	Medium	High
*	**	***

Community Benefits

Consider the following strategies to help improve the resilience of the community overall:

- Provide a resilient potable water supply in site design to allow for universally accessible drinking water
- Design amenity rooms to act as refuge areas for at-risk community members (e.g. seniors) and a central location for emergency support and services.
- Provide occupant education on refuge areas, evacuation measures, exit locations, etc. in multiple languages according to building occupancy
- Designate building or community members with first aid or other experience as emergency coordinators
- Ensure building and community members have access to key information and contact details

Potential Design Conflicts

Take care and ensure resilient strategies do no exacerbate vulnerability and other risks

- Vegetation setbacks may eliminate benefits associated with trees for shading and heat island reduction
- Building designs intended to mitigate the impact of high winds can reduce the effectiveness of natural ventilation systems

Additional Resources

- The Resilience-based Earthquake Design Initiative (REDi™) Rating System
- Minimum Backup Power Guidelines for MURBs
- Enterprise Green Communities' Strategies for Multifamily Building Resilience
- Enhancing the Livability and Resilience of Multi-Unit Residential Buildings (MURBs), MURB Design Guide
- Protect Your Home From Hail

INTEGRAL GROUP

BC HOUSING RESEARCH CENTRE

WILDFIRES

Risks to Buildings, Occupant Safety & Environment

- Damage to, or destruction of buildings
- Utility service interruption
- Potential loss of property and personal assets
- Decreased outdoor and indoor air quality and associated risk to human health
- Risk of human injury or loss of life through exposure to fire, smoke, and/or decreased air quality

Wildfires pose a serious threat to building safety. Risks occur when the close combustion of natural fuels (e.g. trees, grasses and shrubs) spread to human-made structures. Wildfires at the urban interface are made more complex because combustible building materials compound with out fuel sources. At the wildland-urban interface, fires can start either outside and spread to adjacent structures, or originate inside, then ignite vegetation and spread through the wilderness. Interface fires are projected to increase in severity and magnitude as a result of climate change, and can in turn lead to air quality advisories across the province. This sheet is intended to start conversations about mitigating these risks.

Site Strategies

Strategy	Cost	Impact	Alignment
Identify prevailing wind direction and airshed characteristics to determine direction of potential fires	$	***	
Conduct a full risk assessment, considering fuel types, building location relative to slope, and the nature of the structure	$$	***	
Maintain 10m setback from all combustible materials to create a natural firebreak. Increase this setback for structures or vegetation closest to the forest interface	$	***	
Install outdoor water fixtures (e.g. taps and sprinklers) connected to a gravity-fed source in a location easily accessible to building occupants	$	***	

Design Strategies

Strategy	Cost	Impact	Alignment
Include mesh debris screens (3 mm) in gutters, eaves and vents to reduce accumulation of flammable vegetation and limit areas exposed to sparks and embers	$	*	
Install a chimney spark arrestor to reduce release of sparks and embers to surrounding areas	$	*	
Select higher performance fire-retardant or -resistant siding materials (e.g. stucco, metal siding, brick, concrete and fibre cement)	$$	***	
Select fire-retardant roofing materials, such as metal, asphalt, clay and composite rubber tiles with Class A UL/ASTM rating – avoid green roofs for buildings at the wildland-urban interface	$$	***	
Use double-paned tempered windows and frames with an air barrier seal to provide greater air quality protection and heat resistance	$$	**	
Ensure building and garage entry doors are fire-rated and sealed with an air barrier	$	**	
Install high-efficiency air filtration media (MERV 11 or higher) for all outdoor air building ventilation systems to improve indoor air quality	$$	***	
Install air cleaners equipped with highest-efficiency particle air (HEPA) filters and activated carbon filters in refuge areas (e.g. amenity spaces)	$$$	***	
Make use of demand-controlled ventilation based on CO2 levels to reduce the introduction of outdoor air beyond required air flow rates.	$$$	**	
Install mechanical systems such as air source heat pumps that allow for cooling during fire events	$$	***	
Design a common building area to act as a cooling room or clean air refuge	$	***	
Connect cooling and ventilation systems in refuge areas to a source of back-up power.	$$	**	
Ensure a minimum of 72 hours of fuel storage for power to refuge area and key services, including building pumps, fans, emergency lighting, and security systems	$$	***	
Design building entry and exits that can be operated manually	$	***	

Operations Strategies

Strategy	Cost	Impact	Alignment
Trees should be set back 10m from all buildings and combustible materials	$	***	
Plant fire-resistant vegetation with moist, supple leaves and low sap or resin production	$	*	
Ensure planting groups are a minimum of 6m apart, and trees are a minimum 3m apart	$	*	
Prune lower branches within 6' (1.8m) of ground	$	*	
Regularly mow lawn areas and check roof, gutters, and eaves to remove flammable vegetation	$	*	
Inspect, maintain and replace high-efficiency air filtration media for all outdoor air building ventilation systems	$	**	
Close building openings to temporarily reduce the intake of outdoor air during extreme events	$	***	
Plan, rehearse, and identify preparedness procedures necessary to maintain a successful refuge area (e.g. testing equipment, checking shelf life of stored provisions)	$	*	
Provide occupant education on refuge areas, evacuation measures, exit locations, etc.	$	***	
Educate building maintenance staff in firefighting/resistance measures (e.g. operating sprinklers, wetting down surfaces, removing flammables)	$	***	
Provide sufficient personal protective equipment for building occupants, (e.g. N95 masks or N95 respirators) to minimize exposure to particulate matter	$	**	
Ensure personal cooling devices are available to building occupants (e.g. cooling blankets)	$	*	
Ensure there is adequate means for people who don't have cars or need assistance to evacuate the vicinity (e.g. public transportation or a carpool-evacuation plan)	$	*	
Ensure alternate egress routes are available and known to building occupants	$	**	

Community Benefits

Consider the following strategies to help improve the resilience of the community overall:

- Provide access to local outdoor air quality data and indoor CO2 levels via occupant displays
- Design amenity rooms to act as cooling centres/clean air refuge areas for at-risk community members (e.g. seniors) and a central location for emergency support and services
- Ensure refuge areas and common spaces are designed to foster social connection, mental health, and overall cultural safety
- Ensure building connection to community fire response plans (e.g. notification systems)

Potential Design Conflicts

Take care and ensure resilient strategies do no exacerbate vulnerability and other risks

- Vegetation setbacks may eliminate benefits associated with trees for shading and heat island reduction
- Consider the durability of siding materials to withstand storms, freeze/thaw and seismic events
- Consider the impact of roofing materials on the heat island effect
- Passive ventilation strategies that rely on natural air flow to cool and ventilate a building may exacerbate indoor air quality issues during times of poor air quality (e.g. forest fire smoke). Ensure buildings have back-up cooling and ventilation systems that allow for mechanical ventilation when necessary.

Power Outages & Emergencies · Air Quality · Flood Events · Severe Storms · Seismic Events · Heat Waves

Relative Cost/ Cost Premium

Low	Medium	High
$	$$	$$$

Relative Impact

Low	Medium	High
*	**	***

Additional Resources

- Government of BC: Current Air Quality Data Map – Air Quality Health Index
- Government of BC: FireSmart Homeowner's Manual
- Government of BC: FireSmart Your Property

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BC HOUSING RESEARCH CENTRE

2022-016 - Climate Risk Elements for Buildings

UBC Sustainability Scholars - OPEN Technologies

May – July 2022