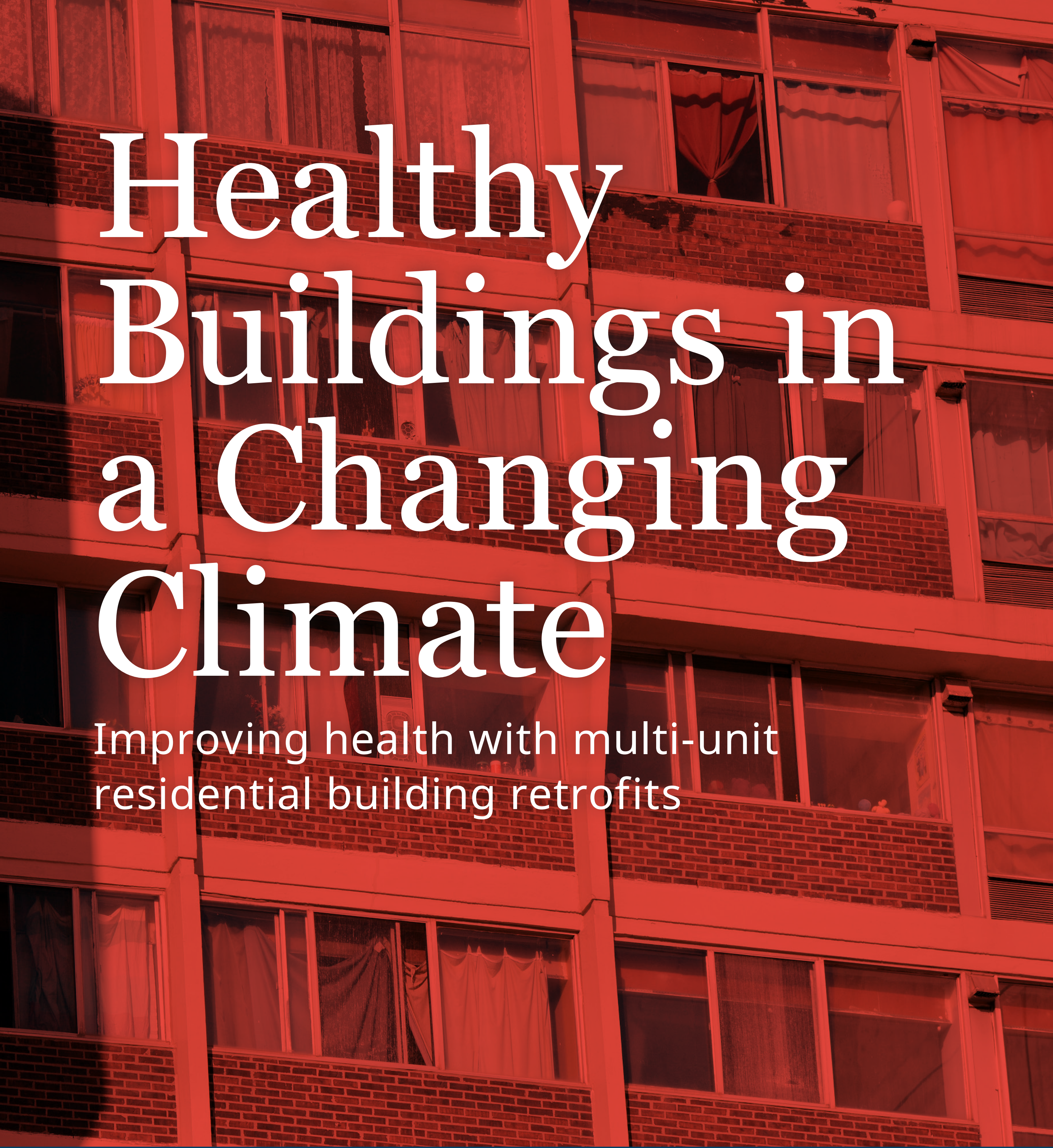

Healthy Buildings in a Changing Climate

Improving health with multi-unit residential building retrofits

July 2024

Raidin Blue, Betsy Agar

PEMBINA Institute

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Recommended citation: Blue, Raidin and Betsy Agar. *Healthy Buildings in a Changing Climate: Improving health with multi-unit residential building retrofits*. The Pembina Institute, 2024.

ISBN 1-897390-68-8

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Acknowledgements

The Pembina Institute wishes to thank the Alberta Ecotrust Foundation for their generous support.

The Alberta Ecotrust Foundation is an environmental charity working to create a healthier environment for all Albertans. Alberta Ecotrust is a long-standing and critical source of funding, training, and skill building for Alberta's environmental community. Alberta Ecotrust is a founding member of the Low Carbon Cities Canada (LC3) network and provides a suite of aligned programs. Alberta Ecotrust funded this research to identify and minimize barriers to retrofits, aiming to reduce emissions from existing buildings in Alberta and make retrofits more attainable.

ALBERTA ecotrust

The Pembina Institute also thanks the Real Estate Foundation of BC and the Ronald S. Roadburg Foundation for their support.

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RONALD S ROADBURG FOUNDATION

The Pembina Institute acknowledges that the work we steward and those we serve span across many Nations. We respectfully acknowledge the space our organization is headquartered in as the traditional and ancestral territories of the Blackfoot Confederacy, comprised of the bands Siksika, Piikani, and Kainai, the Îyârhe Nakoda Nations, including the bands of Goodstoney, Chiniki, and Bearspaw, and the Tsuut'ina Dené. These Lands are also home to the Métis Nation of Alberta — Region 3 whose Peoples have deep relationships with the Land.

These acknowledgements are some of the beginning steps on a journey of several generations. We share them in the spirit of truth, justice, reconciliation, and to contribute to a more equitable and inclusive future for all of society.

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Executive summary

Our climate has significantly changed over the last ten years. Once-in-a-hundred-year weather events are happening every few years, entire communities are being displaced from wildfires, and hundreds of people in Canada have died from extreme heat. Existing infrastructure was built for less frequent extreme weather events, and climate change is creating an imperative to retrofit existing buildings to keep people healthy and safe. Governments, utilities, insurance and financial sector representatives, and building owners need to proactively plan for occupant health outcomes and see these as intrinsic to building asset management planning.

Vulnerability to climate change impacts can be elevated due to increased sensitivity, increased exposure, and low adaptive capacity. Buildings, where people spend 90% of their lives, can escalate vulnerability by increasing exposure and thereby requiring adaptive measures (e.g. cooling systems) that are expensive to install and operate.

Done right, building retrofits can help limit exposure to climate impacts and enhance adaptive capacity to reduce vulnerability, especially for people with elevated sensitivity. Particularly important are measures aimed at ensuring buildings are well-sealed to protect against heat and contaminants leaking in from outside and to guard against water infiltration during flooding or storm events; shading to reduce heat absorption is also crucial.

Adaptation needs to be carried out with long-term objectives and sustainability in mind. To address immediate extreme heat, active cooling measures like heat pumps and air conditioning units can be installed quickly and save lives. However, those who need these most can also have the lowest adaptive capacity (limited mobility, access to capital) and agency, therefore they need government and building owner intervention to make these changes.

Deep retrofits are a key pathway to ensuring our homes are healthier, safer, more resilient to extreme weather, and more affordable to heat and cool. The federal government will need to partner with the provinces to enable a renovation wave by investing on the order of $10-15 billion per year for 20 years to deep retrofit our homes and buildings.[1] Retrofits are no-regrets solutions that provide resilience to escalating climate change impacts while also lowering Canada's emissions, but undertaking retrofits on the scale needed will require coordinated effort by a range of actors:

[1] Madi Kennedy and Tom-Pierre Frappé-Sénéclauze, *Canada's Renovation Wave: A plan for jobs and climate* (Pembina Institute, 2021). https://www.pembina.org/pub/canadas-renovation-wave

- **Building owners:** To collaborate with tenants to identify vulnerable communities and determine exposure risks, sensitivities, and appropriate climate adaptation measures, and to incorporate implementation into capital renewal plans and funds.
- **Insurance and financial sectors:** To help building owners pre-emptively avoid human health and safety risks by developing products that reward owners for investing in upgrades that reduce exposure.
- **Governments:** To help ease deep retrofit costs and customer journey through funding; concierge services; guidance including resilience measures, codes and standards (such as maximum temperatures); support identification and adaptation measure for vulnerable communities; and coordinated demand side management programs.

1. Introduction

The connection between building conditions, climate change and occupant health has been highlighted in recent years by events such as the COVID-19 pandemic and increasingly frequent and extreme weather events. As governments across Canada work to accelerate deep retrofits to decrease energy consumption and carbon emissions, a holistic and integrated approach can provide benefits beyond energy and carbon savings. Retrofits that incorporate upgrades to ventilation, heating, cooling, building envelope and system controls can improve health and safety.

This report unpacks the climate change impacts on occupant health, specifically for people living in multi-unit residential buildings (MURBs).[2] In particular, we discuss four key climate change risks: extreme heat; flooding and reduced water quality; changes in infectious agents; wildfire smoke and reduced air quality.[3] We also explore the role deep retrofits can play in helping to reduce the health impacts associated with climate risks, especially for vulnerable occupants.

1.1 Vulnerability

Climate change vulnerability is defined by a population's levels of sensitivity, exposure, and adaptive capacity. Sensitivity describes how a person is affected by climate events and depends on personal characteristics such as health and age. Exposure is determined by surrounding natural and built environment conditions. Adaptive capacity is the ability to adjust and adapt to climate impacts. The interaction between sensitivity, exposure, and adaptive capacity can lead to health impacts, as illustrated in Figure 1.

[2] MURBs are buildings comprised of a common entrance and separate units that are also known as apartments and constructed for dwelling purposes. Categories include low-rise (2-3 floors, minimum of 4 units); mid-rise (4-9 floors); high-rise (10+ floors).

[3] British Columbia Ministry of Environment and Climate Change Strategy, *Preliminary Strategic Climate Risk Assessment* (2019). https://www2.gov.bc.ca/gov/content/environment/climate-change/adaptation/risk-assessment

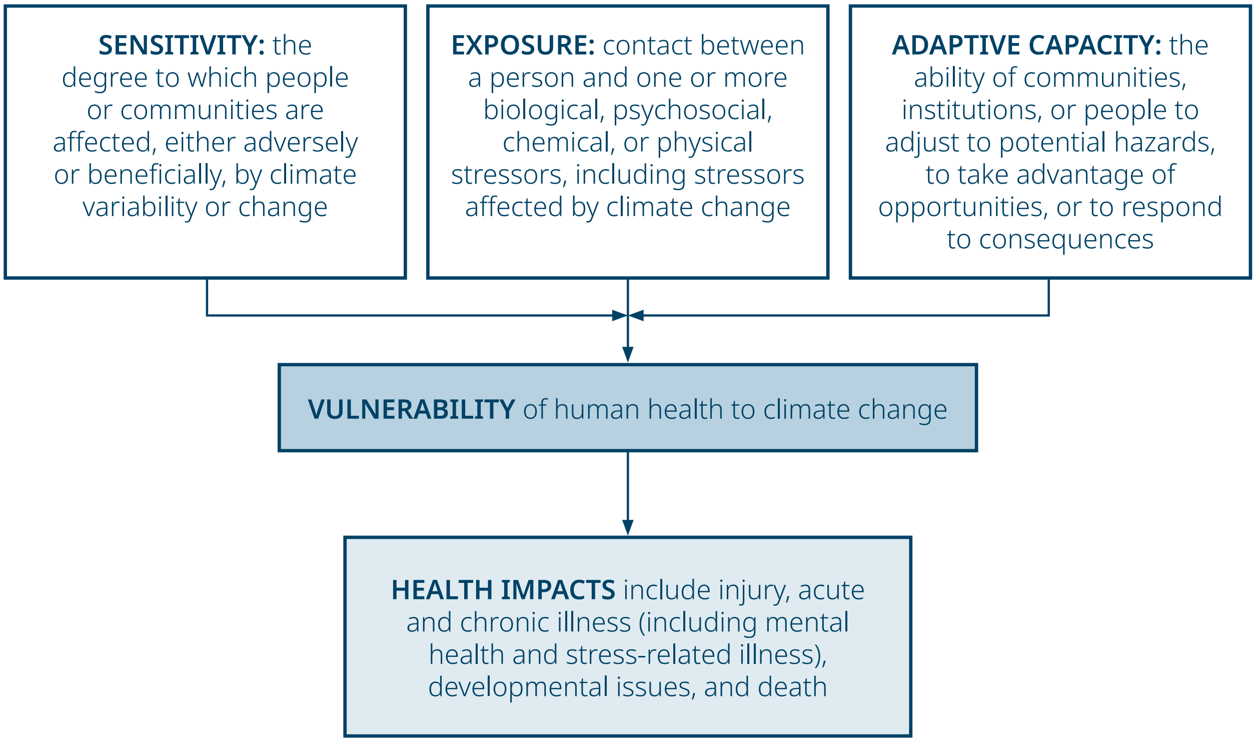

Figure 1. Determinants of vulnerability

Source: Adapted from Health Canada[4]

- **Sensitivity**: Certain demographics are more sensitive and less able to adapt to weather extremes. Sensitivity, and thus vulnerability, can be higher among occupants who are 65 years and older and living with existing chronic conditions or disabilities because of the potentially compounding effects. Sensitivities are not easily adjusted.
- **Exposure**: Exposure to extreme weather events can cause acute symptoms even among individuals in good health, and long-term exposure can lead to development of chronic health conditions. Vulnerability to health impacts of climate change can also be exacerbated by systemic inequities, resulting in some populations being more exposed to hazards than others.[5] However, an otherwise healthy person living in a home with high degrees of exposure to climate impacts can be vulnerable. Exposure can be adjusted.

[4] Health Canada, *Climate change and health vulnerability and adaptation assessment: workbook for the Canadian health sector* (2022), Figure 2. https://www.canada.ca/en/health-canada/services/publications/healthy-living/climate-health-adapt-vulnerability-adaptation-assessments-workbook.html

[5] Vancouver Coastal Health and Fraser Health, *Climate Change and Health Vulnerability and Capacity Assessment: Summary Report* (2022). https://www.vch.ca/sites/default/files/import/documents/HealthADAPT-Vulnerability-Capacity-Summary.pdf

- **Adaptive capacity**: Adaptive capacity can be described as the ability to develop resilience and adjust to climate outcomes and is a function of numerous factors, including access to financial, educational, and community resources. Adaptive capacity allows people to take measures to limit exposure, which will reduce their vulnerability.

Social determinants of health are another framework for understanding and predicting vulnerability. [6] Personal, social, economic, and environmental factors that determine individual and population health, such as living with low income and/or energy poverty, living in poor quality housing, and being part of a marginalized community, can increase vulnerability to climate impacts.[7] Vancouver Coastal Health has identified factors that increase human vulnerability and risk exposure to climate-related health impacts. For instance, heat-related emergency room visits were reported as highest in neighbourhoods where occupants faced higher levels of social isolation, advanced age, pre-existing health conditions, mental illnesses, substance dependence, a lack of green spaces, and poverty.[8]

Vancouver Coastal Health (VCH) summarized the proportion of the region's population living with social determinants of health that increased their vulnerability to climate impacts, as shown in Figure 2. These statistics vary by province and even health region: 15% of Albertans are age 65 and over (a quarter of whom live alone), whereas 18% of the VCH region are in that age group; and 9% of the VCH population are low income, and 11% in Alberta; prevalence rates are seen in Alberta for chronic diseases at 3% for chronic obstructive pulmonary disease (COPD), 9% for diabetes, and 20% for hypertension, and in VCH at 5% COPD, 9% diabetes, and 7% heart disease.[9] These statistics are good starting positions for identifying and quantifying climate vulnerability; in Alberta, these and more metrics can be found through the *Healthier Together* community health dashboard.

[6] Government of Canada, "Social determinants of health and health inequalities." https://www.canada.ca/en/public-health/services/health-promotion/population-health/what-determines-health.html

[7] Sorsha Roberts, "Key Facts: Poverty and Poor Health," *Health Poverty Action,* January 10, 2018. https://www.healthpovertyaction.org/news-events/key-facts-poverty-and-poor-health/

[8] Vancouver Coastal Health, *Emergency Department Impacts Due to an Unprecedented Extreme Heat Event in Vancouver Coastal Health, 2021* (2021), 1. https://www.vch.ca/sites/default/files/2023-11/ED-Heat-Related-Visits-During-2021-Heat-Dome.pdf

[9] Alberta Health Services, "Healthier Together," 2018. https://www.healthiertogether.ca/prevention-data/alberta-community-health-dashboard/community-cancer-prevention-screening-dashboard/

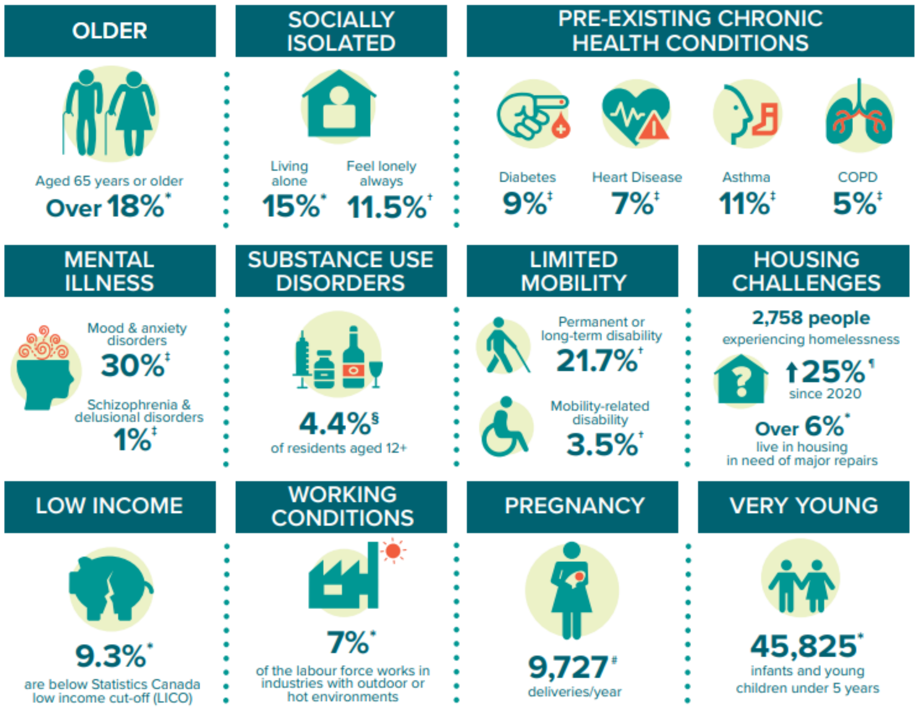

Figure 2. Factors that increase risk for climate-related health impacts, and the proportion of each within the Vancouver Coastal Health Population

Source: Vancouver Coastal Health[10]

1.2 Growing climate risks and impacts

Whether bringing too much water or not enough, or producing temperatures too cold or too hot, climate change affects the integrity of buildings and infrastructure and threatens occupant health. Climate hazards, like rising temperatures, create localized impacts, such as extreme heat events. Our buildings were designed for weather patterns that are now historic. In the instance of rising temperatures and extreme heat, these changes are increasingly resulting in heat-related health impacts. Following the vulnerability language introduced in the previous section, our exposure is increasing. Key climate hazards and their related outcomes and health impacts are illustrated in Figure 3.

[10] Vancouver Coastal Health Chief Medical Health Officer, *Protecting Population Health in a Climate Emergency* (2023), 9, Figure 1. https://www.vch.ca/en/chief-medical-health-officer-report

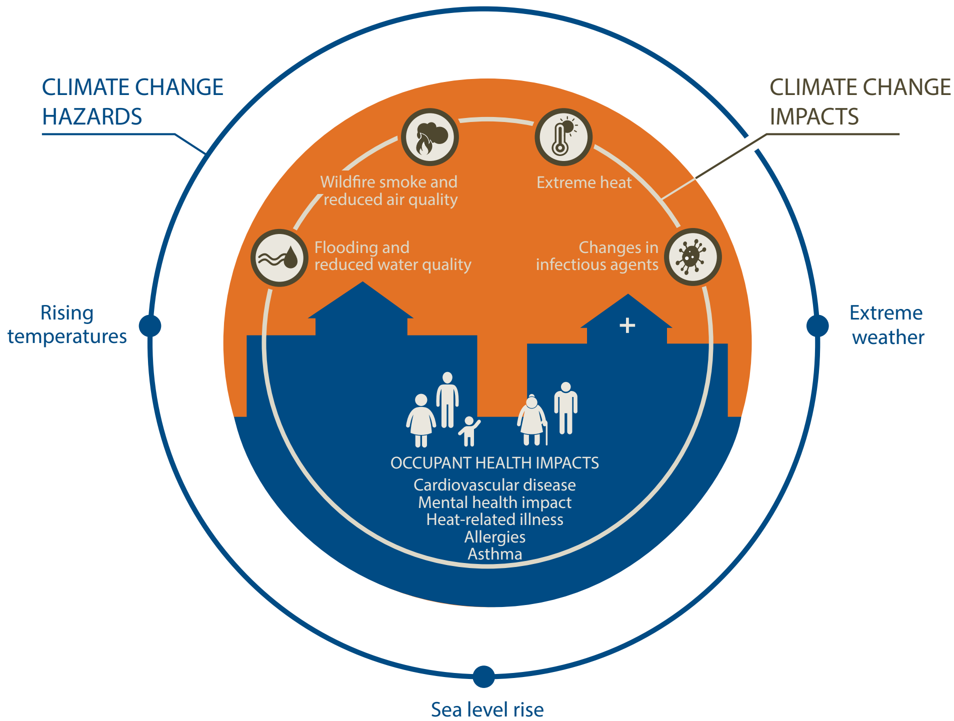

Figure 3. Climate change hazards, outcomes, and related health impacts on building occupants.

Adapted from Ministry of Environment and Climate Change Strategy and the B.C. Climate Action Secretariat[11]

2023 marked the hottest year on record, according to the European Union's Copernicus Climate Change Service, with global temperatures 1.48°C above pre-industrial levels; comparatively, only four other years have been above 1.2°C above this level (2016, 2017, 2019, and 2020).[12] Examples of increasing risks and impacts are described below:

[11] B.C. Ministry of Environment and Climate Change Strategy, *Addressing Climate and Health Risks in BC: Public Health*. https://www2.gov.bc.ca/assets/gov/environment/climate-change/adaptation/health/final_climate_and_health_backgrounder_public_health.pdf

[12] Copernicus Climate Change Services, "2023 is the hottest year on record, with global temperatures close to 1.5°C limit," media release, January 9, 2024. https://climate.copernicus.eu/copernicus-2023-hottest-year-record

- **Extreme heat**: In Canada, extreme heat events, especially intense heat waves and heat domes, are the leading weather-related cause of death.[13] Between June 25 and July 1, 2021, 619 people died in the B.C. heat dome, 98% of whom were indoors.[14] Excessive heat can cause symptoms like nausea, cramps and dizziness, and at the extreme, when the body is not able to manage the prolonged heat, it can result in delirium, loss of consciousness and death.[15] Indoor overheating is becoming a greater risk as climate change leads to more frequent heat events.[16] Construction quality, age and presence or absence of adequate cooling and ventilation systems all contribute to a building's capacity to hold or shed heat and risk of the occupants suffering from heat-related illnesses.
- **Flooding and reduced water quality**: Flooding is a climate threat that poses immediate dangers to infrastructure as well as humans. Floods are often accompanied by decreases in water quality when runoff introduces pollutants to surface water, groundwater, and soil. Most pollutants can be removed from drinking water, but damage caused by floods, or other climate-induced disasters (landslide, power failures, etc.), can take water treatment offline, leaving water unsafe to drink and increasing human health risks.[17] This can increase exposure to waterborne diseases such as cholera or infections from giardia, E. coli, or cryptosporidium; such outbreaks have led to deaths and left communities like Walkerton, Ontario and North Battleford, Saskatchewan scrambling for medications and drinking water as tap water became undrinkable. After a flooding event, indoor air quality of impacted buildings can decrease owing to mould growth and other contaminants introduced by the floodwaters.

[13] B.C. Coroners Service, *Extreme Heat and Human Mortality: A Review of the Heat-Related Deaths in B.C. in Summer 2021* (2022), 11. https://www2.gov.bc.ca/assets/gov/birth-adoption-death-marriage-and-divorce/deaths/coroners-service/death-review-panel/extreme_heat_death_review_panel_report.pdf

[14] *Extreme heat and human mortality*, 5.

[15] Tanya Lewis, "Why Extreme Heat Is So Deadly," *Scientific American*, July 22, 2021. https://www.scientificamerican.com/article/why-extreme-heat-is-so-deadly/

[16] National Collaborating Centre for Environmental Health, "Preventing indoor overheating," August 23, 2023. https://ncceh.ca/resources/subject-guides/preventing-indoor-overheating

[17] Sarah Wollschlaeger, Ayan Sadhu, Ghazal Ebrahimi and Angi Woo, "Investigation of climate change impacts on long-term care facility occupants," *City and Environment Interactions* 13, no. 100077 (2022). https://www.sciencedirect.com/science/article/pii/S2590252021000222

- **Changes in infectious agents**: In addition to increasing human exposure to diseases and other contaminants through poor indoor air quality and drinking water, climate change is increasing the spread of diseases and expanding to broader geographic areas. This is related to the way diseases spread, commonly through contact with insects, other animals, fungi, and water.[18] Extreme weather events may create opportunities for more clustered disease outbreaks.[19]
- **Wildfire smoke and reduced air quality**: Similarly, longer, more frequent, intense and widely spread wildfires are increasing exposure to particulates, gases, and vapour containing chemicals both outdoors and inside buildings. Particulate matter and other wildfire pollutants damage respiratory systems, causing lung inflammation and potentially exacerbating chronic allergy and respiratory conditions. These impacts lead to increased risk of cardiovascular events and susceptibility to respiratory viruses (see Appendix A for more examples and details).[20]

[18] Centre for Disease Control, *Our Risk for Infectious Diseases is Increasing Because of Climate Change* (2022). https://www.cdc.gov/fungal/media/pdfs/ncezid-climate-change-and-infectious-diseases.pdf

[19] "Investigation of climate change impacts on long-term care facility occupants."

[20] B.C. Public Service, *Wildfire smoke, air quality and your health.* https://www2.gov.bc.ca/assets/gov/careers/managers-supervisors/managing-occupational-health-safety/wildfire_smoke_health_concerns.pdf

2. Healthy, safe buildings

Many of the best measures to keep people healthy and safe while indoors are implemented at the new construction stage; for example, building shape, orientation, and the window-to-wall area ratio are all determined at the outset of a building's life cycle. Resilience measures are being introduced to building codes, but 80% of the buildings that will exist in 2050 have already been built and most vintage buildings are not ready for the increasing impacts they are already experiencing.

Deep retrofits can offer no-regrets solutions to preparing existing buildings for a changing climate while also lowering the emissions that contribute to climate change. Some building design and retrofit strategies are particularly suited to improving a building's performance along with improving the adaptive capacity of people living inside. In Appendix B, the impact of construction and retrofit strategies on occupants' ability to adapt to climate change has been tabulated and categorized. A selection of these is discussed below.

- **Insulation**: Increasing the thermal performance of a building's roof and walls with insulating materials helps regulate the indoor air temperatures, thereby decreasing mechanical heating and cooling energy needs and utility costs of heating in the winter and cooling in the summer. Buildings designed to reduce heat loss can also increase resilience of occupants during power outages that disable heating systems. Combined with air sealing and ventilation, insulation also helps regulate relative humidity (the amount of moisture air can hold at a given temperature), which is critical for preventing moisture accumulation and mould growth.
- **Windows**: Well-installed, high-performance windows are also critical components for providing climate resilience. While the window-to-wall ratio is largely fixed at the start of a building's life, improvements to window shading and thermal performance of the glass and frames are effective measures to regulate heat and moisture and seal out pollutants. At a minimum, windows at the end of their life cycle should be replaced with double- or triple-pane insulated glass units with thermally broken frames depending on the local climate and building characteristics. Ensuring proper sealing with the surrounding air barrier in the wall assembly during installation will also guard against smoke and heat transfer through air or water leaks during storms and floods.
- **Filtration**: Exposure to airborne diseases and wildfire smoke can be limited further by filtering outside air brought in through the ventilation systems. Filtration is measured by the particle size a filter can trap and stop from entering the system (the industry standard is the Minimum Efficiency Reporting Value **or** MERV). During acute events, such as wildfires, standard filters can be swapped out for higher MERV-rated filters (a

minimum of MERV 13 is recommended by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers)[21]. The indoor air must pass through the system filter regularly to remove the small particles that are most concerning for health.[22] After the event, the lower-rated filters should be re-installed into the ventilation system as they require less energy to operate (they have less restrictive airflow and the mechanical equipment does not have to work as hard). Continuous ventilation is also critical for preventing accumulation of radon, a risk that can increase with improvements to air tightness. [23]

- **Cooling**: At times of more extreme heat, passive cooling provided by insulation and shading, for example, will need to be supplemented with active cooling measures, such as heat pumps set to cooling mode. In 2017, only 32% of households in B.C. and 38% in the Atlantic provinces reported being equipped with air conditioning, far below the Canadian average of 61%; Ontario has the highest rate at 85%, followed by Quebec at 58% and the prairie provinces with 49%.[24] In the Lower Mainland, one of Canada's mildest climates, air conditioner use increased from one-fifth of customers to one-third, nearer the B.C. average, following the 2021 heat dome.[25]

Unfortunately, cost is a significant barrier that puts longer-term deep retrofit solutions out of reach of many Canadians, especially low-income households living with energy poverty. For active mechanical cooling, an increasing requirement of emergency preparedness, portable air conditioning units can provide immediate relief that can save lives during extreme heat events — but only for those who can afford to buy the units and the electricity needed to power them and who have permission to install them.

Various municipalities across Canada have begun implementing and exploring maximum temperature allowances in residential buildings. These bylaws typically attempt to require building owners to maintain at least one room per rental unit from exceeding 26°C. In August 2023, New Westminster City Council directed staff to explore tools available to the city to adopt

[21] AHSRAE, *Planning Framework for Protecting Commercial Building Occupants from Smoke During Wildfire Events* (2022), 5. https://www.ashrae.org/file%20library/technical%20resources/covid-19/guidance-for-commercial-building-occupants-from-smoke-during-wildfire-events.pdf

[22] Vancouver Coastal Health, *Wildfire smoke: schools and childcare facilities*, (2024) 2. https://www.vch.ca/en/document-library/wildfire-smoke-schools-childcare

[23] Government of Canada, *Radon and energy retrofits* (2023). https://www.canada.ca/en/health-canada/services/publications/health-risks-safety/radon-energy-retrofits.html

[24] Matthew Quick and Michael Tjepkema, *The prevalence of household air conditioning in Canada* (Statistics Canada, 2023). https://www150.statcan.gc.ca/n1/pub/82-003-x/2023007/article/00002-eng.htm

[25] *Protecting Population Health in a Climate Emergency*, 22.

such a bylaw; the councillors directly cited the deaths from the 2021 heat wave as motivating factors.[26]

[26] City of New Westminster, *Motion 8.1.a: Cooling Equipment in Rental Units* (2023). https://pub-newwestcity.escribemeetings.com/FileStream.ashx?DocumentId=16755

3. Responsible actors

Deep retrofits provide public health benefits, but the costs are not readily shared, often leaving vulnerable populations living in poor-quality housing to suffer most acutely. Other actors who may have more opportunity and responsibility for incentivizing or implementing retrofits include:

- **Building owners**: Tenants benefit most from deep retrofits but have the least agency to act; building owners make decisions based on returns on investment but the health and human resilience benefits are accrued externally, off their balance sheets. Setting aside this 'split incentive,' the monetary value of health and human resilience benefits or risks is not well understood and is therefore challenging to account for in cost-benefit analyses. Building owners need to be working with tenants to ensure their homes are healthy environments and safe to occupy in the event of escalating climate impacts.
- **Insurance and finance**: Insurance systems are reacting to climate impacts through premiums and revocations. Following recent disasters, like the 2021 flooding in B.C., many customers had their insurance eligibility revoked because the risks were too high.[27] The insurance industry is certainly evolving and being shaped following recent climate impacts.[28] Retrofit and new construction measures that proactively protect the property are entering the market (e.g., Cooperators outlines strategies to manage premium costs by protecting the building in the face of wind, hail, and fire risks[29]). However, retrofit measures that can help protect human health, such as switching to a heat pump to add cooling and remove a source of carbon monoxide, are assessed based on replacement costs, which can increase rather than decrease premiums.
- **Governments**: While a similar separation between public health and housing construction and retrofits is evident in most government programs, Canada's first National Adaptation Strategy is starting to change that. In its recognition that the built environment is a social determinant of health, the strategy lists the number of households with cooling as a resilience metric.[30]

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[27] Amy Smart, "B.C. flood survivor warns others to check insurance amid increase in climate disasters," *CBC News*, April 15, 2022. https://www.cbc.ca/news/canada/british-columbia/bc-climate-disasters-floods-insurance-1.6421266

[28] Insurance Bureau of Canada, "Canadians need flood protection." https://www.ibc.ca/issues-and-advocacy/canadians-need-flood-protection

[29] Co-operators General Insurance Company, "What's behind the rising cost of home insurance?" https://www.cooperators.ca/en/group/group-insurance/insurance-tips/how-insurance-rates-are-calculated

[30] Government of Canada, *National Adaptation Strategy* (2023). https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/national-adaptation-strategy.html

In a positive step, the Canadian Board for Harmonized Construction Codes (CHBCC) identifies climate change adaptation as a priority, and measures to reduce overheating risk are slated to be incorporated into Canada's 2025 national model building codes. The CBHCC states it is considering the role of codes in addressing climate impacts beyond overheating but whether this would address building or human resilience is not clear.[31]

[31] Canadian Board for Harmonized Construction Codes, "2025 Code Priorities." https://cbhcc-cchcc.ca/en/2025-code-priorities/

4. Recommendations

Extreme weather events and their impacts are increasing in severity and frequency as the climate changes. The resulting health impacts can be mitigated by thoughtful planning, but coordinated investment is needed.

Rental buildings typically have a split-incentive problem in that building owners bear the costs of capital upgrades while tenants enjoy the non-energy benefits such as improved health and, in many cases, the energy cost savings. Tenants who live in outdated infrastructure can be vulnerable through increased exposure, and they are often limited in their adaptive capacity because only the owner has the agency to makes changes to the building. To avoid rent increases that could deepen the current housing affordability crisis, owners need alternative cost recovery mechanisms, such as insurance and financial products that reward proactive adaptation measures and public funding that recognizes the health benefits of retrofits.

4.1 Building owner actions

Building owners can maximize capital renewal planning by integrating building and occupant resilience objectives and targets, such as those expected in coming building codes and being set through local government performance standards, into asset planning. This could include planning for adaptation measures to:

- Minimize heat gains and infiltration of heat, smoke and water, especially during extreme heat events, by upgrading building envelopes (roofs, walls and windows) with airtightness, insulation and shading.
- Monitor air quality for particulate matter, carbon dioxide, carbon monoxide and radon and indoor environmental quality for temperature and relative humidity, where appropriate. Building owners and operators need wildfire smoke plans that include measures to reduce smoke entry and enhance filtration by increasing recirculation of indoor air through high-efficiency air filtration media (e.g., HEPA or MERV 13 or higher).
- Provide active cooling and continuous fresh air by installing mechanical cooling.
- Automate building control systems and implement energy conservation measures to ensure the building is operating optimally.

By engaging tenants, building owners can identify elevated exposure and sensitivities to guide retrofit decisions, such as by:

- Developing check-in systems with vulnerable tenants, particularly during and in anticipation of extreme weather events.

- Co-developing design solutions attuned to tenant needs.
- Fostering retrofit champions among tenants who can help communicate the retrofit process and benefits to fellow tenants and bring forward tenant concerns and post-retrofit experiences.

4.2 Insurance and financial sector actions

Insurance and financial sector actors can help building owners pre-emptively avoid human health and safety risks by developing products that reward owners for investing in upgrades that reduce exposure risks. This could include reductions in insurance premiums and borrowing costs for projects that include adaptation measures such as:

- Integration of passive energy conservation and shading measures that help reduce risk of exposure to extreme heat.
- Installation of active cooling, ventilation, and air filtration to ensure filtered air through filtered intake or recirculation as appropriate and to reduce accumulation of indoor air contaminants such as radon.
- Removal of equipment powered by fuels that can increase indoor air contaminants such as carbon monoxide.

4.3 Government actions

Deep retrofitting existing buildings is imperative to meeting net-zero emissions targets, but also to ready buildings for climate change impacts that Canadians are already experiencing.

The Canadian government expanded Infrastructure Canada’s mandate to include housing, signalling recognition that housing is critical infrastructure. Equally critical is making sure adaptation measures that provide public health benefits, such as avoided health and recovery costs, are implemented in Canadian homes and buildings. Government intervention to help building owners implement adaptation measures include continued development of regulation, such as resilience measures in building codes and standards, and programs that provide funding, concierge services and technical guidance to help ease deep retrofit costs and the customer journey. Specifically, such interventions should include:

- Setting and adhering to home adaptation targets, developing an accountability mechanism, and coordinating resources, programs and regulations integrated into the National Housing Strategy, the Canada Green Building Strategy, and the National Adaptation Strategy.

- Providing deep retrofits at zero cost to low-income households living with energy poverty; the Pembina Institute estimates an average of $2.8 billion per year is required from 2025 to 2050.[32]
- Implementing bylaws and amending strata/condominium and landlord acts to protect tenant affordability and legislate the right to cool.
- Actively plan for future heat waves and work with vulnerable communities (those living alone, elderly, those with multiple sensitivities) to ensure they have access to active cooling measures in anticipation of heat waves.
- Funding further research into the relationships between deep retrofits and their associated health and resilience benefits, the value of avoided healthcare costs, especially for vulnerable populations and how to socialize the costs of the resultant public health benefits.
- Working with utilities to align demand-side management programs to reduce energy consumption and peak energy demand to help avoid costly expansion of generation and distribution capacity.
- Actively coordinating public and utility resources to encourage and support building owners and retrofit service providers to incorporate adaptation measures into deep retrofits projects and programs.

[32] Jessica McIlroy, Betsy Agar and Emma Harris, *Better Buildings for All: Relieving energy poverty through deep retrofits* (Pembina Institute, 2024), 1. https://www.pembina.org/pub/better-buildings-all

Appendix A. Health conditions and diseases exacerbated by climate change

Table 1. Health conditions and diseases exacerbated by climate change

Health conditions and diseases exacerbated by climate change	Risk factors	Exacerbating climate change impact			
		Extreme heat	Wildfire smoke, reduced air quality	Flooding, reduced water quality	Infectious agents
Heat and humidity related illnesses (e.g. heat exhaustion, heat stroke)	Age 65 and over and/or existing chronic illness[i]	X			
Renal and urinary illnesses[ii] (e.g. fluid and electrolyte imbalance; renal failure, nephritis and other kidney disorders; urinary tract infection[iii])	Age 65 and over[iv]	X			
Airborne infectious disease (e.g. influenza and coronavirus)[v]	Ages 65 and over and/or existing chronic illness (most notably, asthma)[vi]				X
Vector-borne infectious disease (e.g. West Nile virus illness, Lyme disease)[vii]	Adults older than 55, but exposure is the greatest risk factor (i.e. living near endemic areas)[viii] *In the case of West Nile virus and Lyme disease, risk will be higher for occupants near standing water or wooded areas, respectively.*[ix]	X			X

Cardiovascular diseases (e.g. cardiac dysrhythmias and ischemic heart disease) and heart attacks[x,xi]	Hypertension, smoking, obesity, and diabetes[xii,xiii]	X	X		
Stroke[xiv]	History of TIA or stroke events, hypertension, arteriosclerotic heart disease, smoking and/or diabetes[xv]	X	X		
Acute cognitive impairment[xvi]	Dementia, including Alzheimer's disease		X		
Adverse side effects from and/or decreased efficacy of medication[xvii]	Individuals taking medications that impair thermoregulation or psychiatric medications	X			
Mental health impacts[xviii]	Mood or anxiety disorders[xix]	X	X	X	X
Allergies[xx]	Allergies	X	X	X	
Exacerbate diabetes[xxi]	Diabetes	X			
Exacerbation or onset of COPD: chronic bronchitis and emphysema symptoms[xxii]	Cardiopulmonary disease *Smoking, asthma, obesity, and being age 65+ all increase risk for developing COPD.*[xxiii]		X		
Lower and upper respiratory infections[xxiv]	Cardiopulmonary disease		X		
Gastrointestinal diseases and water-borne infectious diseases (e.g. cholera, giardia, leptospirosis, or appendicitis)[xxv]	Bowel disorders[xxvi] *Immunocompromised adults, children, and elderly have the greatest risk of mortality*	X	X	X	X
Cancer, primarily breast[xxvii] and lung[xxviii]	Females and former smokers are at greater risk, but all occupants have some risk.		X		X
Asthma-related medical problems[xxix]	Asthma	X	X	X	
Acute bronchitis[xxx]	Children, ages 14 and under		X		

Impact on neurodevelopment[xxxi]	Pregnant women *Infants are at risk, based on exposure during pregnancy*		X		
Infant mortality[xxxii]	Infants (ages 0-1)		X		
Prenatal insult*, preterm and low birth weight[xxxiii] **Prenatal insult is an environmental impact affecting or threatening life*	Pregnant women *Infants are at risk, based on exposure during pregnancy*	X	X		

Full references are found in Appendix C. Bibliography.

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[iv] Extreme heat: (Bobb et al., 2014); (Yip & Woo, 2018)

[v] Infectious agents: (Wu et al., 2016)

[vi] (Public Health Agency of Canada, 2017)

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[xxi] Extreme heat: (Guo et al., 2018)

[xxii] Air pollution, ambient and household: (World Bank and Institute for Health Metrics and Evaluation, 2016a); Wildfires: (Matz, 2020) and (Yao, 2020) (Breathe - the lung association, 2020);

[xxiii] COPD risk: (de Marco et al., 2011; McGeachie, 2017; Osman et al., 2017)

[xxiv] Air quality: (Vermont Department of Health, 2018), (World Bank and Institute for Health Metrics and Evaluation, 2016b); Wildfires: (Matz, 2020)

[xxv] Extreme heat: (Health Canada, 2020), (Huang et al., 2011) ; Extreme heat and flooding: (Lemmen et al., 2008); Flooding: (Public Health Agency of Canada, 2018) (Wade et al., 2004); Extreme precipitation: (Chen, M.-J. et al., 2012); Infectious agents: (Wu et al., 2016); Air pollution: (Chen, C.-C. & Yang, 2018); (Kaplan et al., 2009)

[xxvi] GI risk and sensitive populations: (Schwartz et al., 2000); (Wade et al., 2004)

[xxvii] Air quality: (Reynolds, 2013) as cited in (Tonn et al., 2014)

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[xxix] Air quality: (Tonn et al., 2014); Wildfires: (Matz, 2020), (Breathe - the lung association, 2020); Asthma symptoms exacerbated by wet weather — a potential cause of flooding: (D'Amato et al., 2007); Extreme heat, humidity, weather changes and rain: (Asthma and Allergy Foundation of America, n.d.); High temperatures are worse for asthma in ages 65+: (Ma et al., 2019)

[xxx] Air quality: (Romley et al., 2012); Bronchitis in children from wildfire smoke (Matz, 2020) ; Wildfires (Henderson, 2019) and (Reid, 2019)

[xxxi] (Kim et al., 2014)

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[xxxiii] Extreme heat: (Konkel, 2019): Wildfires: (Holstius et al., 2012)

Appendix B. Building design strategies that provide climate resilience

Table 2. Building design strategies that provide climate resilience

Core climate change impact	Design strategies to provide climate resilience
Cooling — Passive	
Exteme heat	Building shape and massing [a] Building orientation [a] Thermal mass / Wall and roof thermal performance [a,b,c] Window design — reduced window-to-wall ratio (WWR) [a,b] Exterior (more effective) or interior shading — window shades (physical) [a,b,c] Shading — window glazing (SHGC) [a,b,c] Shading — window glazing (dynamic or electrochromic) [a,b] Shading — window coatings [a] Natural ventilation — single sided ventilation [a] Natural ventilation — cross flow ventilation [a,c]
Extreme heat, flooding and reduced water quality	Cool or green roofs [a,c] Shading — vegetation [a,c]
Extreme heat, wildfire smoke and reduced air quality	Window design — thermal performance (U-factor and sealing) [a,b,c]

Core climate change impact	Design strategies to provide climate resilience
Cooling — Active	
Extreme heat	Heat recovery ventilation (HRV) with bypass [a,b] Exhaust fans to drive air movement [a] Temper supply air [a] Integrated heating and cooling — hydronic system [a,b] Central or distributed cooling (e.g., heat pumps) [a,b,c] Variable refrigerant flow (VRF) Systems [a] Mixed mode systems [a]
Ventilation	
Extreme heat, infectious agents	Dedicated outdoor air systems [a]
Wildfire smoke and reduced air quality	High-efficiency air filtration media (i.e. HEPA or MERV 13 or higher) [c]
Building layout / floor plan	
Extreme heat, wildfire smoke and reduced air quality	Design a common building area to act as a cooling room or clean air refuge [a,c] Place equipment and furniture with air circulation, temperature control, and pollutant removal functions of the HVAC systems in mind [c]
Wildfire smoke and reduced air quality, flooding and reduced water quality	Design building entry and exits that can be operated manually [c]

Core climate change impact	Design strategies to provide climate resilience
Flood preparedness	
Flooding and reduced water quality	Use sealants and shields on windows, doors, and walls to reduce the seepage, or withstand pressures, of floodwaters [c] Ensure key services (e.g. electrical rooms, back-up power, elevator controls) are located on higher floors at low/no risk of flooding [c] Protect electrical equipment with waterproof enclosures [c] Design site storm water conveyance away from structures for increased volumes and flows [c] 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 [c]
Power systems	
Extreme heat	Investigate opportunities to use solar energy technologies to power cooling systems or chillers [c]
Extreme heat, wildfire smoke and reduced air quality	Ensure backup power to critical systems and areas [c]
Building materials / equipment	
Extreme heat	Use light-coloured building materials [c] Use high-efficiency lighting, equipment, and appliances [c]
Flooding and reduced water quality	Select higher performance, water-resistant building materials [c]
Wildfire and reduced air quality	Use fire-retardant materials [c] Install a chimney spark arrestor [c] Ensure building and garage entry doors are fire-rated and sealed with an air barrier [c] Use building materials and furnishings that are low in volatile organic compounds [c]

Core climate change impact	Design strategies to provide climate resilience
Extreme heat, wildfire smoke and reduced air quality	Use double-paned tempered windows and frames with an air barrier seal [c]

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