Unlocking private investment in Canadian flood resilient home retrofits: a return on investment research summary

Evans, Cheryl

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Unlocking Private Investment in Canadian Flood Resilient Home Retrofits:

A Return on Investment Research Summary

Submitted to: Louis Poirier, Researcher

Organization Name: National Research Council Canada

Submitted by: Cheryl Evans, Principal Consultant

Organization Name: Climate Ready Together Ltd.

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Executive Summary

Canadian governments, businesses, and residents currently spend a combined average of $2.9 billion every year repairing damage to homes caused by fluvial, pluvial, and coastal flooding. The distribution of losses is particularly concentrated in homes exposed to the highest levels of flood hazard. For example, homes within the top 10% (approximately 1.5 million) experience 89.3% of all losses per year whereas the top 1% (approximately 109,000) experience 34.1% (Public Safety Canada, 2022). To date very few Canadian households have invested in flood resilient retrofits before flooding occurs, opting instead to wait for government disaster recovery programs to provide support if and when flooding occurs. This reactive approach unnecessarily exposes Canadians, particularly socially vulnerable households within high-risk zones, to dire social and economic consequences (Wright et al., 2022). Without implementing adequate voluntary and regulatory flood risk reduction measures experts project that annual costs associated with repairing home flood damages may triple by 2030 (Ziolecki et al., 2020).

This paper examines the grey and peer-reviewed literature that is currently available to help drive proactive private side investment in flood resilient home retrofits, identifies where gaps exist, and points to additional research that is needed to bolster retrofit adoption.

The majority of research describes home flood mitigation approaches using the PARA framework (protect, accommodate, retreat, avoid) and expresses results as a benefit cost ratio (BCR). A BCR compares the total expected benefits to society for the life of a building (75 years for new builds and 50 years for retrofits) as a result of completing mitigative actions compared to related installation and maintenance costs (Doberstein et al., 2019). The research consistently documents the power of

public and private incentives to increase the BCR of flood resilient retrofits and drive preventative action. It also emphasizes the importance of building all new homes to meet flood resilient standards to maximize the long-term benefits to society (Porter & Yuan, 2020; Porter et al., 2023). BCR estimates for dry flood proofing (protect) range from 11:1 for flood resilient new home construction (Porter & Scawthorn, 2020) to 6:1 for flood resilient retrofits (Porter et al., 2019). Wet flood proofing (accommodate) BCR estimates range from 6:1 for 1' (30cm) elevation above the 100-year flood plain to 5:1 for 5' (150cm) elevation above the 100-year flood plain (American Flood Coalition, 2022). BCR estimates for retreat range from 6:1 over 20 years (Porter et al., 2019) to 6:1 over 30 years (Nelson & Camp, 2020). Two studies proposed a methodology for estimating BCR associated with land use planning initiatives to eliminate flood risk (avoid), but did not generate any BCR results (Mechler et al., 2014; De Risi et al., 2018).

To unlock private side investment in proactive flood resilient retrofits and new builds the research identifies opportunities for all participants in the real estate value chain (builders, developers, retailers, insurers, lenders, and local governments) to work together to raise public awareness of flood risks and incentivize improved flood resilience (Porter & Yuan, 2020; Porter et al., 2023; Giannitsos, 2023; Krueger, 2022; Minano & Peddle, 2018). Support for flood resilient home retrofits in high-risk zones should be prioritized, particularly for homes that provide the country's most affordable housing units, including basement apartments, social housing, rental homes, and apartment buildings. This is critical to ensure access to safe, reliable and attainable housing for Canada's vulnerable populations (Wright et al., 2022). Updating building codes and eliminating perverse legislation and policies that incentivize development in high-risk flood zones is also necessary to fortify the long-term flood resilience of Canada's housing stock (Porter & Scawthorn, 2020).

Introduction

Property damage from home flooding is on the rise in Canada. A lack of flood resilient requirements in the National Building Code, increased development in flood plains, the destruction of natural ecosystems such as wetlands and forest that mitigate flood impacts, the increased average size of homes over the past 50 years, and the growing popularity of converting flood-prone basements into living spaces puts more people, physical, and financial assets in harm's way each year across the nation. Climate change is also contributing to increased flooding due to sea level rise (coastal flooding) and extreme weather events such as rainfall microbursts, atmospheric rivers, and rapid snowmelts (pluvial flooding) (Bakos et al., 2022).

Currently, an estimated 1.5 million Canadian households (roughly 3.7 million people) live in locations at high risk of riverine (fluvial), coastal or heavy rainfall (pluvial) flooding. All households are exposed to some level of pluvial flood risk (Public Safety Canada, 2022). The Federal government's Task Force on Flood Insurance and Relocation (Public Safety Canada, 2022) published a national flood risk assessment of all residential properties in 2022. They estimated that Canada currently averages $2.9 billion in annual losses from flood damages to homes exposed to all levels of fluvial, pluvial, and coastal flooding. The distribution of losses is highly concentrated in homes exposed to the highest levels of flood hazard. For example, homes ranked within the top 10% (approximately 1.5 million) experience 89.3% of all losses whereas the top 1% (approximately 109,000) of homes experience 34.1%. The remaining 10.7% of losses are distributed amongst the remaining 90% of Canadian households. The report estimates the average annual loss (AAL) for the top 10% at $262 or more per year and the top 1% at $4,150 per year. Quebec, Ontario, and British Columbia have the highest number of residential properties within the top 10% and 1% highest exposure to flood risk, in part due to their large population sizes (Public Safety Canada, 2022).

In Canada today, these top 10% (1.5 million) high-risk households do not have access to affordable flood insurance (Insurance Bureau of Canada, 2024), reducing the capacity of owners and property managers to repair or rebuild following small-scale flood events. Lack of access to affordable flood insurance also leaves tenants without coverages to restore damaged belongings or pay for temporary accommodation while they await repairs. During catastrophic flood events however property owners, managers, and tenants may access taxpayer funded Disaster Financial Assistance Arrangements (DFAA), further reducing the incentive to self-fund flood resilient retrofits before disaster strikes. Exacerbating this challenge in Canada, the DFAA currently focuses on restoring homes to pre-flood conditions recreating flood risks instead of reducing them.

Flooding has greater consequences for renters than property owners. Rental units, which provide critical lower cost housing options for socially vulnerable peoples, including duplexes and multi-unit residential buildings, are more likely to be bulldozed than single family homes after experiencing significant flood damage and take longer to repair. The resulting rental unit supply crunch can increase rents, forcing residents to consider relocating to more affordable homes within their communities or leaving town in search of affordable rents. Where workable solutions are not available people may become precariously housed or unhoused (Peacock et al., 2018).

Local governments, property owners, home builders, banks, realtors, home inspectors, and appraisers benefit directly from supporting increased development in high-risk areas through increased revenues but face minimal consequences for doing so. If a catastrophic flood occurs the federal, provincial, or territorial government pays up to 90% of reconstruction costs, effectively subsidizing development and reconstruction in high-risk zones (Public Safety Canada, 2022).

Without implementing adequate voluntary and regulatory flood risk reduction measures to remove the perverse incentive to build more homes in areas at high risk of flooding, experts project that flood damage costs may triple by 2030, increasing the exposure of Canadians, particularly socially

vulnerable households, to dire social and economic consequences. Flood resilient retrofits offer an immediate opportunity to reduce flood risks for all Canadian households. Unfortunately, an interconnected set of barriers limit public awareness of flood risk and diminish motivation to invest in flood resilient retrofits. For example, a recent study of 2,500 people living in designated flood risk areas across the country indicated that 94% were not aware that they were living in a high-risk zone, 47% were not concerned about flooding, 75% have not purchased flood insurance (optional sewer backup or overland flood coverages), and 55% have not taken preventative action to reduce their flood risk (Ziolecki et al., 2020). Fortunately, a revamped DFAA will come into effect on April 1, 2025. The significant policy and funding overhaul will increase the BCR of flood resilient retrofits, help to support flood risk awareness and reduce the perverse incentive to approve new home construction in high-risk zones. It will accomplish these significant shifts by introducing new incentives to help provincial/ territorial and local governments incentivize flood resilient home retrofits before flooding occurs and require home repairs and reconstruction to meet minimum flood resilient standards following catastrophic flooding events (Public Safety Canada, 2025).

Research Overview

The National Research Council of Canada (NRC) is pursuing a wide variety of research projects that focus on strengthening household level resilience to fluvial, pluvial, and coastal flooding. To complement research that focuses on structural improvements to reduce home flood risk and/or minimize damage if a flood occurs (thereby strengthening resilience), NRC would like to define the return on investment (ROI) for completing specific flood-resilient home retrofits under each type of flooding scenario (pluvial, fluvial, and coastal).

Research Scope

Residential buildings in scope for this research include detached, semi-detached, townhomes and multi-unit residential buildings of all heights. Temporary flood barriers and green infrastructure solutions, such as bioswales, rain gardens, and green roofs are out of scope for this research. Available peer-reviewed and grey literature has been reviewed from Canada and the United States. Some relevant international papers have also been considered.

Research Goals

The goal of providing this scenario-based information is to 1) help homeowners, property managers, and tenants make ROI-informed choices between a variety of retrofit options, and to 2) motivate action to strengthen resilience.

Research Objectives

The research includes the following objectives

1. Determine what research (peer-reviewed and grey literature) is currently available that documents ROI for completing residential flood resilient retrofits.
2. Identify where knowledge gaps exist, including household-level barriers to completing retrofits.
3. Identify next steps to consider to a) address knowledge gaps, and b) to improve uptake of flood resilient home retrofits.

Research Methodology

To find relevant peer-reviewed and grey literature key word searches were completed using the Royal Roads University Library collections database and Google Scholar. Key word searches included the words home AND flood AND resilient AND retrofit AND ROI with and without AND CANADA, backwater valve AND retrofit AND ROI with and without AND CANADA, sump pump AND retrofit AND ROI with and without AND CANADA, ROI AND planning policies to reduce flood risk with and without AND CANADA,

property buyouts AND flood AND ROI with and without AND CANADA. A recent PhD dissertation from Harvard University offered additional relevant resources (Omiya, 2024). A Google search of resilient home retrofits was also completed and new report releases on LinkedIn rounded out the data collection. These searches yielded primarily mixed methods research that commonly included a blend of quantitative (building type, elevation and inundation mapping analysis, site surveys, benefit cost and return on investment calculations) and qualitative methods (semi-structured interviews, online surveys, focus groups, behavioural observation).

Definitions

To mitigate home flood risks a variety of approaches can be used. A commonly cited framework for describing these approaches in Canadian research is referred to using the acronym PARA (protect, accommodate, retreat, avoid). A variety of terms are used to describe the outcomes of social and economic analyses associated with various PARA approaches (Doberstein et al., 2019).

Protect: Protect refers to community scale defenses such as dikes and pumping stations that are designed to block water from entering populated areas. It also refers to household level dry flood proofing methods such as installing and maintaining sump pumps and backwater valves to keep water out of homes to prevent damage. Temporary barriers that block water entry from the periphery of the building or through windows and doors are also included in this general category but are excluded from this research.

Accommodate: Accommodate refers to mitigation approaches that allow water to enter landscapes and structures and recede without causing structural damage. Also known as wet flood proofing, measures include installing flood vents in the lower level of a house to neutralize hydrostatic pressure during flood events and elevating a home on piers.

Retreat: Retreat refers to the process of removing structures from high-risk flood zones. Expropriation and buyouts are examples of methods that facilitate retreat-based flood risk mitigation.

Avoid: Avoid describes the implementation of legislation, planning and development policies that prevent construction of structures and infrastructure in high-risk zones through development guidelines and restrictive by-laws (Doberstein et al., 2019).

The information in this section is laid out based on the PARA framework for flood risk mitigation. Research presented includes concepts including return on investment (ROI), benefit cost ratio (BCR), and relative cost.

Return on Investment: Return on Investment (ROI) calculates the financial gain from an investment relative to its cost by dividing gain over cost. ROI is expressed as a percentage.

Benefit Cost Ratio: Benefit cost ratio (BCR) compares the total expected benefits to society as a whole to the total expected costs. Common BCR considerations found in this research include dollar values assigned to property loss, additional living expenses, indirect economic loss, insurance costs, deaths, injuries, instances of post-traumatic stress disorder (PTSD), and some environmental costs. Factors considered in BCR calculations vary widely. The time period considered to calculate total expected costs varies as well but is typically 50 years to account for the life span of a home that is being retrofitted and 75 years for a new build (Porter & Scawthorn, 2020). BCR is expressed as a ratio of total expected benefits: total expected costs (e.g., 6:1) meaning that $6 of benefit can be expected for every $1 dollar spent. A BCR may also be expressed as a number by dividing the value of the benefit by the value of the cost. If the result is greater than 1 the project is advisable as the benefits outweigh the costs.

Relative Cost: Relative cost compares the costs of 2 or more items and ranks them from lowest to highest.

Discussion

The first section of this report highlights flood resilient home retrofit research that compares all PARA approaches. The second section identifies available research about each of the approaches. The third section focuses on barriers to adoption of flood resilient retrofits and enablers to improve uptake rates and highlights examples of analogous research that may provide insights into how drive flood resilient home retrofits. The fourth section provides a research gap analysis, and the final section identifies short-, medium-, and long-term initiatives that should be considered to drive private side investment in flood resilient retrofits.

Comparative PARA Research

Research on the relative costs and BCR associated with various PARA approaches rank home flood retrofits from lowest to highest cost based on the type of flooding and the type of home construction. Commonly cited Canadian (Behm et al., 2021) and American comparative rankings research (FEMA, 2014) focus only on options for riverine and coastal flooding and do not consider heavy rainfall (pluvial) flooding in their rankings. These studies state that lowest cost retrofit option is wet proofing for homes with frame, masonry veneer, or masonry construction with a crawlspace or basement. The highest cost is for the relocation of a frame, masonry veneer, or masonry construction with slab-on-grade foundation. The research also notes that the costs associated with demolition and relocation associated with property buyouts vary widely (Behm et al., 2021; FEMA, 2014). Please see Table 1 below for additional information.

Table 1: Relative Costs of Various Retrofit Measures

Table 3-12. Relative Costs of Various Retrofit Measures

Construction Type	Existing Foundation	Measure	Retrofit	Relative Cost
Frame, Masonry Veneer, or Masonry	Crawlspace or Basement	Wet Floodproofing 	Wet floodproof crawlspace to a height of 4 feet above lowest adjacent grade or wet floodproof unfinished basement to a height of 8 feet above basement floor	Lowest 
Masonry Veneer or Masonry	Slab-on-Grade or Crawlspace	Dry Floodproofing 	Dry floodproof to a maximum height of 3 feet above lowest adjacent grade	
Frame, Masonry Veneer, or Masonry	Basement, Crawlspace, or Open Foundation	Barrier Systems 	Levee constructed to 6 feet above grade or floodwall constructed to 4 feet above grade	
Frame, Masonry Veneer, or Masonry	Basement, Crawlspace, or Open Foundation	Elevation 	Elevate on continuous foundation walls or open foundation	
Frame, Masonry Veneer, or Masonry	Basement, Crawlspace, or Open Foundation	Relocation 	Elevate on continuous foundation walls or open foundation	
Frame, Masonry Veneer, or Masonry	Slab-on-Grade	Elevation 	Elevate on continuous foundation walls or open foundation	
Frame, Masonry Veneer, or Masonry	Slab-on-Grade	Relocation 	Elevate on continuous foundation walls or open foundation	Highest
Frame, Masonry Veneer, or Masonry	Slab-on-Grade, Crawlspace, Basement, or Open Foundation	Demolition 	Demolish existing building and buy or build a home elsewhere	Varies

Source: FEMA, 2014, p. 3-38

Over the estimated lifetime of a private sector building (75 years for new builds and 50 years for retrofits) American research completed by Porter et al. (2019) calculates an overall 6:1 BCR for applying a combination of five (5) flood resilient retrofit approaches for single family homes with basements in the 100-year floodplain. The overall BCR was calculated by summing the BCR of a weighted combination of flood retrofit approaches based on best available data including 60% buyout, 20% home elevation,

10%, wet flood proofing basements, 5% air conditioning/ heat pump and ductwork elevation, and 5% furnace and water heater elevation.

Although the relative cost research (FEMA, 2014) demonstrated that some flood resilient home retrofits cost less than others, research by Porter et al. (2019) observed that high-cost options that receive post-flood recovery funding through private and government-funded insurance programs have a higher BCR than lower cost options that do not. For example, the most expensive retrofit options (1) buyouts (BCR 6:1) and 2) elevation (BCR 2:1) are commonly eligible for funding support through America's National Flood Insurance Program (NFIP), with public funds boosting their BCR. The remaining three lower cost options are not eligible for NFIP funding, limiting their BCR, including (1) wet flood proofing by installing flood vents and using flood resistant finishes (BCR 2.41:1), 2) elevating air conditioners or heat pumps and elevating duct work (BCR 2:1), and 3) relocating furnaces and water heaters from basements and crawlspaces to upper floors (BCR 1.5:1) (Porter et al., 2019).

Micro scale options appraisals from the United States demonstrate the critical value of site-specific comparative analysis to help residents identify the lowest possible cost for effective mitigation, thereby helping to drive action. They also commented on the significant influence that post-flood insurance recovery funding has on motivation to act. One researcher noted that using dry flood proofing methods for homes with slab on grade foundations was the preferred method at 35%–45% of homes studies in Venice Beach, California, representing a significant cost savings over wet flood proofing (elevation) methods that were the preferred method for the remaining 55-65% of homes (De Ruig et al., 2020). A Massachusetts micro-level study revealed a BCR far exceeding national-scale estimates with an average 32:1 BCR to repair homes to pre-impact condition (BCR boosted by NFIP funding), and 20:1 BCR for retrofitting (elevation) (BCR boosted by NFIP funding). They also calculated a relocation BCR of 0.10:1 (no NFIP funding), noting that relocation would not be desirable or financially viable without significant external financial incentives (Omiya, 2024). Both studies emphasized the critical importance of retrofit

cost and affordability as key factors that determined which, if any, preventative actions would be taken. They also noted that the availability of post-disaster recovery assistance encouraged people to wait for a flood to occur rather than self-fund flood resilient retrofits to avoid flood damages.

Singular Approach Research

Several studies were found that highlighted BCR, ROI, and relative cost calculations for singular approaches to flood resilient home retrofits including protect, accommodate, retreat, and avoid. Results varied based on the retrofit approach evaluated, the level of flood risk, and whether or not the retrofit option was eligible for insurance coverages. BCR estimates for dry flood proofing (protect) ranged 11:1 for flood resilient new home construction (Porter & Scawthorn, 2020) to 6:1 for flood resilient retrofits (Porter et al., 2019). Wet flood proofing (accommodate) BCR estimates ranged from 6:1 for 1' (30cm) elevation, to 5:1 for 5' (150cm) elevation (American Flood Coalition, 2022). BCR estimates for retreat ranged from 6:1 over 20 years (Porter et al., 2019) to 6:1 over 30 years (Nelson & Camp, 2020). Two studies proposed a methodology for estimating BCR associated with using land use planning initiatives to eliminate flood risk (avoid), but did not generate any BCR results (Mechler et al., 2014; De Risi et al., 2018).

Protect

Available grey and peer-reviewed literature that identifies BCR for using the protect approach to mitigate home flood risk is limited. For homes with basements, Canadian and American research that focuses on dry flood proofing for extreme rainfall (pluvial) flooding retrofits suggest this can be a very low-cost retrofit approach ($0-$5,000). It also suggests that because this is the most common type of flooding and that simple, low-cost preventative actions can easily be taken by owners and tenants alike, it is the most likely retrofit approach for residents to adopt (Evans & Feltmate, 2018; Porter et al., 2023). A Canadian study calculates an overall 11:1 BCR for adopting best practices for flood resilient new home construction (dry flood proofing) outlined in Canada's National Guidelines for the Flood Resilience of

Buildings (Z800-19) (Porter & Scawthorn, 2020). This guidance identifies flood resilient best practices for single family homes, duplexes and townhomes. It identifies detailed dry flood proofing methods and also recommends that all buildings have their lowest entrance at least at the level of the 100-year floodplain with no freeboard (one foot below the recommended minimum elevation required under ASCE/SEI 24-14, Flood Resistant Design and Construction (American Society of Civil Engineers 2014)). It is also important to note that the best practices in this guideline are not applicable for strengthening riverine and coastal home flood resilience and may not be applicable to rural, remote, and/or Indigenous communities.

One Canadian report identified the return on investment associated with the construction of the Manitoba Red River Floodway as exceeding 400% but provides no details about how this figure was calculated (Kovacs & Sandink, 2013). A dry flood proofing case study, published in 2023, features the flood resilient retrofit of a 100-year-old apartment building in New York's lower east side (Schoeman, 2023). The researcher notes that the BCR of 6:1 for flood resilient building retrofits estimated in Natural Hazard Mitigation Saves (Porter et al., 2019) was cited to make the business case to property managers to approve the project. The retrofit included relocating all of the building's mechanical and electrical systems out of the basement and above the 100-year floodplain with 1' of freeboard. The retrofit took 3 years to complete and cost $599,000 USD. Although a BCR is not specifically calculated the author estimates that the building managers could save hundreds of thousands of dollars from losses avoided over the next 30 years based on flood forecast modelling. The discussion section of the report emphasizes the critical importance of including comprehensive social and financial benefits when calculating BCR to strengthen the value proposition for protecting affordable rental housing units. They point to total expected benefits including reduced flood risks, improved housing continuity for residents, improved business continuity for building managers, and the potential for reduced insurance premiums for building owners and tenants. They also advocate for community-scale dry proofing in concert with

building scale retrofits stating, “given the dependency on infrastructure systems like public transportation, utilities and a network of sewage and storm-water pipes, implementing a localized building intervention is only as strong as the community-wide infrastructure” (Schoeman, 2023, page 128). One Canadian report echoes Schoeman’s calls for taking an integrated community and building scale approach to mitigating home flood risk by assessing private and public side contributions to infiltration and inflow. Case studies from Hamilton, Metro Vancouver, York Region and Columbus Ohio illustrate the complexities associated with generating lot level BCR associated with completing dry floodproofing retrofits (Sandink, 2015). Another Canadian study completed in 2021 examines the complex interrelationships between public and private side causes of basement flooding. It also emphasizes that building owners, tenants, and landlords experience different social and economic impacts from flood events and therefore face unique barriers and enablers to adopting flood resilient retrofits. This research highlights the critical importance of basement apartment flood risk reduction to protect socio-economically vulnerable residents (Sandink and Binns, 2021).

Accommodate

The most commonly studied approach to flood resilient home retrofits is accommodate. The majority of studies focus on wet flood proofing retrofits in New Orleans following Hurricane Katrina (2005) and Hurricane Isaac (2012). These studies consider avoided losses based on actual flood damages and modeled avoided losses over the course of the building’s life, estimated at 75 years. A 2022 study penned by the American Flood Coalition calculated a 6:1 BCR for elevating buildings located adjacent to rivers by 1’ above the 100-year floodplain and a BCR of 5:1 for elevating buildings 5’. Over a 7-year period losses avoided equalled $79,000 per structure, representing a 74% return on investment based on the cost of previous repairs. A loss avoidance study of three communities in New Orleans whose homes were elevated 1’ above the 100-year floodplain following Hurricane Katrina had a return on investment ranging from 68% to 179% in St. Tammany and Jefferson Parish respectively. The study also

mentions community co-benefits associated with home elevation including increased property values, stronger community tax base and improved economic stability. The research posits that projected increases in the frequency and severity of flooding events associated with hurricanes in New Orleans will increase the return on investment associated with home elevation (Bourdeau, 2015). Another New Orleans ROI study featuring homes in Jefferson Parish compared options for elevation, reconstruction and acquisition (relocation) using avoided losses and simulated losses based on probabilistic events over the lifetime of the homes. Using the avoided loss method reconstruction was the preferred option whereas with the probabilistic model elevation was preferred (Bilandi, 2018).

A 2022 study introduces a life-cycle benefit-cost analysis (LCBCA) approach for optimizing freeboard height for a new, single-family residences. It concludes that adding two feet of freeboard at time of construction at a cost of $10,403, or 4.5% of the base flood elevation cost, yields a BCR>1 for the homeowner, the community and the National Flood Insurance Program (Gnan et al, 2022).

Retreat

Very few studies document the BCR associated with removing homes from the 100-year floodplain. Natural Hazard Mitigation Saves estimates a US nation-wide BCR of 6:1 over 20 years associated with removing homes from the floodplain and permanently converting private lands into public open space (Porter et al., 2019). A micro-scale case study that quantified the benefits a home buyout in Nashville-Davidson County, Tennessee also calculated a 6:1 BCR over 30 years (Nelson & Camp, 2020). Thistlethwaite et al. (2023) published a report that provides case studies of property buyout programs in Gatineau, Quebec, High River, Alberta, and Grand Forks, British Columbia. No specific BCR calculations are provided however the authors state that an initial benefit cost analysis was conducted for Grand Forks, BC by project consultant NOR-EX Engineering LTD. (2019) and that the calculated BCR exceeded the minimum 3.4:1 BCR required to qualify for assistance through the Disaster Mitigation and Adaptation Fund (DMAF). Studies that calculate BCR for retreat options are likely to increase in Canada

in the coming years as the federal government works to update its Disaster Financial Assistance (DFA) requirements and rollout out the proposed National Flood Insurance Program (IBC, 2024).

Avoid

Studies that quantify the BCR of community planning measures to avoid flood risk do not exist for the Canadian context and are the rarest of all PARA studies internationally. Two studies present methodologies that may be considered for adaptation to the Canadian context. A case study example from Dar es Salaam, Tanzania, which faces annual river floods, utilizes an innovative methodology for examining Life Cycle Cost (LCC) and Return on Investment (ROI) as potential decision variables for evaluating the economic performance (ROI) and financial feasibility (LCC) of a suite of flood mitigation strategies over time. The key results of the study indicate that the highest-performing flood mitigation options combine both conventional interventions such a community-scale mitigation measures (dams and levees), household scale mitigation measures and ecosystem rehabilitation. This research methodology could be adapted for use in Canada to support the integrated consideration of community-scale and lot-level PARA structural flood mitigation measures alongside nature-based solutions to mitigate flood risk (De Risi et al., 2018).

An American study by Mechler et al. (2014) compares a variety of options including cost-benefit analysis, cost-effectiveness analysis, and multi-criteria analysis to support flood risk management decision-making at the community scale. Both of these research papers could be examined by Canadian researchers to determine if any of the studied forms analyses (Life Cycle Cost, ROI, financial feasibility, cost-benefit analysis, cost-effectiveness analysis, multi-criteria analysis) could serve as effective community-scale flood resilient decision-support tools for this country's planners and legislators.

Very few studies are currently available that examine the BCR, ROI, and relative costs of singular flood resilient retrofit options (protect, accommodate, retreat, avoid). The majority of Canadian studies have generated their findings based on adapting American research for the Canadian context. Although

there are some studies that identify BCR for owners of single-family homes, there are very few studies that articulate BCR for tenants, building owners/ managers for rental properties including basement apartments and multi-unit residential buildings. No singular PARA Canadians studies have been completed that calculate BCR, ROI or relative costs for flood resilient retrofits in remote, rural and/ or Indigenous communities.

Barriers and Enablers to Resilient Home Retrofits

This section discusses barriers and enablers to the adoption of flood resilient home retrofits identified in grey and peer-reviewed literature. It also provides examples of analogous research that provides additional insights into how to unlock private investment in flood resilient home retrofits.

Available research that examines barriers and enablers to resilient home retrofits identifies the critical role that business and governments have to play in influencing the resilient retrofit decisions made by building owners, tenants, landlords. Roadmap to Resilience Incentivization (Porter & Yuan, 2020), an American white paper, summarizes the key findings of consultations with the key stakeholders in the real estate value chain. These include building science experts, lenders, insurers, developers, property owners, real estate agents, property appraisers, and members of the public. The paper states that a key barrier to property owners investing in resilient home retrofits is that they only see a small part of the benefit from their investment. Property owners bear the cost of improving resilience while others (taxing authorities, lenders, insurers) enjoy free co-benefits including improved business continuity, income and profitability.

They point to two main options for strengthening new and existing home resilience including integrating flood resilience mandates into building codes and increasing financial incentives to property owners with funding and promotional support of governments, insurers and lenders. They explain that the key barrier to updating building codes is that they focus on life safety, not society's long-term

benefits. Building codes also prioritize affordability over efficiency and resilience. The researchers explain how incentivization can shift the BCR for flood resilient new construction that exceeds building code requirements. Table 2 below illustrates that when developers, owners, lenders, tenants and the communities share the costs associated with flood resilient construction the BCR can shift for developers, lenders, and community (who currently share no costs) from 0 to a BCR of 4.7. They also note that the BCR can shift from 2.5 for owners and 5.4 for tenants without incentivization to a BCR of 4.7 for both parties if costs are shared. It is interesting, and perhaps an important caution, to note that the BCR for tenants is reduced when resilient retrofit costs are passed onto them through higher rents (Porter & Yuan, 2020).

Table 2: Case study: resilience incentivizes flood-resilient construction

Case study: resilience incentivizes flood-resilient construction

Stakeholder	Cost			Benefit	Benefit-cost ratio	
	No incentive	Transfer	With incentive	Benefit	No incentive	With incentive
Developer	$-	$90	$90	$420	∞	4.7
Owner	$4,500	($2,100)	$2,400	$11,000	2.5	4.7
Lender	$-	$290	$290	$1,300	∞	4.7
Tenant	$4,500	$670	$5,100	$24,000	5.4	4.7
Community	$-	$1,000	$1,000	$4,700	∞	4.7
Total	$9,000	$-	$9,000	$42,000	4.7	4.7

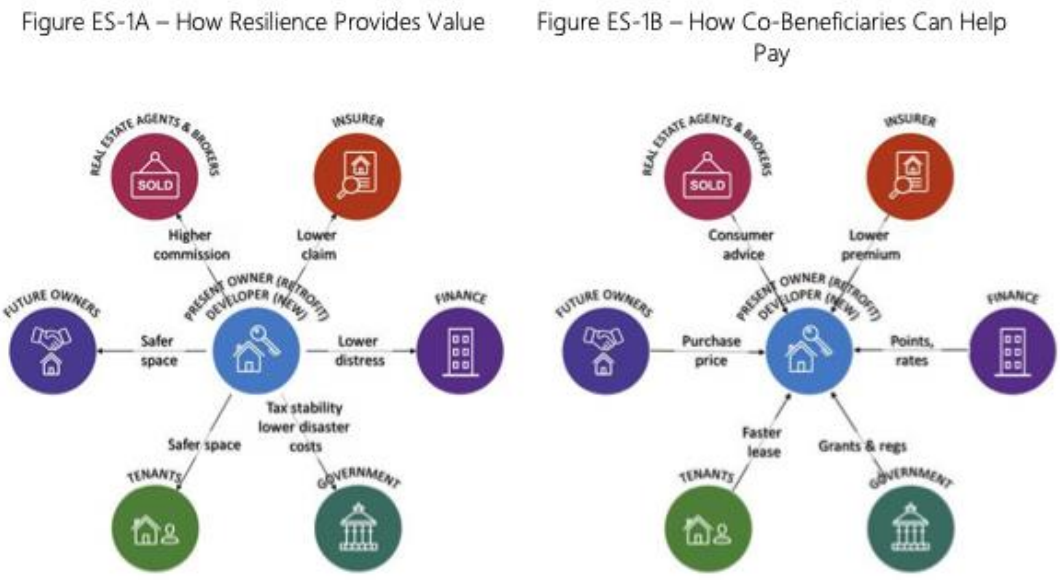
Source: Porter and Yuan, 2020, p. 6

The report recommends the completion of BCR calculations for all parties in the value chain to help them build the business case within their own organization to incentivize flood resilience. ROI guidelines for engineers, lenders, insurers, tax and governments will help to establish the financial justification for risk adjustments to insurance premiums and mortgages as well as government-issued financial incentives and low interest loans. This information will also help realtors to clearly articulate the flood resilience benefits to prospective buyers (potential insurance reductions, higher coverage

limits, mortgage discounts, enhanced financial stability, reduced loss and/or disruption of use property) and sellers (potential quicker home sales and higher resale prices).

A follow-up to the initial white paper was published in 2023 that identifies a) what drives the decisions of all key actors in the real estate value chain, and b) how to create incentive programs that demonstrate an improved BCR for each party (Porter et al., 2023). Please see Figure 1 below.

Figure 1: How Resilience Provides Value and How Co-Beneficiaries Can Help Pay



Source: Porter et al., 2023, p. v

The report identifies a roadmap to bolster home flood resilience. Highlights include the creation of a home flood resilience certification program and the completion of several community-based pilot studies. Although the study focuses on pluvial flooding, the authors note that the same concepts can be applied to drive flood resilient home retrofits in locations exposed to riverine and coastal flooding.

Several researchers indicate that flood resilient homes protect property values and should be highlighted to motivate flood resilient retrofits. A first of its kind Canadian study quantified the real estate impacts of catastrophic flooding in five Canadian cities within 6 months of experiencing one or two catastrophic floods (triggering a minimum of $25 million in home insurance claims per event). The study quantifies the negative impacts of home flooding on real estate transactions. Flood impacts were evaluated in Grand Forks (British Columbia, 2018), Burlington (Ontario, 2014), Toronto (Ontario, 2019), Ottawa (Ontario, 2019 and 2017) and Gatineau (Quebec, 2017). The study compared the real estate impacts on flood-impacted versus comparable non-impacted homes in the community. On average the

research quantified an 8.2% reduction in sale price, a 19.8% increase of days on the market, and a 44.3% reduction of number of homes on the market (Bakos et al., 2022). In addition to providing protection from post-flood home value depreciation, the U.S. Government Accountability Office (2015) notes that in one community, homes with greater flood resilience, built with 3' (90cm) freeboard above the 100-year floodplain sold faster than those built to lower elevation levels (Porter et al., 2023).

A number of additional Canadian reports point to opportunities to build collaborative efforts between all parties in the real estate value chain to drive uptake of flood resilient retrofits. To address the resident knowledge gap about flood risks they emphasize the importance of plain language, publicly available, community-scale flood risk maps. To raise awareness about tailored opportunities to reduce risks, they emphasize the importance of creating educational partnerships with lenders, realtors, insurance brokers, non-governmental organizations, and governments. Key information that they emphasize sharing to motivate adoption of flood resilient retrofits before a flood occurs include available municipal/ provincial/ territorial grants, incentives and low interest loans available to reduce upfront costs. They also suggest highlighting the BCR of specific flood resilient retrofits and promoting available insurance and mortgage discounts that reward home flood resilience. Finally, they stress the importance of all parties sharing consistent information that is practical, affordable, and relevant to individuals based on their property ownership status (owner, renter, landlord) (Giannitsos, 2023; Krueger, 2022; Minano & Peddle). Two analogous American studies identified barriers and enablers for increasing adoption of hurricane resilient and energy efficient retrofits for multi-unit residential buildings (Powell et al., 2022; Calder, 2020). These studies highlight the importance of articulating the benefits of resilient retrofits in ways that appeal most to the particular audience. For example, both owners and tenants are interested in plain language information about reduced insurance premiums, improved housing/ business stability, and lower operational costs. Business owners/ managers and their

lenders are most interested in understanding the BCR, ROI and estimated rate of return of specific retrofits over 20 years to build the business case for their boards and investors.

Canadian property owners can currently compare their flood resilient home retrofit options through the newly launched Climate Resilient Retrofits website and access self-help resources to take action (Partners for Action, 2025). This website's plain language, searchable multi-hazard database and self-help toolkit support data-driven, multi-hazard and energy-efficient decision-making to help people make the most of their retrofit investments by achieving multiple benefits and avoiding maladaptation (fixing one problem while creating another).

An analogous Canadian study calculated the BCR associated with following national best practice guidance to retrofit existing homes and to build new homes at high, medium, and low levels of exposure to wildfire hazards (Porter et al., 2021). See table 3 below for more information. This research indicates that the best BCR is associated with building new wildfire resilient homes (34:1) in high hazard zones as opposed to retrofitting existing ones (14:1) and that the highest BCR is associated with high hazard locations, second best is associated with moderate hazard locations, and the lowest BCR is associated with low hazard locations. The research also notes the highest BCR is associated with vegetation control (a low-cost maintenance activity) and that climate change is projected to increase Canadian wildfire hazard exposures over time, thereby increasing the BCR. This research is clear, concise, and very easy for all audiences to understand. Many of these same principles apply to the BCR related to strengthening home flood resilience and warrant research using a similar methodology.

Table 3: Homeowner costs, benefits, and benefit-cost ratios

Table ES-1. Homeowner costs, benefits, and benefit-cost ratios

	High hazard	Moderate hazard	Low hazard
Existing house			
Benefit	$286,000	$41,000	$2,000
Cost: non-combustible construction	$21,000	$21,000	$28,000
Cost: vegetation control	$9,000	$9,000	$8,000
BCR: non-combustible construction	14	2	0.1
BCR: vegetation control	32	5	0.2
New house			
Benefit	$370,000	$53,000	$5,000
Cost: non-combustible construction	$11,000	$11,000	$1,000
Cost: vegetation control	$4,000	$4,000	$4,000
BCR: non-combustible construction	34	5	5
BCR: vegetation control	93	13	1

Source: Porter et al, 2021, p iii

Research Gap Analysis

Arguably, the most comprehensive flood resilient retrofit research for Canada is Estimating the benefits of Climate Resilient Buildings and Core Public Infrastructure (CRBCPI) (Porter & Scawthorn, 2020). This document uses the benefit transfer method to estimate a CBR of 11:1 for adopting NRC National Guidelines for Flood Resilient Buildings (2019). Although this guideline identifies comprehensive best practises for home dry flood proofing in urban environments, it only mentions high level best practice considerations for riverine flooding and does not discuss coastal home flood mitigation. The guideline also specifies that its best practices may not be relevant to rural, remote and Indigenous communities. Therefore, additional Canadian best practice guidance development is required to address these gaps.

The majority of available research focuses on single family homes and the BCR, ROI, and relative costs to support flood resilient retrofit decision-making by the homeowner. Research gaps exist to support flood resilient retrofit decision-making for tenants and landlords of rental units including basement apartments, rental detached, semi-detached, townhomes and multi-unit residential buildings

of all sizes. BCR, ROI, and relative cost analyses are also needed for all other parties in the real estate value chain for all building types to help them make the business case for incentivizing flood resilient retrofits before flooding occurs.

Research gaps also exist with multi-hazard BCR, ROI, and relative cost calculations. Additional research is needed to help property owners and managers select retrofit options that achieve co-benefits including multi-hazard resilience and improved energy efficiency, and avoid maladaptation (decreasing resilience to other hazards and/ or decreasing energy efficiency).

A critical research gap exists in identifying the BCR, ROI, and relative costs for specific home retrofits by approach, by hazard, and property types. Without a detailed understanding of the risk reduction impact associated with making specific flood resilient retrofits (e.g., installing a backwater valve in a home at high risk of pluvial flooding versus low risk of pluvial flooding) it is very difficult for insurance companies, banks, and local governments to justify providing grants, incentives, discounts, and low interest loans to drive specific flood resilient retrofits. Without these interventions to reduce price, increase BCR, and improve ROI for the property owners and managers, the adoption of flood resilient home retrofits before flooding occurs will remain limited.

Conclusion

The bad news is that repairing damage from home flooding currently costs Canadians an average of $2.9 billion per year. Distribution of losses is particularly concentrated in homes exposed to the highest levels of flood hazard. For example, homes within the top 10% (approximately 1.5 million) experience 89.3% of all losses per year whereas the top 1% (approximately 109,000) experience 34.1%. Very few Canadians living in high-risk zones have invested in flood resilient retrofits, unnecessarily exposing residents, particularly vulnerable populations, to dire social and economic consequences.

Without implementing adequate voluntary and regulatory flood risk reduction measures experts project that annual costs associated with repairing home flood damages may triple by 2030.

The good news is that research indicates flood resilient retrofits yield an average BCR of 6:1 and a BCR of 11:1 or higher can be achieved by building flood resilient new homes. All participants in the real estate value chain (developers, builders, realtors, lenders, local governments) can work together to unlock private side investment in flood resilient retrofits and new builds by incentivizing and rewarding flood risk reduction. Support for flood resilient home retrofits in high-risk zones should be prioritized, particularly for homes that provide the country's most affordable housing units, including basement apartments, social housing, rental homes, and apartment buildings. Updating building codes and eliminating perverse legislation and policies that incentivize development in high-risk flood zones is also necessary to fortify the long-term flood resilience of Canada's housing stock.

Next Steps

Socially vulnerable populations are disproportionately affected by flooding including renters, women, people with low incomes, newcomers to Canada and those living in rural, remote and/ or Indigenous communities (Wright et al., 2022). The Canadians who would benefit most from having 1) access to plain language, user-friendly, tailored BCR, ROI, and relative cost information and 2) retrofit discounts, subsidies, and low to no-interest loans are also currently the most underrepresented in flood resilient research. To address these gaps and help drive the adoption of flood resilient retrofits for all Canadians before floods occur, the following short-, medium- and long-term options should be considered.

Short Term

- Promote and distribute existing user-friendly research and educational materials via all stakeholders in the real estate value chain

- Promote existing lot-level flood risk assessment programs to help residents identify their flood risks and practical opportunities to reduce risk
- Adapt existing research and outreach materials to be applicable to tenants and property managers, promote and distribute this material via all stakeholders in the real estate value chain
- Strengthen existing collaborations and build new connections between all stakeholders in the real estate value chain to strengthen coordination of efforts to strengthen home flood resilience

Medium Term

- Collaborate with subject matter experts, stakeholders and Rights Holders to develop national best practice guidance for pluvial, fluvial and coastal flood resilient detached, semi-detached, and townhomes across Canada including in rural, remote and Indigenous communities
- Complete BCR, ROI, and relative costs research for flood resilient retrofits following best practice guidance for pluvial, fluvial and coastal flood resilient detached, semi-detached, and townhomes across Canada including in rural, remote and Indigenous communities
- Complete comparative BCR, ROI, and relative cost research for all stakeholders in the real estate value chain to help make the business case for supporting flood resilient subsidies, discounts, grants, and low interest loans
- Expand flood resilient ROI research to include temporary flood barriers and nature-based solutions

Longer Term

- Integrate flood resilient best practices into the National Building Code and Provincial/ Territorial Policy Statements and community development guidelines
- Create a publicly accessible flood risk database that allows property owners to search for a subject property, understand its current and future flood risk under various climate change

scenarios, identify flood resilient retrofit options, and compare associated costs and BCR under different climate change scenarios to support data-driven decision-making.

By implementing short-, medium-, and long-term initiatives Canadians can work together to achieve a flood-resilient future.

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