Low on battery: residential energy retrofitting programs across continental climates in North America

By Assim Sayed Mohammed

Submitted to Nik Luka
School of Urban Planning
McGill University
Montréal, Québec, Canada

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Executive Summary / Résumé

Problem context: Governments need to determine how to best address energy shortages that will become commonplace over the next decade. Not only are fossil fuels being phased out to maintain commitments to climate-change policy, but the replacement baseline technologies are becoming increasingly expensive and politically unpopular, such as nuclear and hydroelectricity. This is especially important for rapidly-growing jurisdictions with continental climates, as annual energy needs are changing due to climate change, while demand increases with the added population. A strategy that has become commonplace to alleviate predicted energy shortages is to encourage energy retrofits in dwellings. In some cases, these projects are subsidized through government programs to incentivize energy efficient practices. This research project aims to understand how these programs differ in terms of governance, financing, strategies, scope of eligible retrofits, and outreach to residents. The programs studied include six jurisdictions with similar continental climates in Canada and the United States.

Methodology: This research project has two main goals. The first is to understand how retrofit programs are implemented and the barriers that exist for residents to participate in them. By conducting an academic literature review of journal articles, these methods and barriers are understood. The second goal is to explore how various jurisdictions in Canada and the United States implement retrofit programs in practice, and the gaps in implementation, financing, and accessibility that exist within them. This goal is achieved through a systematic review of grey literature including policy documents, program reviews, and third-party studies of the residential retrofit programs in the selected jurisdictions.

Findings: The findings indicate that each jurisdiction takes on a "bespoke" approach to retrofit contracting, financing, and assessment. While the programs may fit some of the unique needs of their respective jurisdiction, the lack of coordination among jurisdictions highlights issues with scalability for mass retrofitting initiatives. Accessibility to the programs assessed is limited, as programs either apply only to single-family dwellings, or only to large apartment buildings, but not both, and they rarely are applicable to other housing typologies. Little consideration is given to tenant rights and to the potential impact of retrofits exacerbating housing affordability issues.

Recommendations: An in-depth analysis of how much participation is received for the programs studied, as well as the protections they offer for tenants can help provide the framework for a more successful retrofit program that can be translated across jurisdictions. Furthermore, additional research needs to be conducted in jurisdictions internationally to understand how financing for retrofit programs can be made more equitable and barrier-free. In particular, the development of a retrofit strategy that can be applied broadly to a variety of building types, reduces the high up-front costs for property owners, and prevents the displacement of tenants should be the focus of future energy retrofit program studies.

Contexte du problème : Les gouvernements doivent déterminer la meilleure façon de remédier aux pénuries d'énergie qui deviendront monnaie courante au cours de la prochaine décennie. Non seulement les combustibles fossiles sont progressivement éliminés pour maintenir les engagements politiques en matière de changement climatique, mais les technologies alternatives de base deviennent de plus en plus chères et politiquement impopulaires, telles que le nucléaire et l'hydroélectricité. Ceci est particulièrement important pour les juridictions à croissance rapide avec des climats continentaux, car les besoins énergétiques annuels changent en raison du changement climatique, tandis que la demande augmente avec la population supplémentaire. Une stratégie devenue courante pour atténuer les pénuries d'énergie anticipées consiste à encourager les rénovations énergétiques dans les maisons. Dans certains cas, ces projets sont subventionnés par des programmes gouvernementaux pour encourager les pratiques éconergétiques. Ce projet de recherche vise à comprendre comment ces programmes diffèrent en termes de gouvernance, de financement, de stratégies, de portée des rénovations éligibles et de sensibilisation des résidents. Les programmes étudiés incluent six juridictions avec des climats continentaux similaires au Canada et aux États-Unis.

Méthodologie : Ce projet de recherche a deux objectifs principaux. Le premier est de comprendre comment les programmes de rénovation sont mis en œuvre et les obstacles qui empêchent les résidents d'y participer. En procédant à une revue de la littérature académique des articles de revues, ces méthodes et obstacles sont compris. Le deuxième objectif est d'explorer comment diverses juridictions au Canada et aux États-Unis mettent en œuvre des programmes de modernisation dans la pratique, et les lacunes de mise en œuvre, de financement et d'accessibilité

qui existent en leur sein. Cet objectif est atteint grâce à une revue systématique de la littérature grise, y compris des documents de politique, des revues de programmes et des études de tiers sur les programmes de rénovation domiciliaire dans des juridictions sélectionnées.

Constatations : Les constatations indiquent que chaque administration adopte une approche personnalisée pour la passation de marchés, le financement et l'évaluation des rénovations. Bien que les programmes puissent répondre à certains des besoins uniques de leur juridiction respective, le manque de coordination entre les juridictions met en évidence les problèmes d'évolutivité des initiatives de rénovation de masse. L'accessibilité à l'ensemble des programmes évalués est limitée, car les programmes ne concernent que les maisons unifamiliales ou uniquement les grands immeubles d'appartements, mais pas les deux, avec peu d'applicabilité pour d'autres typologies résidentielles. De plus, on peut constater une manque d'attention accordée aux droits des locataires et aux impacts potentiels des rénovations sur l'aggravation des problèmes d'abordabilité des logements.

Recommandations : Une analyse approfondie du degré de participation reçue pour les programmes étudiés – ainsi que les protections que l'on offre aux locataires – peut aider à bâtir des programmes de rénovation plus efficaces qui l'on peut étendre à toutes les juridictions. De plus, des recherches supplémentaires doivent être menées dans les juridictions internationales pour comprendre comment le financement des programmes de rénovation peut être rendu plus équitable et sans obstacle. En particulier, l'élaboration d'une stratégie de rénovation qui peut être appliquée sans distinction à une variété de types de bâtiments, réduit les coûts initiaux élevés pour les propriétaires et empêche le déplacement des locataires devrait être au centre des études pour les futurs programmes de rénovation.

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Chapter One: Introduction

Preface

This project is being conducted in collaboration with ReCONstruct, with support from the Natural Sciences and Engineering Research Council of Canada (NSERC). ReCONstruct is a multidisciplinary project that is focused on exploring retrofit solutions including prefabricated building envelopes, building stock modelling, retrofit policy scalability, and public engagement. The project is led primarily by faculty members at McGill University's Peter Guo-hua Fu School of Architecture, with partners at Carleton University, the University of Toronto, Hydro-Québec, Natural Resources Canada (NRCan), and the Ministère de l'Énergie et des Ressources Naturelles (MERN), amongst others.

Context

The residential sector is among the largest consumers of energy globally. Temperature regulation in buildings alone makes up 40% of global energy consumption (Pedinotti-Castelle et al., 2019; Friedman, Becker, and Erell, 2018). The older a building is, the more energy it consumes due to insulation degradation and electrical inefficiencies (Friedman et al., 2018). This, combined with a changing climate, means cities in continental climate regions are faced with growing energy efficiency concerns (Pedinotti-Castelle et al., 2019; Friedman et al., 2018). Across North American urban centres, there is significant variation in average age and typology of the housing stock. Furthermore, while some jurisdictions have high proportions of renewable energy, others still rely heavily on fossil fuels. Thus, there are variations in the energy goals of these jurisdictions, where some are more concerned about energy shortages and efficiencies, while others are focused on reducing their carbon footprint and emissions. Regardless, how these jurisdictions manage energy demand today and for the future can provide insight into how governments can learn from policies developed internationally.

A promising strategy for improved energy efficiency is to undertake residential energy retrofitting (Kikuchi, Bristow, and Kennedy, 2009). This involves the updating or replacing of energy-using systems in a building to make them more efficient (Kikuchi, 2009; Gram-Hanssen, Jensen, and Friis, 2018). Various jurisdictions from around the world have created policies to make retrofitting a climate-action goal, providing incentives to households and property owners

to make their dwellings more energy efficient (Gram-Hanssen et al., 2018). Energy retrofits come in many forms, encompassing any work done on any system in a building that makes energy usage lower for the same outcome, such as maintaining an internal temperature of 21°C. In the case of residential buildings, this can be in the form of improving insulation, adding green infrastructure, implementing photovoltaics, making the building envelope more airtight, adding smart thermostats, converting to electrical heating and cooking, and sealing windows and doors, among many other possibilities. Despite the flexibility and benefits of retrofitting, a study from Israel found that while the benefits of energy efficiency are known to be high, there is little willingness to undertake retrofit projects, even government-sponsored programs exist (Freidman et al., 2018). This is due to numerous reasons, ranging from finances to lack of awareness of programs (Friedman et al., 2018). Additionally, discrepancies in the ownership structures of different residential typologies makes the establishment of an all-encompassing retrofit program challenging. For example, the logistics of offering the same level of support for single-family dwellings that are owner-occupied, and condominium complexes with a mix of owner-occupied and leased units are extremely complex. Thus, the ability of many residents to apply to available retrofit programs is limited.

This Supervised Research Project explores how state-funded retrofit programs across jurisdictions with continental climates in Canada and the United States compare. Such programs focus predominantly on small owner-occupied dwellings, such as single-family dwellings and rowhouses. In part, this is because detached dwellings comprise the majority of dwelling types in Canada and the United States, at 53.6% and 67% respectively (Statistics Canada, 2019; Neal, Goodman, and Young, 2020). It nevertheless is also a symptom of how complicated it can be to implement deep-energy retrofit on building systems defined by mixed forms of ownership, access, and use. Exceptions to this are Quebec's Rénoclimat program and New York City's PACE initiative, the latter of which only applies to large residential, commercial, and institutional buildings.

The intent of this research is two-fold. The first goal is to understand how retrofit programs are implemented and the barriers that exist for residents to participate in them. By conducting an academic literature review of journal articles, these methods and barriers are understood. The second goal is to explore how various jurisdictions in Canada and the United States implement

retrofit programs in practice, and the gaps in implementation, financing, and accessibility that exist within them. The recommendations explore how these programs can be improved to better fit the needs of residents and environmental goals. Specifically, by laying out the six barriers to participation described by Freidman et al. (2018), the gaps in these programs are better understood.

It is imperative that governments develop tools to incentivize residential energy retrofitting. By making dwellings more efficient and resilient in terms of energy usage as well as ecosystem impacts, the long-term costs for households will be reduced, with the added benefits of improvements in the residential sector's energy footprint, and the betterment of energy security for future generations.

Barriers to Retrofitting and Retrofit Complications

Energy retrofitting is a key form of climate adaptation that has positive outcomes for both human health and global climate efforts (Klemm, Lenzholzer, and van den Brink, 2017). However, despite the extensive assistance for owner-occupiers to undertake retrofitting projects in their dwellings, there is often low participation in these programs. According to Friedman et al. (2018), there are six broad reasons for this. The first reason is a lack of awareness of the benefits of retrofitting the dwelling. Residents may not be able to pinpoint or understand where energy efficiencies in their dwelling are coming from, or may not realize their bills can be lowered without sacrificing comfort. The second reason is because of finances, particularly the long payback period of retrofits. The upfront costs, even with subsidies, may be too high for residents, and thus continuing to pay higher bills over a longer period seems more palatable. This is the same logic that applies to long-term payment schemes with small down payments, where monthly installments are more accessible than purchasing items or services upfront. The third barrier is the difficulty in applying a cost on non-energy benefits. These benefits, which can be thought of as positive externalities within the dwelling, include comfort, cleanliness, and environmental stewardship. Financially strained residents may not view these benefits as providing enough return on their investment. The fourth cause of low participation are organizational barriers, in which there may be multiple people involved in the decision-making concerning a dwelling. This can happen if the residents are not owner-occupiers, or if the owned property is a large apartment building or complex, which is a common occurrence in many large

cities. The fifth barrier consists of social and behavioural factors. Households may make other decisions to save on energy costs that appear more feasible in the short term, or may not understand that retrofitting can contribute to energy savings. Lastly, the sixth reason for low participation in retrofitting programs is technical barriers. While new builds take energy efficiency into account from the beginning, existing buildings are for more difficult to change, especially if there are historically significant or supporting structures that cannot be altered.

In cases where retrofit work is undertaken, there can be unintended consequences, particularly tenant displacement. Due to the nature of retrofit work, typically only owners of the dwelling have the power to embark on major energy retrofits. Thus a tenant-occupied dwelling may need to be vacated in order for the work to be completed. Additionally, to recover the investment, the owner may then choose to increase the dwelling's rent, effectively discouraging low-income households from occupying the dwelling. In effect, this phenomenon has come to be known as low-carbon or green gentrification, whereby neighbourhoods are made more affluent by either inadvertently or in some cases intentionally displacing low-income populations by means of green infrastructure (Bouzarovski, Frankowski, and Tirado Herrero, 2018; Bissonnette, et al., 2018). Targeted urban regeneration, which is the focus of several mass residential energy retrofitting programs, has resulted in low-carbon gentrification in Gdansk, Poland (Bouzarovski et al., 2018). The phenomenon is becoming increasingly common as governments provide subsidies for the implementation of green infrastructure, potentially providing incentives for the displacement of low-income communities through climate action (Bouzarovski et al., 2018). Thus retrofit programs must consider not only the climate benefits of energy efficiency measures, but how to apply mass retrofitting equitably and through the involvement of tenants and low-income residents.

Methodology

The jurisdictions were selected on the basis of population limits, GDP per capita, and climate type. The population of the jurisdiction must be higher than 5,000,000 persons, and less than 25,000,000 persons. The GDP per capita must be higher than 35,000 USD, and the climate of the jurisdiction must be in the Group D (Continental) range of climates according to the Koppen climate classification system. Based on these constraints, the six jurisdictions selected are British Columbia, Ontario, and Quebec in Canada, and Michigan, New York, and Washington in the

United States. Although other jurisdictions exist within both countries that fall under or close to the constraints highlighted above, the provinces and states selected share commonalties with each other through culture in addition to climate and economics. There are arguably greater cultural ties between Washington and British Columbia than with other states and provinces within their own respective countries. Furthermore, New York and Ontario occupy similar political and economic niches within their own countries, while Michigan and Ontario share similar cultures as they are both former auto-industrial economies within the broader Great Lakes region. Finally, Quebec is being included as a unique player in the North American context, with a unique housing stock, legal system, and culture that can help frame discrepancies in policy development. However, despite many cultural and geographic similarities between Canada and the United States, the two countries still have significant differences in governance, politics, legal systems, cultural values, and demographics. These differences have shaped the two countries' cities, including the organization of housing and the relationships between private dwelling owners and their local governments (Goldberg and Mercer, 1986). Furthermore, the delegation of powers in the two countries are not equal, such that states and provinces take on different governance roles, and thus may not have the legal ability to undertake identical programs (Goldberg and Mercer, 1986). Table 1 defines these jurisdictions according to the constraints set for this project.

Table 1: selected jurisdictions for residential retrofit program review

Jurisdiction	**Population (Statistics Canada, 2022a; U.S. Department of Commerce, 2020)**	**GDP per capita (USD 2020) (Statistics Canada, 2022b; U.S. Department of Commerce, 2022)**	**Koppen climate zone(s)**
British Columbia	5,000,879	$46,108	BSk, Cfb, Csb, Dfb, Dfc, Dsb, Dsc, ET
Ontario	14,223,942	$45,434	Dfa, Dfb, Dfc
Quebec	8,501,833	$39,372	Dfb, Dfc, ET
Michigan	10,077,331	$52,820	Dfa, Dfb
New York	20,201,249	$88,420	Dfa, Dfb
Washington	7,705,281	$79,040	BSk, BWk, Cfb, Csa, Csb, Dfb, Dsa, Dsb

A systematic grey-literature review was selected as the method of choice to explore how the six selected jurisdictions implement retrofit programs in practice, and the gaps that exist within them. Grey-literature reviews are useful for harvesting information that is not academic in nature, including policy critiques and research that aims to inform policy development (Giustini, 2019). Since many government-sponsored programs are only accessible through websites with no hard documentation such as PDFs or other filetypes, a grey-literature review is the most logical option for identifying and reviewing retrofit programs. Setting the scope and constraints of the research are imperative prior to conducting a grey-literature review, particularly in the case of reviews conducted via search engines such as Google or Google Scholar (Mahood, Van Eerd, and Irvin, 2014). The vast availability of information and generalized algorithm of Google means that even complex searches yield potentially millions of results, adding noise to valuable data (Mahood et al., 2014). Thus using a more specific search syntax using obligatory key words and country code domains can narrow the results from the searches. Furthermore, understanding when to stop searching is important in preventing further noise being added to the data (Giustini, 2019).

The basic search syntax on Google is as follows: *"Jurisdiction Name" AND "residential" AND "retrofit" AND "energy" AND "efficient" site: country code domain*. An example for the search completed for Ontario would read as: *"Ontario" AND "residential" AND "retrofit" AND "energy" AND "efficient" site:ca*. The protocol for identifying relevant web pages was to explore the first page of results, and proceed to the second page regardless of whether page one yielded a relevant website. If page two yielded a relevant website, then it was protocol to advance to page three, and so on. If no relevant websites were found on page two, then the search was declared complete. The relevant website must be a government website of some sort, including those of government corporations. In cases where no relevant websites or state-funded retrofit programs were found on pages one and two, then the jurisdiction name was changed to the largest city within that jurisdiction. For example, in the case of Ontario where many policies are delegated to the municipal level, the jurisdiction name *"Toronto"* was also used, due to the absence of a provincial policy.

Upon finding a relevant website, a thorough scan of retrofit program's eligibility, financial aid, scope of retrofits, and application process was conducted. Eligibility includes information regarding restrictions on the types of dwellings that can apply for the program, such as detached, semi-detached, and apartments. Eligibility also includes the scope of work conducted in some cases, such that excessive damage to the dwelling can disqualify the building from receiving funding for retrofit work. Finally, owner-occupation and applicant information is an important consideration for determining if a dwelling is eligible to receive funding. Financial aid information includes the maximum receivable amount of money from the government that can be used for retrofit projects in the dwelling. The funding structure is also a critical piece of this section, such as understanding how loan repayments are made, if necessary. The scope of retrofits describes the types of projects that an applicant can request funding for under the program guidelines. Finally, the application process section explores the necessary information and paperwork that an applicant needs to provide in order to receive approval for funding. This process also explores to whom that information must be provided, and the long-term conditions of receiving funding.

Chapter Two: Program Review

The preceding chapter illustrated the need for retrofit work in the existing building stock as a climate change adaptation measure, while acknowledging the barriers and consequences of retrofit programs when not implemented carefully. This chapter summarizes the results of the systematic grey-literature review outlined in the methodology sub-section of Chapter One, highlighting the details of the financing strategies and application processes of each of the six jurisdictions selected.

The six jurisdictions assessed in this project all have unique governing strategies and thus different methods of incentivising retrofits for residents. Financial aid for retrofits between the programs varies widely, with some offering less than $15,000 as a maximum, while others reach the hundreds of thousands. The type of financial aid also varies, with programs offering loans, grants, or rebates to incentivize retrofits. Table 2 organizes the retrofit programs and their basic financial information for each of the six jurisdictions studied.

Table 2: Summary of selected jurisdictions' retrofit programs

Jurisdiction	**Program Name**	**Maximum Financial Aid**	**Aid Type**
British Columbia	CleanBC Better Homes	Variable for different projects: ~$16,300	Rebate
Ontario	Various Municipal (e.g. Home Energy Loan Program in Toronto)	$125,000	Property Tax Loan
Quebec	Rénoclimat	Variable for different projects: ~$12,000	Rebate
Michigan	Michigan Saves	Variable depending on county: $1,000 - $100,000	Loan

New York	PACE: Property assessed clean energy – Local Law 96	Variable – negotiated with private lender based on project complexity	Property Tax Loan
Washington	Washington State Community Action Partnership & Seattle City Light	WSCAP - $500 Seattle City Light - none	Rebate

Canada

British Columbia, Ontario, and Quebec are the three largest provinces in Canada, each with their own unique energy mix, management strategies, and electricity problems. Due to the differences in production capacity, ownership, and energy mix, the costs of electricity vary widely between the three provinces. For example, 91% of British Columbia's and 97% of Quebec's energy is provided through renewable and non-emitting sources of electricity, notably hydroelectricity, while neighbouring Ontario gets majority of its power from nuclear plants (Canada Energy Regulator, 2022a; Canada Energy Regulator, 2022b; Canada Energy Regulator, 2022c). Furthermore, Quebec's entire grid is managed by a sole public agency, Hydro Quebec, while Ontario's grid system is split by production, distribution, and transmission, of which the latter is privately managed by Hydro One (Canada Energy Regulator, 2022b). Quebec has a large supply of electricity and thus exports much of its excess production to the United States and neighbouring provinces (Canada Energy Regulator, 2022c). Conversely, Ontario is in need of greater production, and is faced with soaring energy costs due to rapidly increasing demand and a complicated structure of ownership of the energy grid. The consequence of these provincial differences in production and supply is that retrofitting programs vary significantly between jurisdictions. This includes the political will to fund retrofitting programs, the scale of government which operates them, and the level of involvement from the private sector.

In May 2021, the Government of Canada introduced the Canada Greener Homes Grant (CGHG) in an effort to help residents and provincial governments relieve some of the energy burden currently inflicting their grids. The initiative provides owner-occupants with a grant of up to $600 for a pre-retrofit *EnerGuide* assessment of the dwelling, and up to $5,000 to carry-out

energy retrofit projects (Government of Canada, 2022). The different provinces in this analysis have devised unique ways to incorporate the CGHG in their existing retrofit programs.

British Columbia

British Columbia is a predominantly hydroelectric-dependent province. 91% of the province's 74.2TWh energy supply is hydroelectric, making it one of the cleanest energy grids in Canada in regards to climate change commitments (Canada Energy Regulator, 2022a). However, the British Columbia's dry summers mean that water shortages and advisories are common to maintain the province's reservoirs and a consistent supply of electricity. Furthermore, the province has few commitments to expand hydroelectric production, but demand for electricity is expected to increase by 40% by 2037 relative to 2017 levels (BC Hydro, 2017a). In order to meet this demand, and maintain British Columbia's energy independence, the province needs to significantly increase its electricity production, as well as make consumption more efficient. The province has committed to the construction of the Site C hydroelectric dam at the cost of $16 billion in order to meet some of this increasing demand (BC Hydro, 2017b). Expected to be completed in 2025, the project will provide an additional 5TWh of electricity annually (BC Hydro, 2017c). However, new supply is only expected to meet 22 – 34% of the province's energy needs in the 2030s (BC Hydro, 2017d, Government of British Columbia, 2014). As such, the province has established a long-term plan to make electricity consumption more efficient to reduce the burden on the existing grid. (Government of British Columbia, 2014). This is primarily because the high environmental, social, and financial cost of hydroelectric dams will make them nearly impossible to build in the future. Thus the province has no plans for new hydroelectric dams beyond Site C, and electricity production could rapidly fall behind demand over the next 20 years without robust retrofitting initiatives.

The CleanBC Better Homes program is a joint energy retrofit program managed by BC Hydro, FortisBC, and The Government of British Columbia. The program incentivises residents to make energy efficient improvements to their dwellings by providing rebates for various energy-related renovations. The renovations are broken down into five categories: heat pumps, natural gas furnaces and boilers, water heating, secondary space heating, and building envelope. Under these categories, there are a total of 16 eligible upgrades that qualify for government supported rebates

under the program. Table 3 summarizes the categories of eligible renovations, the specific upgrades under them, and the rebate value available for those works (CleanBC Better Homes, 2022a).

Table 3: Rebate value for eligible upgrades under the CleanBC Better Homes program

Category	Upgrade	Rebate
Heat pumps	Ductless mini-split heat pump	Up to $6,000
	Ductless multi-split heat pump	Up to $6,000
	Tier 1 central ducted heat pump	$1,200
	Tier 2 central ducted heat pump	Up to $6,000
	Dual fuel ducted heat pump	$3,000
	Air-to-water heat pump	$3,000
	Combined space and hot water heat pump	Up to $4,300
	Electrical service upgrade	$500
Natural gas furnaces and boilers	Natural gas furnace	Up to $1,000
	Natural gas boiler	$1,000
	Natural gas combination heating and hot water system	$1,500
Water heating	Natural gas water heater	Up to $1,000
	Electric heat pump water heater	$1,000
Secondary space heating	Natural gas fireplace	$300
Building envelope	Insulation	Up to $5,500
	Windows and doors	Up to $2,000

In order to be eligible for the CleanBC Better Homes program, the applicant must possess a residential utility account with FortisBC, BC Hydro, or a municipal utility. The dwelling must also be primarily heated with one of the following: natural gas or piped-propane supplied by FortisBC, natural gas supplied by Pacific Northern Gas, electricity supplied by FortisBC, BC Hydro, or a municipal utility, or oil or propane not supplied by FortisBC. Dwellings heated primarily by wood or other solid fuels are only eligible for the heat pump, natural gas fireplace,

hot water heater, and EnerGuide Home Evaluation rebates. If electricity is supplied by BC Hydro, there is a minimum consumption that must be met in order to qualify for a rebate. An eligibility tool is available for applicants to assess if their dwelling meets the minimum consumption requirements. The dwelling must also be a year-round residence that is at least 12 months old to quality. Finally, in order to be eligible for an EnerGuide Home Evaluation, the dwelling needs to be an eligible house type and have the appropriate insulation, heating, and energy supply to participate in the program (CleanBC Better Homes, 2022a).

There are two overarching criteria that need to be met for a dwelling to be eligible for an EnerGuide Home Evaluation. Firstly, the dwelling must be some sort of ground-level unit without separate vertical units above, thus excluding units in plexes or apartment buildings. Included in this criterion are single-family detached dwelling, semi-detached dwelling, row houses or townhouses, mobile dwellings on permanent foundations, and floating dwellings that are permanently moored. The second criterion is that dwellings must be in an 'eligible state', such that the dwelling must be on permanent foundations or permanently moored, a heating system must be in place that can achieve a room temperature of 21^{o}C, and the building envelope must be intact. The second criterion allows for up to one missing window or door unit if it is temporarily air sealed. Broken windowpanes must also be temporarily air-sealed for the duration of the blower door test. If the temporary seals fail the blower door test, the dwelling will be considered ineligible for the program. Any renovations taking place before work commences with CleanBC must not affect the building envelope. Finally, the dwelling must have a reliable alternating current (AC) electrical power supply available to operate the equipment for the blower door test. If an AC power supply is not available, the owner-occupier must contact the service organization to provide power to operate the equipment (CleanBC Better Homes, 2022b).

The application process for the CleanBC Better Homes program is laid out on the program website. The applicant needs to ensure they have read the program requirements and terms and conditions before applying. After doing so, the pre-work EnerGuide Home Evaluation can be conducted. The applicant is then free to outsource any of the works listed out in Table 3 to a registered contractor with a valid B.C. business license. After the upgrades are completed, the applicant must complete one or multiple application forms with a utility depending on the nature

of the upgrades, along with a post-work EnerGuide Home Evaluation. There are a number of deadlines that the applicant must meet in order to receive the rebates. For example, the application form for individual upgrades must be submitted within 6 months of the invoice date provided by the contractor. To receive the rebate for the EnerGuide Home Evaluation, as well as the Home Energy Improvement Bonus, the applicant must submit the application form for these services within 6 months of the post-work evaluation. Furthermore, the post-work evaluation must take place within 18 months of the pre-work evaluation. Thus there is an expectation that applicants undergoing retrofits eligible under the CleanBC Better Homes program are able to complete the upgrades within an 18 month timeframe (CleanBC Better Homes, 2022a).

Ontario

Ontario differs from the other two Canadian provinces in this study in that the province's energy supply is separated into five separate organizations. Of these organizations, three are directly involved with the grid system, including The Independent Electricity System Operator (IESO), Ontario Power Generation (OPG), and Hydro One. While the IESO and OPG are crown agencies, Hydro One is a publicly traded corporation. The province currently produces 151.1TWh of electricity annually, of which 60% is nuclear, 26% is hydroelectric, 7% is wind, and 3% is natural gas. (Canada Energy Regulator, 2022b). Most of this energy production is managed by the crown agency OPG. Despite this diverse range of production, Ontario is among the most at-risk provinces for energy strain in Canada. This is due to the cancellation of renewable energy projects that were lined up for construction, and the progressive closure of the Pickering Nuclear Plant (McCarthy, 2018), creating a gap in the province's future energy supply. In 2018, the IESO, the crown agency which manages most of Ontario's electricity distribution network, released a forecast that claimed Ontario would face energy shortages in the summer months beginning in 2023 (McCarthy, 2018). Combined with increasing demand through rapid population growth and expanding electrification of transportation, this shortage of energy production could see electricity prices further increase in coming years. Due to the shortages predicted, the Pickering nuclear plant's closure is now being postponed to 2025 (Ontario Power Generation, 2022).

Ontario currently has no provincewide energy retrofit program, and energy retrofitting policies are largely municipally managed. Municipal governments are granted the freedom to develop and implement their own unique policies to encourage residents to make their dwellings more energy efficient. There are numerous benefits and drawbacks to this governing structure. Notably, one benefit is that municipalities can leverage property tax payments to help residents make payments long-term, as well as allowing costs to be absorbed by the property itself. In addition, the mosaic of different policies makes knowledge transfer and unique solutions more likely to develop, allowing for more innovation in climate policy. A drawback however is that municipalities do not have the same financial strength as a province to provide grants for retrofit work, and are subject to approvals from the provincial government to do so. Furthermore, the mosaic of policies that can create unique solutions can also slow down the development of a cohesive and effective retrofit strategy that works across the province.

Ontario's largest city and capital, Toronto, has developed the Home Energy Loan Program (HELP). The program, as the name suggests, offers loans instead of grants at low interest rates for owner-occupiers to undertake various energy-related renovations to their dwellings (City of Toronto, 2022a). The program offers low-interest loans of up to $125,000 per household to undertake the following eligible works (City of Toronto, 2022a):

- High-efficiency furnaces, boilers, and air conditioners
- Air-source heat pumps
- Window and door replacements
- Basement, attic, and exterior wall insulation
- Air sealing (e.g. weather stripping or caulking)
- Geothermal systems
- High-efficiency water heaters
- Tankless water heaters
- Drain-water heat recovery systems
- Toilet replacements
- Solar hot water systems
- Rooftop solar PV panels
- Electric vehicle charging stations
- Battery storage

Starting in the year 2022, new applicants to HELP will be eligible for 0% interest on the loans for these works (City of Toronto, 2022a). There are several criteria that must be met by the household prior to applying for the program (City of Toronto, 2022a). These criteria include:

- The house must be a detached, semi-detached, or rowhouse property located within the bounds of the City of Toronto (i.e. postal code must begin with "M")
- All the property owners must provide their consent to participation
- Property tax and utility payments to the City of Toronto must be in good standing
- If the property is subject to a mortgage, then written consent from the mortgage lender must be provided.

Once an owner-occupier has confirmed that they meet the criteria above, they can begin the application process. The application process consists of five stages (City of Toronto, 2022a):

1. Complete the Application Form

   The application form, which is linked under the "Application Process" tab of the HELP webpage on the City of Toronto website, asks for simple information regarding the property and the nature of how payments are made for various bills. The form is divided into three groups of required information: A: Applicant Information, B: Property Information, and C: Mortgage Lender Information (City of Toronto, 2022b). Section A: Applicant Information asks for the applicant's name and contact details, relationship to the property (owner, tenant, manager, or other), and a list of up to three property owners. Section B: Property Information asks for details including the address and postal code, the first 15 digits of the Assessment Roll Number from the property's tax bill, the type of dwelling (detached, semi-detached, rowhouse, etc.), the number of units and rooms in the property, the primary mode of heat (gas, electricity, or oil), and who (owners, tenants, or a third party) is responsible for payments for water, electricity, and natural gas bills. Lastly, Section C: Mortgage Lender Information requires the applicant to note whether the property is subject to a mortgage, and if so, to list the financial institutions involved in the mortgage of the dwelling. After the three main sections, the applicant is asked to note how they learned about HELP in Section D, sign on Section E, and voluntarily provide information regarding disability status, senior status, and income information in Section F. Upon receiving approval, the City will send the applicant a funding offer stating the maximum eligible loan for the property.

2. Energy Assessment and Funding Request

   The second stage of the application process is itself divided into two sub-stages:

   a. *Book an energy assessment with an Energy Advisor registered by Natural Resources Canada*

      With the support of the CGHG, the applicant is required to book a basement-to-attic assessment with an Energy Advisor registered by Natural Resources Canada to examine the dwelling's insulation, heating and cooling systems, and to detect any air leaks or drafts. A link to eligible advisors and available rebates and retrofit incentives is provided on the webpage, in partnership with Enbridge Gas. Upon the completion of the assessment, the applicant will receive a Renovation Upgrade Report with recommendations for specific improvements, an EnerGuide rating based on the dwelling's current energy performance, and information on available incentives and rebates.

   b. *Submit your funding request*

      At this stage, the applicant is required to submit a funding request form. The form details a list of retrofits that the applicant intends to conduct on their dwelling based on recommendations from the Energy Advisor, cost estimations provided by a contractor for the retrofit works, and an estimate of rebate and incentive amounts the applicant is eligible for from utility companies (City of Toronto, 2022c).

3. Property Owner Agreement

   Upon receiving approval for the funding request, the City will provide the applicant with a Property Owner Agreement (POA). The agreement is a funding agreement between the owner and the City, which is required to be signed by the owner for the loan to be processed. After the POA is approved, the applicant can request to receive 30% of the loan from Stage 1 immediately.

4. Complete your improvements and submit your project completion report

   The program emphasizes that the owner is responsible for hiring and paying contractors to undertake the retrofit works, as well as obtaining all necessary permits to ensure the improvements are in-line with local regulations. Upon the completion of all retrofit works, the owner is expected to book a second assessment with an Energy Advisor to

verify the improvements and provide a new EnerGuide rating. The owner is then expected to submit a completion form to the City, signed by the Energy Advisor's, listing the invoices from the contractors, and the new EnerGuide rating label.

5. After the completion form has been submitted, loan repayments can begin. The HELP loan is paid via the property taxes on the parcel and the dwelling(s). Repayments are made with eleven monthly installments annually over the course of the loan repayment period. The owner may, at any time, repay the loan in full to clear the outstanding balance. The loan is also attached to the property and not the owner or applicant; thus if the owner chooses to relocate, the repayments become the responsibility of the next owner.

Aside from municipal retrofit programs, there are numerous private firms that assist residents in retrofitting their dwellings in Ontario. This highlights the potential use of energy retrofitting as an investment tool. However, these have not been included in this analysis as they do not fit within the scope of state-sponsored retrofit programs.

Quebec

The province of Quebec is by far the largest producer of electricity in Canada. In total, the province produced 213.7TWh of electricity in 2018, of which 99% came from renewable resources (Canada Energy Regulator, 2022c). Quebec produces more electricity than it consumes and thus exports some of its excess electricity. However, it has a significantly higher demand for electricity than other provinces due to colder winters and the widespread use of electric heating instead of natural gas. As a result, the province's peak demand season for electricity is the winter, which is in contrast to Ontario which experiences its highest demand in the summer (Hydro Quebec, 2022; Government of Ontario, 2020). Although most dwellings in Quebec rely solely on electrical heating, notably baseboards (plinths), many are also connected to natural gas for cooking and heating purposes (Pedinotti-Castelle et al., 2019; Kikuchi et al., 2009). Like in the rest of Canada, this is an opportunity to reduce the environmental footprint of the residential sector. However, even for those dwellings without natural gas, there are still insulation and other systems issues to address that could make dwellings more efficient. Hydroelectricity, though supplying over 90% of the province's electricity, is very expensive and politically unpopular to

build for the future, and will become more expensive to maintain over the coming decades as dams begin to age (Pedinotti- Castelle et al., 2019). Thus, as the province grows, it is important that dwellings in Quebec improve energy efficiency to reduce the burden on future generations' energy security.

Despite the relatively clean production of electricity in Quebec, consumption remains very inefficient and high usage periods can badly strain the energy grid. This in turn can lead to power outages during times where electricity is badly needed, such as during cold snaps. Furthermore, while Quebec produces more electricity than any other province in Canada, it is also among the highest consumers, and it is important for the future of Quebec's energy security to improve energy efficiency in the residential sector. In particular, the province needs to ensure the energy grid is not overburdened while maintaining residents' safety and comfort. The province of Quebec has implemented a strategy to encourage dwelling retrofits by providing subsidies for heating-related improvements. However, the program, called Rénoclimat, has various limitations that act as barriers for residents wishing to make their dwellings more energy efficient. The program is poorly advertised, applies to a narrow range of projects, does little to remove high upfront costs, and only targets owner-occupiers.

In Quebec, the only way to receive the Canada Greener Homes Grant is by enrolling in the Rénoclimat Program. The provincial program provides owner-occupiers with complimentary site visits to provide personalized advice on energy-saving strategies, and also provides financial assistance according to the building's eligibility criteria (Government of Quebec, 2022a). The program only applies to heating and insulation-related retrofits, and does not extend to cooling measures, lighting fixtures, or appliances (Government of Quebec, 2022a). This is an important drawback, particularly as the summer season grows longer and hotter in Quebec, making energy-efficient and environmentally-responsible cooling an important necessity for residents throughout the warmer months (Roberge and Sushama, 2018).

The Rénoclimat Program offers financial support of varying levels, depending on the work undertaken by the applicant. The works are broken down into four eligible categories:

1. Improving insulation

2. Improving air tightness
3. Replacement of doors and windows
4. Installing mechanical systems.

Table 4 explains the financial assistance rates available for owners under the Rénoclimat Program under each category of work. The assistance offered under Rénoclimat is not cumulative with the Canada Greener Homes Grant for a single type of work, and eligible funds from the federal government are exhausted before the Quebec contribution is calculated (Government of Quebec, 2022a).

Table 4: financial assistance available for residential-retrofit projects under Rénoclimat

Retrofit category	**Sub-categories**	**Financial assistance (with conditions)**
Improving insulation	Roof	$35-$975
	Exterior walls	$295-2,440
	Foundation	$130-$1,625
	Exposed floors	$245
Improving air tightness		$245-$490
Replacement of doors and windows		$60 per rough opening in the wall or roof
Installing mechanical systems	Ventilation	$490
	Water heating	$80-$165
	Heating	$2,150-$5,365

There are five broad steps involved in the application to the Rénoclimat Program (Government of Quebec, 2022b):

1. Call Rénoclimat

   The first step to apply for the program is to call the Rénoclimat office to book an appointment for an evaluation
2. Pre-work evaluation

   After establishing an appointment date, an Energy Advisor will conduct a pre-

work evaluation of the dwelling, and provide the applicant with an EnerGuide rating and recommendations for potential retrofit works through an evaluation report. This process is funded by the CGHG.

3. Perform renovations

   The Rénoclimat Program's conditions provide the applicant with the freedom to conduct renovations on their own or hire a contractor. The applicant is advised to use the recommendations in the evaluation report from step 2 in order to guide their work.

4. Post-work evaluation

   Upon completing all retrofit works, the Energy Advisor should be contacted to conduct a post-work evaluation of the dwelling. At this stage, the Energy Advisor will calculate a new EnerGuide rating. The first post-work evaluation is provided free of charge.

5. Following that the applicant has ensured they are eligible for the program, and the necessary information has been provided, the reimbursement through Rénoclimat financial assistance will be mailed to the applicant 10-12 weeks after the post-work evaluation.

In order to be eligible for Rénoclimat rebates, the subject property must be a detached dwelling, duplex, triplex, or residential buildings with no more than three storeys and no more than a 600 m^2 footprint. Residential buildings not meeting these criteria are ineligible for Rénoclimat, including individual units that are part of a larger apartment complex (Government of Quebec, 2022c).

United States

Washington, Michigan, and New York were chosen as the case studies for the United States due to their proximity to the studied Canadian provinces, but also their relatively large distance between each other. Together, they briefly illustrate how retrofit programs work in states in the Pacific Northwest, the Midwest, and the Northeast respectively. The energy consumption and production relationship for the states studied differ significantly from the situation in the Canadian provinces. In particular, the states studied are far less self-sufficient in terms of energy production, and rely heavily on energy imports.

Each state in this study has a relatively different energy mix, but all three have significant dependence on fossil fuels for electricity, unlike the case for British Columbia and Quebec. Washington state has a relatively hydro-dominated energy mix, with 54.77% of production being hydroelectric in 2020 (Washington State Department of Commerce, 2022). Still, 10.18% of the energy mix is coal, and an additional 12.94% comes from natural gas (Washington State Department of Commerce, 2022). The United States Energy Information Administration (EIA) states that 2021 saw an improvement in Washington's energy mix, however, with 64.6% coming from hydroelectricity (EIA, 2022a). However, in that same time period, fossil fuels increased to 17.5% (EIA, 2022a). With hydroelectricity being difficult to expand, reducing what remains of fossil fuel dependence in the state can be made more effective through robust retrofitting programs. Michigan is far more dependent on fossil fuels. The EIA states that roughly 60.5% of Michigan's energy production in 2021 came from fossil fuels (EIA, 2022b). Even more recently however, the Michigan Independent System Operator (MISO), shows that 75.26% of the state's energy mix was fossil fuel-based in June 2022 (MISO, 2022). Of this, roughly half was coal, which is among the most detrimental fuel sources for greenhouse gas emissions and overall environmental impact (MISO, 2022). Finally, the state of New York is heavily dependent on fossil fuels for electricity. The EIA states that 46.3% of the state's energy production in 2021 came from fossil fuels (EIA, 2022c). However, the state has a major north-south divide in regard to its energy mix. While Upstate New York's (zones A-E) energy production is 90% from non-emitting sources, mostly nuclear and hydroelectricity, roughly 77% of Downstate New York's (zones F-K) energy production is from fossil fuels (NYISO, 2021). The vast majority of New York's population lives in the latter half. In addition to this, a large proportion of New York's electricity is imported, which is not accounted for in this energy breakdown. Of the imported electricity, a significant proportion is also from fossil fuels. Thus there is an urgent need for New York to enhance energy efficiency in order to reduce the state's dependence on fossil fuels.

At the federal level, the United States Office of Energy Efficiency and Renewable Energy (EERE) lays out various energy efficiency programs that operate withing the country. Among these programs are Property Assessed Clean Energy (PACE) programs. PACE is a model that is intended to incentivize energy retrofitting and clean building practices for private property using innovative financing schemes (Office of Energy Efficiency & Renewable Energy, 2022). The

overarching goal of the PACE is to remove the high upfront costs of retrofit work for residents and businesses, and in turn allowing participants in a PACE program to pay loans over a longer period of time with low interest rates (Office of Energy Efficiency & Renewable Energy, 2022).

Washington

The state of Washington produces 109.1 TWh of electricity, over half of which comes from hydroelectricity (EIA, 2022a). However, there is still a fluctuating use of fossil fuels in the state that can be easily phased out by reducing energy dependence from buildings. Nevertheless, Washington lacks a robust state-level retrofit program. The exception is the Washington State Community Action Partnership's (CAP) various energy savings programs. However, these programs are only directed towards rural or low-income households. There are three main sub-programs offered by the CAP to assist Washington residents with retrofit work (Community Action Partnership, 2022):

1. Weatherization + Health (Wx+H)
2. Home Repair Loan Program (HRLP)
3. Low-Income Home Energy Assistance Program (LIHEAP).

The Weatherization + Health program is designed to improve the weather resistance of rural dwellings. This includes better protection against precipitation, wind, and heat-related damage. As a by-product of this work, energy bills are also reduced due to improved building envelopes. The Home Repair Loan Program is also targeted towards the rural housing stock. This program acts as a secondary option to the Weatherization + Health program, as dwellings can be deferred from the program depending on the severity of the repairs needed. After necessary worked are completed under HRLP, the owner can apply to complete the remaining eligible work with the Weatherization + Health program. Finally, the Low-Income Home Energy Assistance Program is targeted towards low-income households across Washington state. The program draws funds from a federal block grant program to finance energy retrofits, as to avoid shutoffs during the winter season. Depending on the county in which applicant lives, the owner must schedule an appointment with the particular organization that offers retrofit services in their area. The program website links to an interactive map of the different counties in the state, which can be selected to open a new tab with contact information for the community action group available in

the area. Table 5 summarizes the different counties in Washington state, and the available support provided for retrofit work through LIHEAP. Note that some of the organizations are available for multiple counties. Information regarding the various organizations' availability and operating hours are outdated, as many of them list information for repealed COVID-19 regulations. Furthermore, several organizations still only list application information for the 2020-2021 application year (Community Action Partnership, 2022).

Table 5: Program support by county in Washington state for LIHEAP retrofits

County Name	Organization Name
Adams	Opportunities Industrialization Center (OIC) of Washington
Asotin	Washington State Community Action Partnership
Benton	Benton-Franklin Community Action Committee
Chelan	Chelan-Douglas Community Action Council (CAC)
Clark	Clark Public Utilities
Clallam	Olympic Community Action Programs
Columbia	Blue Mountain Action Council (BMAC)
Cowlitz	Lower Columbia Community Action Council (CAC)
Douglas	Chelan-Douglas Community Action Council (CAC)
Ferry	Rural Resources Community Action
Franklin	Benton-Franklin Community Action Committee
Garfield	Blue Mountain Action Council (BMAC)
Grant	OIC of Washington
Grays Harbor	Coastal Community Action Program
Island	Opportunity Council
Jefferson	Olympic Community Action Programs
King	Multi-Service Center
Kitsap	Kitsap Community Resources
Kittitas	Hopesource
Klickitat	Washington Gorge Action Programs
Lewis	CAC of Lewis, Mason & Thurston Counties Centralia
Lincoln	Rural Resources Community Action
Mason	CAC of Lewis, Mason & Thurston Counties Shelton
Okanogan	Okanogan County CAC
Pacific	Coastal Community Action Program
Pend Oreille	Rural Resources Community Action
Pierce	Pierce County Human Services
San Juan	Opportunity Council

Skagit	Community Action of Skagit County
Skamania	Washington Gorge Action Programs
Snohomish	Snohomish County Human Services Department
Spokane	Spokane Neighborhood Action Partners (SNAP)
Stevens	Rural Resources Community Action
Thurston	CAC of Lewis, Mason & Thurston Counties
Wahkiakum	Lower Columbia CAC
Walla Walla	Blue Mountain Action Council (BMAC)
Whatcom	Opportunity Council
Whitman	Community Action Center
Yakima	Northwest Community Action Center/YVFWC

Table 5 demonstrates that the Washington state's action plan towards residential energy retrofitting is relatively disjointed. There is no central organizing power that manages financing, contracting, and pre-work and post-work assessments of residential retrofit projects. Instead, these powers are delegated to various community groups that operate at regional levels, with only indirect involvement from municipal and state-level governments. There is also no public information regarding the level of funding available, as well as funding structuring, property and dwelling assessments, or how contracting is sourced (Community Action Partnership, 2022).

In addition to the Community Action Partnership's various sub-programs available throughout Washington state, the City of Seattle also has an independent energy savings program called Seattle City Light. However, the program offers only up to $500 in rebates for contracted or "DIY" retrofit work. The program lists out various other methods that owner-occupiers and tenants can use to reduce energy costs, however the messaging between the two target audiences is very asymmetric. In particular, the program acknowledges that owners have the agency and financial capabilities to embark on major retrofit projects and energy auditing, and thus the program provides information for potential contractors to assist with retrofitting. This includes changing windows, heating and cooling systems, and insulation. However, the information provided for renters does not include any substantial information on deep-level changes to the dwelling, and consists mainly of ways to use less energy. This includes the use of LED bulbs, lowering shower time, and avoiding the use of ovens. There is no information regarding retrofitting provided for renters (City of Seattle, 2022).

Michigan

Michigan is a heavily fossil fuel dependent state. Of the 116.0 TWh of electricity produced in the state, 60.5% comes from the burning of fossil fuels (EIA, 2022b). Furthermore, roughly half of the fossil fuel energy in the state is produced by coal (EIA, 2022b). Thus there is a huge opportunity in the state to reduce emissions, both through energy transition, and through improved energy efficiency. The Michigan Public Service Commission lays out various utility programs, financial assistance programs, and workgroups that are available in the state to aid with energy waste reduction (State of Michigan, 2022). Of particular interest is the Michigan Saves financial assistance program, which is designed to make energy retrofitting accessible and affordable. The program has two branches: the Michigan Saves Home Energy Loan Program, and the Business Energy Financing Program (State of Michigan, 2022). Notably, Michigan Saves is supported by the State of Michigan, but the program is itself an NGO that works with residents and businesses to connect with verified lenders to finance energy retrofits (Michigan Saves, 2022a). There are a number of eligible retrofit works for Michigan Saves, including:

- Roofing (asphalt, metal, or membrane)
- Solar photovoltaic (PV) installations
- Insulation (attic, crawl spaces, floors, joists, and walls)
- Low-flow toilets, faucets, and shower heads)
- Windows
- Air sealing
- Remediation (lead, mold, radon, and asbestos) *requires special application and contractor*
- Heating, ventilation, and air conditioning (HVAC)
- Water heater
- Whole-dwelling battery storage
- Electric vehicle (EV) charging stations

The application for the program consists of three overarching steps:

1. Find a contractor

   The process is unique from the other programs in other jurisdictions given that a contractor must be found prior to applying for financing. Once a contractor is established,

based on proximity to the applicant and building type (residential or commercial), a contractor ID number is provided (Michigan Saves, 2022b).

2. Apply for financing

   The ID number is in turn required for the financing application, along with information regarding the applicant's personal information, financial institution, and employment information (Michigan Saves, 2022c).

3. Find a lender

   Depending on the county and desired loan amount, the applicant may be limited to specific lenders. Table 6 describes the eligible lenders for Michigan Saves, and the loans range they offer, the minimum interest rates offered, and maximum repayment period for the loans (Michigan Saves, 2022a). As per the Michigan Saves loan repayment conditions, the loan repayment terms are for one year for every $1,000 up to $4,999. For loans $5,000 and higher, the applicant may choose a repayment term of up to ten years or higher if applicable. There are no annual or early repayment fees (Michigan Saves, 2022a).

Table 6: Eligible lenders for Michigan Saves

Lender	Loan amount	Rate as low as	Repayment period (months)	Eligible counties
Dort Financial Credit Union	$1,000 - $50,000	4.50%	Up to 180	All Michigan counties
Genisys Credit Union	$1,000 - $50,000	4.44%	Up to 180	All Michigan counties
LAFCU	$1,000 - $75,000	5.49%	Up to 180	Barry, Calhoun, Clinton, Eaton, Gratiot, Ingham, Ionia, Jackson, Livingston, Montcalm, Shiawasse
Lake Michigan Credit Union	$1,000 - $40,000	3.99%	Up to 180	All Lower Peninsula counties
MSU Federal Credit Union	$1,000 - $100,000	4.90%	Up to 180	All Lower Peninsula counties

TRUE Community Credit Union (fka Washtenaw Federal Credit Union)	$1,000 - $100,000	4.75%	Up to 180	All Michigan counties

Only single-family dwellings with fewer than four attached units are eligible for funding through Michigan Saves. Michigan Saves also notes that not all applications are guaranteed financing from a lender. In particular, a good credit score may be required to receive loans from one of the lenders listed. However, for households living within the City of Detroit, there is the option to apply for the Detroit Loan Fund. The program notes that if residents within the city are disqualified from receiving loans due to a low credit score, they may be able to apply for funding through the TRUE Community Credit Union, and Michigan Saves will in turn use "alternative underwriting criteria" to determine the applicant's ability to pay (Michigan Saves, 2022a).

New York

New York's energy system is unique in that it has a clear north-south divide in production method. Of the 125.2 TWh of electricity produced in the state, 46.3% comes from fossil fuels (EIA, 2022c). However, in Upstate New York, 90% of the electricity is from hydroelectricity, while Downstate New York's is 77% fossil fuels (NYISO, 2021). While the New York does not have a robust statewide retrofit strategy, the state's largest city, New York City, passed the ambitious Climate Mobilization Act in 2019 (City of New York, 2022). This is important considering that New York City is situated in Downstate New York, where most of the fossil fuel dependence is. Under this act are various local laws that apply to the city's goals of reducing the carbon footprint of all buildings, including:

- Local Law 92, 94 – new buildings and buildings undergoing major roof renovations need to include solar panels, green roofs, or a combination of the two
- Local Law 95 – an amendment to how energy grades are calculated. Also enforces that energy grades must be displayed at the building's entrance, with both a letter grade and the energy score
- Local Law 96 – PACE: property-assessed clean energy to fund energy and water usage retrofits at low-interest rates

- Local Law 97 – all buildings over 25,000 square feet must meet specific carbon reduction targets

The local laws under the Climate Mobilization Act apply to both residential and commercial buildings (City of New York, 2022). However, for the context of this project, focus is placed on how local laws 96 and 97 apply to the residential sector.

Local Law 96

Under local law 96, energy efficiency improvements encompass any renovation or retrofit that reduces the energy consumption of a building while maintaining the same indoor conditions. This includes window and door replacement, lighting, caulking, weatherstripping, air sealing, insulation, and heating and cooling system upgrades. The potential energy efficiency improvements are determined via energy audits by a certified contractor. The audits are intended to identify where energy inefficiencies can be traced, and the potential energy savings that would take place after resolving them (City of New York, 2019a). Eligible buildings include multifamily residential buildings with 3 or more units, commercial buildings, religious and non-profit facilities, health care facilities, and industrial buildings (City of New York, 2019b).

Local law 96 also lays out the structuring and conditions for loans and loan repayments for retrofit work. The law describes the sustainable energy loan program, which allows the administering agency of the retrofit works to use federal grants, federal credit, or funds from the State of New York to finance and applicant's retrofit work. It also grants that the administering agency may choose to partner with non-profit or for-profit organizations to aid the implementation, administration, and enforcement of the retrofit program. The loan repayment period is required to not exceed the average useful life of the systems being implemented (City of New York, 2019a). In some cases, this can be up to 30 years (City of New York, 2019b). Loans are repaid as part of the building's property taxes, and thus there is no real attachment of the loans to the applicant of the program. This structuring allows for repayment to be passed on to new owners of the property (City of New York, 2019b).

Currently, there are no clear application instructions available for the PACE program due to its ongoing development, and its public-private nature. The terms of the financing vary depending on the lender of eligible loans, and thus applicants to the program must communicate directly

with the New York City Energy Efficiency Corporation (NYCEEC), which administers NYC Accelerator: PACE financing. The NYC Accelerator is a service that supports retrofitting in existing buildings by providing free, personalized advisory for energy improvements. Advisors from the NYC Accelerator connect applicants to the PACE program with qualified lenders to provide financing for retrofit work. Financing is intended to be 100% coverage, such that the applicant pays no upfront costs for eligible work, including energy audits (City of New York, 2019b). This means that there are no maximum loans established by the state, and instead the required amount is provided to the applicant to meet the needs of the retrofit work.

Local Law 97

Local law 97 requires buildings over 25,000 square feet to meet certain carbon reduction targets. The law lays out the creation of the Office of Building Energy and Emissions Performance, which will oversee the implementation of building energy and emissions performance laws for existing buildings, new buildings, and major renovation projects. The office will also be responsible for establishing and administering protocols for annual energy usage assessments for buildings. The office will also lead an online portal for annual building energy assessments, conduct audits on buildings to ensure proper reporting, determine penalties for noncompliance, and ensuring the participation of other city departments such as the Department of Environmental Protection, the Department of Housing Preservation and Development, and the Department of Citywide Administrative Services. Local law 97 also lays out the goals and targets of retrofit projects more broadly. In particular, the law states that New York City shall reduce carbon emissions by 40% by 2025 and by 80% by 2050 relative to emissions levels in 2005 (City of New York, 2019c).

As local law 97 is not a program, but a mandate, there is no service to apply to. Buildings seeking to meet their carbon reduction requirements can apply for PACE financing as described in local law 96.

Chapter Three: Analysis

The previous chapter summarized the financial support and application requirements for retrofit programs in six jurisdictions across Canada and the United States. This chapter focuses on understanding how these programs compare to one another, as well as their robustness relative to suggestions for retrofit and other climate change adaptation programs provided by the literature.

Addressing Barriers to Retrofit Program Participation

The six barriers described by Friedman et al. (2018) help understand how retrofitting programs and subsidies can be delivered in a more accessible manner. While none of the six barriers to participation appear to be collectively addressed within any of the programs assessed, individual barriers are addressed in some programs. The six barriers listed by Friedman et al. (2018) are:

1. Lack of awareness of the benefits of retrofitting the dwelling. Residents may not realize their dwelling needs retrofitting.
2. High upfront costs and long payback periods. Residents may not want to undergo retrofit projects due to daunting costs and lengthy returns on investments.
3. Difficulty in applying a cost on non-energy benefits. Positive externalities of retrofitting include comfort, improved health, housing longevity, cleanliness, and environmental stewardship.
4. Organizational barriers. There may be multiple people involved in the decision making processes concerning a dwelling. This can happen if the unit has tenants or if the owned property is a large apartment building or complex.
5. Social and behavioural factors. Residents may make other decisions to save on energy costs that appear more feasible in the short term. They also may be unaware that retrofit programs exist to help them.
6. Technical and legal barriers. While new builds take energy efficiency into account from the beginning, existing buildings are for more difficult to change, especially if there are supporting structures that cannot be altered, or legal restrictions on the altering of historically significant building features.

Barrier 1: Lack of awareness of retrofit benefits

For the purposes of this research paper, it is difficult to assess whether any of the programs

effectively address the first barrier. All of the programs explain what retrofits are, and how they help to reduce energy costs for residents. However, they do not necessarily advertise retrofit benefits to the broader public. Instead, the programs are all designed to be found by applicants as opposed to actively reaching out to high potential residences. The exception to this is local law 97 in New York City, which mandates that large buildings reduce their energy footprint. By so doing, building owners are required undertake retrofits to improve their building's efficiency.

Barrier 2: High upfront costs, long repayment periods

Upfront costs are not addressed through programs that offer rebates after a post-work assessment. This is the case with programs in Washington, British Columbia, and Quebec. However, Toronto's Home Energy Loan Program, Michigan Saves, and New York City's PACE program all offer loans that are specifically intended to remove the high upfront costs of retrofits. These programs all handle this issue in a different manner, however. HELP in Toronto offers a maximum of $125,000 to applicants at interest rates as low as 0%. Applicants can receive a portion of this funding early in the retrofit process to expedite renovations. The loans have long repayment periods and are paid through property taxes. The result is that applicants may not have to pay for retrofit work at all if they choose to sell their dwelling after the work is complete, after which the new owner would be responsible for repaying the retrofit loans through the property's taxes. Michigan Saves is also a loan-based retrofit program, however instead of loans coming from utility companies and the city, the loans come from lenders such as credit unions. The available lenders depend on the county in which the applicant lives, each offering a different amount of funding and interest rates for repayment. Unlike HELP, the loans are not linked directly to the property, and thus are not repaid via property taxes. Property tax repayments of loans are a unique feature of retrofit programs that operate under the management of the municipal government. Since Michigan Saves is operated by a state-sponsored NGO, the organization is unable to leverage property taxes for a repayment scheme. However, PACE in New York City, like HELP, is managed by the local municipal government. Thus the program is able to leverage property taxes for repayment in the same way as HELP works in Toronto. The difference however is that loans have no set maximum, as they are intended to cover 100% of the costs of the eligible retrofit work. The loans are also provided through verified lenders that the applicant must find through the application process, unlike in Toronto where loans are provided

through utility companies. The interest rates are not provided on any of New York City's Local Law 96 websites, as they are negotiated for between the applicant and the lender directly.

Barrier 3: Positive externalities

There are various benefits to retrofitting that are not captured through direct monetary value. These include health-related benefits, improved comfort, environmental stewardship, and improved building longevity. While some of these benefits can have alternate returns on investment, such as improved resale value of the property or cost savings on healthcare, they cannot be captured directly through energy savings. While none of the programs explicitly list these benefits as positive externalities, most of them note how retrofit work can improve property value and personal health. Most often however, the programs note that energy savings are part of a broader commitment to fighting global climate change. Whether this messaging draws in more participation to the programs is unclear.

Barrier 4: Organizational barriers

Housing, in organizational terms, is complex. While there are single-family dwellings that are owned and occupied by the same household (i.e., owner-occupied units), there are millions of dwellings for which tenure is more complex. For example, there are single-family dwellings that are owned and occupied by different individuals, households, and/or organizations, apartment complexes with a single property owner (often a corporation, but sometimes a private individual) and multiple households in rental arrangements with that owner, apartment complexes with multiple owners and multiple occupants, and a range of other combinations. Due to the streamlining of retrofit programs, it is difficult to target all housing types through one policy. As a result, none of the programs assessed in this research have been able to holistically target all the potential housing combinations withing their jurisdiction. All the programs, except for PACE in New York City, are geared towards single-family dwellings, whether they are detached, semi-detached, or townhouses. Some programs, such as Rénoclimat in Quebec and CleanBC Better Homes in British Columbia, extend to single-family dwellings that are not buildings in the legal sense, but which are permanently fixed, such as house trailers (colloquially known as "mobile homes") or, in the case of BC specifically, floating dwellings. The Community Action Partnership programs in Washington are specifically targeted to low-income and rural dwellings, with the goal of improving building longevity and preventing energy shut-off during the winter

months. None of these programs except for Rénoclimat express support for apartment buildings, however even Rénoclimat only extends to three-storey apartment buildings (including plex units), whereas other dwelling types are not eligible. PACE in New York City takes a contrasting approach. The program is designed to address energy efficiency issues in large buildings, including apartment complexes. Local Laws 96 and 97 are targeted towards large apartment complexes, not single-family dwellings. This makes logical sense, as a very large proportion of all dwelling units in New York City are apartment buildings, not detached or other grade-related typologies.

Barrier 5: Social and behavioural factors

Due to low advertising of retrofit programs, residents may be unaware that they can receive financial support to improve their dwelling's energy efficiency. As with the first barrier, residents may not embark on retrofit projects due to a lack of awareness on how to reduce their energy footprint. However, the difference is that social and behavioural barriers do not necessitate that residents do not know how retrofits can assist with their energy costs. Instead, residents may be aware that retrofits can help, but choose not to undergo them in favour of more short-term solutions. Notably, the Seattle City Light program actively encourages short-term behavioural solutions for tenants, but focuses on retrofit solutions for owner-occupiers. This difference in narrative showcases the difficulty in incorporating tenants in retrofit programs, particularly due to the limited legal right tenants have in terms of physical alterations to their dwellings. The remaining programs make little mention of behavioural methods to reduce energy costs, and focus instead on the retrofit aspects of energy savings. However, as with barriers 1 and 3, it is difficult to assess whether the programs effectively advertise their messages, and that they are available to help residents.

Barrier 6: Technical and legal barriers

The final barrier is that there may be legal or technical restrictions that prevent major retrofits from occurring. This is the case with the older building stock in cities, where support structure and heritage designations can make it difficult to alter a building's envelope. This is a barrier that is not explicitly addressed in any of the retrofit programs assessed. The minor exception is that the Community Action Partnership notes that retrofit work under their programs are intended to

conserve rural dwellings. In this case, the retrofit programs work to support heritage buildings and conservation commitments.

Data Availability and Future Research Directions

This Supervised Research Project has explored the ways in which deep-energy retrofit is being encouraged for dwellings, including key aspects of eligibility, the application process, and financial support provided by various retrofit programs in jurisdictions with continental climates in North America. However, this paper does not directly address the success of these programs through data on program enrollment, and the level of energy savings they provide for applicants. The purpose of this project is simply to illustrate the different tools that can be used to encourage retrofitting in the residential sector, and how they are applied in practice by different governments. This research lays the foundation for further studies that focus on how these programs succeed or fail in achieving their goal: reducing the residential sector's burden on the energy grid. Below is a list of recommendation on how this research can be expanded to further understand how retrofit programs can be improved to increase participation and outcomes for residents.

Research on other jurisdictions

To better understand the potential avenues retrofit programs can take, it is worthwhile to examine how other jurisdictions around the world finance retrofit programs. This includes more programs within North America, but also programs overseas.

Data on participation

One of the major gaps in this research has been that there is no publicly available or consistent information regarding how many participants each of these programs receive, and if the programs are meeting their target enrollment. While some programs, like New York City's PACE program, are enforced by law, other programs are administered on a voluntary basis. Thus while in theory all buildings over 25,000 square feet in New York City shall perform retrofits to meet energy reduction requirements, it is difficult to assess how many participants there are in the other programs in this study. This data should be collected directly from the agencies

administering the retrofit programs to better understand which financing, governing, and advertising methods yield the best outcomes in terms of outreach.

Data on pre-work and post-work assessments

A key piece of most of the programs assessed in this study has been that residents must demonstrate a need for retrofits before work is commenced. After work is complete, another assessment is completed to calculate residential energy savings. However, this data on pre-work and post-work energy assessments is not publicly available. Understanding the success of these retrofit programs on a case-by-case basis (i.e., focusing on each dwelling) can help develop more robust retrofit strategies. This includes the scope of eligible work, the amount of funding offered, and the nature of funding itself (e.g., large loans versus small rebates).

Examining tenant protections

A major limitation to all the retrofit programs studied is that they do not offer many options for renters. The results of the grey-literature review of the six jurisdictions' demonstrate that there is little consideration given to the socioeconomic consequences of urban renewal projects and subsidized green infrastructure. The issues raised in Bouzarovski et al. (2018) and Bissonnette et al. (2018), particularly the displacement of low-income communities by means of mass renovation of residential buildings, are not addressed in any of the programs assessed. This is a problem because many of the programs encourage improvements with financial support, using improved property value as an incentive to retrofit. As such there is a risk that retrofit funds could be used to renovate rented dwellings to either sell for profit, or to charge higher rents for future tenants. In many contexts, renovations are considered legally-valid reasons to evict tenants, and thus retrofit work could potentially be used to displace renters and exacerbate high housing costs. An assessment of how the retrofit programs studied, as well as those in other jurisdictions manage tenant-owner relations is important in assessing whether retrofit programs exacerbate renovations. Furthermore, the exploration of retrofit programs that actively involve and protect tenants in the retrofit process can be used as a precedent to improve the programs assessed in this study.

Conclusions

There is a dire need to reduce the impact of the building sector on global greenhouse gas emissions. Buildings make up 40% of global energy consumption, and present a huge opportunity for emissions reductions (Pedinotti-Castelle et al., 2019; Friedman, Becker, and Erell, 2018). Aging buildings consume more energy due to insulation and building envelope degradation, as well as deteriorating electrical systems (Friedman et al., 2018). Furthermore, continental climates are faced with seasonal extremes that make energy consumption a huge issue, particularly for weather resistance and temperature regulation. Combined with a changing climate, cities in continental climate regions are faced with growing energy efficiency concerns (Pedinotti-Castelle et al., 2019; Friedman et al., 2018). This research paper examined how different jurisdictions with continental climates across North America manage these energy concerns through their local energy retrofitting programs. Some of the jurisdictions studied have high proportions of renewable energy, others still heavily rely on fossil fuels. Thus, the framing of energy retrofitting benefits varies between each program, and the goals between jurisdictions can at times be significantly different. Some of the studied programs are more concerned about energy shortages and efficiencies, while others are focused on reducing their carbon footprint and emissions.

Energy retrofits can be as simple as providing extra sealing for windows, or can be deep level, such as a full redo of the building's envelope. Each of these programs sets its own limitations on what types of dwellings are eligible for retrofit funding, the kinds of retrofits that are applicable, and the level of funding that can be received. The findings demonstrate that even within one country, the approach to retrofit programs are significantly different between jurisdictions. Those programs which address some of the barriers from Friedman et al. (2018) may not address others that are effectively managed by a different program. Virtually none of the programs appropriately address all six barriers, leading to the need for more research into how to effectively design these retrofit strategies.

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