Policy Recommendations for Deep Energy Retrofits

by
Raidin Blue Brailsford

supervised by
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A Major Project Report
submitted to the Faculty of Environmental and Urban Change
in partial fulfillment of the requirements for the degree of Master in Environmental Studies
York University, Toronto, Ontario, Canada

2 August 2021

Abstract

The Government of Canada recently released a strengthened climate plan outlining various measures to advance the uptake of residential retrofits. This research aimed to evaluate these measures through a review of academic and grey literature and interviews with green building professionals. Additionally, this research aimed to provide recommendations to the Government of Canada to advance the uptake of residential retrofits. Interview and literature data suggest a more hands-on approach is needed if greenhouse gas emissions in residential buildings are to be lowered. Expensive financing and a complex customer journey remain two of the most substantial barriers to deep energy retrofits. To overcome these barriers, I recommend creating a Crown corporation mandated to deep energy retrofit all residential buildings in Canada with work beginning in social housing and financed through progressive taxation. In this report, I present this work through a Major Research Paper and through a policy brief.

Foreword

I originally came to York University's Master in Environmental Studies program with the intention to study bumble bee conservation. Given the escalation of the climate crisis and mass mobilizations of climate activists in the summer of 2019, I decided to pivot my career and focus on climate change. Specifically, I wanted to learn about climate and energy policy. Fortunately, this program and my faculty advisor, Dr. Sheila Colla, allowed me the flexibility to pivot. Professor Hoicka and her courses *Community, Energy & Planning* and *Fundamentals of Energy Efficiency* as well as my independent study of retrofits and gentrification guided me toward deep energy retrofits for my research. Following a contextual change with the COVID-19 pandemic and the Government of Canada's promise of billions of dollars for residential retrofits, for my Major Research Project I sought to discover the best practices for deep energy retrofitting residential buildings.

This Major Project Report consists of two pieces in fulfillment of my Major Research Project. The first is a Major Research Paper on policy recommendations for deep energy retrofits. The second piece is a policy brief summarizing the Major Research Paper in a convenient form. This research was intended to help me fulfill several Learning Objectives from my Plan of Study.

- Learning Objective 1.2: Deep Energy Retrofits
    - Gain a critical understanding of deep energy retrofits in Canada including their feasibility, business models, financing options, deployment strategies, and state-of-the-art technologies.
- Learning Objective 1.3: Practical Application
    - Discover real life applications of sustainable technologies and innovations and learn about their success and failures.
- Learning Objective 2.2: Policy Options
    - Research and learn about policy options for sustainable energy technologies and innovations that are used internationally and in Canada.
- Learning Objective 3.2: Qualitative Analysis
    - Practice and study qualitative analysis techniques (i.e., policy analysis, interviews).
- Learning Objective 3.3: Research Experience
    - Gain experience conducting and designing research in the social sciences.

Acknowledgements

I acknowledge that I wrote this Major Project Report while living in unceded and occupied Okanagan territory. I also acknowledge that York University stands in Tkaronto, a land with which many Indigenous Nations have long-standing relationships, such as Anishinabek Nation, the Haudenosaunee Confederacy, and the Huron-Wendat. It is now home to many First Nation, Inuit and Métis communities. I acknowledge the current treaty holders are the Mississaugas of the Credit First Nation and that the school grounds are subject to the Dish with One Spoon Wampum Belt Covenant, an agreement to peaceably share and care for the Great Lakes region. In this acknowledgement, I also recognize the many historical and current oppressions colonialism has caused. To correct these injustices, I have committed myself to return the land, from the Okanagan to Tkaronto, to its original caretakers.

I acknowledge Dr. Mark Winfield for his support and guidance as my supervisor. I acknowledge Dr. Sheila Colla for accepting me into this program, her guidance, and for serving as my faculty advisor. And I acknowledge Dr. Christina Hoicka for her invaluable lessons on energy.

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Section 1: Introduction

Purpose

The purpose of this research was to answer the question, *if the goal of the federal government is to lower greenhouse gas emissions and stimulate the economy through investments in retrofits, how should they invest to maximize greenhouse gas emission reduction and job creation?* I began this research project with a few objectives:

- Review academic literature pertinent to building retrofits in Canada;
- Review best-practice technologies and innovations in the retrofit sector;
- Canvass advocates and actors in the green building sector for their recommendations to the federal government on building retrofits;
- Generate a set of recommendations for the federal government on building retrofits;
- Provide a formative evaluation to the federal government based on the review and canvassing.

To best answer this question and complete my objectives, I wrote a Major Research Paper. This composes Section 2 of this Report. To communicate my research and to answer this question in a more digestible form, I wrote a policy brief. This composes Section 3 of this Report.

Section 2: Major Research Paper

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Foreword

This Major Research Paper is one of two pieces in a Major Research Project in partial fulfillment of the requirements for the degree of Master in Environmental Studies in the Faculty of Environmental and Urban Change at York University. The second piece is a policy brief. This research was intended to help me fulfill several Learning Objectives from my Plan of Study.

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List of Figures, Tables, and Boxes

List of Acronyms

CaGBC	Canada Green Building Council
CEAP	Canada's Economic Action Plan
CIB	Canada Infrastructure Bank
CMHC	Canada Mortgage and Housing Corporation
CUPW	Canadian Union of Postal Workers
CUSP	Canadian Urban Sustainability Practitioners Network
DER	Deep energy retrofit
ECCC	Environment and Climate Change Canada
EDC	Export Development Canada
ESA	Energy service agreement
ESCO	Energy service company
ESPC	Energy-saving performance contract
ETIS	Energy technology innovation system
GHG	Greenhouse gas
HELP	Home Energy Loan Program
KfW	Kreditanstalt Für Wiederaufbau
LIC	Local Improvement Charge
MESA	Managed energy service agreement
MURB	Multi-unit residential building
NAPH	North American Passive House Network
NRCan	Natural Resources Canada
OECD	Organization for Economic Cooperation and Development
PACE	Property assessed clean energy
PEER	Prefabricated Exterior Energy Retrofit
SHARP	Social Housing Apartment Retrofit Program
SHRRP	Social Housing Renovation and Retrofit Program
SNM	Strategic niche management

1.0 Introduction

1.1 Background

During the first year of the COVID-19 pandemic, environmental organizations and green building advocates started calling for significant investments in building retrofits as part of a COVID-19 economic recovery (CaGBC, 2020b; Gray, 2020; Torrie et al., 2020). Deep energy retrofits (DER) are an excellent investment for a post-COVID-19 economic recovery because they immediately lower greenhouse gas (GHG) emissions, create local jobs, help create healthier environments for the occupants, and decrease instances of energy poverty. Considering 66% of residential energy is used for space heating and cooling, DER investments could seriously improve people's lives and living conditions in Canada and lower GHG emissions (NRCan, 2018).

State-of-the-art innovations target 50-80% energy reduction post-retrofit or even passive buildings (Harvey, 2013; Ürge-Vorsatz et al., 2020). These types of retrofits follow a whole-of-house understanding, typically emphasize high-performance envelopes, and are offered by programs that feature packages of retrofits (Hoicka & Parker, 2018). A Toronto case study modelled the cost and benefits of DERs in three archetypal houses and showed energy reductions of as much as 67% (Jermyn & Richman, 2016).

Job creation estimates are more difficult to predict because they depend significantly on program design and model assumptions. One model estimated a pan-Canada DER program focused on single-family attached homes and apartment buildings could create 138,000 jobs sustained for 20 years; this model assumed a retrofit rate of 4.5% per year (600,000 dwellings per year: 72,000 single-family detached homes, 340,000 single-family attached homes, and 188,000 apartment units), a scaling-up phase starting in 2021 and a scaling-down phase in 2040, (Kennedy & Frappé-Sénéclauze, 2021). Another model produced similar results, estimating 1.5 million gross jobs by 2030 (150,000 jobs sustained for 10 years) split relatively evenly between renewable energy, retrofits, and energy efficiency (CaGBC, 2020c).

Retrofitting buildings is also proven to increase the health of residents. Research in the UK found a causal link between older and lower-income residents living in poorly heated housing dying from "excess winter mortality" (Wilkinson et al., 2001). Other risks included developing respiratory conditions in children caused by mould and dampness (Dales et al., 1991; Tobins et al., 1987).

Canada defines fuel poverty--similar but with a technical difference to energy poverty--as households spending over 10% of their income on utilities (Canada Energy Regulator, 2017).

Using this metric, an estimated 8% of people in Canada (3 million people) experience energy poverty. Although, other institutions suggest 6% is a superior metric for understanding energy poverty (CUSP, 2019). Research by the Canadian Urban Sustainability Practitioners Network highlighted that those suffering from energy poverty are disproportionately Indigenous, low-income, migrants, and racialized and that these inequities are systemic (CUSP, 2019).

Characterizing Canada's housing stock is essential for understanding retrofits. The housing stock in Canada is displayed in Figure 1.1 (Statistics Canada, 2021). The primary structure and tenure is a single-detached house that is owner-occupied. Most homes are rented in apartment buildings less than five storeys; above five storeys, the ratio is near 50:50. Social housing represents less than 4% of Canada's housing stock (629,000 dwellings) (OECD, 2021). The OECD reported this as less than half the OECD average (Figure 1.2).

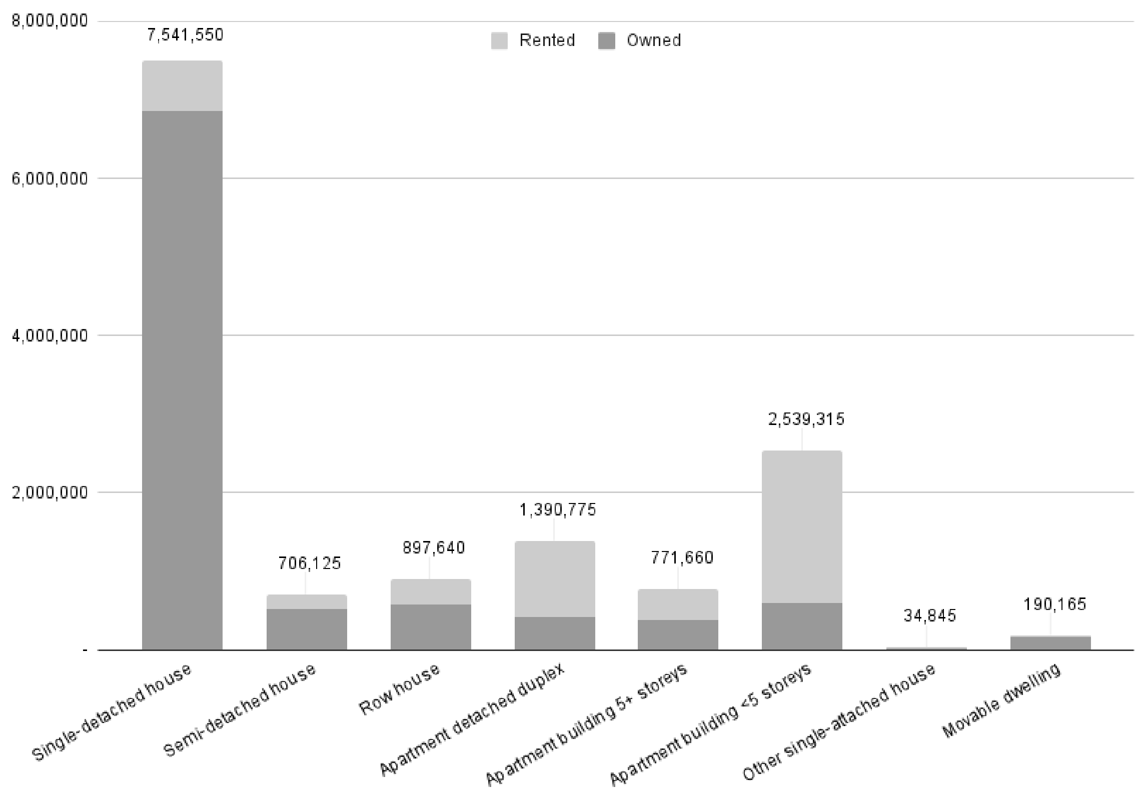

Figure 1.1. Occupied housing stock by structure type and tenure (Statistics Canada, 2021).

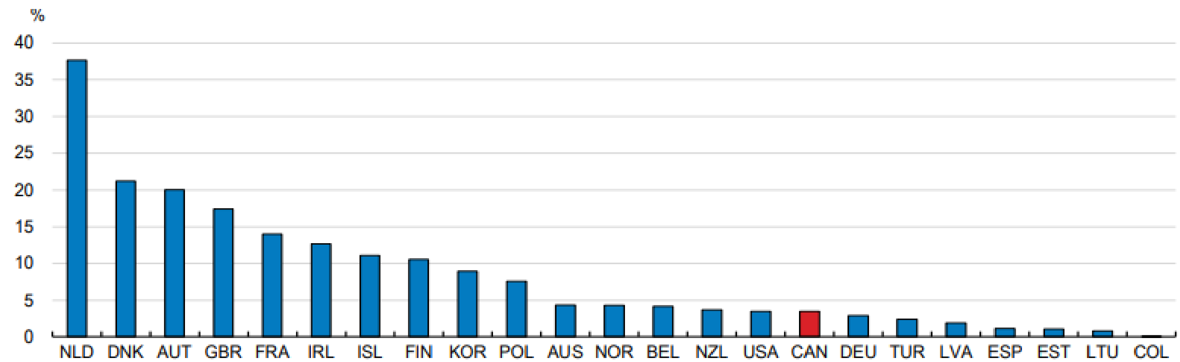

Figure 1.2. Social rental dwellings, as a % of the total housing stock, 2018 or nearest year, extracted from OECD (2021).

Before the pandemic and following the 2019 federal election, the Prime Minister of Canada mandated the Minister of Natural Resources and the Minister of Families, Children and Social Development (responsible for the Canada Mortgage and Housing Corporation (CMHC)) to operationalize a plan to help Canadians make their homes more energy-efficient and climate-resilient. This plan was mandated to include free energy audits to homeowners and landlords and up to $40,000 in interest-free loans for retrofits (Office of the Prime Minister, 2019a, 2019b).

In December of 2020, the Government of Canada released *A Healthy Environment and a Healthy Economy: Canada's strengthened climate plan to create jobs and support people, communities and the planet* (ECCC, 2020). This announcement included new promises for investments in retrofits. The complete list of new measures is available in the appendix. Two key promised measures included:

> "Provide $2.6 billion over seven years, starting in 2020-21, to help homeowners improve their home energy efficiency by providing up to 700,000 grants of up to $5,000 to help homeowners make energy efficient improvements to their homes, up to one million free EnerGuide energy assessments, and support to recruit and train EnerGuide energy auditors to meet increased demand.
>
> Continue working with and building on successful provincial and territorial low-income retrofit programs, to increase the number of low-income households that benefit from energy retrofits. For example, the National Housing Co-Investment Fund provides low-cost repayable loans ($3.46 billion over ten years, starting in 2017-18) and non-repayable contributions ($2.26 billion over ten years, starting in 2017-18) to support energy efficient construction or renovation of affordable homes." (ECCC, 2020)

Since the outset of this research project, the Government of Canada released their 2021 budget (Department of Finance Canada, 2021), which included commitments to DER:

> "Budget 2021 proposes to provide $4.4 billion on a cash basis ($778.7 million on an accrual basis over five years, starting in 2021-22, with $414.1 million in future years) to the Canada Mortgage and Housing Corporation (CMHC) to help homeowners complete deep home retrofits through interest-free loans worth up to $40,000. Loans would be available to homeowners and landlords who undertake retrofits identified through an authorized EnerGuide energy assessment. In combination with available grants announced in the Fall Economic Statement, this would help eligible participants make deeper, more costly retrofits that have the biggest impact in reducing a home's environmental footprint and energy bills. This program will also include a dedicated stream of funding to support low-income homeowners and rental properties serving low-income renters including cooperatives and not-for-profit owned housing.
>
> The program would be available by summer 2021. It would be easily accessible through straightforward online tools, and is expected to help build Canadian supply chains for energy efficient products. It is estimated that more than 200,000 households would take advantage of this opportunity." (Department of Finance Canada, 2021)

Most recently, the Government of Canada launched the Canada Greener Homes Grant (NRCan, 2021a), which included:

> "Up to 700,000 grants of up to $5,000 to help homeowners make energy efficient retrofits to their homes, such as better insulation.
>
> EnerGuide evaluations (worth up to $600) and expert advice to homeowners so they can begin to plan their retrofits.
>
> Recruitment and training of EnerGuide energy advisors to meet the increased demand; this will create new jobs across Canada." (NRCan, 2021a)

This research aimed to review the literature relevant to DERs in Canada and canvass industry actors and advocates to generate recommendations on how the Government of Canada can advance market penetration of DERs and reduce GHG emissions in the residential building sector. The objectives of this research were to:

- Review academic literature pertinent to residential building retrofits in Canada;
- Review best-practice technologies and innovations in the residential building retrofit sector;
- Canvass advocates and actors in the green building sector for their recommendations to the federal government on advancing the uptake of residential DERs;
- Generate a set of recommendations for the federal government on advancing the uptake of residential DERs;
- Provide a formative evaluation of the federal government's residential retrofit plans based on the review and canvassing.

1.2 Theoretical Framework

The theoretical framework for this research project drew on four concepts relevant to building retrofits: the multi-level, multi-phase perspective, the energy technology innovation system, strategic niche management theory, and theories of innovation intermediaries.

1.2.1 Multi-level, Multi-phase Perspective

Central to my understanding for this research was the multi-level, multi-phase perspective on transitions (Figure 1.3) discussed by Loorbach et al. (2017). Their conceptualization drew from the original work by Rip (1995) and Geels (2002). In the piece by Loorbach et al., they provided a multi-level, multi-phase perspective framework for changing societal infrastructure and institutions at the niche, regime, and landscape levels.

This theorization of transitions identified five characteristics. The first was nonlinearity; meaning, transitions do not occur gradually; they proceed in steps or jolts when disruptive change occurs. The second was that they are multi-level in that they exist in a system with a distinguishable context (landscape), dominant configuration (regime), and alternatives (niches). Thirdly, transitions are coevolutionary, which ties in nicely with the previous two characteristics. Transitions do not occur in a linear fashion of causality at one level; transitions result from different phenomena interacting and evolving together at various levels. The concept of a transition itself implies the fourth characteristic: emergence. From the chaotic coevolution emerges a new order. Loorbach et al. (2017) discussed how this new order is unpredictable, but it can be shaped through coordination. They identified the last characteristic of a transition as variation and selection. A system undergoing transition is heterogenous with a variety of innovations and novelty from which actors choose.

In Figures 1.3a and 1.3c, multiple levels are ordered by increasing structuration from niches to regimes to landscapes. Niches are novelties that actors within a system can create, support, or discourage and generally are phenomena with which they can interact and influence. Niches can reach the regime level, disrupt the dominant configuration, and gain stability. This regime change can then influence the landscape (context). At the same time, the landscape exerts pressure on regimes, opening them up for novelties and pressure on niches, bringing them closer or further from the regimes. Through this process, niches coevolve and adapt to the changing landscape. Chaotic abruptions to landscapes can open large windows of opportunity for niches to enter regimes. Periods of landscape stability can make it more difficult for niche innovations to influence the dominant configuration. In Figure 1.3b, socio-technical regime change over time is illustrated through multiple phases with multiple outcomes.

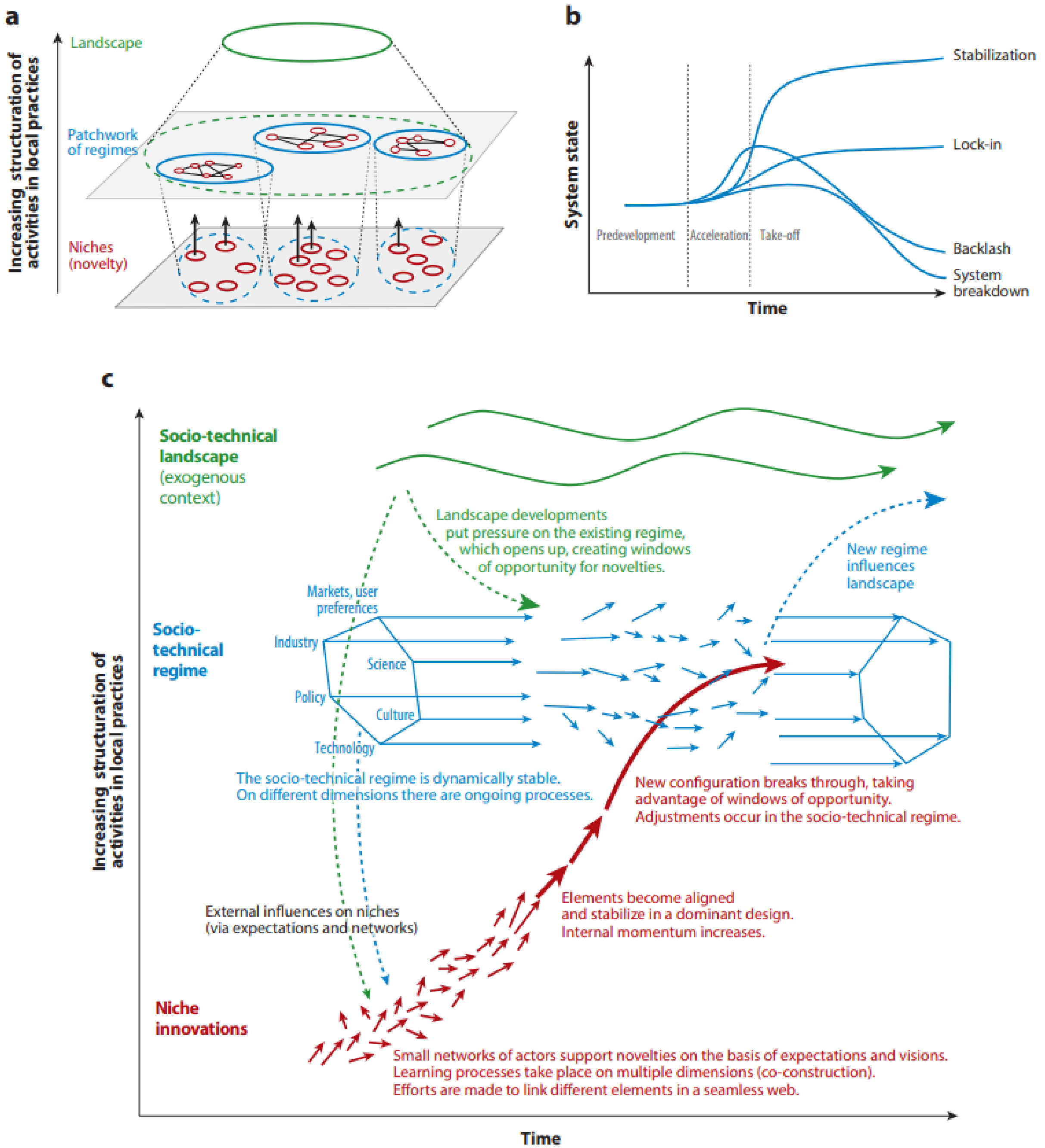

Figure 1.3. The original multi-level, multi-phase perspective on transitions with (a) the multi-level model depicting the coevolution between landscape, socio-technical regimes, and niches; (b) socio-technical regime change as a result of coevolving landscape pressures and emerging niches over time; and (c) the multiphase concept illustrating the nonlinearity of transitions and different types of pathways. Extracted from Loorbach et al. (2017).

1.2.2 Energy Technology Innovation System

The energy technology innovation system (ETIS) described by Gallagher et al. (2012) guided this research. In their seminal review, Gallagher et al. described ETIS as "a systemic perspective on innovation comprising all aspects of energy transformations (supply and demand); all stages of the technology development cycle; and all the major innovation processes, feedbacks, actors, institutions, and networks." The innovation process is illustrated in a chain-linked model (Figure 1.4) to show the feedback processes between the research, development, demonstration, market formation, and diffusion stages. Gallagher et al. emphasized the importance of policymakers to be conscious of the interdependencies within the ETIS to produce more effective policies.

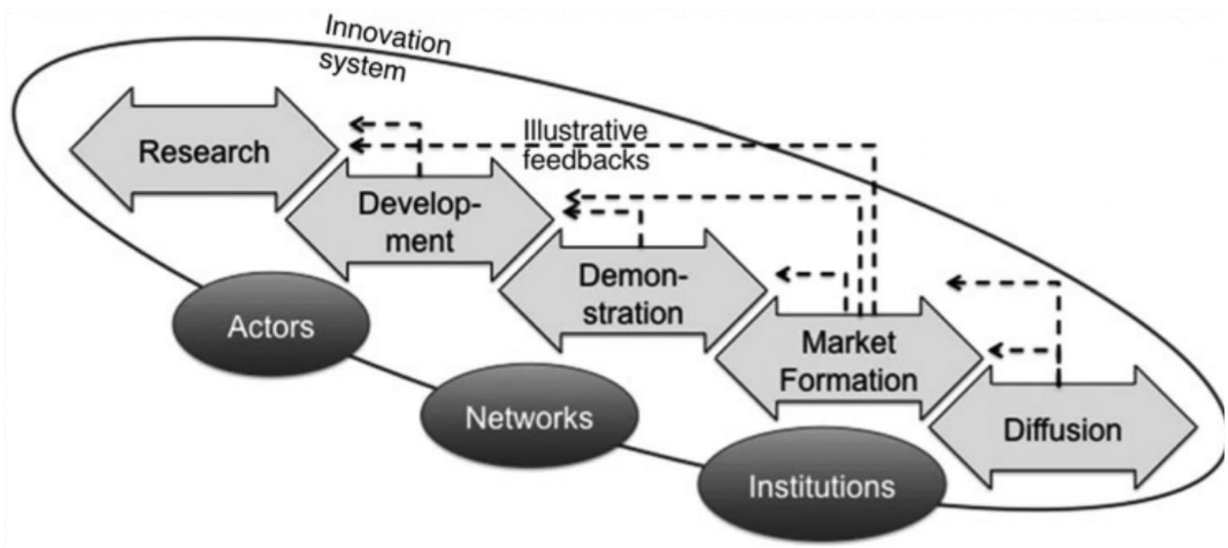

Figure 1.4. Energy technology innovation system diagram extracted from Gallagher et al. (2012).

1.2.3 Strategic Niche Management

Strategic niche management (SNM) was another theory in which I grounded this research. This theory put forward that policymakers and other actors are, in fact, actors capable of playing active roles in the development and management of niches to achieve specific socio-technical changes in regimes and landscapes (Kemp et al., 1998). They theorized SNM as a "strategy for governments to manage the transition process to a different regime." However, non-governmental actors can also engage in SNM to push an agenda. Kemp et al. defined SNM as "a concentrated effort to develop protected spaces for certain applications of a new technology." This process of protecting and pushing the development of niche innovations helped theorize the government's role in increasing uptake of retrofits in Canada.

1.2.4 Innovation Intermediaries

The fourth concept I framed my research around was the idea of intermediaries serving as green champions for innovations. Intermediaries are third-party actors that can assist with community energy projects and are particularly useful for communities with low capacity. They are essential to a sustainable energy transition because of their role in SNM and consolidating, growing, and diffusing niche innovations (Hargreaves et al., 2013). In their interviews with 15 intermediaries in the UK, Hargreaves et al. learned more about their value in energy transitions. They theorized three key roles intermediaries play in niche development and identified a fourth role that has begun to emerge: intermediaries create principles from the lessons they learn; they create libraries for these lessons and principles to be shared, such as websites, blogs, and fact sheets; intermediaries frame and coordinate action inside local projects; and, the fourth role that is emerging, serve as a broker and coordinator of partnerships between projects and actors (Hargreaves et al., 2013).

Gliedt et al. (2018) similarly investigated intermediaries in the United States. They explored the potential for intermediaries to assist with strategies for green job creation, infrastructure changes, technological development, and overall green economic development (Gliedt et al., 2018). To help facilitate this development, Gliedt et al. suggested the multi-level perspective framework sustainability that theorists such as Loorbach et al. (2017) suggested for changing societal infrastructure and institutions. According to Loorbach et al., niche innovations can progress to the regime level during times of uncertainty. The role of intermediaries is to organize these innovations to influence and strengthen a sustainable regime with the capacity to change the landscape (Gliedt et al., 2018).

1.2.5 Relationships Between Theories and Research

The multi-level, multi-phase perspective framework was used for this research because of its understanding of changing societal infrastructure. The COVID-19 pandemic exemplifies the nonlinearity of transitions as many projects and processes were paused when the pandemic began and more will be jolted back to life (or new projects jolted into life) as the pandemic ends. Through this framework, I recognized the pandemic and climate crisis intersection as a disruption of the socio-technical landscape that opened up the socio-technical regime for niche innovations. The pandemic created a demand for shovel-ready and shovel-worthy projects to revitalize economies, and the climate crisis demanded high efficient buildings. To ensure the climate crisis' demands are met, DER niche innovation must increase in structuration and travel into the socio-technical regime so they are included in post-pandemic economic recoveries.

The increasing structuration of niche innovations is aptly conceptualized in the ETIS which was why it was also used for this research. The ETIS displays the pathway niches travel to penetrate into the socio-technical regime. So while DER innovations exist in Canada and the world, they have not fully penetrated into the socio-technical regime, and therefore have not reached the final stage of the ETIS. For these niche innovations to be invested in in an economic recovery, they must progress to the end of the demonstration phase and be ready for market formation and diffusion.

Purposefully working to increase the structuration of niches is SNM. Policymakers can use legislation, agreements, and their influence to move DER niches past demonstration and create markets. That is why, in this research, I investigated what policies policymakers could use to form these markets and diffuse the innovations into the socio-technical regime. Furthermore, third-party actors can engage in SNM, thus Hargreave et al.'s (2013) and Gliedt et al.'s discussions of innovation intermediaries were also central to my framing of this research.

The core underlying understanding of this research was that climate change and the COVID-19 pandemic created a context that opened up regimes for a transition to environmental sustainability and it may take an intermediary or policymakers engaging in SNM for niche innovations to diffuse further down the ETIS into the regime level, and shape a sustainable landscape.

2.0 Methods

This social policy research was applied research grounded in theory. The data collected was analyzed thematically and used to conduct a formative evaluation of the Government of Canada's proposed retrofit policies and to generate a list of recommendations to increase the diffusion of DERs in Canada (Figure 2.1). I drew evaluative criteria from a literature review of retrofits in Canada chosen through purposeful sampling (peer-reviewed and grey literature) and recommendations from green building sector advocates and actors. This evaluation was limited because these are only proposals and their impacts were not yet known.

For the applied research, I canvassed building sector advocates and actors to understand what measures they recommend the federal government implement to scale up the retrofit economy. I conducted semi-structured interviews with seven representatives of the sector chosen through purposeful sampling. The participants included engineers, building science specialists, policy researchers, and CEOs of green building companies. The questions asked are in the appendix. I conducted interviews over video chat, which I recorded with permission, and then transcribed.

I thematically analyzed interview and literature review data. I managed the interview data through a process of familiarization, indexation, data review, and data summary. I then input interview data into a table for visualization. From interview and literature data, I constructed a side-by-side comparison sheet between government proposals, literature review data, and interview data; I sorted the data points into the categories: financing, market creation, training, business model, program design, and building codes/targets. In comparison with the data, I evaluated the government proposals/actions. Using my evaluation built on literature review data and interview data, I abstracted and interpreted analytical concepts and themes and generated recommendations to the federal government for retrofit policies.

From there, I tested the government's proposals and my recommendations against original criteria for good policy: effectiveness, cost-effectiveness, long-term performance, social value, and political acceptance. These criteria are defined in Box 2.1 and posed with a question to be answered by myself given the literature and interview data. They are able to be used to evaluate policies and determine if they will likely serve a collective good, do so cost-effectively, be politically viable, be effective at achieving the intended goal, and if they will deliver long-term results. The good policy criteria were also chosen based on discussions from policy academics. Pal (2014) discussed the importance of impact evaluations and cost-effectiveness analyses. Gibson (2006) discussed many criteria important in assessments; I drew social value as a criteria from their paper.

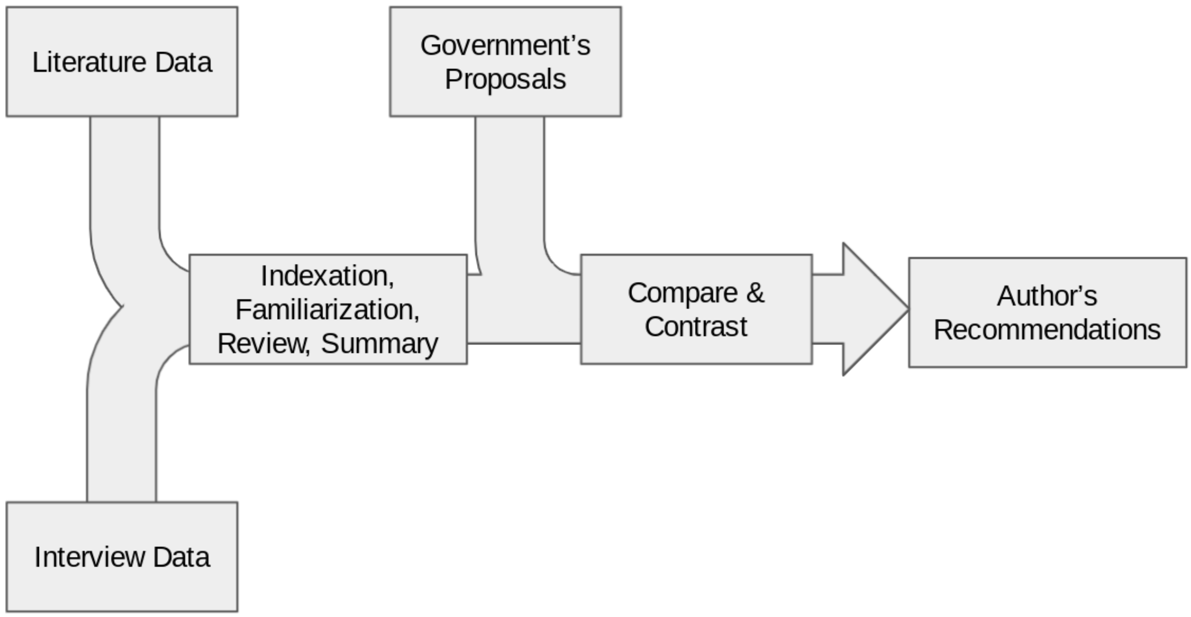

Figure 2.1. Formative evaluation framework.

Box 2.1. Criteria for good policy.

Effectiveness: the policy is successful at lowering GHG emissions in residential buildings.

- Is the policy likely to lower GHG emissions and energy demand in residential buildings?

Cost-effectiveness: the policy successfully lowers GHG emissions in residential buildings in a cost-effective manner.

- Is the policy likely to use money effectively?

Long-term performance: the DERs have long-lived benefits and performance integrity.

- Is the policy likely to produce retrofits with long lasting performance?

Social value: the policy has value beyond GHG emission reduction.

- Is the policy likely to have social benefits beyond decreased GHG emissions and residential energy demand?

Political acceptance: the policy is politically viable.

- Is the policy politically acceptable?

3.0 Literature Review

Here I present a review of grey and academic literature on retrofits in Canada chosen through purposeful sampling based on relevance to this research. The purpose of this review was to gain an understanding of global best practices in DER program design, business models, and financing mechanisms. Given how nascent much of the innovations and technologies are, I discussed numerous technical reports and other grey literature in addition to academic literature. In anticipation of the need for significant market intervention, I also reviewed literature on market intermediaries and social housing. Given the political opportunity, many organizations and authors have published recommendations specific to Canada for increasing the uptake of DERs; these are also presented here. What is not reviewed here, was beyond the scope of this research, but important considerations for DER policies were individual technologies such as high efficiency windows, different types of insulation, heat pumps, or HVAC systems.

3.1 Business Models

Brown (2018) provided an assessment of the leading business models for retrofits.

3.1.1 Atomized Market Model

The dominant model for retrofits is the atomized market model. The customer faces an uncoordinated complex interface in the atomized market model and is unlikely to deliver a comprehensive retrofit. As seen in Figure 3.1.a., the customer interacts with all parties involved individually. Retrofits are typically done in a piecemeal style, increasing the potential drop-out points for customers to abandon the venture for a comprehensive retrofit. The atomized market model is not very successful at decreasing energy demand.

3.1.2 Market Intermediary Model

The market intermediary model (Figure 3.1.b.) is another standard model. In this model, a market intermediary supports the customer by coordinating all the supply chain actors, simplifying the customer interface and journey. The market intermediary model reduces energy demand more than the atomized model but still does not reach the total energy demand reduction potential.

3.1.3 One-stop-shop Model

The one-stop-shop model (Figure 3.1.c.) features greater supply chain integration and a single point of access customer interface. A single company offers energy auditing services and contractors to design, build, and install the retrofits; this facilitates communication between the energy auditor and the contractors to recommend and deliver a whole-of-house retrofit. This model can also include the coordination of financing and, in some cases, has been through cooperatives. The one-stop-shop model better lowers energy demand than the market intermediary or atomized market models because of the simplified customer experience and the communication between supply chain actors.

3.1.4 Energy Service Agreement Model

The energy service agreement (ESA) model is displayed in Figure 3.1.d. In an ESA, the customer signs a contract with an energy supply contractor (ESCO; sometimes called an energy supply company) for guaranteed water temperature, building temperature, and power supply over 15+ years. In exchange, the ESCO designs and builds a comprehensive retrofit and is responsible for the energy services operation. Additionally, ESCOs or third parties finance the capital costs and debt accrued in designing and building the retrofit and operating expenses; the customer is only responsible for paying their significantly reduced energy bill to the utility company and the energy-saving performance contract (ESPC) payments to the ESCO.

ESAs are much more effective at reducing energy demand than the atomized market model, the market intermediary model, and the one-stop-shop model. ESA models rely on a long-term contract between the customer and an ESCO to guarantee quality service with a stipulation of under-performance penalties. Therefore, for the ESCO to deliver the most quality service, they must implement a comprehensive residential retrofit to reduce emissions to an annual net zero. Also, the ESA model shares the simplistic customer journey observed in the market intermediary and one-stop-shop models.

3.1.5 Managed Energy Service Agreement Model

The managed energy service agreement (MESA) model is the most cutting-edge innovation for comprehensive retrofits (Figure 3.1e.). Brown (2018) and Brown, Kivimaa, & Sorrell (Brown, Kivimaa, & Sorrell, 2019) discussed the Energiesprong model and fused it with the MESA model. Under the MESA model, the ESCO simplifies the customer interface by coordinating with the supply chain actors, finance providers, and utility companies to pay the customer's energy bill. The customer only pays their ESPC payments. The MESA model should have a similar impact on energy demand as the ESA model but may see more significant societal results incorporating the Energiesprong model.

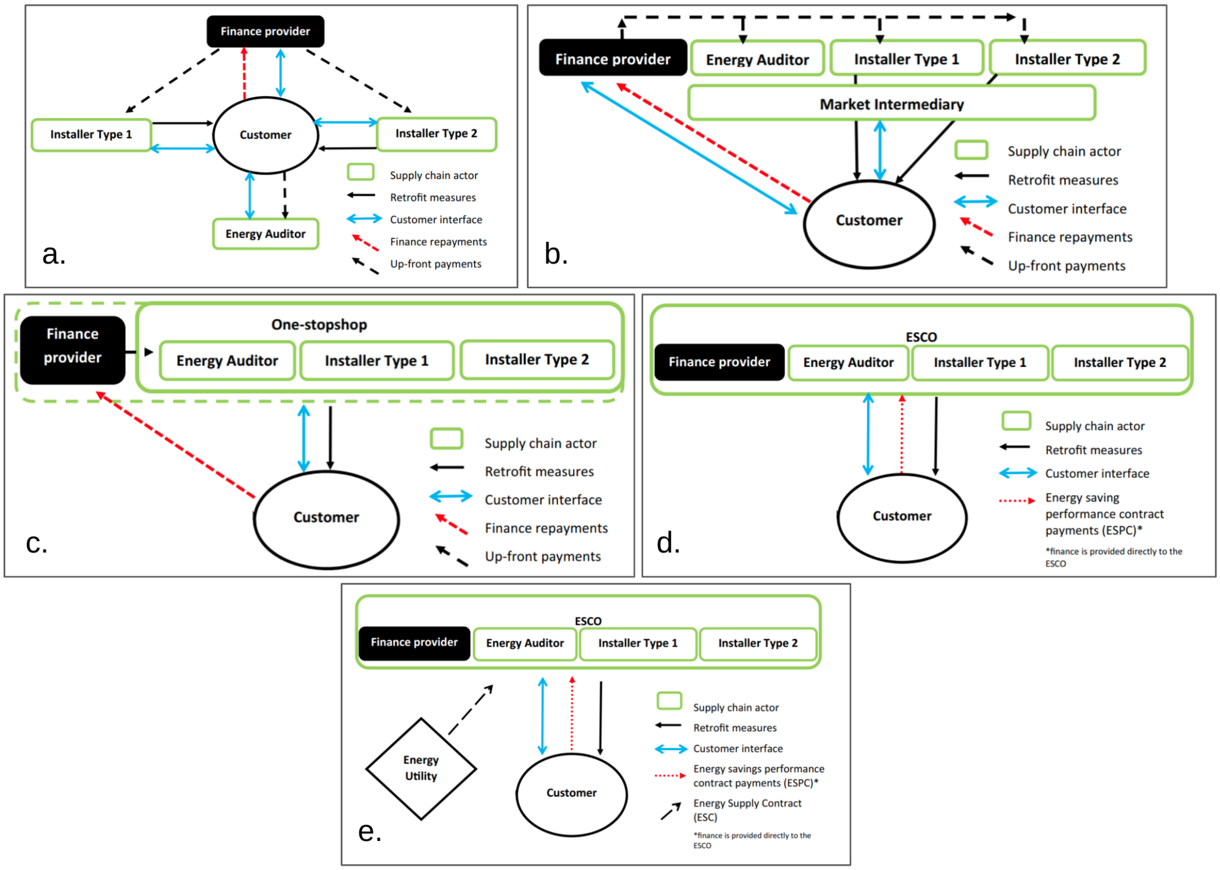

Figure 3.1. Business models for building retrofits, extracted from Brown (2018).

3.2 Energiesprong

Energiesprong (Dutch for 'Energy Leap') is an innovative business model developed in the Netherlands and is considered a cutting-edge innovation by academics and industry (Energiesprong Foundation, 2021). The model aims to comprehensively retrofit homes to net-zero energy consumption promptly with minimal invasiveness. Building dimensions are taken with digital capture technologies (such as LiDAR) to produce a building's digital map. Builders use the digital map to construct envelopes of highly-insulated wall facades and roofs off-site. The panels are then shipped to the site and fitted. Also, households can install renewable heat systems, photovoltaic panels, and ventilation controls to become net-zero and produce more energy than they consume. Most projects target annual net-zero consumption, with program managers offering 30-year guarantees. The 30-year guarantee demonstrates how confident the program managers are in their ability to deliver net-zero results. In the Netherlands, they have retrofitted more than 2,000 homes and reduced installation time to less than one week (Brown et al., 2018; TranSitionZero, 2019). The impact of the pandemic on the projects is unknown, but they were contracted for 111,000 DERs by 2020. The early projects reduced energy consumption by 70% and cost €130,000 per housing unit. The most recent estimates placed costs at €65,000 per unit; managers aim for €40,000 per unit (nearly CAD 60,000) (Ürge-Vorsatz et al., 2020).

The Energiesprong model offers additional benefits because of the highly industrialized process of manufacturing and installing. This process means that energy demand reductions happen much sooner. Additionally, the Energiesprong model emphasizes facade replacement, which can serve as an advertisement and increase the uptake of the model. Households typically finance Energiesprong projects through future energy costs; that is, homeowners pay off the retrofit through a payment plan matched to their energy bill before the retrofit. This payment mechanism means that third parties must subsidize projects; otherwise, high home energy costs will remain high home energy costs.

The Energiesprong Foundation commissioned an independent research group to measure social acceptance in 613 of their retrofitted homes from The Netherlands and in 154 homes they monitored energy performance for a year (TranSitionZero, 2019). They found that in early projects, performance can be an issue, but this is quickly resolved as builders become more practiced in ensuring air-tightness and blower tests are done. Data from 46 of the homes monitored in Heerhugowaard, The Netherlands are shown in Figure 3.2. The left bar shows the contracted performance with photovoltaic production equalling energy demand; the pink dot shows the net balance between production and consumption; one-year monitoring showed production exceeding consumption. Average tenant satisfaction is shown in Table 3.1. Tenants were generally happy with the end result, but not so happy with the process. The researchers said this highlights the importance of meaningfully engaging tenants. Another Energiesprong project out of the UK found tenant satisfaction at a 9.1/10 in a 50 house retrofit (Energiesprong Foundation, 2015).

Various organizations have launched projects following this model in the Netherlands, Germany, the UK, Italy, California, and New York. In Ottawa, Ontario, NRCan piloted the Prefabricated Exterior Energy Retrofit (PEER) project, an ongoing DER of a two-storey housing project with Ottawa Community Housing (NRCan, 2021b). Additionally, NRCan has partnered with Butterwick Construction & Carpentry Ltd. for the DER of Sundance Housing Co-operative in Edmonton, Alberta (Sundance Housing Co-operative, 2021). This project received $2.5 million from the Green Infrastructure fund from NRCan and $2.9 million from other sources (NRCan, 2019). Following the Energiesprong model, they were able to retrofit 15 buildings with 59 units of 1970s wood frame townhouse complexes. In coordination with a local hardware store, the project engineers built the panels in a repurposed Quonset. The project's goal is to achieve net-zero energy-ready performance levels, switch from natural gas heating to electric heating, and are expected to reduce GHG emissions and energy consumption by 70 to 80%.

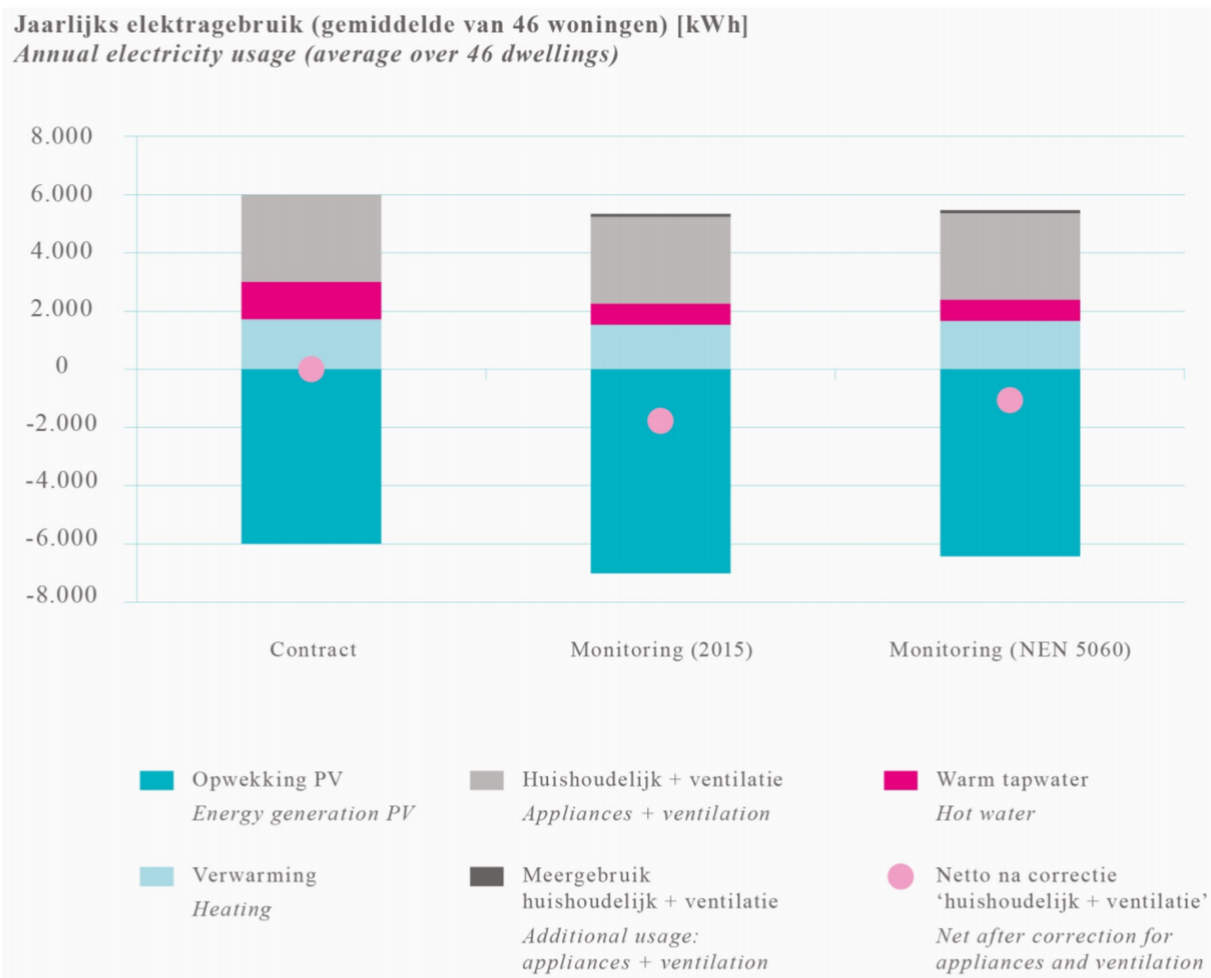

Figure 3.2. Average yearly energy use of 46 homes in Heerhugowaard, extracted from TranSitionZero (2019).

Table 3.1. Tenant satisfaction measured in 613 projects, copied from TranSitionZero (2019).

Averaged tenant satisfaction (on a scale of 1 - 10)	
Information provided	6.1
Appointments	5.8
Planning	5.4
Builders	7.7
End result	7.5

3.3 Financing

The six primary archetypes of finance mechanisms for retrofits were outlined by Brown, Sorrell, et al. (2019) and shown in Table 3.2. In the UK, DERs cost at least CAD 25,000 to 35,000 with 20 year payback periods (Brown, Sorrell, et al., 2019). Payback periods this long are discouraging if the interest rates on loans are not low. Low-interest financing remains a requirement for DERs. Brown, Kivimaa, Rosenow, et al. (2019) remark that, at least in the UK, finance mechanisms are more of an enabler for retrofits than a solution to a barrier; the barrier is a complex customer journey.

3.3.1 Public Loans

Public loans are a common retrofit strategy. A government can provide a low-cost loan to a household to retrofit. Public loans can also be offered from government departments or state-run banks, as is familiar from Germany’s very successful Kreditanstalt Für Wiederaufbau (KfW). Public loans are such successful financing mechanisms for retrofits because governments can offer very low-interest rates, absorb the risk that private lenders will not, and benefit from government subsidies.

The Scottish government offers loans at 0% interest through their Home Energy Scotland loan and Home Energy Efficiency Programme for Scotland equity loans (Scottish Government, 2020). Scotland’s equity loan offers roughly CAD 70,000, and the equity loan is repaid upon sale of the property, so the homeowner does not pay anything.

3.3.2 On-bill Financing

On-bill financing is an innovative mechanism for financing retrofits. The debt is owed to the energy company and paid back through the energy bill through this mechanism. The ‘golden rule’ is that energy savings must be greater or equal to loan repayments. Manitoba Hydro’s on-bill financing has funded almost $300 million in energy efficiency upgrades since 2001;

however, nearly all of these improvements have been for single-measure window, door, or furnace replacements and not deep energy retrofits (Zimring et al., 2014). On-bill financing is criticized later in this paper.

3.3.3 Property Assessed Clean Energy

Property assessed clean energy (PACE) was designed for financing retrofits. Traditionally through PACE, a municipality funds the project, and the customer repays through a property tax. This financing mechanism ties the loan to the property and not the homeowner and provides more security for the investor. More recently, municipalities have acted as facilitators of PACE programs, and private financiers have offered the capital and are owed the debt.

Kennedy et al. (2020) discussed PACE more in-depth than Brown, Sorrell, et al. (2019) and in a Canadian context. They highlighted PACE as an opportunity to unlock private capital for both commercial and residential retrofits. According to them, municipalities require provincial legislation to authorize using PACE programs to finance private property. Kennedy et al. (2020) listed recommendations provincial legislators should consider; a select few include: funding is available for 100% of project costs, programs can access project capital from private and public sources, PACE financing is not counted towards the municipal debt ceiling, and local governments must implement consumer protection measures in program design. They noted that the mortgage industry is less comfortable with PACE programs because mortgages are considered subordinate to property taxes. One method for navigating this issue is to require mortgage-lender consent to qualify for PACE; this became a problem with Toronto's PACE program and is discussed below by Jamali (2015). Kennedy et al. (2020) recommended three program features to avoid this problem: "prohibiting acceleration or extinguishment of PACE assessments in the case of default or foreclosure; clarifying in legislation that the primary lien status only applies to the delinquent portion of the PACE assessment; setting up a third-party loan loss reserve fund."

3.3.4 Others

Brown, Sorrell, et al. (2019) discussed a few more financing mechanisms. Green mortgages are another form of private financing. Like PACE, the debt is secured to the property and paid over typically 25+ years but tied to home equity. ESAs were discussed in the previous section of this paper. Policymakers offer these programs successfully in Europe for deep energy retrofits. Community financing mechanisms such as credit unions use equity capital from multiple individuals to fund retrofits. Traditionally, this is more popular with renewable energy projects but can be applied to DERs. This financing mechanism can be used to create housing cooperatives and for financing apartment building retrofits.

Table 3.2. Finance mechanisms for building retrofits, modified from Brown, Sorrell, et al. (2019).

TYPE OF FINANCE MECHANISM	SOURCE OF CAPITAL	FINANCIAL INSTRUMENT	PROJECT PERFORMANCE	POINT OF SALE	SECURITY AND UNDERWRITING	REPAYMENT CHANNEL
PUBLIC LOAN/ CREDIT ENHANCEMENT	Government spending	Debt	Minimum CO_2 saving	Third party finance provider	No security - basic credit check	Unsecured Loan/ equity release
	Public Bank	Debt (bonds)		Retail bank	No security - basic credit check	Unsecured Loan
	Hybrid – EIB, LEEF & Private lender	Debt		Housing provider	Varies	Revolving phase then full repayment
ON BILL FINANCING/ ON BILL REPAYMENT	Third party private Sector	Debt	Bill neutrality (Golden rule)	Third party finance provider	Energy meter & bill history	Energy Bills
	Energy Utility & public/ credit enhancements	Debt (some securitised examples)	Often Bill neutrality	Energy utility		
PROPERTY ASSESSED CLEAN ENERGY (PACE)	Municipal bond -> private capital	Debt (bonds)	None - approved contractor schemes	Contractor	Lien on property & tax bill-based underwriting	Property taxes
GREEN MORTGAGE	Covered Bond market	Mortgage (equity & debt)	EPC improvement	Mortgage provider	Detailed credit check	Mortgage payments
	Member deposits	Equity				
ENERGY SERVICES AGREEMENT	ESCO -> Public Bank	Debt & Equity	Energy Performance Guarantee	Contractor	Based on ESCO	Energy performance contract
	ESCO -> Institutional investor				Based on ESCO & bill payment history	
COMMUNITY FINANCING	Member share issue	Equity	None	Contractor	Credit check	Hire Purchase agreement-> dividends

3.4 Program Design

Program design is a significantly influential factor in the diffusion of retrofits and is therefore reviewed here.

Hoicka et al. (2014) analyzed four residential retrofit programs delivered consecutively over 12 years in Waterloo, Canada. The four programs differed in design as follows: Program 1 offered information-only (comments from an energy advisor, a customized report, and an energy rating sticker); Program 2 was the continuation of Program 1 with the addition of a performance-based grant (mean $650) for implementing energy efficiency measures within 18 months; Program 3 was also information-only with no financial reward; Program 4 offered prescriptive grants (mean $2,370) based on retrofit type. They found that incentives with verified improvements resulted in higher participation. Based on consistently high demand and that only 16-18% of older homes in the area have participated in the programs, the authors asserted that many houses would still benefit from a program and could be incentivized to participate. In their paper, they also identified many barriers to retrofit adoption in the regional context:

> "lack of visibility of energy usage; lack of appropriate price signals due to relatively low energy prices that do not reflect externalities; the barrier of financing equipment upgrades and renovation projects; factors that are internal to the individual, such as attitudes, norms, mental models, and capabilities; and contextual factors, such as competing priorities, availability of information and products, and the local supply of contractors." (Hoicka et al., 2014)

Finally, Hoicka et al. (2014) recommended that policymakers and program designers "avoid one size fits all programs in favour of designing for particular subsets of the population."

Continuing with the analysis of the residential retrofit programs in Waterloo, Canada, Hoicka & Parker (2018) assessed how well participants followed the "house as a system" approach. This approach emphasizes completing multiple retrofits at once and in a particular order for greater building performance rather than the business-as-usual piecemeal approach. Following the house as a system approach most often means air sealing and insulating the envelope to reduce heat loss as the priority; however, the authors found that participants often upgraded furnaces and windows as singular actions. For the most part, when energy advisors gave more recommendations (on average, they gave four), more participants returned for follow-up assessments. Based on the database of retrofit actions taken compared with data on advice provided, Hoicka & Parker suggested there were more barriers to improving building envelopes than there were to improving heating systems because advisors often recommended envelope improvements as a priority, but participants chose otherwise. The authors discussed how the lack of information and inconvenience may have been barriers. Other general barriers included the time limit and the incompatibility between the grants offered and the programs' intentions to follow the house as a system approach. They also highlighted the success of performance-based grants compared with list-based grants. Hoicka & Parker concluded their study by noting that participants responded well to complex recommendations and that program managers need to emphasize the sequence and priority of retrofits if DERs are the goal.

Brown, Kivimaa, Rosenow, et al. (2019) discussed the systemic challenges of retrofitting residential buildings in the UK and offered policy solutions. The four key systemic challenges for driving retrofit uptake in the UK are capital cost and split incentives; complexity, disruption, timing; information, engagement, trust; and uncertain benefits and quality. To overcome these barriers, they recommended a policy mix of carrots, sticks, and tambourines. For the regulations (sticks), they recommended making energy efficiency an infrastructure priority with national minimum energy efficiency standards and a retrofit quality assurance standard. The authors stressed that financial incentives (carrots) are more likely enablers of retrofits but not drivers. The authors recommended low-interest PACE financing mechanisms secured by the government, property tax reductions for good energy efficiency rating, and income tax rebates. They also recommended applying incentives at critical junctions for greater success, such as when properties change hands, during major renovations or heating replacements. Germany's state-owned bank, KfW, is referenced as a successful financing scheme because of the low capital cost and simplified customer journey. To raise awareness and promote programs (tambourines), the authors recommended creating new institutions and intermediaries. Specifically, they suggested a "National Retrofit Taskforce/Agency" with centralized information and data to provide guidance and monitor outcomes and "area-based intermediaries" for local tailoring and delivery.

Jamali (2015) evaluated the City of Toronto's Home Energy Loan Program (HELP). HELP offers low-interest loans to homeowners through a Local Improvement Charge (LIC) at maximum funding of 5% of the home value; LICs, like PACE, tie the agreement to the property and not the homeowner. While average electricity savings were unimpressive at 2%, participants in the program reduced natural gas consumption on average by 31%. However, grading with the EnerGuide labelling scale showed homes did not advance to "most efficient" home status. On average, participants in HELP increased efficiency from 52 to 65 on a grading scale to 100, with 80+ being "most efficient." The most popular improvement was window replacement (68% of participants). According to participants and the program manager, the most identified barrier to program success was securing the mortgage tender consent. Because mortgages are subordinate liens to property taxes (the finance mechanism for PACE), their consent is required for borrowers to be approved for HELP. The author noted poor marketing, promotion, and uptake of HELP and recommended using some of the $20 million allocated to the program for community-based social marketing. Additionally, the author recommended mandating home energy ratings and disclosing the information at resale, as well as setting clear GHG and energy reduction targets. The author suggested an on-bill financing strategy to overcome the mortgage tender consent barrier, so the loan is still tied to the property, but this requires considerable collaboration between the City and the local utility companies. Jamali (2015) concluded their evaluation by remarking, "HELP is basically assisting homeowners who are already interested in retrofitting their property."

Jermyn & Richman (2016) also studied retrofit strategies in the City of Toronto; their research focused on developing DER strategies for single-family houses in Toronto. They modelled cost and energy reductions of DERs in three archetypal houses: Century Home, War Time Home, and Semi-Detached Century Home (Figure 3.3). These retrofits often targeted a 50% reduction in energy use from 204 kWh/m^2 to 100 kWh/m^2. They modelled for heating and cooling energy intensity goals of 75 kWh/m^2 and 25 kWh/m^2 (the Passive House EnerPHit estimated equivalency). Jermyn & Richman found that meeting both targets was achievable. Their modelling data showed that furnace efficiency and building envelope were the most important for ensuring energy intensity reductions, and windows were one of the more cost-intensive retrofits. The model selected for the lowest cost per unit of energy saved over a one-year modelling period. So furnace upgrades were selected first for the Century Home and the Semi-Detached Century Home because they were cost-effective energy reductions, not because they made the most significant impact on energy intensity. Their data showed furnace interventions only lowered energy intensity by less than 10 kWh/m^2. At the same time, other measures like air sealing and insulating walls, slab and basement yielded energy intensity reductions between 11 and 36 kWh/m^2. On the other hand, in the War Time Home, furnace replacement was selected second and yielded 23 kWh/m^2 energy intensity reduction. The authors believed the model produced this result based on the assumption that War Time Homes had older, less efficient furnaces than the other archetypes (R. Richman, personal communication, June 9, 2021). Total capital cost estimates ranged from $30,000 to 80,000 depending on building archetype and energy intensity target (Table 3.3). Jermyn & Richman noted that cost depends on the house's surface area and geometry, particularly with larger surface area to volume ratios. The authors identified two main drawbacks: first, because many retrofits interventions are on the interior, homeowners could lose between 5 and 40 m^2 in floor space depending on home archetype; second, the capital cost is likely to prohibit the average homeowner from investing, so they recommended government grants for DERs.

Figure 3.3. Century Home archetype (left) and War Time Home archetype (right) extracted from Jermyn & Richman (2016).

Table 3.3. Capital cost to reach performance targets by archetype in Jermyn & Richman (2016).

Archetype	75 kWh/m^2	EnerPHIT$_{EQUIV}$
Century	$45,353	$77,080
Century-semi	$35,422	$56,257
War time	$29,504	$53,250

3.5 Third-Party Interventionists

As introduced in a previous section of this report, innovation intermediaries can play critical roles in advancing the diffusion of DERs in the ETIS (Gliedt et al., 2018; Hargreaves et al., 2013). A newer and less discussed understanding of transitions introduced the idea of middle actors (Janda & Parag, 2013). Intermediaries and middle actors are similar but different, and I categorize them together as third-party interventionists. I explore intermediaries and middle actors more in-depth here.

Kivimaa & Martiskainen (2018) conducted a systematic case study review of intermediaries in Europe from 2005 to 2015. They identified ten intermediaries: local authority agents (planners, energy managers), municipal housing corporations, private housing corporations, business network organizations, independent groups, government energy agencies, government innovation agencies, consultants, regional energy utilities, and international competition. Of these ten types, public sector intermediaries were the most common. They found four different processes through which intermediaries influenced innovation in low-energy buildings: they facilitated building projects; they aimed to create niche markets for new innovations; they implemented new practices in publicly owned or social housing stock; they supported processes to develop new business models. Based on the evidence found in their review, Kivimaa & Martiskainen (2018) saw retrofit market creation and innovation as unlikely without intermediaries.

Kivimaa et al. (2019) built a typology of intermediaries in transitions based on a systematic review of academic literature from 2003 to 2017. The authors grounded their review and typology with a conceptual background in multi-level perspective, strategic niche management, transition management, and technological innovation systems. They identified five types:

> "A *systemic intermediary* operating on all levels (niche, regime, landscape), promoting an explicit transition agenda and taking the lead in aiming for change on the whole system level.
>
> A *regime-based transition intermediary* that is tied through, for example, institutional arrangements or interests to the prevailing socio-technical regime but

> has a specific mandate or goal to promote transition and, thus, interacts (often) with a range of niches or the whole system.
>
> A *niche intermediary* typically working to experiment and advance activities of a particular niche, and trying to influence the prevailing socio-technical system for that niche's benefit.
>
> A *process intermediary* that facilitates a change process or a niche project rather than broader niche (or TIS) level; often without explicit individual agency or agenda, but in support of context-specific (project-based or spatially located) and/or external (niche, regime) priorities set by other actors.
>
> A *user intermediary* translating new niche technologies to users and user preferences to developers and regime actors, qualifying the value of technology offers available." (Kivimaa et al. 2019)

They then proposed a definition of "transition intermediaries":

> "[...] actors and platforms that positively influence sustainability transition processes by linking actors and activities, and their related skills and resources, or by connecting transition visions and demands of networks of actors with existing regimes in order to create momentum for socio-technical system change, to create new collaborations within and across niche technologies, ideas and markets, and to disrupt dominant unsustainable socio-technical configurations." (Kivimaa et al. 2019)

Reflecting on their typology, Kivimaa et al. (2019) put forward a few conclusions on systemic and niche intermediaries. They concluded that "[s]ystemic intermediaries are crucial to guide transitions from a whole system perspective", and that they have "the potential to disrupt existing socio-technical configurations and to assess a range of viable alternatives across multiple niches, regimes and spatial scales." For niche intermediaries, they concluded that they are also crucial for their role in "connect[ing] different experimental projects and aggregat[ing] the build-up of new solutions for future socio-technical configurations." They also concluded that systemic and niche intermediaries "need the support of an ecology of different intermediaries as the challenge of sustainability transitions is huge." From these conclusions, Kivimaa et al. (2019) called for policies to monitor transitions and intermediaries and establish new and support existing intermediaries. However, they were unable to conclude how governments can purposefully employ intermediaries to direct transitions.

Janda & Parag (2013) put forward the idea of "middle actors" or "middles." They conceptualized middles as building professionals and practitioners capable of influencing upstream to government, downstream to clients and customers, and sideways to other actors in the building sector; Janda & Parag (2013) clarified the modes of influence to be enabling or disabling technology adoption, mediating strategy, and aggregating knowledge. Building professional and practitioner influences in the three directions are detailed in Table 3.4.

Table 3.4. Building professionals and practitioners: middle-out directions and modes of influence, re-created from Janda & Parag (2013).

		Direction of influence		
		Upstream	Downstream	Sideways
Modes of influence	Enabling	Middle agents can support (or inhibit) efficiency opportunities required by governments and utilities	Professionals can variably encourage or discourage low-carbon technologies in specific projects and designs for which they are hired	Innovations and practices are transferred to professional communities through social learning and professional norms and requirements
	Mediating	Professionals can influence the trajectory of their professional requirements; they may also shape government policy through reports and consultations	Innovations and practices may propagate between middle agents as competitive business opportunities; groups may change to accommodate new opportunities	Innovations and practices may propagate between middle agents as competitive business opportunities; groups may change to accommodate new opportunities
	Aggregating	Aggregating across portfolios to maximize and mainstream savings opportunities for utilities or government	Aggregating across portfolios to maximize understanding for clients, particularly important in small businesses without dedicated capacity	Aggregating between businesses and professional firms to improve learning and knowledge sharing

Building on their conceptualization of middles, Parag & Janda (2014) discussed the agency and capacity of middles and developed that discussion into a “middle-out” framework, at the same time clarifying the difference between intermediaries and middles. To differentiate middles and intermediaries, they problematized the word “intermediary”. Intermediaries are understood as third parties that can broker and facilitate engagement between actors. Parag & Janda (2014) argue this understanding semantically excludes the idea of a “there” between these two actors. Middle actors, on the other hand, do produce an understanding of a “there”. To aid in this understanding, they suggest the term “middle-out” to point to their engagement direction and to complement the terms “top-down” and “bottom-up”. An additional important difference is that intermediaries are more ephemeral and may come and go from the ETIS while middles are embedded in it. The authors defined “agency” as “actors’ willingness and capabilities to make their own free choices,” and “capacity” as “actors’ capability to perform the choices they made." As this relates to residential energy use, top actors such as utility companies often have the capacity to make changes but lack agency. In contrast, consumers have agency but often lack capacity. Parag & Janda (2014) explained that middles have the agency and capacity to create change. They then argued that middles are more than filler and possess better moral, financial, technical, and social positions than other actors; because of these attributes, they can act outwards to increase the agency and capacity of other actors to create change. Janda et al. (2014) discussed middles with a case study from France:

> "[...] the firm Pouget has developed a multi-skilled method for insulating the interior of cooperatively-owned blocks of flats. This multi-family living arrangement poses a collective action problem, as all flat owners would have to jointly agree to pay to upgrade the exterior of the building to insulate it externally. Individual flat owners could decide independently to insulate the interior of their own flat, but hassle and disruption of internal building works could be a barrier. Pouget offers an innovative service that minimizes this hassle by taking detailed measurements in one site visit, cutting materials offsite, and using multi-skilled workers to complete the installation. Their quick fit internal insulation installation takes only 10 h to complete on site and raises the energy rating […] This is a "middle actor" innovation which could not have been "demanded" by customers nor mandated by government. As such, it has *downstream* effects by giving potential customers a new choice of how to insulate their properties." (Janda et al. 2014)

The authors offered other case studies of middles from the UK and France. From their analysis of these case studies, Janda et al. (2014) suggested that builders were actively seeking to increase their agency and capacity in the UK and France.

Cauvain & Karvonen (2018) recognized social housing providers as middles capable of facilitating low carbon transitions and accelerating and diffusing innovations. They highlighted that social housing providers "have multiple motivations and strategies of influence to combine low-carbon innovations with their pre-existing commitments to social housing provision." Table 3.5, copied from Cauvain & Karvonen (2018), summarizes the innovative roles social housing providers play as middles with agency and capacity. Cauvain & Karvonen (2018) learned from their interviews with social housing providers that lowering carbon emissions was not a primary motivator but to protect the social housing sector; the authors pointed this motivation out as another difference between these middles and intermediaries.

Table 3.5. Low carbon innovator roles of social housing providers, copied from Cauvain & Karvonen (2018).

Role	Agency	Capacity	Direction of Influence
Sectoral innovator	Anti-poverty and quality of life, long-term business model for social housing	Advice, engagement practical assistance and signposting often beyond carbon and energy topics	Downstream, sideways
Social innovator	Behavioural change for tenants, awareness raising about energy and carbon	Information campaigns, demonstrators, staff and customer training, partnership building	Downstream, sideways
Process innovator	Technical, financial and policy innovations, learning by doing	Planning and executing low-carbon installations and monitoring performance, experiments and pilots, interpreting policy, financial and business planning, case studies	Sideways, upstream
Civic innovator	Situated change across different sectors to achieve energy efficiency and low carbon goals	Influence through networks, partnerships, procurement and contract management, advocacy, coalition building, political engagement	Downstream, sideways, upstream

3.6 Social Housing

As recognized in the previous section, social housing is an important sector for the diffusion of DER innovations because social housing providers have more capacity than private sector individuals, and they have a mandated interest in providing healthy, affordable residences.

In their recent book, Tsenkova (2021d) evaluated retrofit programs in Toronto, Vancouver, Edmonton, and Calgary's affordable housing sectors during and after *Canada's Economic Action Plan* (CEAP) and offered valuable lessons for the design, planning, and implementation of energy retrofits programs in Canada.

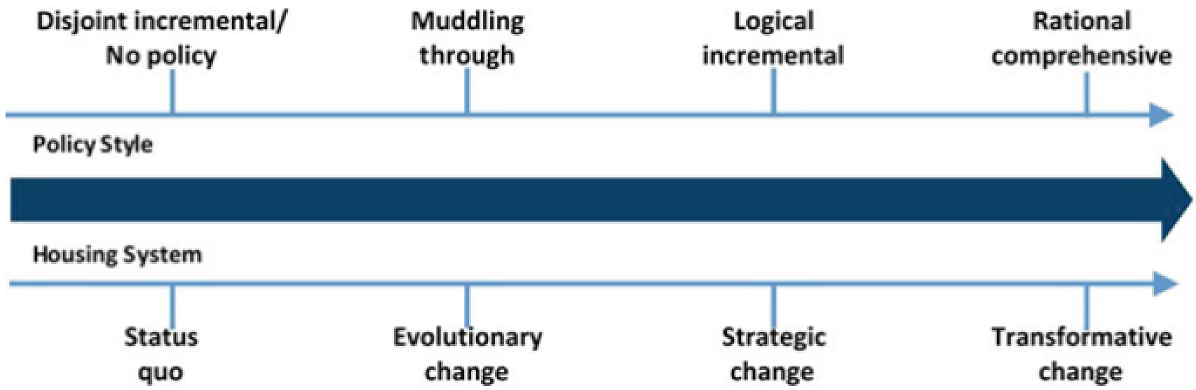

Figure 3.4. Housing Policy Design Continuum extracted from Tsenkova (2021b)

They theorized a "Housing Policy Design Continuum" (Figure 3.4) to illustrate the relationship between policy choices and housing systems (Tsenkova, 2021b). In the idealized model, rational policy-making involves goal setting, analysis of strategies, and choosing the most efficient and effective path leading to transformative change. Incremental policy-making acts through trial-and-error, conceding some efficiency and effectiveness for change over more time. When trial-and-error does not lead to strategic change, Tsenkova referred to this as "muddling through" and noted that the lack of continuity and commitment can reverse positive outcomes. When policy-makers employ disjointed and incremental policies, the status quo persists. As of 2021, Tsenkova characterized Canada's energy-efficient affordable housing policy style as "muddling through." Tsenkova credited the importance of federal initiatives such as the *National Housing Strategy* and various green building programs. Still, they insisted a long-term strategy for social and affordable housing is needed in Canada. It needs to be complemented with large-scale retrofit programs systematically supported financially and through regulation (Tsenkova, 2021h).

Through *CEAP* and *BC Housing Renovation Partnership*, governments provided comprehensive packages for retrofits and improvements in British Columbia's social housing sector--primarily in Vancouver (Tsenkova, 2021a). They noted positives of the program like the grant structure, which keeps rent low, and the incorporation of ESCOs made the program run more efficiently due to their one-stop-shop model. Tsenkova pointed out a challenge of this initiative, as the managers often had to choose between retrofits and outstanding repairs. Furthermore, post-retrofit energy efficiency measurements were not taken, so it was difficult to judge efficacy. The greatest challenge that Tsenkova highlighted was the lack of sustainable funding; interview data with program managers clearly state that the venture was a job creation program, not a housing program. While the initiative was positive, Tsenkova evaluated the policy style as more trial-and-error than strategic.

In Ontario, the province partnered with the federal government through *CEAP* and created the *Social Housing Renovation and Retrofit Program* (*SHRRP*) and the *Renewable Energy Initiative*. Nearly 300 projects received grant funding for retrofits across Ontario and about 16% in Toronto. Funding was allocated through "notional fairness," meaning applicants received financing in proportion to their share of social housing units in Ontario. Limited institutional capacity of small community-based non-profit running the retrofit programs and pre-existing unresolved capital needs affected the implementation of *SHRRP* (Tsenkova, 2021c). Tsenkova attributed part of the City of Toronto's success to its institutional framework (Figure 3.5). The City of Toronto's Shelter, Support and Housing Administration Division was responsible for administering *SHRRP*, which Tsenkova argued allowed for more effective and efficient funds management. Tsenkova described their approach as strategic for their integration of energy efficiency with capital needs. At the same time, program managers noted it was stressful and time-consuming. Furthermore, the funding was only temporary, and a long-term and consistent funding model is needed.

Social housing programs in Calgary and Edmonton saw considerable upgrades through *CEAP* (Tsenkova, 2021f). Window and door replacement, roofs, and heating/mechanical system upgrades were the preferred investment in programs in both cities; Tsenkova presumed this to be due to financing. Lack of data limited their analysis, but Tsenkova was not convinced energy efficiency was a priority in either city. Program managers noted difficulties with tight deadlines, capacity issues, and difficulty qualifying for funds due to complex guidelines and procedures.

After *CEAP*, Tsenkova noted a shift in energy efficiency priorities towards reducing GHG emissions (Tsenkova, 2021e). Reviewing the retrofit programs in Alberta, Ontario, and British Columbia from 2014 to 2018, Tsenkova emphasized the importance of institutional partnerships and collaboration as a strategy for implementation. Post-*CEAP*, energy audits became standard practice and programs incentivized GHG emission reduction. Vancouver continues to provide retrofits through partnerships with utility companies; programs in Alberta and Ontario lost funding or were withdrawn after changes in government. As a result, post-*CEAP* retrofits were less successful and systematic. Drawing back to their Housing Policy Design Continuum (Figure 3.4), Tsenkova evaluated this period as de-evolutionary.

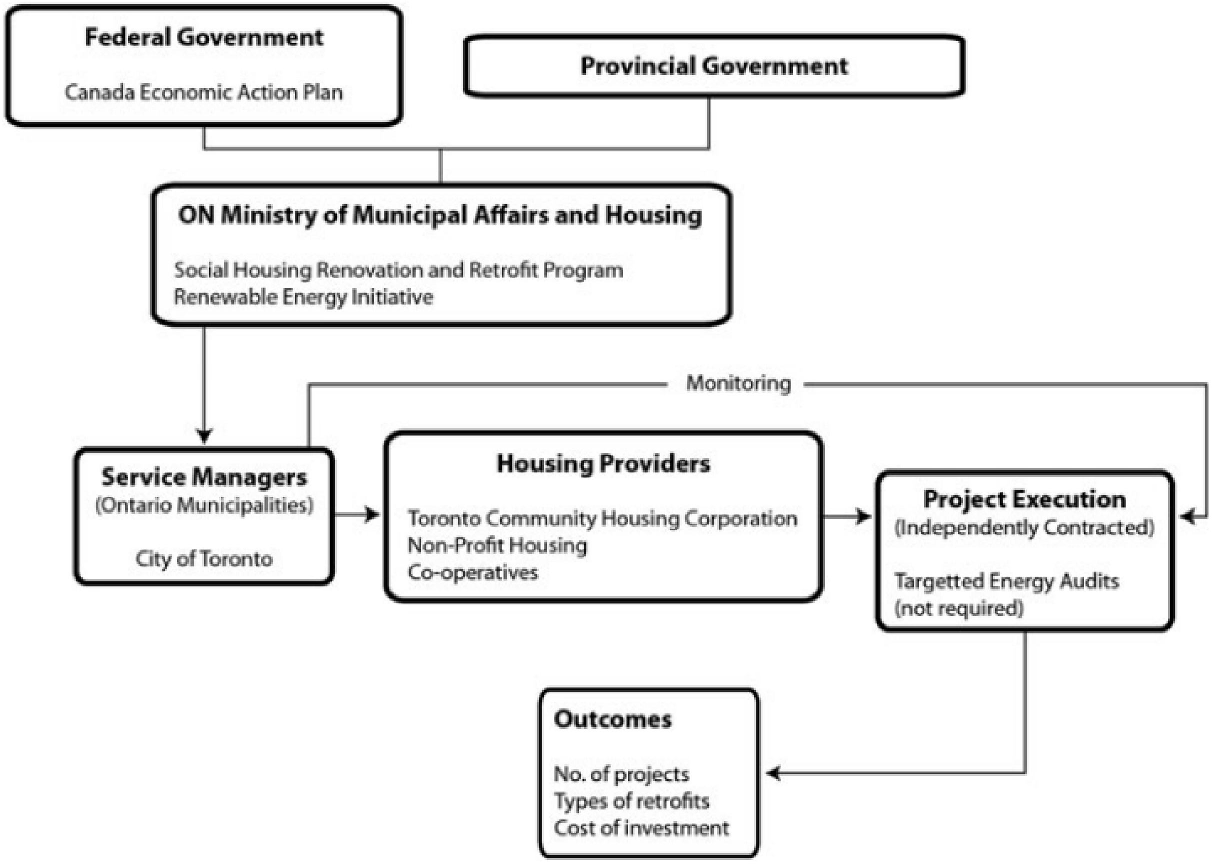

Figure 3.5. Institutional framework of social housing renovation and retrofit programs in Toronto extracted from Tsenkova (2021c).

Tsenkova concluded their book with an evaluation, key (non-comprehensive) recommendations for future retrofit programs, and a new framework for energy efficient retrofits in social housing (Tsenkova, 2021g). They said that federal and provincial governments have followed an incremental model of policy design and implementation and are “muddling through”:

> “It proceeds through ‘trial and error,’ often with complex and decentralised relationships at different levels of policy-making and implementation. The outcomes in the social housing system do not imply fundamentally new approaches, but a response to problems of lower quality, deferred maintenance and high energy intensity.” (Tsenkova, 2021h)

Key directions in policy style recommended to achieve transformative change in the social housing sector are outlined in Box 3.1. Tsenkova also stressed, “[i]n the context of post-pandemic economic recovery, there is an excellent opportunity to invest in a greener and more inclusive future” (2021g).

The three main challenges Tsenkova identified are the lack of institutional capacity of housing providers to navigate administrative processes, the lack of economically viable energy retrofitting technologies, and the lack of funding. To overcome these challenges, they proposed a "'3i' Framework for New Energy Efficient Retrofits in Social Housing" (Tsenkova, 2021g). They anchored this framework into three streams: inventory, innovation, and investment. Tsenkova argued this framework promotes effective management of processes driven by a more holistic and comprehensive vision for sustainable delivery by providing one-stop services that centralize functions. They approached this framework by combining Toronto's effective centralization and Vancouver's successful partnership in managing and delivering retrofits.

Box 3.1. Key directions for transformative change for energy efficient retrofits in social housing, copied and simplified from Tsenkova (2021g).

1. The federal and provincial governments need to secure funding for the continuation of retrofit programs with well-defined program targets that link general quality improvements in the social housing sector to energy efficiency retrofits.

2. Provincial governments, in partnership with financial institutions, need to identify a suite of economic incentives such as soft loans, low cost secondary mortgages, credit lines and loan guarantees to allow leveraging of additional funds for renewal and energy efficiency retrofits by social housing providers.

3. Provincial governments, in partnership with the largest social housing providers, need to provide systematic training and capacity building to improve the governance and decision-making around capital planning projects.

4. Federal and provincial governments, in partnership with the largest social housing providers, need to disseminate evidence from ex-post evaluation of select best practices to overcome capacity and information constraints in the sector.

5. Federal and provincial government agencies need to commit to monitoring and evaluating energy retrofit programs.

6. Establishing an institutional framework at the municipal level building on partnerships for efficient and effective program administration is highly recommended.

The *inventory stream* centralizes data to one provincial or municipal institution that can use its capacity to help housing organizations access funding and ensure equitable and effective use of resources. Tsenkova believed this will facilitate more comprehensive planning and create economies of scale that encourage private sector participation.

Tsenkova recommended a non-profit manage the *innovation stream*. It would be responsible for coordinating contractors, utility companies, and other private sector actors to develop tailor-made and economically sustainable retrofits. They highlighted the BC Non-profit Housing Association and the Pembina Institute as examples for their work to bring Energiesprong to British Columbia's social housing sector.

The third "i" is for the *investment stream*. Tsenkova gave the City of Toronto and Toronto Community Housing Corporation as examples showing that municipal governments can be the one-stop receiver of all funding sources. Tied with managing the *inventory stream*, this work relieves the hurdles and barriers of complex applications preventing housing providers from accessing capital for comprehensive retrofits.

3.7 Net-Zero Global Building Sector

Ürge-Vorsatz et al. (2020) recently reviewed advances in key options, strategies, and barriers to advancing the net-zero global building sector. Their review demonstrated that net- or nearly-zero energy buildings are achievable in most building types and climate systems with current technology and skills.

The review focused on the international Passive House standard as a standard of excellence in building energy efficiency. Passive House buildings are not to exceed 15 kW/(m^2 x year) for heating or cooling or a maximum energy load of 10 W/m^2 at any time in a heating-dominated climate like Canada; this is typically a 75 to 95% decrease in annual heating and cooling demand. The reviewers reinforced that the Passive House energy standard of performance is possible in all climate zones. Ürge-Vorsatz et al. identified the need to prioritize building envelopes that eliminate thermal bridges and ensure airtightness to achieve the Passive House standard. Additionally, heating and cooling loads can be managed partly by shading and un-shading windows to capture or reduce solar heat gain. They showcased the Saskatchewan Conservation House built in 1977 as an international best practice for its four-decade-old, highly efficient envelope.

Citing a 2019 report from the North American Passive House Network, the reviewers noted the Pennsylvania Housing Finance Authority only found an average 3% difference between conventional projects and Passive House builds (NAPH, 2019). Ürge-Vorsatz et al. compared this with a British Columbia Energy Step Code study that also found the cost of an energy efficient building totalled around 3% different from the cost of conventional build (BC Housing & Energy Step Code Council, 2018). This demonstrates that new builds at the Passive House standard are affordable. However, the authors clarified that DERs are expensive and require new solutions or subsidized financing. They also highlighted the Energiesprong program as a cost-saving strategy for its industrialization of the supply chain.

Ürge-Vorsatz et al. identified financing as a key barrier to advanced high-efficiency buildings and DERs. They argued that most real estate investors expect short returns on investments, but DERs take 10-20 years to pay back, and most homeowners lack the significant capital required. At length, they criticized on-bill financing through ESCOs:

> "Private financing, energy service company (ESCO) arrangements or other on-the-bill financing schemes are unlikely to be sufficient to bridge the financing gaps, as involving third parties introduces further costs, making the payback gap

> even larger and withering the circle of overall cost-effective retrofits. In general, ESCO-based arrangements in the building sector can be problematic when the lock-in effect is considered, given that such commercial arrangements prioritize low hanging fruit, or finding the most cost-effective solutions and leaving out the less attractive ones [(Bertoldi & Boza-Kiss, 2017)]. However, it is the less attractive elements of building envelope refurbishment that provide the greatest long-term benefits and without which true deep energy retrofits are not possible. A systemic approach to deep energy retrofits is also cost-effective, but the longer payback times and thus reduced return on investment (ROI) results in investors cherry-picking incremental solutions rather than the systemic ones." (Ürge-Vorsatz et al., 2020)

Other barriers include complexity and nuisance, which they suggested the one-stop-shop model as a solution. In multi-unit residential buildings (MURBs), occupants and owners must agree on the retrofit and financing. Except for Energiesprong, many DER projects required occupants to relocate temporarily, a decision that may disincentivize deeper retrofits for shallower measures.

In terms of policy and program solutions, Ürge-Vorsatz et al. highlighted building codes among the most effective climate policies. Germany's Passive House model remains a global showcase. China was highlighted as the leader in ultra-low-energy buildings. In just eight years, they created more than 7 million square metres of nearly-zero-energy buildings (Fu et al., 2019); this was credited to their clear, well-defined, and stringent efficiency standards. Brussels was also highlighted as a significant case study for adopting the Passive House standard. Over seven years, the region went from having among the least efficient buildings in western Europe to the most efficient building code. Between 2004 and 2014, heating and energy use per capita dropped by 25% and GHG emission by 16%. Local authorities rolled out the program in three phases: awareness, incentives, demonstration; support and large-scale implementation; and massive investment in new and retrofitted buildings.

Ürge-Vorsatz et al. concluded the article with summary points. All are quoted in Box 3.2.

Box 3.2. Summary points on advances toward a net-zero global building sector extracted from Ürge-Vorsatz et al. (2020).

1. The transformation of the building sector toward net-zero energy and low embodied carbon buildings is a key component of meeting climate neutrality targets, because the building sector contributes approximately 36% to final energy demand and 39% to process-related greenhouse gas emissions.

2. Recent advances in building design, know-how, construction, operation and retrofit, as well as low-carbon or even carbon storing building materials suggest that the building sector could become climate neutral in itself.

3. There is a wide range of net- and nearly-zero building terms, standards and definitions. Our article provides a summary figure that navigates the reader to understand the differences among these.

4. The evidence from the reviewed literature indicates that it is possible to reliably and affordably achieve net or nearly-zero energy building outcomes all over the world in most building types and

climates with systems, technologies and skills that already exist, and at costs that are in the range of conventional buildings.

5. The evidence shows that the key to net-zero targets is the maximization of energy efficiency for all building energy uses, with the remaining energy loads to be covered from locally produced renewable energy sources. The greatest technological challenges to net-zero energy buildings are in high-rise commercial buildings in hot and humid climates as well as for retrofitted historic heritage buildings, but solutions and best practices exist for these, too.

6. Although net and nearly-zero energy buildings increasingly achieve market success, there are many significant barriers worldwide to their wider adoption. However, recognizing their environmental, climate, social, health, productivity, economic, and other advantages, many jurisdictions have successfully introduced policies and incentives to overcome these barriers and thus increase their market penetrations. China alone has built more than 7 million square meters of Passive Houses with significantly more under construction; New York City, Vancouver, Brussels, Tyrol, and other jurisdictions have introduced innovative policies and incentives to catalyze market transformation toward Passive House standard buildings.

7. Strategies to minimize embodied energy and carbon in building materials are gaining significant attention and include material efficiency, recycled and reused materials, durable components, design and new materials, replacing carbon-intensive materials by bio-based ones, as well as carbon capture and utilization.

8. The review of literature for this article reinforced the existence of the significant gap and time lag between the advanced professional knowledge and scientific documentation, and thus recommends strengthened research and publication in co-production among these communities in order to enhance the broader uptake of these advanced solutions as well as their wider inclusion in climate and energy policy portfolios and modeling.

3.8 Recommendations from Literature

Several advocacy groups and academics have published recommendations to Canadian governments on improving residential energy efficiency; I outline some of these recommendations here.

Canada Green Building Council (CaGBC) is a leading non-profit association in Canada, and they offered recommendations to the federal government in anticipation of the 2021 federal budget (CaGBC, 2020a):

- "Advance workplace development and employment by investing $100 million to retrain workers who lost employment due to COVID-19 into green building jobs;

- “Catalyze a low-carbon retrofit economy by allocating $50 million for 0% financing of energy audits, deploy $10 billion through the Canada Infrastructure Bank (CIB) to finance low-carbon retrofits, establish a standardized approach for developing and evaluating energy efficiency projects, and work with stakeholders to establish an industry-driven retrofit program.

- “Stimulate zero-carbon construction projects by requiring all federally-funded buildings to achieve zero-carbon performance, invest $20 million in embodied carbon research, develop a National Building Code, and grant $1 billion, scaled to performance, for public and private sector buildings to ensure they are built to achieve low-carbon performance.”

CaGBC published a reaction to the 2021 federal budget, saying the budget "demonstrate[s] positive momentum" and that they were "pleased to see the federal government continue its green building leadership by supporting the construction and retrofit of federal buildings to zero carbon standards" (CaGBC, 2021).

Efficiency Canada is an energy efficiency think tank based out of Carleton University's Sustainable Energy Research Centre; they presented five recommendations to the federal government in anticipation of the 2021 budget (Efficiency Canada, 2020):

- "Provide $1.5 billion in funding to expand green building workforce training;
- "Provide $10.4 billion over three years to the low-carbon economy fund to expand provincial and municipal energy efficiency portfolios;
- "Provide $13 billion to create a building retrofit finance program through CMHC and CIB;
- "Provide $2 billion for large-scale building retrofit demonstration projects;
- "Incentivize provinces to adopt high energy performance tiers of the 2020 model national building codes."

Efficiency Canada also outlined a 5-year investment plan (Table 3.6). Over five years, they estimated retrofits in 1.5 million residential homes, 752,000 MURBs dwellings, and 113 million square metres of commercial and institutional buildings; 132,172 jobs sustained for five years; average annual GDP increase of $32 billion, $160 billion in total; and annual GHG emission reduction of 20.4 Mt CO_2e.

Table 3.6. 5-year investment plan, copied from Efficiency Canada (2020).

Initiative	Billions ($)
Training the green building workforce	1.5
Immediately expand provincial and municipal energy efficiency portfolios (3 years)	
Program cost	10.4
Participant cost	8.1
Building Retrofit Finance Platform	
Public investment	13.0
Private investment	35.1
Retrofit at Scale Demonstrations	
Public investment	2.0
Private investment	1.0
Total	71.1
Public	26.9
Private/partner	44.2

The Climate Action Committee for the City of Toronto published a report outlining best building performance practices from leading global cities. It provided recommendations to the City based on their analysis (Foppiano et al., 2020). They recommended expanding annual benchmarking and reporting requirements, enhancing the marketing strategy for HELP, increasing free/low-cost contractor training for DERs, establishing Toronto Green Standard monitoring through Ontario's Energy & Water Reporting and Benchmarking policy, and ensuring non-compliance penalties are administered.

Recognizing Canada's underinvestment in DERs, Hoicka & Das (2020) reviewed energy use and building retrofits in Canada. They provided five recommendations:

- "Focus innovation on deep energy retrofit processes, not singular retrofit actions;
- "Maximize both social and environmental benefits;
- "Improve data gathering and availability for analysis and delivery;
- "Innovate for a process of decisions and to avoid "dropouts" during the retrofit process;
- "Focus innovation on business models that maximize benefits."

Tsenkova provided recommendations to Canadian governments for achieving transformative change in social housing retrofits (see Box 3.1 in section 3.6 Social Housing) (Tsenkova, 2021d).

Frappé-Sénéclauze is the Director for Buildings and Urban Solutions with the clean energy think tank, the Pembina Institute; a month into the pandemic, they published recommendations for a green stimulus (Frappé-Sénéclauze, 2020). They recommended refurbishing Canada's building stock at a rate of 2-3% per year and using codes and regulations as the primary policy tool. Their recommendations that are relevant to residential retrofits are quoted in Box 3.3.

Box 3.3. Recommendations on retrofits, extracted from Frappé-Sénéclauze (2020).

Retrofits in homes

1. Increase the Greener Home retrofit target and pair loans with outcome-based grants: Increase loan maximums for homes from $40,000 to up to $100,000 and provide grants to cover a significant portion of the retrofit cost. Offer homeowners a financing package (including loan and grant) that becomes more advantageous based on the depth of carbon reduction achieved and the reduction in peak electricity consumption. Use pre/post energy audits to assess outcomes.

2. Partner with retail banks and financial technology firms for program delivery: Contractors and retail banks have unique opportunities to engage homeowners when investment decisions are made: when something fails, and when a home is being sold or remortgaged. The federal government should partner with retail banks and fintech firms that provide lending products to contractors to deliver government-backed financing programs. This public-private partnership model has been successfully used by the KfW development bank in Germany to roll out more than 27 billion euros in loans and grants.

3. Align with residential PACE programming: FCM is working with several municipalities across the country to set up PACE financing programs. Coordination with these programs should be facilitated by ensuring that low-cost financing available through the federal government is accessible through the PACE programs. This might take some time to bring to fruition, and should be worked on in tandem with the partnership with retail banks discussed above. In the meantime, providing PACE participants with the option to access a top-up grant comparable to the value of the interest buy-back offered by the government would ensure these federally-backed pilot programs are not competing against another federal program.

4. Allow the formula to vary by market segment, region, and equity considerations: The formula established to assess grant size and total allowable loan could be adapted to allow for regional variations in grid intensity, due to market contexts, and based on the level of economic stimulus sought. Top-ups should be provided for low-income, remote, and Indigenous communities based on geographic area and/or based on low-income thresholds. Programs could be launched nationally relatively quickly with minimum incentives. Formulas for more advanced incentives could then be developed in collaboration with provinces and territories, each given access to a pool of funding to distribute based on regional considerations. Access to this incentive funding pool should be made conditional on the implementation of PCF objectives for building codes and labelling.

5. Develop low-cost labelling tools aligned with EnerGuide, and work with provinces and territories to implement labelling requirements at point of sale or rental: An alternative to a full audit can be generated based on available databases and through a simple questionnaire to be filled in by homeowners. Natural Resources Canada could develop such a tool and integrate it with the EnerGuide home energy rating system as a pre-assessment tool. The pre-assessment could be used to comply with point-of-sale and point-of-rental labelling requirements, allowing provinces and territories to move faster toward adoption of this PCF commitment. As well, this pre-assessment could be paired with customer-centric web interfaces, be used to upsell incentive and loan programs, and facilitate access to contractors. Such pre-assessments could be sufficient to create a market signal and could be upgraded to a full audit by owners who plan to conduct retrofits. Such remote-based pre-assessment would benefit from a structured energy data strategy (see Recommendation 15).

6. Create an ongoing funding mechanism for low-carbon finance programs distinct from general revenues: Outcome-based programs as outlined above offer the advantage that the funding levels can be adjusted over time based on political priorities while maintaining the continuity of the program. Another way to increase the resiliency of these programs is to fund them through a dedicated fund replenished through the issuance of green bonds, similarly to what Germany is doing in partnership with the KfW bank. In this successful public-private partnership, the government sells bonds on capital markets to fund a mix of low-interest (1–3%) loans and grants which local retail banks can offer to their customers. The economic activity resulting from the investment has been shown to return four to five times more money to the public coffers than the costs the program demands, which is more than sufficient to repay the bonds.

<u>Retrofits in affordable housing</u>

7. Create a top-up fund for NHS-funded retrofits and new construction projects that achieve deep carbon reductions: Right now, projects accessing NHS [National Housing Strategy] funding must achieve at least a 25% reduction in carbon pollution; this leaves many opportunities for carbon reduction unfunded. Adding a top-up fund to enable societies to go directly to deep retrofits (60–80% GHG reductions) would seize opportunities that would otherwise be missed for increased resiliency, carbon reductions, and economic activity in projects that are scheduled for design and construction in the coming years.

8. Require stronger climate resiliency in NHS-funded projects: Decarbonization of the social housing sector by 2050 should be an explicit objective for the Canada Mortgage and Housing Corporation (CMHC); co-investment funding should be guided by these outcomes and the minimum carbon reductions expected from these investments should be increased. The co-investment fund also needs a clearer framework to assess and require integration of climate adaptation measures in these once-in-a-generation upgrades. Many synergies between deep retrofits and climate risk protection are routinely being missed; they should be seized to ensure the long-term health and viability of our social housing sector.

9. Provide more flexibility on meeting accessibility targets in retrofit situations: Co-investment fund requirements for accessibility upgrades are very costly in retrofit situations. Accessibility goals of the NHS could more effectively be met by ensuring a greater share of units in new construction projects meet accessibility criteria, and by allowing more flexible tests for accessibility upgrades in existing buildings.

10. Create a market-rental preservation program: Apartment buildings built in the 1960s, ’70s, and ’80s form the backbone of affordable rental housing in Canada and are an essential part of our economic infrastructure: workers having a place to call home is as necessary as roads and bridges to a competitive economy. The federal government should create a market-rental preservation program incenting landlords to repair and retrofit relatively affordable units without increasing rents beyond inflation — discouraging tenant-displacing measures such as “renoviction,” improving housing quality, and reducing carbon pollution.

Integration with Pan-Canadian Framework commitments and other policies

14. Invest $500 million in workforce development and training: The transition to low-carbon buildings requires professionals, contractors and trades that understand best practices for the design and construction of high-performance buildings and retrofits. The current slowdown in various sectors provides an opportunity to provide distance education programs to upgrade and retool more workers with skills that are in high demand in the green building sector. We support the Canada Green Building Council and Efficiency Canada’s recommendation to provide $500 million for training for Canada’s low-carbon building workforce.

15. Make access to a portion of funds for incentives and capacity building conditional on advancing regulatory roadmaps for a zero-carbon building sector by 2050: Without these policies in place, incentive programs will remain ineffective. The federal government should provide capacity-building funding for provincial code adoption, local code enforcement, and implementation of universal home-energy labelling. This funding should be conditional on provinces adopting the 2020 model codes and developing roadmaps to prepare the construction industry for enforcement of the net-zero energy ready code by 2030, as committed in the PCF. Similarly, a dedicated fund should be created to support provincial development of retrofit roadmaps leading to net-zero carbon buildings by 2050.

16. Add an explicit climate objective in codes: Create a set of stepped performance-based metrics for operational carbon intensity, embedded carbon intensity, and peak electricity demand, and work with provincial, territorial, and local governments to establish regional roadmaps toward these goals and a staged implementation of these requirements for existing buildings. Include prescriptive requirements for other resiliency objectives (e.g. climate adaptation, seismic, and accessibility).

17. Adopt high-performance regulations sooner: Accelerate the switch to heat pump technology by setting a target for all heating equipment on sale in Canada to meet an energy performance greater than 100% before 2030. The “aspirational goals” set at the 2018 Energy and Mines Ministers’ Conference should be firmed up and advanced in consideration of the current climate emergency. Additional support should be provided to initiatives underway to support training, certification, and supply chain development.

18. Facilitate access to building data by citizens, governments, and companies: Task the Canadian Centre for Energy Information to develop a building data framework to support policy development, energy and land-use planning, asset risk evaluation, market development, web-based applications, and big-data tools. This framework should include open-data policies for local, provincial, and federal building-related databases, implementation of data quality standards, and standardization of data exchange protocols.

19. Include low-carbon heating equipment, grid-interactive building components, and other high-performance building components when defining zero-emission technologies eligible for tax cuts.

20. Form a cross-ministerial working group for the coordination of a retrofit building strategy.

Kennedy & Frappé-Sénéclauze (2021) used a heuristic model to calculate the benefits of a pan-Canada "renovation wave." Their report was published two weeks before the deadline for this paper, so a complete analysis of their findings was not feasible. Their report included a set of recommendations which were quoted in Box 3.4. They presented the job creation and emission reduction potential of a pan-Canada retrofit program assuming a ramp up phase from 2021 to 2025 from the current 1% annual retrofit rate to 4.5% and a ramp down phase in 2040. By 2040, they estimated $277 billion is needed in government investment, an increase from the federal government's proposed $2 billion annually to $10 to $15 billion. They recommend governments pay for the majority of retrofits and show that for every dollar spent on such a program, $2 to $5 will return to the public coffer, meaning the retrofits "pay for themselves." Their modelling also showed a national decrease in residential electricity demand by 10%, an 89% reduction in residential carbon emissions. As well, they estimated 138,000 jobs sustained for 20 years.

Table 3.7. Impact of a nation-wide "renovation wave" extracted from Kennedy & Frappé-Sénéclauze (2021).

	Detached homes	Attached homes	Apartments
Retrofits per year	340,000	71,000	188,000
	Total: 598,000 dwellings		
Total Investment needed	$277 billion by 2040		
Electricity demand	-10%		
Carbon reductions from sector achieved by 2050	89%[9]		
Annual energy bill savings in 2050	$10.8 billion		
GDP growth per year[10]	$33.6 billion		
Jobs created[11]	138,000		

Box 3.4. Recommendations for a pan-Canada "renovation wave" extracted from Kennedy & Frappé-Sénéclauze (2021).

Target setting

- The federal government should create a vision for a nation-wide renovation wave aiming at decarbonizing the vintage stock by 2040.

Financing and incentives

- The federal government, in partnership with the provinces, should commit public investments on the order of **~$10-15 billion per year over the next ten years** to enable this renovation wave, including:
  - ~$10 billion per year to fund deep retrofits for residential and commercial buildings, with programs covering 50-75% of retrofit costs.
  - $2 billion per year to fund no-cost deep retrofits for low-income households and top-up for the renovation of social housing through the National Housing Strategy.
  - $300 million per year in skill development, capacity building and recruitment to grow the energy efficiency and green building workforce, with funds earmarked to increasing its diversity.
  - $100 million per year to fund market development initiatives to resolve systemic barriers to deep retrofits and facilitate large-scale roll out of new integrated retrofit offerings
  - $100 million per year to fund research, development and demonstration of key retrofit technologies.
- Retrofit funding should be disbursed through a small number of large programs, to minimize market confusion and ensure efficacy of public investments. This could include channelling funds through established programs (municipal, provincial, utility).
- Access to federal funds for the renovation wave should be made contingent on provinces committing and implementing regulatory roadmaps for a zero-carbon building sector.
- The federal government should capitalize a loan guarantee program to reduce the risk to private financing of building retrofits and CMHC should support the roll out and harmonization of PACE financing across Canada.

Regulation

- The federal government should partner with provinces to align the following regulatory commitments towards a zero-carbon building sector. Governments should provide early signals and timelines for implementing these policies to allow capacity building, and incentivize early adoption.
- Carbon intensity limits for new and existing buildings.
- Energy performance standards requiring all heating equipment to have a coefficient of performance greater than 100% sometime between 2025 and 2030 (i.e. ahead of the 'aspirational' target set for 2035).
- Benchmarking, labelling, and public disclosure policies to inform real estate market assessment of performance, comfort, climate risks, and carbon risks.

Data and Transparency

- Open-data policies, data quality standards, and data exchange protocols to enable data-driven user-centered decision tools for energy investment and market potential analysis.

3.9 Summary

The purpose of this review was to gain a critical understanding of best practices in DER program design, business models, financing mechanisms, the role and capabilities of third-party interventionists and social housing providers, and present recommendations from others and organizations.

The review shows there are various business models for retrofitting residential buildings. The MESA model fused with the Energiesprong was the most recommended in the literature for delivering DERs (Brown, 2018; Brown et al., 2018; Ürge-Vorsatz et al., 2020). The MESA model has been successful because it eases the customer journey, reduces dropout points, and organizes the supply chain. Industrialization, prefabrication, and panelization likewise has created a more organized supply chain, safer working conditions, minimized disruptions to occupants, lowered costs, and made dramatic reductions in energy consumption.

There were competing recommendations for financing mechanisms. Proponents of Energiesprong often pushed on-bill financing (Brown, Kivimaa, & Sorrell, 2019; Energiesprong Foundation, 2021) while other authors criticized the mechanism (Ürge-Vorsatz et al., 2020). Authors spoke positively of PACE (Brown, Sorrell, et al., 2019; Kennedy et al., 2020), but programs like this have struggled in Toronto, Ontario (Jamali, 2015). This is quite problematic because DERs need to be done if Canada is to drastically lower its GHG emissions, but DERs are incredibly expensive. Two authors proposed funding retrofits through progressive taxation, with the government funding 100% of retrofits for low income demographics, and 50% to 75% for the rest (Kennedy & Frappé-Sénéclauze, 2021).

In terms of program design, authors consistently highlighted the importance of whole-of-house retrofits (Hoicka et al., 2014; Jermyn & Richman, 2016) and even showed that Passive House standards are realistic in Canada (Jermyn & Richman, 2016; Ürge-Vorsatz et al., 2020). However, to achieve such results, significant market intervention is needed, which is why authors highlighted the need for market intermediaries (Brown et al., 2018; Brown, Kivimaa, & Sorrell, 2019; Gliedt et al., 2018; Hargreaves et al., 2013; Kivimaa et al., 2019; Kivimaa & Martiskainen, 2018). Few authors in particular noted the potential for social housing providers to leverage their capacity and agency to help create markets for DERs (Cauvain & Karvonen, 2018; Parag & Janda, 2014; Tsenkova, 2021d).

If a pan-Canada DER program were realized, most green building advocates in Canada estimate in the range of 138,000 jobs created and sustained for more than a decade (CaGBC, 2020c; Efficiency Canada, 2020; Frappé-Sénéclauze, 2020; Kennedy & Frappé-Sénéclauze, 2021). They also recommended government spending in the range of $10 to $15 billion over one to three years for as many as 20 years, compared with the government's planned $7 billion over seven years. Efficiency Canada (2020) recommended moving at a rate of 400,000 dwellings per year for five years with the most focus being on single family homes, while researchers from the Pembina Institute suggest ramping up to 600,000 dwellings per year and also focusing on single family homes with slightly more than a 2:1 ratio of single family homes to MURBs (Kennedy & Frappé-Sénéclauze, 2021).

4.0 Semi-Structured Interviews

Interview data are visualized in Table 4.1. I thematically analyzed transcriptions and created an index of key themes and common phrases. Interview participants were anonymized and labelled P1-7. If an interviewee said something similar to the indexed phrases, the participant received an X in their column.

Most participants said $5,000 grants were not enough money to incentivize meaningful retrofits; one participant even paused for a moment in the interview to search for words and then described the $5,000 grant as “piss in the wind.” Although, a few did say the grant structure is a great incentive. Participants were more enthused by the prospect of a $40,000 interest-free loan, although the majority still thought more money is needed. Additionally, participants were concerned that money could be wasted; some suggested tying financing to performance. Three participants suggested PACE as an alternative financing mechanism. One interviewee suggested partnering with financial institutions and cited the Vancouver City Savings Credit Union (Vancity) as an example, saying, “we’re going to need tons of benevolent banks.”

To help create a market, most participants suggested the federal government work in the social housing sector. They also said the federal government could help disseminate knowledge and provide funding. One participant said that money alone cannot create a market and that the government needs to start big projects.

In terms of training, most interviewees believed that the skills required for DERs are easily trained up, although additional tools and training are needed for Energiesprong approaches that require photogrammetry. Two participants suggested the government pay tuition fees for trade schools to incentivize enrollment. Generally, participants liked free training for energy advisors, but one participant was critical and said that the curriculum needs updating to DER-level.

Most participants emphasized the need for holistic design if the retrofits are to impact energy demand and GHG emissions. Many interviewees suggested that programs should target the social housing sector to help create economies of scale. One interviewee even suggested taking a more strategic focus by only targeting the social housing sector and MURBs and not to “waste” resources on single-family homes as “there’s huge potential to simply fritter the money.” Most participants organically brought up the Energiesprong business model without my intervention and suggested it as a good (some saying best) business model for program delivery.

Almost all participants suggested using more robust building codes as a policy tool to enforce energy demand reductions in inefficient buildings. Similarly, most participants said before and after energy audits are essential for success.

Table 4.1. Data visualization of interview transcripts.

Category	Common Phrases	P1	P2	P3	P4	P5	P6	P7
Financing	$5,000 grants are not enough money	X	X		X	X		X
	Grants are great incentives	X					X	X
	$40,000 interest-free loans is a good amount of funding				X	X		X
	More than $40,000 is needed	X	X		X	X		
	PACE financing is a sound system		X			X	X	
	Tie financing to performance	X					X	
	This money could be wasted		X	X		X		
	Make partnerships with financial institutions				X			
	Longer payback periods are needed	X			X	X		X
Market Creation	Funding for five to seven years gives industry security		X					
	More work needs to be done to disseminate knowledge				X	X	X	X
	The government needs to lead and launch big projects	X						
Training	The government should pay for training						X	X
	More energy advisors are needed			X				
	Most skills required are easily trainable			X	X	X		X
	The current energy advisor curriculum is inadequate			X				
Program Design	Industry needs to play a bigger role in designing programs		X					
	Retrofits need to be done holistically		X	X	X	X	X	
	Desired outcomes need to be communicated			X			X	
	Target social housing first		X	X	X		X	
	Do not target single families homes; focus on MURBs			X				
	Use existing program structures	X						X
	Energiesprong is a good business model for delivery	X		X	X	X	X	
	Target homeowners when properties change ownership				X			
Building Codes and Targets	Set building performance targets		X				X	X
	Set stronger building codes with strong enforcement		X	X	X	X	X	X
	We need a building labelling system		X					
	Set a national building code that includes retrofits		X			X	X	
	Track progress with before and after energy audits	X	X	X		X	X	

5.0 Discussion, Evaluation, and Recommendations

Through this research, I set out to increase my understanding of the retrofit landscape in Canada and the role of the federal government in increasing the uptake of DERs. The two outcomes of this research are a formative evaluation of the Government of Canada's retrofit plans and a set of recommendations on how to advance the uptake of DERs.

5.1 Discussion

There is no lack of technical solutions for DERing residential buildings in Canada. As discussed by Ürge-Vorsatz et al. (2020), 75-95% reduction in annual heating and cooling loads is possible in Canada's climate. The Saskatchewan Conservation House in Regina, Saskatchewan remains a four-decade-old example of the capabilities to keep residential energy demand low during frigid winters and sweltering summers. Likewise, Jermyn & Richman's modelling of three archetypal Toronto homes confirmed that reducing energy demand from 200 kWh/m^2 to 25 kWh/m^2 is realistic (2016). Ürge-Vorsatz et al.'s review (2020) also demonstrated that millions of square metres of buildings could be DERed to nearly-zero-energy before 2030. The Belgians were able to transform their buildings from the least efficient to among most efficient in seven years, and the Chinese became the global leader in eight. An interview participant echoed this: "[t]he Belgians are no smarter than we are."

5.1.1 Barriers

Regardless, there are significant barriers to DERing a home in Canada. In Canada, if a homeowner were interested in retrofitting their home, they would face many challenges characteristic of Brown's (2018) atomized market model: a complex interface and a difficult customer journey. They would have a difficult time locating reliable contractors, creating many drop-out points, be uncertain of benefits, quality, and potential, require a significant amount of free time and needs tens of thousands of dollars available to significantly lower their energy demand (Brown, Kivimaa, Rosenow, et al., 2019; Ürge-Vorsatz et al., 2020). With the Government of Canada's new programs, interested homeowners could get a free EnerGuide energy assessment and qualify for a $5,000 grant. Hopefully, soon, they will also be able to apply for the promised $40,000 zero-interest loan. What would likely happen is a customer would settle for a single retrofit such as a window replacement or fuel switching (Hoicka & Parker, 2018), and they would not make a significant change in their energy demand (Jamali, 2015), even though they have the potential for a DER (Jermyn & Richman, 2016; Ürge-Vorsatz et al., 2020). Some interview participants were aware of this dilemma, “any amount of money can simply be wasted. And historically, we’ve been wasting the money we invest.”

5.1.2 Financing

A few innovative financing mechanisms could assist in increasing the uptake of DERs and there are a few others that will likely fail. As discussed above, there are some positives and negatives to the federal government’s announcement to offer 700,000 $5,000 grants as well as $40,000 zero-interest loans. Interview participants liked the zero-interest public loans but said more funding is needed. Jermyn & Richman’s (2016) modelling showed capital costs could range to as high as $80,000 and Frappé-Sénéclauze (2020) recommended raising the maximum loan to $100,000. PACE financing mechanisms were suggested by multiple interview participants as well in literature (Brown, Kivimaa, Rosenow, et al., 2019; Frappé-Sénéclauze, 2020; Jamali, 2015; Kennedy et al., 2020). As noted by Jamali (2015) and Kennedy et al. (2020), mortgage lenders that did not want to subordinate their liens to more property taxes restricted PACE programs like Toronto’s HELP. Jamali (2015) recommended on-bill financing so the debt is still tied to the property but mortgage lender consent is unnecessary. However, Cauvain et al. (2018) and Ürge-Vorsatz et al. (2020) problematized on-bill financing. Kennedy et al. (2020) recommended program features to navigate the mortgage lender consent issue. Still, a problem with the PACE and loan financing structures is that occupants would have to agree to monthly payments for 20 to 30 years. Additionally, because climate mitigation is a collective responsibility, it is more equitable to finance DERs through taxes.

Tsenkova (2021g) offered the innovative solution of making municipal governments the one-stop receiver of all funding sources. This funding mechanism stands out because it loops back to solving the complex customer interface problem and the difficulty of navigating programs. Municipalities can also administer more targeted programming than federal institutions. Participants and interview data also pointed to credit unions and public banks as financing options (Brown, Sorrell, et al., 2019; Frappé-Sénéclauze, 2020). Germany’s state-owned KfW increased the size of its grants and loans in July 2021. KfW’s most significant offer to private homeowners seeking to retrofit their homes is €75,000 loans paired with €75,000 grants (totalling around CAD 110,000) (KfW, 2021).

Canada does not have a state-owned bank accessible to private citizens. However, CIB, CMHC, or Export Development Canada (EDC) could set up similar grant/loan programs with the funding going to municipalities. Another option proposed by the Canadian Union of Postal Workers (CUPW) is postal banking (CUPW, 2019). CUPW has attempted to market this program to the Government of Canada as a mechanism to finance green infrastructure projects.

The proposal is interesting because it builds on existing infrastructure with over 6,200 post offices across Canada, uses a trusted institution with over 100 years of banking experience, and helps resolve the growing problem of “banking deserts" in rural communities and inner-city neighbourhoods (Anderson, 2018).

Another banking solution proposed by a participant was to mimic the work of Vancity. The credit union is a great funding model for DERs because they are member-driven, democratic organizations that invest in local communities to create local jobs and wealth. According to their 2019 Annual Report, Vancity gave out $12 billion in residential mortgages in 2019 (Vancity, 2020). To ensure money is not “wasted” on shallow retrofits, participant and literature data (CaGBC, 2020a; Frappé-Sénéclauze, 2020; Hoicka & Parker, 2018) pointed to performance-based financing. Regardless of this variety of financial instruments, one of the most important findings from this research is that while financing is a significant barrier to DERs (Ürge-Vorsatz et al., 2020), financing is only an enabler of DERs and unlikely to incentive investments without an integrated business model (Brown, Sorrell, et al., 2019). Furthermore, as mentioned above, funding can and has historically been wasted on shallow retrofits.

5.1.3 Energiesprong

Both literature and interview data suggested the Energiesprong model as the best delivery model for DERs. Almost every interview participant steered the conversation to the Energiesprong model as an example of a successful retrofit program. A few participants have even used the Energiesprong model in their practice. Participants highly valued the model because industrialization lowers costs, photogrammetry ensures precision, prefabrication reduces workplace hazards such as weather exposure and the quick installation time. Brown (2018), Brown, Kivimaa, Rosenow, et al. (2019), and Ürge-Vorsatz et al. (2020) all also discussed Energiesprong as a key innovation in the future of DERs. One flaw with the Energiesprong model is that it is often financed through future energy savings (on-bill financing), which Cauvain et al. (2018) criticized as “neoliberal” and a “rolling back of the state.” Likewise, Ürge-Vorsatz et al. (2020) had serious criticisms of this financing mechanism.

A problem in the acceleration of the DER market is that critical niche innovations are still attempting to penetrate the socio-technical configuration (Figure 1.3). Given that almost every interview participant mentioned Energiesprong on their own accord, the innovation has likely influenced the landscape. Furthermore, the Government of Canada itself has begun piloting projects of this style (NRCan, 2021b). To my understanding, Energiesprong is in the demonstration phase along the ETIS; intermediaries are trying to form markets, and there are project demonstrations, but I would not characterize this niche innovation as “diffused” (Figure 1.4).

5.1.4 Third-Party Interventionists

Intermediaries can play essential roles in SNM to advance the diffusion DERs and further their penetration into the socio-technical configuration. Systemic intermediaries can play a crucial role in disrupting the existing socio-technical configuration to create windows of opportunity for DER innovations to emerge and gain influence at the regime level in the multi-level perspective framework (Figure 1.3) (Kivimaa et al., 2019; Loorbach et al., 2017). Niche intermediaries can support and build up niches as new solutions for future socio-technical configurations so that they can enter these windows of opportunity (Kivimaa et al., 2019). To support niche development, niche intermediaries can act as libraries and librarians, collecting and conglomerating lessons, as well as managers coordinating actions and brokering partnerships (Hargreaves et al., 2013). As discussed by an interviewee, a new niche intermediary, RetrofitCanada, is emerging to support DER knowledge sharing (RetrofitCanada, 2021).

Social housing providers, as middle actors, offer an ideal space for niche innovations to grow, learn, and adapt for more successful penetration into the socio-technical configuration. A majority of participants suggested that the federal government start in social housing before retrofitting individual houses. Tsenkova (2021g) also recommended retrofit programs in social housing as an excellent opportunity for a post-pandemic recovery. Targeting social housing would mean hundreds of units could be DERed through a single transaction, and low-income residents would benefit. Canada has a total social housing stock of 629,000 dwellings (OECD, 2021), which is slightly above the 2-3% annual retrofit rate recommended by Frappé-Sénéclauze (2020). Also, by focussing on social housing, regulators can ensure participants invest in holistic DERs, and that money is not wasted on shallow retrofits. By developing DER niches, such as industrialization and the process of envelope panelization and prefabrication, in the social housing sector, skills and practices can be built up for a wider launch into private sector housing.

The federal government can support social housing providers in SNM of DER innovations. Increasing funding is a primary channel through which the federal government can help social housing providers and the SNM of DERs. Social housing providers already have the agency, but increasing funding will increase their capacity to hire more staff, dedicate time to downstream communication with residents, restore outstanding maintenance issues, and invest in DERs. Additionally, the federal government can support social housing providers in SNM by facilitating lateral communication of knowledge between social housing providers and building professionals and upstream communication to provincial, territorial, and municipal governments and the federal government's agencies. Knowledge sharing, practice, and learning can help improve and popularize DER innovations, increasing their penetration into the socio-technical regime. After DER innovations are fully incorporated into the socio-technical regime, the federal government can shift to change at the landscape level in private sector commercial and residential properties by mandating and enforcing more robust building codes and offering incentives.

5.2 Recommendations

Here I present a set of recommendations for the Government of Canada to increase the uptake of DERs to lower GHG emissions in the residential building sector (Box 5.1).

One of the main barriers to DERs in Canada is market creation. It is difficult if not impossible for private homeowners, social housing providers, or other residential building owners to find contractors capable of orchestrating a DER. DER niches are emerging and intermediaries are working to ensure they penetrate into the regime level, but this process needs to be accelerated. That is why I propose the federal government create a Crown corporation that operates following the Energiesprong business model with the mandate to DER all buildings in Canada, starting with social housing and then private sector residential buildings. This allows the federal government to directly manage DER niches and advance the development, deployment, and diffusion of these technologies. This Crown corporation should follow the MESA business model and hire and train builders, operate warehouses for panel prefabrication, install DERs, and conduct energy audits. Adding domestic energy production will add significant complication so instead of aiming for net-zero energy performance, program managers should aim for net-zero ready with energy demand as low as possible. Furthermore, by targeting social housing, a federal DER program will effectively serve lower income communities. To ensure customer satisfaction and avoid paternalistic attitudes, tenants are to be meaningfully engaged and involved in the DER design process.

Equity is a major theme behind these recommendations. Lowering emissions and combating climate change are collective struggles Canadians face. That is why DERing the residential building stock should be a collective action, and financed through equitable and collective means. There were many financing mechanisms proposed by interview participants and found in the literature. They all exhibit pros and cons as they attempt to navigate the difficult task of financing expensive energy efficiency upgrades. Therefore, because climate change is a collective struggle, I propose our response be collectively and equitably financed through progressive taxation. The federal government can distribute funding through CMHC, CIB, or EDC to municipalities for more equitable, efficient, and targeted distribution. The federal government should then instruct municipalities to tie funding to performance with grants directed at projects that target and achieve greater energy demand reductions.

A pan-Canada retrofit strategy must be created in collaboration with municipal, territorial, Indigenous, and provincial governments to ensure energy reduction targets are high and shallow retrofits do not lock out energy savings. This strategy should plan to begin DERs in the social housing sector through the federal DER Crown corporation. After social housing, private sector MURBs and houses can be DERed. Strategizing a pan-Canada retrofit plan in this order allows for skills and technologies to be further developed and perfected in the public sector before incentivizing private sector investments that risk implementing shallow retrofits and wasting money.

Box 5.1. Policy recommendations to the Government of Canada to increase the uptake of DERs.

Strategic Direction

- In partnership with Indigenous and subnational governments, create a strategy for DERing all residential buildings in Canada, starting in social housing and then moving to private sector MURBs followed by houses.
- Pause the Canada Greener Homes Grant and other programs targeting detached single family homes until a DER building code has been created.

Program Design

- Use the Energiesprong model of industrialization, prefabrication, and panelization as the structure for a DER program following NRCan's PEER project.
- Create a Crown corporation with the company's mandate being to DER all buildings in Canada. This company will hire and train builders, operate warehouses for envelope panel prefabrication, install panels, conduct energy audits, and monitor DERs as part of a long-term performance guarantee.
- Meaningfully engage with building occupants to ensure customer satisfaction with the design and retrofit process.

Training

- Fund 100% of the tuition fees for trades schools.
- Partner with RetrofitCanada to facilitate DER knowledge sharing.

Targets/Building Codes

- In partnership with provinces and territories, establish a DER building code by 2022 and a new-build building code by 2024.
- Aim for DERs to reduce energy demand to net-zero ready.

Financing

- Direct all funding to municipalities for decentralized and strategic distribution.
- Instruct municipalities to tie funding to performance with more grants going to projects that achieve greater energy demand reductions.
- Finance the retrofits through progressive taxation.

5.3 Evaluation

The Government of Canada's proposed retrofit program and my recommendations were evaluated using two tests. The first is a compare and contrast of proposals and recommendations against literature and interview data. The second is a test of good policy with original criteria.

5.3.1 Compare and Contrast

Government proposals, interview data, and literature data were sorted into six thematic categories for analysis by comparison. The tables showing the comparison are in the appendix (Tables 9.1-9.6). Table 5.1 summarized these tables and included my recommendations.

In terms of financing, the government proposals do not align well with literature and interview data. While participants appreciated the grant financing structure, $5,000 was seen as not substantial enough to incentivize DERs. Participants were more enthusiastic about the $40,000 zero-interest loans. However, literature data suggested the loan financing structure will not be attracted and that $40,000 still is not enough for a holistic DER. Interview and literature data pointed toward other financing mechanisms such as PACE, credit unions, and public banks such as Germany's KfW. I recommend directing funding to municipalities and financing DERs through taxation. This aligns with some literature but the academic discussion is admittedly divided on the topic.

The government's proposals for market transformation lack detail and are unlikely to trigger significant market transformation. Interview participants said that having the funding available for five to seven years does send good signals to the market but that the signals need to be stronger and for DERs. Literature and interview data indicated a more hands-on approach is required to create a DER market. The Market Transformation Roadmap needs an update. In line with the literature and some participants, I recommend starting out in social housing as a safe initial market to build up skills and knowledge.

Training more energy advisors is a promising proposal, but more training is needed. While participants said most skills for retrofitting could be trained on the job reasonably quickly, investments are needed to create a larger workforce and train for more specific skills such as photogrammetry. One participant also said that the energy advisor curriculum needs to be updated to match the requirements of DERs.

There were no proposed business models, so I assumed the program will continue with business-as-usual--which is the atomized market delivery model--and be unlikely to promote DERs. Interview participants were clear in that the Energiesprong model is the best delivery model. Literature data also suggested the Energiesprong model as a state-of-the-art innovation. Interview participants and literature suggested carrots, sticks, and tambourines to create a market, and operate under the assumption that the private sector will produce a business to carry out the Energiesprong model. However, my recommendation is for the Government of Canada to create a Crown corporation dedicated to DERing Canada's building stock because it is apparent there are significant barriers to market creation, and Crown corporations are among the most impactful market intervention tools governments can use.

There were also very few details on the program design. It appears the federal government intends to provide some funding and support retrofit programs at the provincial and territorial levels. Interview and participant data stressed the importance of having a long-term strategy, goal-setting, and targeted programming.

The proposals for a retrofit code by 2025 and a net-zero energy ready building code by 2030 are significant developments. Literature data highlighted building codes as among the most effective climate policies. Interview participants also strongly supported more regulation and stricter building codes. Some participants recommended accelerating the building code timeline.

The government's proposals did not align well with the interview and literature data. All in all, the government proposals are modest in some respects and inadequate in others. If the goal is to reduce residential GHG emissions, a long-term strategy and carefully designed plan are needed to create a market and increase demand for DERs. My recommendations were based on the literature and interview data, and are much more likely to create and market and increase demand for DERs.

Table 5.1. Summary of data, proposals, and recommendations.

Categories	Literature data	Interview data	Proposals	Author's Recommendations
Financing	PACE, performance-based grants, low-interest public loans, and credit unions are useful financing mechanisms. Federal and provincial governments should invest a combined $15 billion per year for ten years. Pay for retrofits through taxation, funding 50-75% of retrofits, 100% for low-income housing.	$5,000 is not enough, $40,000 is much better. DERs can cost between $40,000 to $300,000. Grants are better than loans but should be tied to performance. Other financing mechanisms like PACE, credit unions, and KfW should be explored.	$4.4 billion for zero interest loans $40,000 loans over five years. $2.6 billion for 700,000 grants up to $5,000 over five years.	Direct all funding to municipalities for decentralized and strategic distribution. Instruct municipalities to tie funding to performance with more grants going to projects that achieve greater energy demand reductions. Finance the retrofits through progressive taxation.
Market creation	The social housing sector can be used as a safe first market to help grow the market. Provide $10.4 billion over three years to the low-carbon economy fund to expand provincial and municipal energy efficiency portfolios. Provide $2 billion for large-scale building retrofit demonstration projects.	Invest in thousands of big projects, not pilots, to lower emissions and incentive the private sector. Contracting on a mass scale, as done with Toronto Community Housing Corporation, helps create markets. Money is not enough to transform the market, stronger intervention is needed particularly if we are aiming for DERs.	Working with provincial and territorial partners and with industry to advance technology and uptake of the next generation of low emission, high-efficiency space and water heating equipment and windows, building on the Market Transformation Roadmap. Working with the building materials sector and other stakeholders to develop a robust, low-emissions building materials supply chain to ensure Canadian, locally-sourced products are available, including low-carbon cement, energy efficient windows and insulation.	In partnership with Indigenous and subnational governments, create a strategy for DERing all residential buildings in Canada, starting in social housing and then moving to private sector MURBs followed by houses.
Training	Provincial governments, in partnership with the largest social housing providers, need to provide systematic training and capacity building to improve the governance and decision-making around capital planning projects. Invest $300 to $500 million in training.	Most skills required are easily trainable. Government can pay for tuition to trades to help build a workforce. Partner with them so they can train people to deliver Energiesprong.	$10 million to recruit, train and mentor 2,000 people to conduct energy audits.	Fund 100% of the tuition fees for trades schools. Partner with RetrofitCanada to facilitate DER knowledge sharing.

Business models	MESA is the best model because it eases the customer journey. Energiesprong is the best real-world example of a successful deep energy retrofit business model.	Energiesprong is the best model for delivery.	Continue with the atomized market model.	Create a Crown corporation with the company’s mandate being to DER all buildings in Canada. This company will hire and train builders, operate warehouses for envelope panel prefabrication, install panels, conduct energy audits, and monitor for long-term performance guarantee.
Program design	Canada needs a long-term strategy for social and affordable housing complemented with large-scale, whole-of-house retrofits supported financially and through regulations. Use a combination of tambourines, carrots, and sticks to raise awareness, incentivize, and regulate. Work with stakeholders to establish an industry driven retrofits program.	Do not target single-family homes. Start in social housing to create a market and then move to private sector MURBs followed by single-family homes. Use existing programs, do not create new complex programs. Allocate money to FCM.	Finance programs mentioned above. Continuing to work with and build on successful provincial and territorial low-income retrofit programs, to increase the number of low-income households that benefit from energy retrofits.	Use the Energiesprong model of industrialization, prefabrication, and panelization as the structure for a DER program following NRCan’s PEER project.
Targets and building codes	Stronger building codes are the most effective tool. Passive House standards are achievable. Aim for a retrofit rate of 4% to 5% per year.	Stronger building codes that are enforced are the most effective tool. If you do not use a stick, people will just say it is cost-prohibitive. A 40% to 50% reduction in energy demand is a good starting point. But we need 50%+. Aim for Passive House standard. The 2030 net-zero energy building code needs to come sooner. We need a national building step code that includes renovations and retrofits.	Continuing to work with provincial and territorial governments to develop a new model “retrofit” code for existing buildings by 2022, with the goal of collaborating with provinces and territories to have this code in place by 2025. Develop and adopt increasingly stringent model building codes, with the ultimate goal of a net-zero energy ready model building code by 2030. One million free energy audits // up to $600 to help with the cost of home energy evaluations.	In partnership with provinces and territories, establish a DER building code by 2022 and a new-build building code by 2024. Aim for DERs to reduce energy demand to net-zero ready.

5.3.2 Good Policy Test

The good policy test is a useful test because it gives assurance that policies will serve a collective good, do so cost-effectively, and be politically viable. However, this test has major limitations because the proposals and my recommendations have no data that can be assessed. Therefore, the government's proposed retrofit policies and my recommendations were assessed using assumptions established from my literature review and interview data. The results of the test are shown in Table 5.2.

Overall, my recommendations were better aligned with the good policy criteria than the Government of Canada's proposals. Interview and literature data both suggested that my recommendation to follow the Energiesprong approach will be more effective at lowering GHG emissions than the government's piecemeal approach (Ürge-Vorsatz et al., 2020; Jamali 2015; Hoicka et al., 2014; Jermyn & Richman, 2016). My recommendations would certainly cost more; however, researchers have shown return on investments as high as five times the money spent due to lowered energy demand and health care costs (Kennedy & Frappé-Sénéclauze, 2021). Additionally, literature and interview data suggested the government's investments are likely to be wasted on shallow and ineffective retrofits (Jamali, 2015; Hoicka et al., 2014). Long-term performance is difficult to assess because the federal government does not have performance targets and Energiesprong projects are all less than 11 years old. But, because Energiesprong program managers often offer 30-year guarantees, they are confident in the process to deliver long-lasting results. Literature and interview data both suggested the government's proposals will primarily benefit middle class households already interested in undergoing retrofits (Jamali, 2015). My recommendations, on the other hand, specifically target low-income households living in social housing as the priority demographic. And, most advocates estimate large investments in retrofits like I recommended could create in the range of 138,000 long-lasting jobs (CaGBC, 2020; Efficiency Canada, 2020; Kennedy & Frappé-Sénéclauze, 2021). Of course, the government's own proposals are politically acceptable; my recommendations have strong indicators for political acceptance but also doubts. First, the Energiesprong model has already been invested in by government entities such as BC Housing, Ottawa Community Housing, and NRCan. Second, bold climate action consistently polls well across Canada. The doubt comes in the form of market intervention: the federal government has shown a favour to public-private-partnership and subsidization in their tenure since 2015; nationalization or creating Crown corporations do not seem to be politically interesting; although, CMHC is an existing and long-lasting Crown corporation that could be capable of such work.

Table 5.2. Policy evaluation of government proposals and author recommendations.

Good policy criteria	Government's Proposals	Author's Recommendations
Effective: Is the policy likely to lower GHG emissions and energy demand in residential buildings?	No. Interview and literature data both suggested that piecemeal retrofits offered through small grants and moderate loans will not result in many DER. Customers will continue to struggle to navigate the complex procedure and many contractors required to DER a home.	Yes. Energiesprong has shown to be a global best-practice in lowering residential GHG emissions and came highly recommended from nearly all interview participants. In many cases, Energiesprong projects are able to achieve net-zero, net-zero ready, or an energy demand less than 75 kWh/m^2.
Cost-effective: Is the policy likely to use money effectively?	No. Some interview participants said that the money allocated to this program will be wasted on ineffective retrofits. Literature and interview data also suggested the money will be spent on shallow retrofits.	Likely. Monetary estimates were beyond the scope of this research but Energiesprong has been shown to decrease costs. Some advocates recommended the government invest $10 to $15 billion annually, far more than what the government has proposed . However, their modelling data showed that four to five times the return on investment from energy savings and health care costs.
Long-term performance: Is the policy likely to produce retrofits with long lasting performance?	Uncertain. This depends on the performance target and none have been set. Shallow retrofits can have long-lasting, yet small, effects.	Likely. The Energiesprong model for DERs has only been around for 11 years so there is not any long-term performance data. However, program managers often offer 30-year guarantees because of their confidence in DERs to have long-lasting effects. The Saskatchewan Conservation House has shown that DERs deliver results for decades.
Social value: Is the policy likely to have social benefits beyond decreased GHG emissions and residential energy demand?	No. Interview and literature data both suggested these policies will likely only benefit middle class families already interested in doing a retrofit. There may be some additional job creation, but it is difficult to discern if it will be from government policies or natural market development.	Yes. The recommendations specifically target low-income families living in social housing as a priority. DERs have even been shown to increase health outcomes of the residents. And job estimates for retrofit programs of my recommended size are around 138,000 jobs lasting 10 to 20 years. Social housing revitalization projects may also encourage a sense of pride among the residents.
Political acceptance: Is the policy politically acceptable?	Yes. The federal government along with a handful of provincial and municipal governments have shown enthusiasm for retrofit programs. Public support for climate action is also strong.	Somewhat. Government bodies--such as BC Housing, Ottawa Community Housing, and NRCan--have shown great interest and invested in Energiesprong-style approaches. There is also large public support for bold climate action. Therefore, my recommendations are politically acceptable. However, the current federal government has shown through their proposals that creating a Crown corporation and spending $10 to 15 billion annually is politically unlikely.

6.0 Conclusion

If Canada is to meet its Paris Agreement targets, it must make major investments in DERs. As it stands, DERs are expensive and complicated to implement. The federal government's proposed retrofit measures are moderate in some respects but inadequate in others. To meet our Paris Agreement targets and lower GHG emissions, the federal government must coordinate a national strategy on DERs.

The recommendations put forward in this paper represent a culmination of research based in the multi-level, multi-phase perspective theory, ETIS theor, SNM theory, and theories of innovation intermediaries and built with data from academic and grey literature and from semi-structured interviews with green building professionals. The review covered business models, financing mechanisms, global best-practices, and the role of intermediaries in energy transitions.

In this research, I aimed to provide policy recommendations to the federal government to advance the uptake of residential retrofits. If the federal government intends to lower GHG emissions and energy demand in residential buildings, they should coordinate a national strategy with provincial, territorial, Indigenous, and municipal governments, create a Crown corporation to implement DERs, follow the Energiesprong model, start work in social housing and then move to private sector MURBs followed by single family housing, finance through progressive taxation, and accelerate the creation and implementation of a retrofit building code and net-zero energy ready building code.

7.0 Future Research

Future research should focus on measuring the success of the Canada Greener Homes Grant and the $40,000 zero-interest loan in terms of GHG and energy reductions achieved. It would also be interesting to see demographic information of people who are receiving the funding. More research should investigate the GHG and energy reduction potential of a targeted DER program focussed on social housing and costing studies.

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9.0 Appendix

9.1 Questions asked in semi-structured interviews

1. Are you satisfied with the federal government's proposed new measures?
    a. The proposed new measures can be found here: https://www.canada.ca/content/dam/eccc/documents/pdf/climate-change/climate-pan/annex_homes_buildings.pdf
    b. What about these new measures do you find promising?
    c. What about these new measures do you find disappointing?
    d. What about these new measures do you have mixed feelings about?

2. In your professional opinion, what is preventing the creation of an economy of scale for retrofits in Canada?
    a. Supplies
    b. Capital
    c. Training
    d. Demand

3. What policy recommendations do you have for the federal government to increase the rolling out of deep energy retrofits?

4. Since the start of this project, Budget 2021 was released and it contained important information relevant to retrofits so I also ask for your comment on the follow extraction from the budget:

> The 2020 Fall Economic Statement put forward a program to provide Canadians with one million free energy audits and up to 700,000 grants, valued at up to $5,000, to complete energy efficient home improvements. To help homeowners and build on these measures:
>
> Budget 2021 proposes to provide $4.4 billion on a cash basis ($778.7 million on an accrual basis over five years, starting in 2021-22, with $414.1 million in future years) to the Canada Mortgage and Housing Corporation (CMHC) to help homeowners complete deep home retrofits through interest-free loans worth up to $40,000. Loans would be available to homeowners and landlords who undertake retrofits identified through an authorized EnerGuide energy assessment. In combination with available grants announced in the Fall Economic Statement, this would help eligible participants make deeper, more costly retrofits that have the biggest impact in reducing a home's environmental footprint and energy bills. This program will also include a dedicated stream of funding to support low-income homeowners and rental properties serving low-income renters including cooperatives and not-for-profit owned housing.
>
> The program would be available by summer 2021. It would be easily accessible through straightforward online tools, and is expected to help build Canadian supply chains for energy efficient products. It is estimated that more than 200,000 households would take advantage of this opportunity.

5. Is there anyone you recommend I interview for this project?

<u>9.2 New retrofit measures announced in *A healthy environment and a healthy economy*</u>

- Providing $2.6 billion over seven years, starting in 2020-21, to help homeowners improve their home energy efficiency by providing up to 700,000 grants of up to $5,000 to help homeowners make energy-efficient improvements to their homes, up to one million free EnerGuide energy assessments, and support to recruit and train EnerGuide energy auditors to meet increased demand.

- Investing $1.5 billion over three years for green and inclusive community buildings through retrofits, repairs, upgrades and new builds, which would support good jobs and local economic growth, contribute to climate objectives and serve disadvantaged populations.

- Requiring that at least 10% of this $1.5 billion in funding be allocated to projects serving First Nations, Inuit and Métis communities, including Indigenous populations in urban centres.

- Conducting Canada's first-ever national infrastructure assessment, starting in 2021, to help identify needs and priorities in the built environment, and undertake long-term planning towards a net-zero emissions future.

- Continuing to work with and build on successful provincial and territorial low-income retrofit programs, to increase the number of low-income households that benefit from energy retrofits.

- Outlining details of a low-cost loan program that integrates and builds on available energy audits and grants, and which can be easily accessed by Canadians.

- Working with provincial and territorial partners and with industry to advance technology and uptake of the next generation of low emission, high-efficiency space and water heating equipment and windows, building on the Market Transformation Roadmap.Working with the building materials sector and other stakeholders to develop a robust, low-emissions building materials supply chain to ensure Canadian, locally-sourced products are available, including low-carbon cement, energy efficient windows and insulation.

- Continuing to work with provincial and territorial governments to develop a new model "retrofit" code for existing buildings by 2022, with the goal of collaborating with provinces and territories to have this code in place by 2025.

- Accelerating work with provincial and territorial governments to develop and adopt increasingly stringent model building codes, with the ultimate goal of a net-zero energy ready model building code by 2030.

9.3 Comparison tables used in evaluation

Figure 9.1. Comparison table: financing

Government Proposal	Literature Review Data	Interview Data	Evaluation
$4.4 billion to CMHC for 0% interest loans up to $40,000 over five years.	Public loans and low-interest financing are a requirement for DERs. Germany's KfW and Scotland's HEEP are examples of successful programs (Brown, Sorrell, et al., 2019).	$5k is not a lot of money but grants are nice.	$40,000 in zero-interest loans offered over five years and $5,000 grants over seven years is a good combination but does not match up to the expectations of industry or literature.
$2.6 billion over seven years for 700,000 grants up to $5,000.	PACE financing, with the debt tied to the property and not the homeowner, is a useful financing mechanism (Brown, Sorrell, et al., 2019; Brown et al., 2019; Frappé-Sénéclauze, 2020).	A $40k interest-free loan is much better (50k would be great) depending on the payback period.	Personal debt financing mechanisms are not attractive, $7 billion allocated in the budget will not be enough to make a meaningful impact, and funding should be tied to performance.
	Performance-based grants are more successful than list-based grants (Hoicka & Parker, 2018; Frappé-Sénéclauze, 2020).	Varying cost estimates: $40k for 40% and $120k per suite for an 80% energy reduction; $60-100k per household for single-detached, $40-60k per MURB suite; meaningful DERs costing $150-300k; $50k for a house.	There is also a concerning lack of details on how accessible the funding will be.
	Capital cost is a major barrier, government investment is needed (Brown, Sorrell, et al., 2018; Jamali, 2015; Jermyn & Richman, 2016; Ürge-Vorsatz et al., 2020)	PACE/LICs are good financing systems, better than interest-free loans.	
	Provincial governments, in partnership with financial institutions, need to identify a suite of economic incentives such as soft loans, low cost secondary mortgages, credit lines and loan guarantees to allow leveraging of additional funds for renewal and energy efficiency retrofits by social housing providers. Funding should be directed to municipal governments (Tsenkova, 2021h).	More credit unions such as Vancity are needed.	
	Catalyze a low-carbon retrofit economy by allocating $50 million for 0% financing of energy audits, deploy $10 billion through the CIB to finance	Grants are really important for community housing, low-cost financing for MURBs.	

	low-carbon retrofits (CaGBC, 2020a).		
	Increase loan maximums for homes from $40,000 to 100,000 and provide grants to cover a significant portion of the retrofit cost (Frappé-Sénéclauze, 2020).	Financing should be tied to a gradient. 40% emission reduction from retrofit, $40k grant.	
	Create an ongoing funding mechanism for low-carbon finance programs distinct from general revenues (Frappé-Sénéclauze, 2020).	Success will also depend on how easy it is to access funding.	
	The formula established to assess grant size and the total loan could be adapted to allow for regional variation, economic standing, equity-seeking, Indigenous communities (Frappé-Sénéclauze, 2020).	Allow for longer payback periods, in the range of 25 years.	
	Include low-carbon heating equipment, grid-interactive building components, and other high-performance building components when defining zero-emission technologies eligible for tax cuts (Frappé-Sénéclauze, 2020).		
	Provide $13 billion to create a building retrofit finance program through CMHC and CIB (Efficiency Canada, 2020).		

Figure 9.2. Comparison table: market creation

Government Proposal	Literature Review Data	Interview Data	Evaluation
Working with the building materials sector and other stakeholders to develop a robust, low-emissions building materials supply chain to ensure Canadian, locally-sourced products are available, including low-carbon cement, energy efficient windows and insulation.	Provide $10.4 billion over three years to the low-carbon economy fund to expand provincial and municipal energy efficiency portfolios. Provide $2 billion for large-scale building retrofit demonstration projects (Efficiency Canada, 2020).	Focus on funding, policymaking, awareness, help with knowledge dissemination, mandating, capacity-building. An interviewee referenced a new website, https://retrofitcanada.com/, designed for knowledge sharing. Governments should support nonprofits to open dialogue between industry and government.	Having funding available over 5-7 years helps create a market because it gives industry security that previous retrofit programs have lacked.
Working with provincial and territorial partners and with industry to advance technology and uptake of the next generation of low emission, high-efficiency space and water heating equipment and windows, building on the Market Transformation Roadmap.	Middles, such as social housing providers, have the agency and capacity for market creation (Janda et al., 2014; Cauvain & Karvonen, 2018).	The seven-year program is great, it gives industry security not seen in previous programs.	More direct work is needed from the government to demonstrate best practices and disseminate knowledge.
$4.4 billion to CMHC for 0% interest loans up to $40,000 over five years.	Dependent on the work of intermediaries (Kivimaa & Martiskainen, 2018).	Money is not enough to transform the market, stronger intervention is needed particularly if we are aiming for DERs.	An update is needed on the Market Transformation Roadmap.
$2.6 billion over seven years for 700,000 grants up to $5,000.	Federal and provincial governments, in partnership with the largest social housing providers, need to disseminate evidence from an ex-post evaluation of select best practices to overcome capacity and information constraints in the sector. A non-profit is recommended to streamlining innovation (Tsenkova, 2021h).	Invest in thousands of big projects, not pilots, to lower emissions and incentive the private sector. Contracting on a mass scale, as done with Toronto Community Housing Corporation, helps create markets.	
	Dependent on the work of intermediaries (Kivimaa & Martiskainen, 2018).	The government needs to make it as easy to retrofit a home as it is to buy an electric vehicle. They need to build a cohort of professions that can help homeowners navigate the process.	

Figure 9.3. Comparison table: training

Government Proposal	Literature Review Data	Interview Data	Evaluation
$10 million to recruit, train and mentor 2,000 people to conduct energy audits.	Provincial governments, in partnership with the largest social housing providers, need to provide systematic training and capacity building to improve the governance and decision-making around capital planning projects (Tsenkova, 2021h).	Pre-fabricated panelization is not difficult manufacturing or carpentry. Interviewee built their manufacturing line in a Quonset with the support of a local hardware store.	Training more energy advisors is good but current energy advisor skill levels and tools are inadequate for DERs.
	Advance workplace development and employment by investing $100 million to retrain workers who lost employment due to COVID-19 into green building jobs (CaGBC, 2020a).	Current energy advisor skills, energy modelling tools like HOT2000 are inadequate for DERs. Training them up wouldn't be hard. We also need more energy advisors in more locations.	Training also needs to be done in other trades including photogrammetry.
	Invest $500 million in workforce development and training (Frappé-Sénéclauze, 2020).	Government can put up the money to pay for tuition at the college, university, or trade level.	
	Provide $1.5 billion in funding to expand green building workforce training (Efficiency Canada, 2020).	You need to create demand before skills will be built up through doing the work. And then work needs to be done to facilitate knowledge sharing.	
	$300 million per year for skill development, capacity building and recruitment, with funds earmarked to increase diversity in the retrofit economy (Kennedy & Frappé-Sénéclauze, 2021).	Partner with academic institutions so they train for outcomes such as Energiesprong.	
		Some training is needed for photogrammetry and software. These are essentially nonexistent skills right now.	

Figure 9.4. Comparison table: business model

Government Proposal	Literature Review Data	Interview Data	Evaluation
Continue with the atomized market model.	MESA model is best because it eases the customer journey by amalgamating the market (Brown, 2018).	Energiesprong (prefabricated panels, industrialized manufacturing) is the best model for delivery but will require major government investment.	The proposed business model is unlikely to promote DERs.
	The Energiesprong business model is highly beneficial because of the industrialized process of manufacturing and installation (Ürge-Vorsatz et al., 2020; Brown et al., 2018).	Major government investment will have to pay for the first bunch of units. As industry experience increases, costs will go down and so will utility bills, this will offset the large investment, and the government can ratchet down how much they contribute.	This process will be difficult for customers to navigate.
	Focus on business models that maximize benefits (Hoicka & Das, 2020).		

Figure 9.5. Comparison table: program design

Government Proposal	Literature Review Data	Interview Data	Evaluation
$4.4 billion to CMHC for 0% interest loans up to $40,000 over five years.	Avoid one-size-fits-all programs, design programs for subsets of the population. People will respond to effective incentives (Hoicka et al., 2014).	Energy advisors need to be engaged more in designing programs.	Few details on program design leave customers and industry in the dark.
$2.6 billion over seven years for 700,000 grants up to $5,000.	Provide thorough information on the energetic, social, and health benefits of envelope upgrades and "house as a system" thinking (Hoicka & Parker, 2018; Hoicka & Das, 2020).	Instead of creating complex new programs for people to navigate, use existing programs and increase their funding. Allocate to FCM and let them manage the funds.	Specific desired outcomes are unknown.
Continuing to work with and build on successful provincial and territorial low-income retrofit programs, to increase the number of low-income households that benefit from energy retrofits.	Create intermediaries to promote programs and raise awareness (tambourines); incentives will enable but not drive retrofits (carrots); national minimum energy efficiency standards are good forms of regulation (sticks) (Brown et al., 2019; Jamali, 2015).	Single-family homes should not be the target for this program. The primary target should be MURBs in the affordable housing sector where you can build scale and then export to the private sector and commercial buildings.	
	Canada needs a long-term strategy for social and affordable housing complemented with large-scale retrofit programs supported financially and through regulation (Tsenkova, 2021i).	Money has to be spent effectively with clear outcomes, not on shallow retrofits, otherwise the money will be wasted and it will lock in future emissions.	
	Form a cross-ministerial working group for the coordination of a retrofit building strategy (Frappé-Sénéclauze, 2020).	Retrofits need to be done holistically.	
	Partner with retail banks to engage homeowners when investment decisions are made (Frappé-Sénéclauze, 2020).	Target when property changes ownership for instigating energy performance.	
	Standardize the approach for developing and evaluating retrofit projects. Work with stakeholders to establish an industry driven retrofit program (CaGBC, 2020a).		
	Federal and provincial government agencies need to commit to monitoring and evaluating energy retrofit programs (Tsenkova, 2021h; Hoicka & Das, 2020).		

Figure 9.6. Comparison table: targets and building codes

Government Proposal	Literature Review Data	Interview Data	Evaluation
Loans would be available if retrofits undertaken are identified through an authorized EnerGuide energy assessment	75 kWh/m^2 and 25 kWh/m^2 (the Passive House EnerPHit estimated equivalency) are achievable (Jermyn & Richman, 2016).	Governments need to be clear in desired outcomes so we can start building toward them.	A retrofit code is a great idea but the timeline is misaligned with funding.
One million free energy audits // up to $600 to help with the cost of home energy evaluations	Canada needs well-defined program targets that link general quality improvements in the social housing sector to energy efficiency retrofits (Tsenkova, 2021h).	Pre- and post-audits are essential for tracking progress. There needs to be a retrofit code.	Free energy audits are good, they should be provided free before and after retrofitting.
Continuing to work with provincial and territorial governments to develop a new model “retrofit” code for existing buildings by 2022, with the goal of collaborating with provinces and territories to have this code in place by 2025.	It is possible to reliably and affordably achieve net or nearly-zero energy building outcomes all over the world in most building types and climates with systems, technologies and skills that already exist, and at costs that are in the range of conventional buildings (Ürge-Vorsatz et al., 2020).	Governments need to make it expensive to build and operate inefficient buildings, and make them easy to retrofit.	A net-zero energy ready model building is essential but the 2030 timeline is too far away.
Accelerating work with provincial and territorial governments to develop and adopt increasingly stringent model building codes, with the ultimate goal of a net-zero energy ready model building code by 2030.	Stimulate zero-carbon construction projects by requiring all federally-funded buildings to achieve zero-carbon performance, invest $20 million in embodied carbon research, develop a National Building Code, and grant $1 billion, scaled to performance, for public and private sector buildings to ensure they are built to achieve low-carbon performance (CaGBC, 2020a).	Set building performance targets. Aim for Passive House standard.	More regulation and enforcement are needed.
Conducting Canada’s first-ever national infrastructure assessment, starting in 2021, to help identify needs and priorities in the built environment, and undertake long-term planning towards a net-zero emissions future.	Make access to a portion of funds for incentives and capacity building conditional on advancing regulatory roadmaps for a zero-carbon building sector by 2050. Create a set of stepped performance-based metrics for operational carbon intensity, embedded carbon intensity, and peak electricity	There is a problem with the lack of building code enforcement, more inspections are needed.	

	demand (Frappé-Sénéclauze, 2020).		
	Create a top-up fund for NHS-funded retrofits and new construction projects that achieve deep carbon reductions. Require stronger climate resiliency in NHS-funded projects (Frappé-Sénéclauze, 2020).	We need a national building step code that includes renovations and retrofits. The 2030 net-zero energy building code needs to come sooner.	
	Develop low-cost labelling tools aligned with EnerGuide, and work with provinces and territories to implement labelling requirements at point of sale or rental (Frappé-Sénéclauze, 2020).	A 40% to 50% reduction in energy demand is a good starting point. But we need 50%+.	
	Incentivize provinces to adopt high energy performance tiers of the 2020 model national building codes (Efficiency Canada, 2020).	If you do not use a stick, people will just say it is cost-prohibitive.	

Section 3: Policy Brief

Build Back Better with Deep Energy Retrofits: A Research Project

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August 2021

Executive Summary

The Government of Canada has committed to funding retrofits as part of a post-COVID-19 economic recovery. Most of the excitement has been around the Canada Greener Homes Grant, the promise of $40,000 interest-free loans, and updates to the national building codes. However, if Canada is to meet its 2030 and 2050 emissions reduction targets, a more strategic approach to residential buildings is needed. Ambitious investments could create 140,000 jobs in the retrofit sector that can be sustained for at least two decades. And by 2050, residential greenhouse gas emissions could drop by 89%. To get there, researchers estimate we must retrofit 3% to 4% of the housing stock every year -- nearly 600,000 dwellings annually. Researchers also estimate that every dollar invested in retrofits will return $2 to $5 to public coffers in health, electricity, and energy savings. Because of significant barriers to retrofit market creation, I recommend the Government of Canada create a Crown corporation tasked with deep energy retrofitting all buildings in Canada. I also recommend that they start in social housing as a safe first market that prioritizes low-income communities. The Energiesprong model for delivering retrofits has proven to be an international best practice and is highly recommended by industry leaders. Canada must take projects like NRCan's Prefabricated Exterior Energy Retrofit project with Ottawa Community Housing and advance them from demonstration to national deployment.

Context

In December of 2020, the Government of Canada released *A Healthy Environment and a Healthy Economy: Canada's strengthened climate plan to create jobs and support people, communities and the planet*. This announcement included new promises for investments in retrofits such as 700,000 grants of up to $5,000 to help homeowners make energy efficiency improvements to their homes -- which has been realized through the Canada Greener Homes Grant -- and to work with provincial and territorial governments to develop a retrofit code by 2025 and a net-zero energy ready model building code by 2030. Additionally, in Budget 2021, the federal government proposed to help homeowners complete deep energy retrofits through interest-free loans worth up to $40,000. These announcements inspired the focus for my Master in Environmental Studies research project.

Early into the pandemic, green building advocates began calling for a post-COVID-19 green recovery focused on building retrofits.[1,2] Retrofits stand out as a green recovery investment because they have a high job creation potential, create jobs across Canada in our communities, make healthier homes, and lower our greenhouse gas emissions. Additionally, as we saw with British Columbia's deadly heatwave, it is critically important that we build up climate resiliency, such as with deep energy retrofits.[3]

Efficiency Canada estimated that with a $26.9 billion public investment over five years, we could retrofit 1.5 million residential homes, 752,000 multi-unit residential buildings, and 113 million square metres of commercial and institutional space.[4] With this investment, they also estimate we could create 132,000 jobs sustained for five years and achieve an annual GHG emission reduction of 20.4 Mt CO_2e.

Researchers from Pembina Institute calculated the benefits of a pan-Canada "renovation wave."[5] They modelled for a long-term strategy to decarbonize all buildings in Canada by 2050 completely. To do so, Canada needs to invest $10 to $15 billion annually from now until 2040. This investment would reduce residential GHG emission by 89% by 2050, sustain 138,000 jobs from now until 2050, and retrofit 598,000 dwellings a year (411,000 homes and 188,000 apartments).

As demonstrated in Canada's *Strengthened Climate Plan*, retrofits deserve to be a priority investment to help Canadians recover from the COVID-19 pandemic and reposition themselves for the fight against climate change.

Methods

For my master's research project, I reviewed academic literature on deep energy retrofits and canvassed industry leaders for their feedback on the Government of Canada's retrofit proposals outlined in their *Strengthened Climate Plan*. The recommendations given in this brief represent a culmination of my discussions with green building leaders and my review of global best practices.

Policy Recommendations

Strategic direction

- In partnership with Indigenous and subnational governments, **create a strategy to deep energy retrofit all residential buildings in Canada that starts in social housing** and then moving to private sector MURBs followed by houses.
- **Pause the Canada Greener Homes Grant** and other programs targeting detached single-family homes until a deep energy retrofit building code has been created.

Launching into the private sector for retrofits before a retrofit building code has been established or a deep energy retrofit market has been created will likely cause homeowners to invest in shallow retrofits. This is damaging to a national retrofit strategy because shallow retrofits will waste money and lockout future energy savings. Instead, social housing can be used as a safe first market to build up skills in a workforce and perfect practices while prioritizing low-income communities.

Program design

- **Use the Energiesprong model** of industrialization, prefabrication, and panelization as the structure for a deep energy retrofit program **following NRCan's Prefabricated Exterior Energy Retrofit project.**
- **Create a Crown corporation with the company's mandate being to deep energy retrofit all buildings in Canada.** This company will hire and train builders, operate warehouses for envelope panel prefabrication, install panels, conduct energy audits, and monitor deep energy retrofits as part of a long-term performance guarantee.
- **Meaningfully engage with building occupants** to ensure customer satisfaction with the design and retrofit process.

The Energiespong (dutch for 'energy leap') model is the global best practice in deep energy retrofits. Builders go on-site, create a photogrammetric map of a building, and prefabricate an airtight panelized envelope off-site. This model has proven to lower costs, minimize disturbance to residents, and provide a safer working environment for builders. In addition, meaningfully engaging residents in the design process can significantly improve customer satisfaction. A few start-ups in Canada are working with this model, and NRCan has piloted a project with Ottawa Community House. Still, significant market intervention is needed for a more successful launch. That is why Canada must create a Crown corporation, one of the most effective and powerful market tools available for use, that follows the Energiesprong model and operates at a national level.

Training

- **Fund 100% of the tuition fees for trades schools.**
- **Partner with RetrofitCanada** to facilitate deep energy retrofit knowledge sharing.

Green building sector leaders are confident we can quickly train up most skills for retrofitting buildings, but Canada must partner with academic institutions to train for desired outcomes. Non-profits, like RetrofitCanada, are doing work to share lessons learned while completing deep energy retrofits and using models like Energiesprong, but they are under-resourced. Canada can step in and assist through funding and facilitation.

Targets/Building Codes

- In partnership with provinces and territories, **establish a deep energy retrofit building code by 2022 and a new-build building code by 2024.**
- Aim for DERs to **reduce energy demand to net-zero ready.**

Building codes are the most effective policy for lowering greenhouse gas emissions in buildings. That is why it is crucial Canada fast-tracks its deep energy retrofit building code and builds up enforcement capacity.

The building code must be ambitious as well. Researchers in Toronto and global reviews have shown that Passive House or net-zero ready buildings are possible in climates all across Canada with available technologies.[6,7]

Financing

- **Direct all funding to municipalities** for decentralized and strategic distribution.
- Instruct municipalities to **tie funding to performance** with more grants going to projects that achieve more significant energy demand reductions.
- **Finance the retrofits through progressive taxation.**

Retrofits are undeniably expensive when we try to finance them ourselves. However, if we pay for them together, they pay for themselves. Pembina Institute researchers demonstrated that every dollar spent on building retrofits would return $2 to $5 in energy savings and health care costs.[5] The most efficient and equitable way to pay for deep energy retrofits is through progressive taxation. Fighting climate change and lowering our greenhouse gas emissions are collective struggles that should be paid for through collective, progressive taxation.

Conclusion

As the pandemic nears its end and Canadians are reawakening to the climate crisis, deep energy retrofits emerge as a clear solution to create jobs, building climate resilience, and lower greenhouse gas emissions. Significant investments today and sustained into the future will pay for themselves in improved health outcomes, climate resiliency, and reduced electricity and energy demand. Creating a Crown corporation is the most effective market tool governments can use to move industries to where the public needs them to be and is therefore highly recommended.

To meet Canada's climate objectives, deep energy retrofitting the building stock is not a matter of *if* but a matter of *when*. And a post-COVID-19 economic recovery is an excellent starting point.

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