Research to Understand the Success of Building Retrofit Programs in BC

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Disclaimer

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

Community Energy Association

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Executive Summary

The growing emphasis on climate action in British Columbia (BC), Canada, and on a global scale has led to a surge in the implementation of retrofit programs with greater ambition. Notably, a considerable number of new programs in BC and other parts of Canada are specifically focused on air-source heat pumps, and their preliminary results have attracted considerable attention. This trend is not unique to Canada; similar patterns are being observed in various regions around the world, signaling an increasing interest in and commitment to retrofit programs aimed at enhancing energy efficiency and reducing greenhouse gas emissions. This collective effort reflects a broader global commitment to combat climate change and transition toward more sustainable and environmentally friendly energy solutions.

The study undertaken here has delved into various building retrofit programs, seeking to examine the actual results achieved in terms of energy savings and greenhouse gas (GHG) emissions reduction. The overarching goal of the study has been to understand the factors contributing to the success of these retrofit programs and to analyze the evaluation techniques employed to assess their achievements. By investigating and analyzing these retrofit programs, the study aims to provide valuable insights into what works in the field of building retrofits, offering a better understanding of the key factors that contribute to their success. Additionally, the examination of evaluation techniques provides a deeper understanding of how these programs measure their impacts, helping to identify best practices in assessing the effectiveness of energy-saving and emissions-reducing initiatives in the built environment. This research serves as a valuable resource for policymakers, program managers, and stakeholders interested in designing, implementing, and optimizing building retrofit programs to achieve meaningful energy efficiency and GHG reduction goals. The following table is the summary of 6 retrofit programs from BC, which are documented as case studies in this report.

Table E1. *Summary of 6 retrofit programs from BC*

Program	Description	Evaluation Method	Success Factors	Energy Savings	GHG Reduction
Residential Home Renovation Rebate Program (F2012 – F2014 and F2014 – F2019)	There are two phases of the Residential Home Renovation Rebate Program – LiveSmart BC (F2012-F2014) and Home Renovation Rebate programs (F2014-F2019). The fundamental idea behind this program was to offer incentives to homeowners for the installation of additional energy-efficient measures.	Participant Survey, Non-Participant Survey, and Residential End-Use Studies	Net energy savings, peak demand saving, participant's satisfaction level and attitudes towards the program, recommend to others, different program related indicators like no. of participants	19.3 GWh/Year between F2014 and F2019, and 8.9 GWh/year in F2013	No calculation
Energy Conservation Assistance Program Basic (F2012-F2016)	The Low-Income Program, operated by BC Hydro, is an initiative aimed at helping residential customers who meet income eligibility criteria reduce their energy expenses.	Participant Survey and Residential End-Use Studies	Net energy savings, peak demand saving, participant's satisfaction level, ability or willingness to pay bills in full and on time	6.3 GWh/year	No calculation
Saanich Oil to Heat Pump Financing Program	The Saanich Oil to Heat Pump Financing Program is designed with the aim of expediting the adoption of heat pumps for space heating by alleviating the initial financial obstacles that homeowners typically encounter when undertaking such upgrades.	Registration Survey, and Modelled GHG reduction and energy savings based on pre-upgrade EnerGuide Home Evaluation	GHG reduction, energy savings, 0% interest, no fee financial support, physical marketing materials, reserved spot for income qualified participants	907 GJ per year for 15 participants	85.7 tCO_{2e} per year for 15 participants
Bring it Home 4 the Climate Pilot Program (Sep 2020 – Jan 2021)	Bring It Home 4 the Climate (BIH) program offers support and education to homeowners in the capital region who are interested in making their homes more environmentally friendly in terms of climate impact.	Participant Survey	Program outreach and promotion, provision of EnerGuide Home Evaluation Subsidy, participant's satisfaction level, recommend to others, well-received workshops, virtual home energy check-ups	No calculation	No calculation
Home Energy Loan Program (HELP)	Since 2013, the City of Penticton has been operating its Home Energy Loan Program (HELP), which extends loans to residential customers for the purpose of retrofitting their homes to enhance energy efficiency.	Measurement of energy savings, no of participants, types and sizes of upgrades	Low risk, low free-ridership, low rejection rate, high revenues, low administrative costs	108,280 kWh	No calculation
Nelson Ecosave - REEP	The Regional District of Central Kootenay has introduced the REEP program with the primary aim of reducing greenhouse gas emissions in residential retrofits and new construction projects.	D and E EnerGuide Assessments	GHG reductions and energy savings	42.90 GJ per home	1.32 tCO_{2e} per home

Measuring the reduction in energy consumption and the resulting decrease in greenhouse gas emissions represents a foundational evaluation method. These metrics provide a quantifiable assessment of the environmental impact of retrofit programs and help in tracking progress toward emissions reduction objectives. Gathering feedback from program participants through surveys, interviews, and focus groups plays a critical role in assessing the user experience, identifying areas for enhancement, and gauging overall satisfaction. Continuously monitoring and verifying the performance of retrofitted buildings is essential to ensure their ongoing energy efficiency. This practice helps prevent the rebound effect, which occurs when energy savings are eroded due to changes in occupant behavior or equipment malfunctions. Evaluating the long-term impact of retrofit programs, including their contribution to Canada's emission reduction targets and the sustainability of retrofitted buildings, is crucial for assessing their effectiveness over time. This comprehensive evaluation approach enables Canada to progress toward its environmental and sustainability objectives, benefiting homeowners, businesses, and the economy at large. Retrofit programs extend beyond emissions reduction; they pave the way toward a greener, more prosperous future for all Canadians, aligning with the nation's commitment to environmental stewardship and sustainability. By continually refining and enhancing these programs based on evaluation results, Canada can further advance its environmental goals while fostering positive outcomes for its citizens and the environment.

In conclusion, evaluating retrofit programs is a multifaceted process that demands thorough assessment and strategic planning. By conducting comprehensive audits, prioritizing projects, and weighing cost-effectiveness, organizations can make informed decisions to improve energy efficiency, reduce environmental impact, and enhance overall building performance. Continuous monitoring and a commitment to adaptability are essential to ensure the long-term success and sustainability of retrofit initiatives.

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Introduction

Background

Communities, provinces, and countries worldwide are making efforts to achieve significant reductions in greenhouse gas (GHG) emissions. In order to meet the targets set by the Intergovernmental Panel on Climate Change (IPCC) of limiting global warming to 1.5°C, emissions must be reduced by approximately 50% below 2010 levels by 2030, and completely eliminated by 2050. While there are viable strategies to achieve emission reductions in various sectors, retrofitting existing buildings presents a considerable challenge. The majority of buildings that will exist in 2030 and 2050 are already standing today, requiring extensive retrofitting to contribute to these goals. Retrofitting half of the low-density residential buildings to become GHG neutral by 2030, and achieving this for all buildings by 2050, is an immense undertaking. In practice, this implies that each community must strive to achieve annual retrofit rates of around 4-7%, where each retrofitted building achieves zero or very low GHG emissions.

Numerous building energy retrofit programs have been in operation for many years, but comprehensive quantitative results, particularly in terms of GHG emission reductions, have often not been collected or widely disseminated. The Community Energy Association (CEA) has found that in cases where quantitative results and estimates of GHG emission reductions have been made available, there is uncertainty whether any retrofit programs have come close to meeting the required reductions. Several retrofit programs have been identified by CEA that fall significantly short of expectations, including older programs that have shown no discernible reduction in GHG emissions despite being in place for years. While numerous studies of retrofit programs have been conducted, many of these studies lack detailed quantification, particularly regarding GHG emission reductions.

With the growing focus on climate action in British Columbia (BC), Canada, and worldwide, an increasing number of retrofit programs are being implemented with greater ambition. This includes a significant number of new programs in BC and other parts of Canada that specifically target air source heat pumps, with preliminary results from these programs generating significant interest. Similar trends are observed in other regions across the globe, indicating an escalating interest in such retrofit programs.

Scope and Objectives of the Study

Through this study, some building retrofit programs were studied with an aim to investigate what results have actually been achieved in terms of energy saving and GHG emissions reduction. This study tried to figure out the success factors of these retrofit program along with the evaluation techniques they are following to assess their successes. The followings are some specific objectives:

i. To conduct research on the available literature and conduct interviews with people in the retrofit programs and related activities/ organizations, with a focus on BC retrofit programs

ii. To collect any quantitative data including GHG emission reduction data from the existing retrofit programs, and develop a list of key criteria including a list of Key Performance Indicators

iii. To identify the successful programs with their success factors

Methodology

Literature Review and Background Research

Literature review and background research were conducted to identify relevant retrofit programs. Some of the academic journal articles were also reviewed to investigate the evaluation techniques adopted by different retrofit programs. Besides, background information related to different retrofit programs, specially from BC were studied. To gain a comprehensive understanding of any program, both active and completed retrofit programs were examined to analyze their achievements and difficulties.

Emails and Interviews

Personnel from CEA, BC Hydro, and ZEBx helped by providing information and doing email introductions to set up interviews. Most of the interviews were over Zoom/Teams. Some of the contact personnel from retrofit programs also responded through emails and provided required information or shared relevant reports on their retrofit programs. Followings are the list of retrofit programs for which the key contact person was contacted and/or interviewed:

i. Home Energy Navigator/ Bring It Home 4 The Climate Program

ii. LiveSmart BC

iii. Home Renovation Rebate Program

iv. Energy Conservation Assistance Program

v. Saanich Oil to Heat Pump Financing Program

vi. Home energy loan program (HELP), Penticton

vii. Nelson Ecosave – REEP

viii. Retrofit Accelerator Program, Toronto

ix. Community Efficiency Financing Initiative

x. Efficiency Nova Scotia Retrofit Program

Analysis

After reviewing secondary literature and background information, and collecting information through emails and interviews, each retrofit program from BC was analyzed as a case study to document its post-retrofit evaluation method, success factors, energy saving and GHG reduction by the program. Discussion about the success factors and evaluation methods have been provided in separate sections based on the findings from different retrofit programs.

Limitations

The research took place over a period of 3.5 months and was limited by the amount of time available to conduct interviews, difficulties in finding the post-retrofit evaluation reports containing energy-saving and GHG reduction information.

Case Studies: Retrofit Programs in British Columbia

Residential Home Renovation Rebate Program (F2012 – F2014 and F2014 – F2019)

Overview

There are two phases of the Residential Home Renovation Rebate Program – LiveSmart BC and Home Renovation Rebate programs. The fundamental idea behind this program was to offer incentives to homeowners for the installation of additional energy-efficient measures. LiveSmart BC began in April 2008 as a collaboration between the former B.C. Ministry of Energy and Mines, BC Hydro, and FortisBC. Qualifying upgrades for homes heated with electricity under LiveSmart BC included improvements to the building envelope (such as insulation, draft proofing, windows, and doors), ventilation enhancements (heat recovery ventilators, bathroom fans), and upgrades to the heating system (such as heat pumps). Homes heated with gas were eligible for incentives related to high-efficiency gas furnaces featuring variable speed motors, leading to electricity savings. After undergoing a mandatory home energy assessment conducted by a Certified Energy Advisor, homeowners could opt to carry out one or more of these retrofit projects. However, in F2014, funding from the provincial government for LiveSmart BC was discontinued, resulting in the program's conclusion.

In July 2014, the collaboration between BC Hydro and FortisBC resulted in the introduction of the Home Renovation Rebate Program. BC Hydro's involvement in the program targeted homes heated with electricity. Qualifying residences encompassed single-family detached homes, side-by-side duplexes, townhouses or row houses, and mobile homes on a permanent foundation (with apartments being excluded). The program provided rebates for enhancements made to the building envelope, as well as the space and hot water heating systems, along with ventilation. Additionally, it featured a bonus for multi-measure upgrades involving draft proofing, windows, and doors. This iteration of the program remained in operation until the conclusion of September 2018.

Evaluation Method

LiveSmart BC and Home Renovation Rebate programs were evaluated based on some research questions and objectives through participants surveys and analysis. Table 1 is summarizing the research objectives, questions, data collection and analysis methods. Along with the attitudes and satisfaction with the Home Renovation Rebate Program, they also measured participant experience and outcomes, including any home upgrades they completed without a rebate. Participant surveys, non-participant surveys, and residential end-use studies were the media to evaluate these programs.

Success Factors

These programs reported the number of participants, percentage share of all program-eligible households, number of upgrades and/or heat pumps installed, the estimated number of participants that completed upgrades without rebates, the estimated number of program-eligible non-participants that completed the upgrade, etc. in their evaluation report, which can be treated as success factors. Besides, participants' satisfaction level and attitudes towards the program is one of the main success factors of the program. They also considered if the participants would recommend the program to others or not. Moreover, they reported the net electricity and peak demand savings in their evaluation report.

Table 1. *Evaluation objectives, research questions, data, and methods of analysis for LiveSmart BC and Home Renovation Rebate programs*

Evaluation Objectives	Research Questions	Data	Method
Profile program participants	- No of participants - Participants' characteristics - Mostly accessed rebates - Reasons to participate	- 2018 Home Renovation Rebate Participant Survey (n=1,904) - Program administrative data - 2017 Residential End-Use Study (n=7,027)	Frequencies; cross tabulations
Measure participant experience and outcomes, including any home upgrades they completed without a rebate	- How did they become aware? - Participants' opinions of various facets of the program - Various outcomes of participating in the program - Extent to complete other upgrades without a rebate	- 2018 Home Renovation Rebate Participant Survey (n=1,904)	Frequencies; cross tabulations
Measure non-participant awareness of the program and any home upgrades they completed	- Extent of awareness among program-eligible non-participants - Extent of completing their upgrade activities by the program-eligible non-participants - Reasons of not participating in the program	- 2018 Home Renovation Rebate Non-Participant Survey (n=858) - 2017 Residential End-Use Study (n=7,027)	Frequencies; cross tabulations
Estimate net electricity and peak demand savings for the Home Renovation Rebate program F2014 to F2019	- Free ridership associated with each type of upgrade implemented - Net energy savings from the rebated upgrades - Electricity savings from unrebated upgrades - Overall net electricity and peak demand savings resulting from the program overall	- Program administrative data - BC Hydro billing system data - BC Assessment property data - Weather data - 2018 Home Renovation Rebate Participant Survey (n=1,904) - 2018 Home Renovation Rebate Non-Participant Survey (n=858)	- Quasi-experimental design with comparison group (variation in adoption) - Pre/post billing analysis (regression modelling) - Engineering estimates - Free ridership and spillover decision tree analysis
Estimate net electricity and peak demand savings for LiveSmart for F2012-F2014	- Net evaluated electricity and peak demand savings for LiveSmart from F2012 to F2014	- Program administrative data - Evaluated net savings results from the F2009 - F2011 LiveSmart evaluation	Extrapolation of evaluated net unit savings results to F2012 - F2014 participants

Energy Saving

The total annual electricity savings resulting from the Home Renovation Rebate Program were determined by combining insights from various methods – quasi-experimental design with comparison group, pre/post billing analysis, engineering estimates, and free ridership and spillover decision tree analysis.

a. **Electricity Savings for Heat Pump and Insulation Upgrades Completed with Rebates:** This portion of the savings calculation focused on upgrades involving heat pumps and insulation that program participants carried out using the rebates provided. A billing analysis was conducted to generate estimates, and these estimates were positioned between gross and net savings. Notably, they encompassed the electricity savings resulting from these upgrades, including any spillover effects from improvements made by these households that were not covered by the rebates. However, it's important to note that these estimates did not account for free ridership, where participants might have taken advantage of rebates without significantly altering their energy usage. In essence, the program assessed the impact of rebates on electricity consumption, acknowledging that the effects fell somewhere between the total savings (gross) and savings purely attributable to the rebates (net). This approach considered the broader energy-saving context, including the influence of participant-initiated upgrades beyond what the rebates covered. However, it did not factor in situations where participants might have received rebates without substantially reducing their energy consumption (free ridership).

   These programs reported that the average annual energy savings (kWh/year) per household was 1,366 for ductless heat pumps and 1,283 for all types of insulation.

b. **Electricity Savings for Door/Window, Draft proofing, and Bathroom Fan Upgrades Completed with Rebates:** The participants' electricity savings resulting from doors/windows, draft proofing, and bathroom fans, which were completed with rebates, were collectively estimated to amount to 0.34 GWh/year. Unlike the calculations for heat pumps and insulation, these savings were determined through a different method. This variance was due to the anticipated challenges in statistically analyzing savings, primarily because of the limited number of installations and the relatively small level of savings associated with these measures. To be more specific, the savings were computed by utilizing the actual household counts from the program tracking database, coupled with gross unit savings estimates obtained from engineering analysis, interviews with program personnel, and additional research sources. Additionally, survey research data on free ridership was factored in, with rates of 0.12 for draft proofing, 0.44 for doors/windows, and 0.55 for bathroom fans.

c. **Other Spillover Electricity Savings:** Since the program savings for heat pump installations and insulation upgrades, as estimated through billing analysis, already account for spillover savings, they calculated the spillover electricity savings for participants who independently completed doors/windows, draft proofing, and bathroom fan upgrades without rebates as a separate estimate, amounting to roughly 82,000 kWh/year. The spillover electricity savings associated with upgrade activities carried out by individuals eligible for the program but who did not participate were estimated to be significantly greater, totaling around 5.1 GWh/year.

d. **Total Annual Electricity Savings:** The total annual electricity savings for the Home Renovation Rebate Program during the evaluation period were estimated to be 10.8 GWh/year, in contrast to the reported savings of 19.3 GWh/year. Besides, the peak demand savings were estimated to be 4.1 MW, which was reported at 7.3 MW during the evaluation period. The primary factor contributing to the difference between the reported and evaluated savings is the disparity between the engineering estimates used for heat pumps and insulation in the reported savings calculation and the evaluated savings derived from billing analysis.

e. **Net Electricity and Peak Demand Savings for LiveSmart BC Program:** The reported energy savings for this program in F2012, F2013, and F2014 were 8.5, 8.9, and 1.1 GWh/year respectively. Besides, the reported peak demand savings were 3.2, 3.4, and 0.4 MW respectively. These are almost the same as evaluated energy and peak demand savings. The reported and evaluated values for F2014 were relatively small because there was a reduction in the number and type of retrofits offered in F2014 and the number of participants was lower.

GHG Reduction

These programs did not mention anything about GHG reduction in their evaluation reports.

Energy Conservation Assistance Program (ECAP) Basic (F2012 - F2016)

Overview

The Low-Income Program, operated by BC Hydro, is an initiative aimed at helping residential customers who meet income eligibility criteria reduce their energy expenses. Throughout the evaluation period, this program furnished income-qualifying BC Hydro residential customers with complimentary energy-efficient products and facilitated the installation of energy-efficient upgrades by contractors.

The primary objectives of this program were as follows:

- Enhance the accessibility of energy efficiency measures for low-income customers by addressing significant barriers such as affordability, availability, and awareness.
- Generate energy savings for BC Hydro through the implementation of energy-efficient measures.
- Empower low-income customers to decrease their energy consumption and utility bills through energy efficiency enhancements.
- Elevate awareness and knowledge about energy conservation among low-income customers.

One component of the program was the Energy Savings Kit (ESK), which consisted of basic, cost-effective energy-saving measures that homeowners or tenants could install themselves. The ESK included items such as energy-efficient light bulbs, faucet aerators, window film, and a refrigerator thermometer. The installation of these kit components resulted in energy savings in areas such as lighting, space heating, and water heating.

Additionally, the program offered the Energy Conservation Assistance Program (ECAP) Basic package to income-eligible residential customers residing in single-family homes, duplexes, townhouses, or mobile homes. Qualified applicants received a fundamental home energy audit, the installation of energy-saving products, and education on energy-saving practices provided by contractors. The specific installations varied based on the findings of the basic audit and included products designed to improve lighting efficiency, enhance space heating, and optimize water heating. In some cases, customers were also eligible for a refrigerator replacement.

Evaluation Method

Energy Conservation Assistance Program (ECAP) Basic was evaluated based on some research question and objectives through participants surveys and analysis. Table 2 is summarizing the research objectives, questions, data collection and analysis methods.

Success Factors

This program also conducted residential end use survey and participant survey to find out participant's satisfaction level. They also kept the track of program data to store the information of different types of installments done by the participants. A statistical analysis conducted on a specific subset of program participants, specifically those who installed both an Energy Savings Kit (ESK) and took part in the Energy Conservation Assistance Program (ECAP) Basic, unveiled notable improvements in electricity bill payment performance among individuals who had a track record of late payments before joining the program. The programs had a statistically significant influence on their ability or willingness to pay their bills in full and on time.

Table 2. *Evaluation objectives, research questions, data, and methods of analysis for Energy Conservation Assistance Program (ECAP) Basic*

Evaluation Objectives	Research Questions	Data	Method
Understand the program's target market and barriers to energy efficiency	- Participants' characteristics - Barriers to energy efficiency improvement among low income customers - Difference among participants and general population	- 2012 and 2014 Residential End Use Survey - Statistics Canada - Literature Review - BC Hydro 2015 Rate Design Application	Qualitative research
Assess the participant experience and measures installed through the ESK offer	- Installation rate by kit component - Level of ease to install kit contents - Participant's satisfaction - Extent to purchase on their own - Extent of recommending to others	- 2014-15 ESK Apartment Participant Survey (N=460) - 2014-15 ESK House Participant Survey (N=544)	Cross tabulations
Assess the participant experience and measures installed through the ECAP Basic offer	- Installed measures through the ECAP Basic offer - How did participants learn about the offer? - Additional energy savings actions - Participant's satisfaction	- 2014-15 ECAP Participant Survey (N=722)	Cross tabulations
Estimate net electricity energy and demand savings for the ESK and ECAP Basic offers	- Net electricity savings from ESK by fiscal year - Net electricity savings from ECAP Basic offer by fiscal year	- Electricity consumption data - BC Hydro account data - Program tracking data - Weather data	- Quasi-experimental design with variation in adoption - ANCOVA fixed effects modelling
Assess the effect of program participation on electricity bill payment performance	- How does participation in the Low-Income Program impact the bill payment performance of participating homes?	- Program tracking data - Creditworthiness score data - Electricity consumption data	- Quasi-experimental design - ANCOVA fixed effects modelling

Energy Saving

Energy savings was estimated by conducting statistical analysis using electricity consumption and other data. The analysis involved quasi-experimental design with variation in adoption and ANCOVA fixed effects modelling. The approach employed for estimating net electric energy savings served multiple purposes, offering insights into savings persistence, the typical daily pattern of savings, and variations in savings throughout the year. Peak demand savings were determined by utilizing the evaluated shape of savings. The reported energy savings for both ESK and ECAP Basic offers for F2016 was 2.8 GWh/year, where the evaluated one was 4.3 GWh/year. Besides, the peak demand savings was reported as 0.6 MW and evaluated as 0.9 MW in F2016. ECAP Basic evaluated savings totaled 7.3 GWh per year or 116 per cent of reported savings of 6.3 GWh per year. The evaluation did not encompass electricity savings arising from the program's Advanced Weatherization and Apartment Direct Install offerings, and as a result, these savings were not factored into the evaluated savings.

GHG Reduction

These programs did not mention anything about GHG reduction in their evaluation reports.

Saanich Oil to Heat Pump Financing Program (Ongoing)

Overview

The Saanich Oil to Heat Pump Financing Program is designed with the aim of expediting the adoption of heat pumps for space heating by alleviating the initial financial obstacles that homeowners typically encounter when undertaking such upgrades. The program's pilot phase was initiated on April 4th and has gathered significant interest, as the standard slots were fully subscribed within two weeks, and the available slots for income-qualified participants were occupied within six months. As of December 2022, 52 participants subscribed and 29 signed the financing agreements. Total of 15 retrofits have already been done among the 52 participants. The initial target for the Pilot was set at 50 participants. However, thanks to some Income-Qualified participants not requiring the full financing amount, the program was able to accommodate an additional two participants beyond the original target.

Evaluation Method

They have conducted registration survey to know from where the participants heard about the program, duration of stay, age and household income, type and size of homes, age of homes, why they are accessing the program, and why they are interested in replacing their oil heating system with a heat pump. They modelled the GHG reduction and energy savings by the program based on the pre-upgrade EnerGuide home evaluation provided by the participants. The pre-upgrade EnerGuide evaluation provides estimates on current home emissions from various energy fuels and estimated energy reduction from completing a heat pump upgrade from primary space heating.

Success Factors

This program listed some factors which can be good signs of their success. For example, they mentioned providing 0% interest and no fee financial support which attract a lot of people to participate. The program had a significant impact on 85% of the participants' decisions to proceed with their heat pump upgrades. Among these participants, 51% stated that the program either made the upgrade financially feasible or expedited their upgrade plans, while 34% reported that they had not considered a heat pump upgrade at all prior to the program's availability. Furthermore, 76% of respondents indicated that the upfront and/or borrowing costs associated with a heat pump were prohibitively expensive without the option of 0% interest financing. The evaluation report also mentioned physical marketing materials as an important consideration to reach potential participants. Besides, reserved spots for income-qualified participants can also be considered as a success factor. With this objective in mind, the program was structured to directly compensate contractors. This arrangement ensured that homeowners would not be required to make any out-of-pocket payments for the financed amount at any point during the process. Moreover, the modelled reductions in energy usage and emissions serve as compelling evidence of the substantial energy savings and environmental advantages that can be attained by adopting efficient electrification methods for home space heating, particularly through the use of heat pumps.

Energy Saving

The EnerGuide-modeled energy reductions reveal that participants' homes anticipated energy reductions of 44% in their total household energy usage on average. This reduction varies, ranging from 25% to 60%. As a result, the Saanich Oil to Heat Pump program has already accomplished an estimated energy savings of 907 gigajoules (GJ) per year from the 15 participants who have successfully completed their upgrades. This figure is expected to increase significantly to an estimated 2043.5 GJ per year once all 31 participants who have presently submitted an EnerGuide report have installed their heat pumps.

GHG Reduction

According to the EnerGuide models of the 15 participants who have successfully completed their upgrades, the Oil to Heat Pump program has already led to a reduction of approximately 85.7 metric tons of carbon dioxide equivalent (tCO2e) per year in greenhouse gas emissions in Saanich. This figure is expected to double to an estimated 171.5 tCO2e per year once all 31 participants who have currently submitted an EnerGuide report have installed their heat pumps.

Bring it Home 4 the Climate Pilot Program (Sep 2020 – Jan 2021)

Overview

In collaboration with the Capital Regional District, the City of Victoria, the Township of Esquimalt, the District of Saanich, and the District of Central Saanich, City Green has established and managed the Bring It Home 4 the Climate (BIH) program to offer support and education to homeowners in the capital region who are interested in making their homes more environmentally friendly in terms of climate impact. The BIH Pilot Program was specifically crafted to involve and assist homeowners and organizations that are keen on playing a role as catalysts for change in their community. The program's primary goal was to reduce energy consumption and lower the carbon footprint of participating homes. Through the BIH Program, community members were empowered to act, inspire others, raise awareness about climate-friendly practices, and enhance their homes for improved energy efficiency. The pilot program started in September 2020 and lasted till January 31, 2021, and 359 households from 13 municipalities participated in this program. The development of this program was made possible through funding support from the Federation of Canadian Municipalities' Transition 2050 Grant program. The program offers several key components:

i. **Virtual Home Energy Check-Up:** Total of 69 Participants received free expert advice through an innovative and COVID-19 safe Virtual Home Energy Check-Up.

ii. **Educational Workshops:** The program conducts educational workshops to help homeowners understand and implement energy-efficient practices.

iii. **EnerGuide Subsidies:** Total of 101 EnerGuide subsidies are provided to participants, enabling them to improve the energy efficiency of their homes.

iv. **Efficiency Resources:** The program equips participants with a range of efficiency resources and information.

During the Pilot Phase of the program, a total of 52 upgrades were successfully completed by survey respondents. The most frequent upgrades undertaken were related to windows and doors, as well as mini-split/multi-split heat pumps. Approximately 32% of survey respondents carried out a remarkable three upgrades. Additionally, 42% of survey participants expressed intentions to complete upgrades within the next two years, with a total of 55 upgrades in the planning stage. The most common planned energy upgrades include improvements to windows and doors, along with draft proofing. Notably, 29% of respondents are considering space heating upgrades, and an impressive 75% of those planning such upgrades intend to install a heat pump.

Evaluation Method

They evaluated the program based on participant survey but there was no calculation for energy savings and GHG reductions.

Success Factors

They listed program outreach and promotions as a success factor as participant registration increased during the peak outreach and promotion period. Provision of the EnerGuide Home Evaluation Subsidy was another important factor as there was consistent uptake and all available subsidies were expended. Well-received workshops, participant's satisfaction level, recommendation to others by the participants, virtual home energy check-up are some other success factors discussed in the evaluation report.

Energy Saving

No calculation for energy savings by the pilot program.

GHG Reduction

No calculation for GHG reduction by the pilot program.

Home Energy Loan Program (HELP), Penticton

Overview

Since 2013, the City of Penticton has been operating its Home Energy Loan Program (HELP), which extends loans to residential customers for the purpose of retrofitting their homes to enhance energy efficiency. These loans are available in varying amounts, starting from a minimum of $1,000 and going up to a maximum of $10,000. Participants repay these loans through convenient monthly deductions from their utility bills. HELP can work in conjunction with Fortis BC’s rebates for insulation, air sealing, and other upgrades like the replacement of doors and windows. To qualify for this program, you must meet the following criteria:

- You must be the registered owner(s) of the property undergoing the upgrades.
- You should be a customer of Penticton Electric Utility, and the utility account should be in the name(s) of the registered owner(s).
- You must meet the City of Penticton's credit approval requirements.

As of December 2022, they received 278 applications and issued loans to 102 households. They spent around $785,229 and the goal is to spend $1,174,000.

Evaluation Method

They have listed some elements of a program evaluation study:

- **Process Evaluation:** Assessing the program's processes to determine if it is being executed as originally intended. This involves identifying any deviations from the program's design and recommending adjustments to enhance its effectiveness.

- **Quantification of Key Performance Indicators (KPIs):** Measuring and quantifying the program's key performance indicators, which may include metrics such as energy savings, greenhouse gas (GHG) emissions reductions, the number of participants, and the types and sizes of upgrades supported. This helps gauge the program's impact and effectiveness.
- **Recommended Scaling Strategies:** Providing recommendations for strategies to scale up the environmental and energy performance impacts of the program. This may involve suggesting ways to expand the program to reach a larger audience or achieve greater results in terms of energy efficiency and environmental benefits.

Success Factors

They have mentioned low risk (no defaulters), low free-ridership, low rejection rate, high interest earned, low administrative costs, revenues, etc. as success factors. Over the past six years, this program has generated a significant amount of revenue, amounting to $101,000. This revenue has primarily been derived from the interest earned on loans provided through the program. It's important to note that this revenue figure does not include expenditures related to wages, which suggests that the program has been successful in generating income while keeping operational costs, excluding wages, at a lower amount of $25,500.

Energy Saving

The average loan amount provided for the replacement of windows, doors, hot water tanks, and furnaces was $7,698. These upgrades have collectively resulted in a substantial energy savings of 108,280 kilowatt-hours (kWh). To put these energy savings into perspective, it's equivalent to the energy consumption of approximately 9.8 homes, based on the average electrical consumption of 916 kWh per month (or 10,992 kWh per year) for households in Penticton.

The calculation of these energy savings was conducted using 24 months of historical metered electrical consumption data from each participant. This analysis compared the 12 months of electrical consumption before the energy retrofits with the 12 months following the retrofits. It's worth noting that participants who completed their retrofits through HELP in 2022 were not included in this analysis due to insufficient data. In summary, the program has demonstrated its success by delivering substantial energy savings of 108,280 kWh, and the revenue generated from interest has covered the program's operational costs, excluding the loaned amounts.

GHG Reduction

In addition to the program's low participation rate, another notable shortcoming is the absence of a quantified assessment of greenhouse gas (GHG) emissions reductions resulting from the retrofits carried out by residents through HELP. A significant challenge in understanding these emissions reductions is the lack of accessible data on natural gas consumption, which is a crucial factor for accurately calculating GHG emissions reductions, especially in cases involving heating system upgrades. This data limitation makes it difficult to comprehensively evaluate the environmental impact of the program's retrofits.

Nelson Ecosave – Regional Energy Efficiency Program (REEP)

Overview

The Regional Energy Efficiency Program (REEP) began as a City of Nelson initiative in 2012 (it was then known as Ecosave) and was expanded in 2019 to include the Regional District of Central Kootenay. The primary aim of the program is to reduce greenhouse gas emissions in residential retrofits by assisting residents in navigating the complex web of rebates and grants that exist at the federal and provincial levels. The program offers several benefits, including:

- **Reduced Home Evaluation:** Participants receive a discounted home evaluation conducted by a Certified Energy Advisor.
- **Rebates through CleanBC:** The program provides access to rebates offered through the CleanBC initiative, encouraging energy-efficient upgrades.
- **On-Bill Financing:** Residents can take advantage of on-bill financing options facilitated through the City of Nelson, making it easier to finance energy-efficient improvements.
- **Information Sessions:** Retrofit information sessions are conducted across the region to educate residents about energy-saving opportunities.
- **Online Tools:** The program offers online tools like 'the Great Escape,' enabling residents to visualize and understand how much heat is being lost through their homes.

The Ecosave Program expanded its coverage to encompass the entire Kootenay region, further extending the reach and impact of energy-efficient retrofits and greenhouse gas reduction efforts.

Evaluation Method

They have evaluated the project based on D and E EnerGuide Assessments. In 2022, 94 only D assessments were completed and 40 DE pair assessments were completed.

Success Factors

GHG reductions and energy savings are the common success factors. They used some emission factors and energy densities from the 2020 BC Best Practices Methodology for Quantifying GHG Emissions, to convert raw data to GJs for energy savings and tCO_2e for GHG reduction. They did not mention other success factors explicitly.

Energy Saving

Potential energy savings from 94 D assessments in 2022 is 9,585 GJ in total, and 101.97 GJ per home. For the 40 DE pair assessments in 2022, potential energy savings was 3,213 GJ in total, and 80.33 GJ per home. On the other hand, the actual energy saving was 1,716 GJ in total, and 42.90 GJ per home.

GHG Reduction

Potential GHG reduction from 94 D assessments in 2022 was 354.2 tCO2e in total, and 3.77 tCO2e/home, where 80% will be from natural gas. For the 40 DE pair assessments in 2022, potential GHG reduction was 115.8 tCO2e in total, and 2.90 tCO2e/home. On the other hand, realized GHG reduction was 52.8 tCO2e in total, and 1.32 tCO2e/home.

Summarizing Success Factors of a Retrofit Program

Based on the case studies, the success factors of a retrofit program can be classified into different types as follows:

Environmental Factors

High GHG reduction is the environmental factor relevant to any retrofit program.

Energy-Related Factors

High net electricity/energy savings and peak demand savings are the energy-related success factors for a retrofit program.

Economic Factors

Economic factors are the followings –

i. Reserved spots for income-qualified participants
ii. Provision of zero interest rebate
iii. No fee financial support – Virtual Home energy Check-ups
iv. Provision of EnerGuide Home Evaluation Subsidy
v. High revenue earned through interest of loans
vi. Low administrative cost
vii. Ability and willingness to pay electricity bills in full and on time by the households who had a track record of late payments
viii. Low risk/ no defaulters
ix. Low free-ridership

Program Outreach, Promotion, and Coverage-Related Factors

The factors specific to programs are the followings –

i. High number of participants

ii. High percentage share of all program-eligible households

iii. Number of upgrades and/or number of heat pumps installed

iv. Estimated number of participants to complete upgrades without rebates

v. Estimated number of program-eligible non-participants to complete upgrades

vi. Workshops with many participants

vii. Physical marketing materials

viii. Low rejection rate for the applicants

Social Factors

Social success factors are mostly identified through the Participants surveys. They are –

i. Participant's satisfaction level

ii. Participant's attitudes towards the program

iii. Whether the participants will recommend this program to others or not

Recommendations on the Key Success Factors of a Retrofit Program

This section will give some general recommendations on the key factors that are relevant to the success of a retrofit program. A retrofit program aims to improve the energy efficiency, functionality, safety, and sustainability of existing buildings or infrastructure. Success in such programs can be measured by various factors, and achieving these factors often requires careful planning, execution, and ongoing monitoring. Here are some key success factors for a retrofit program:

i. **Clear and Well-Defined Goals:** A retrofit program should have clearly defined goals and targets, such as specific energy efficiency improvements or GHG emission reduction targets, reduced maintenance costs, enhanced comfort, etc. These goals should be measurable, realistic, and aligned with broader sustainability objectives.

ii. **Adequate Funding and Resources:** Sufficient financial resources and technical expertise are essential for implementing a successful retrofit program. Access to funding sources, grants, incentives, and low-cost financing options can help overcome financial barriers and encourage participation from building owners. Additionally, having a skilled workforce, including contractors and energy auditors, is important for the successful execution of retrofit projects.

iii. **Comprehensive Energy Audits and Assessments:** Conducting thorough energy audits and assessments of buildings is critical to identify energy-saving opportunities and prioritize retrofit measures. These assessments should consider the building's current energy performance, identify areas of improvement, and provide cost-effective recommendations specific to each building's characteristics.

iv. **Technological Solutions and Innovation:** A successful retrofit program should leverage innovative technologies and solutions to maximize energy efficiency gains. This may include the adoption of energy-efficient equipment, advanced building automation systems, renewable energy integration, and smart energy management systems.

v. **Stakeholder Engagement and Collaboration:** Active involvement and collaboration of various stakeholders are crucial for the success of a retrofit program. This includes building owners, residents, government agencies, utilities, contractors, and community organizations. Engaging stakeholders from the beginning ensures buy-in, support, and participation throughout the program.

vi. **Education and Outreach:** Providing education and awareness campaigns to building owners and occupants about the benefits of retrofitting and energy efficiency is essential.

Informing them about available incentives, potential cost savings, and environmental impacts can encourage participation and behavioral changes.

vii. **Policy and Regulatory Support:** Supportive policy frameworks and regulations can significantly contribute to the success of retrofit programs. This includes building codes, energy efficiency standards, streamlined permitting processes, and incentives or mandates that encourage retrofitting.

viii. **Monitoring, Evaluation, and Continuous Improvement:** Regular monitoring and evaluation of retrofit projects are crucial to track progress, measure energy savings, and identify areas for improvement. Adjustments can be made based on feedback and lessons learned to optimize the program's effectiveness over time.

ix. **Reporting:** Transparent reporting of the program's outcomes, including energy savings, GHG emission reductions, and cost-effectiveness, is crucial for accountability and demonstrating the program's success to stakeholders and the public.

x. **Long-Term Sustainability Planning:** A successful retrofit program should incorporate long-term sustainability planning. This involves considering the lifespan of retrofit measures, future energy efficiency upgrades, and maintenance requirements to ensure the long-term benefits and durability of the retrofitted buildings.

Methods to Evaluate a Retrofit Program

Retrofit programs typically evaluate their programs in terms of energy savings and GHG reduction. For estimating the energy savings and GHG reduction, they follow different methods which are discussed as follows:

Simple Difference Studies - Comparing Pre-retrofit and Post-retrofit Energy Consumption

Simple difference studies, which began in the late 1970s, have been commonly used in residential retrofit program evaluations. In these studies, savings are assessed by comparing the difference in energy consumption for households before and after undergoing a home retrofit. This approach is known as the simple difference technique and is valued for its cost-effectiveness. However, it's important to note some limitations of this approach:

i. **Small Sample Sizes:** Most studies utilizing this design involve a small number of homes in the program evaluation.

ii. **Lack of Control Group:** Simple difference studies typically do not incorporate a control group to measure changes in energy consumption. This absence of a control group makes it challenging to determine the true impact of the retrofit program, as it cannot account for external factors influencing energy usage.

iii. **Self-Selection Bias:** These studies often do not consider households' voluntary decisions to retrofit their homes. This can introduce bias because households that choose to retrofit their homes may differ in important ways from those that do not, potentially leading to overestimation or underestimation of the program's effects. The heterogeneity between households that opt for retrofitting and those that do not raises concerns about the accuracy and validity of the evaluation estimates obtained through simple difference studies. While these studies offer a cost-effective method for assessing energy savings, they should be interpreted with caution due to their limitations in addressing potential sources of bias and confounding factors (Giandomenico et al., 2022).

Cross-Sectional Studies – Comparing Savings of Participants with a Non-participant Control Group

Cross-sectional studies were another approach used in early evaluation studies of residential retrofit programs. These studies assess savings by comparing a group of houses that underwent retrofitting through the program to a control group that did not participate in the program. Typically, the control group consists of eligible nonparticipants or potential future program participants. Here are some key characteristics and limitations of cross-sectional studies:

i. **Control Group Choice:** In cross-sectional studies, the control group is often made up of eligible nonparticipants or individuals who might participate in the program in the future. This choice is influenced by concerns about differences between households that voluntarily join retrofit programs and those that do not. Comparing program participants to future participants is seen as a stronger comparison because they share some similarities in terms of interest or eligibility.

ii. **Bias and Selection Effects:** Despite the choice of a more similar control group, savings estimates in cross-sectional studies may still be biased due to the absence of randomization. Unobservable variables that influence program participation and timing can affect the results.

iii. **Control for Selection:** Some cross-sectional studies attempt to account for self-selection into the treatment group by using techniques like propensity score matching or modeling households' selection into retrofit programs. However, these approaches are limited because they can only use observed variables to model selection into treatment.

iv. **Inability to Compare Over Time:** Cross-sectional designs lack the ability to compare treatment effects over time. They provide a portrait of savings at a specific point but cannot track changes in energy consumption and cost-effectiveness over the long term (Giandomenico et al., 2022).

Difference-in-Difference Studies – Comparing Energy Consumption of Participants with Non-Participants

Difference-in-difference studies have gained popularity in recent evaluations of energy efficiency retrofit programs. These studies aim to compare changes in electricity or fuel consumption over time in residential buildings that have undergone energy efficiency retrofits and those that have not participated in such programs. While this method provides insights into the relationship between retrofit program participation and energy consumption within individual households, it may still yield biased estimates of the causal impact of these programs on energy savings. Here are key considerations and challenges associated with these studies:

i. **Self-Selection Bias:** One of the primary challenges in these studies is the presence of self-selection bias. Households choose to participate in retrofit programs, and this choice may be correlated with other household-specific variables that also change over time. For instance, households with higher disposable income may be more likely to afford retrofits and retrofit decisions may coincide with specific life events or circumstances. These unobservable household-specific changes can confound the estimates of the retrofit program's effect.

ii. **Confounding Variables:** In addition to self-selection bias, households may undertake other renovations or improvements alongside the targeted retrofit investment. These concurrent changes over time can be difficult for researchers to observe and account for, further complicating the isolation of the causal impact of the retrofit program.

Despite these challenges, these studies are considered valuable because they allow researchers to explore changes in energy consumption before and after retrofit program participation. To mitigate bias and improve the accuracy of estimates, researchers often employ statistical techniques and controls for observable variables. However, the presence of unobservable factors and the potential for confounding variables remain important considerations when interpreting the results of these studies (Giandomenico et al., 2022).

Randomized Controlled Trials (RCTs)

Randomized controlled trials (RCTs) for residential retrofit programs present a rigorous approach to evaluation but are challenging to implement because program participation is voluntary. In RCTs of retrofit programs, researchers provide randomized encouragement to households to participate in the program. Since the encouragement is randomly assigned, it allows for statistical adjustments to account for self-selection bias in the program. However, it's important to note that the estimates of program savings in RCTs apply specifically to households that were induced to participate in the retrofit program due to randomized encouragement. RCTs offer the highest level of internal validity compared to other study designs because they address the issue of self-selection bias through random assignment. This allows for more robust estimates of the causal impact of the retrofit program on energy savings. On the other hand, RCTs for residential retrofit programs have been limited due to the voluntary nature of participation and the challenges in conducting randomized trials in this context (Giandomenico et al., 2022).

Comparing Pre-EnerGuide Assessment and Simulated Energy Savings

EnerGuide is a standardized energy performance rating system used in Canada to evaluate the energy efficiency of residential buildings. It provides homeowners with an energy rating and recommendations for improving energy efficiency. EnerGuide evaluations involve on-site inspections and measurements of the actual building, including insulation levels, windows, heating and cooling systems, and more. Retrofit programs can evaluate their program by comparing the EnerGuide Evaluation data with simulated post-retrofit energy consumption data. Simulated energy savings predict how changes in building components or systems will affect energy consumption and efficiency. Simulated energy savings rely on input data, including building characteristics, climate data, equipment specifications, and occupancy patterns. These inputs are used to create a virtual model of the building or system.

Comparing Pre and Post-Retrofit EnerGuide Assessment Data

Another approach can be comparing pre and post-retrofit EnerGuide assessment data to see the changes in energy consumption and building performances.

Recommendations for Evaluating a Retrofit Program

A retrofit program can be evaluated based on different key indicators. The following sections describe the important key performance indicators for a retrofit program.

i. **Energy Efficiency Improvements:** The energy consumption of the building should be compared with the pre-retrofit condition to see if there is any change in terms of energy consumption and/or energy cost and/or peak demand, etc.

ii. **Environmental Impact:** Reduction in carbon emission resulting from energy saving and use of sustainable materials should be assessed. Reduction in water usage and the conservation of other resources like materials and land should also be assessed.

iii. **Participant's Satisfaction and Comfort:** There should be a end-of-the program survey to know participant's experience throughout the program and how their comfort level have been enhanced after the retrofit.

iv. **Financial Performance:** The return on investment can be calculated by comparing the retrofit costs to the energy savings and other benefits over a specific period. Besides, the payback period can be estimated to know how long it takes for the retrofit investment to be recovered through energy cost savings.

v. **Energy Monitoring and Building Performance Analytics:**

It's essential to establish clear objectives and key performance indicators at the outset of the retrofit program to facilitate effective evaluation. Regularly reviewing and analyzing these metrics will help gauge the success of the retrofit and inform any necessary adjustments or improvements.

Conclusion

In conclusion, the retrofit programs in Canada represent a critical component of the country's efforts to combat climate change, reduce greenhouse gas emissions, and create a sustainable future. These programs have seen some success over the years, and their continued effectiveness depends on a combination of key success factors and robust evaluation methods. The unwavering commitment of federal, provincial, and municipal governments to prioritize energy efficiency and emissions reduction through retrofit programs has been instrumental in their success. Financial incentives, including grants, rebates, and tax incentives, have played a pivotal role in encouraging homeowners and businesses to participate in retrofit programs. These incentives help offset the upfront costs associated with energy-efficient upgrades and make them more accessible to a broader range of Canadians. Raising public awareness about the benefits of retrofitting and providing educational resources has been crucial. Canadians need to understand the environmental, economic, and health advantages of retrofitting to make informed decisions about their properties. Advances in building technologies and energy-efficient solutions have made it easier and more cost-effective to retrofit homes and commercial buildings. Innovations in HVAC systems, insulation materials, and smart technology have contributed to the success of these programs.

Measuring the reduction in energy consumption and associated greenhouse gas emissions is a fundamental evaluation method. These metrics quantify the environmental impact of retrofit programs and track progress toward emissions reduction goals. Gathering feedback from program participants through surveys, interviews, and focus groups helps assess the user experience, identify areas for improvement, and gauge overall satisfaction. Regularly monitoring and verifying retrofitted buildings ensure that they continue operating efficiently over time. This prevents the rebound effect, where energy savings are eroded due to changes in occupant behaviour or equipment malfunctions. Evaluating the long-term impact of retrofit programs, such as their contribution to Canada's emission reduction targets and the sustainability of retrofitted buildings, is crucial for assessing their effectiveness over time. By continually refining and improving these programs based on evaluation results, Canada can move closer to achieving its environmental and sustainability goals while benefiting homeowners, businesses, and the economy as a whole. Retrofit programs are not just a means of reducing emissions; they are a pathway toward a greener, more prosperous future for all Canadians.

References

BC Hydro. (2018). Demand Side Management Milestone Evaluation Summary Report F2018. Accessed through personal communication.

BC Hydro. (2021). Demand Side Management Milestone Evaluation Summary Report F2021. Accessed through personal communication.

Bring It Home 4 The Climate. (2021). Bring It Home 4 Climate Pilot Phase Final Report. Accessed through personal communication.

City Green Solutions. (2023). Saanich Oil to Heat Pump Financing Program Interim Report. Accessed through personal communication.

City of Penticton. (2022). Home Energy Loan Program Extension. Accessed through personal communication.

Community Energy Association. (2023). Nelson REEP 2022 EnerGuide Assessments. Summary of EnerGuide D and E Assessments – 2022. Accessed through personal communication.

Giandomenico, L., Papineau, M., & Rivers, N. (2022). A Systematic Review of Energy Efficiency Home Retrofit Evaluation Studies. *Annual Review of Resource Economics*, *14*(1), 689–708. https://doi.org/10.1146/annurev-resource-111920-124353