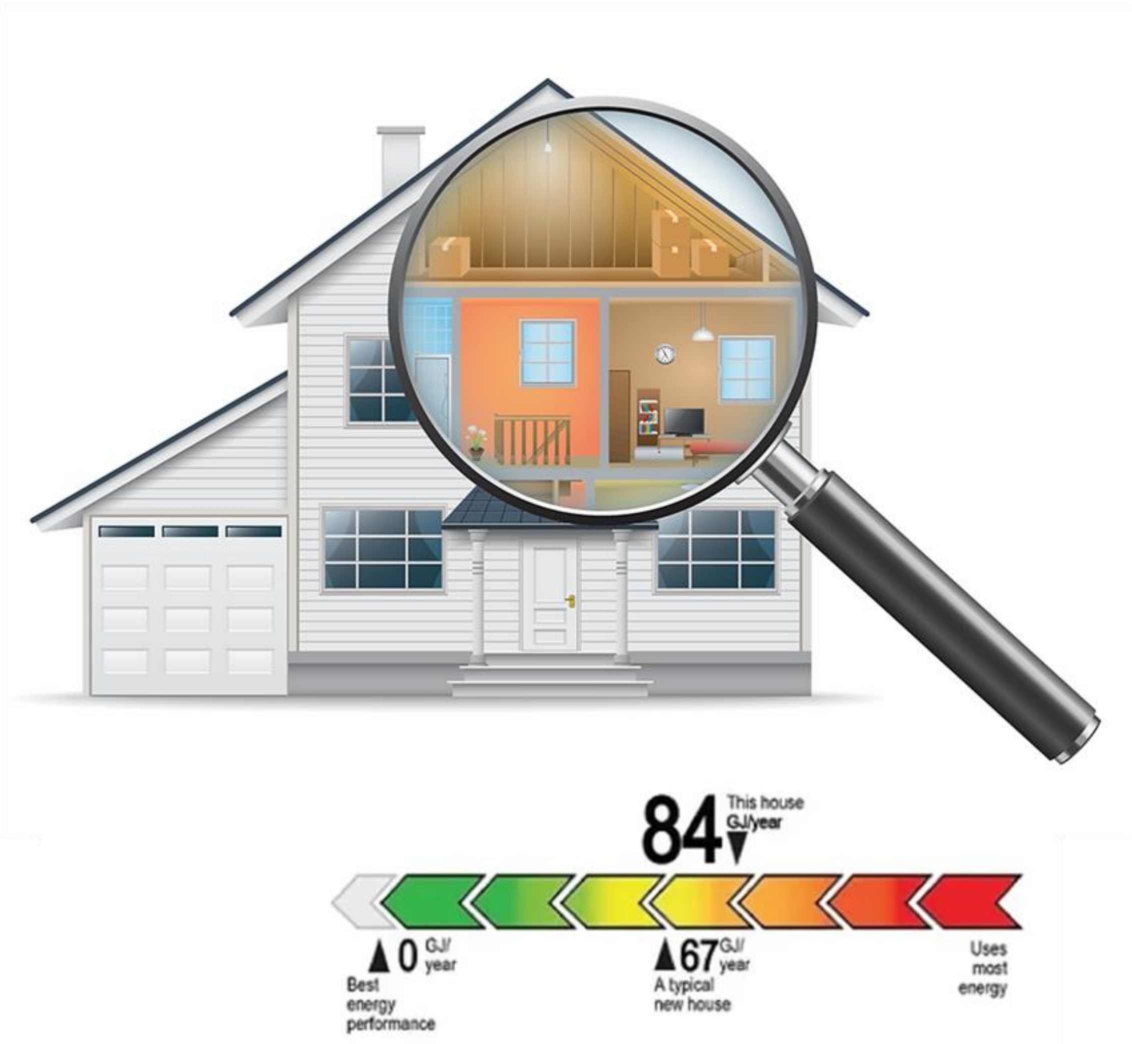

Residential retrofits: Analyzing EnerGuide evaluations and creating emission reduction scenario

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Disclaimer

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I respectfully acknowledge my position as an uninvited guest living on the land of the traditional, ancestral, and unceded territory of the Syilx/Okanagan people.

Executive Summary

The Community Energy Association (CEA) is supporting BC communities in achieving IPCC 1.5°C targets by focusing on significant emissions reductions in buildings, transportation, and solid waste. Recognizing the challenges of retrofitting existing buildings to meet the CleanBC and Federal Green Building standards, CEA aims to analyze EnerGuide assessment data to identify correlations between retrofit types and energy/GHG reductions, while also developing a basic emissions scenario to assist municipalities with residential retrofit programs. This research will help communities implement substantial GHG emission reductions by 2030 and 2050.

The analysis of EnerGuide assessment data from NRCan focuses on homes in BC, categorizing them into four climatic zones. North Vancouver and Kelowna represent zones 4 and 5, respectively, while all records from zones 6 and 7/8 are included. After compiling data from the 0-100 and GJ rating systems, separate Excel sheets were created for each climatic zone by filtering the CLIENTCITY field. The analysis considered 11 types of retrofits (excluding Energy Star doors and windows) to determine if each retrofit was recommended or completed for each house. Summary tables for each zone were then prepared, detailing the number of houses eligible for upgrades, those that completed upgrades, those upgraded based on recommendations, the number of upgrades in different years, and the total number of retrofits performed in each house.

To calculate energy savings, data from the following fields was utilized: electricity consumption (EGHFCONELEC), natural gas consumption (EGHFCONNGAS), and total energy savings (EGHFCONTOTAL). For 'D' evaluations, these fields represent consumption before retrofits, while 'E' evaluations reflect post-retrofit consumption. The difference between these values indicates the energy savings achieved after upgrades. To calculate GHG emissions reduction, the energy savings from electricity and natural gas were multiplied by their respective emission factors. The emission factor for electricity was 0.0000113 tCO_2e per kWh of consumption, while the emission factor for natural gas was 0.001937 tCO_2e per m^3. Additionally, energy savings and GHG reductions per square meter were calculated by dividing total savings by the FLOORAREA field.

Energy savings and GHG emission reduction values were normalized using Heating Degree Days (HDD) and Cooling Degree Days (CDD) for each zone. These normalized values were then multiplied by the respective HDD and CDD for BC and Pemberton. Finally, the

average energy savings and GHG reduction potentials were calculated for both BC and Pemberton, providing insights into the effectiveness of retrofits across different climates. After calculating the average energy savings and GHG reduction potentials per square meter for BC and Pemberton for specific types or combinations of retrofits, the number of houses needed to achieve the 2030 emission reduction targets for both regions was determined. This analysis will yield the number of homes requiring various upgrades to meet the GHG reduction goals set for BC and Pemberton by 2030.

In total, the number of DE evaluations was 4,237 for zone 4 (North Vancouver), 4,264 for zone 5 (Kelowna), 6,199 for zone 6, and 1,374 for zones 7 and 8 combined. Most retrofitting occurred between 2008 and 2013, with a noticeable increase in 2022 and 2023. The data indicates that houses with two types of retrofits were the most common, while those with three, four, or five types of retrofits also showed significant numbers. The analysis plotted the average total energy savings, along with savings from electricity and natural gas (both total and per square meter), against the number of upgrades to identify trends across different climatic zones. The graphs included trendline equations and R-squared values, demonstrating a strong positive correlation between the average total energy savings and the number of upgrades in all climatic zones. Similarly, savings from natural gas consumption also showed a strong positive relationship with the number of upgrades (Figure E1). Conversely, average energy savings from electricity consumption were negatively correlated with the number of upgrades, suggesting that upgrades involving greater electrification—such as replacing natural gas furnaces with heat pumps—tend to increase overall electricity consumption.

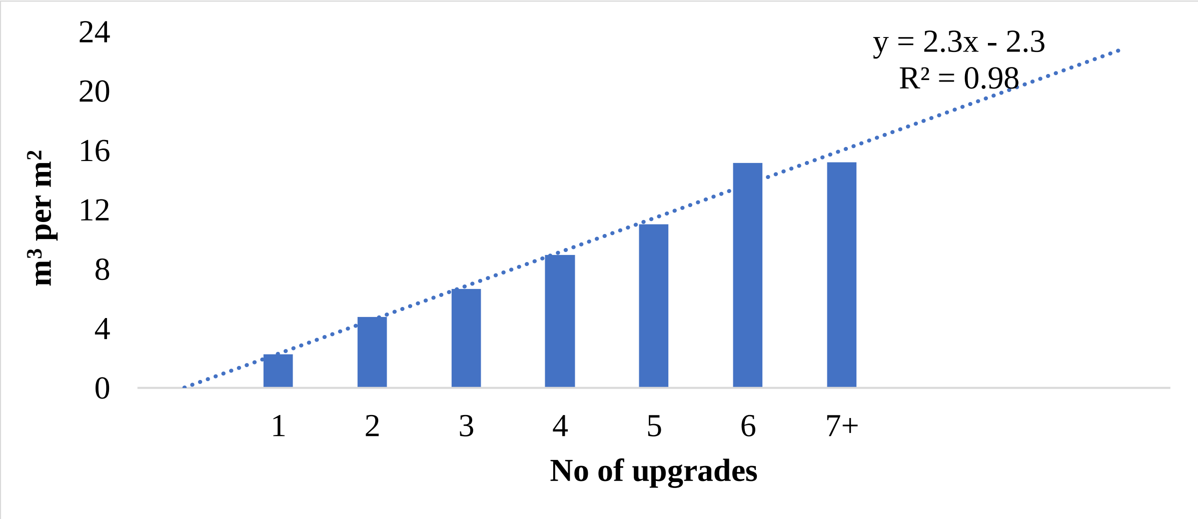

Figure E1. Average of total energy saving from gas consumption in m^3 per m^2 for different numbers of upgrades in zone 6

Similar to energy savings, GHG reduction showed a strong positive correlation with the number of upgrades—indicating that as the number of upgrades increases, total GHG reduction also increases. However, GHG reduction from electricity usage was negligible compared to that from natural gas. The increase in electrification following upgrades often leads to higher electricity consumption, resulting in minimal or negative GHG reductions from electricity savings. In contrast, GHG reduction from natural gas savings was substantial across all climatic zones (Figure E2).

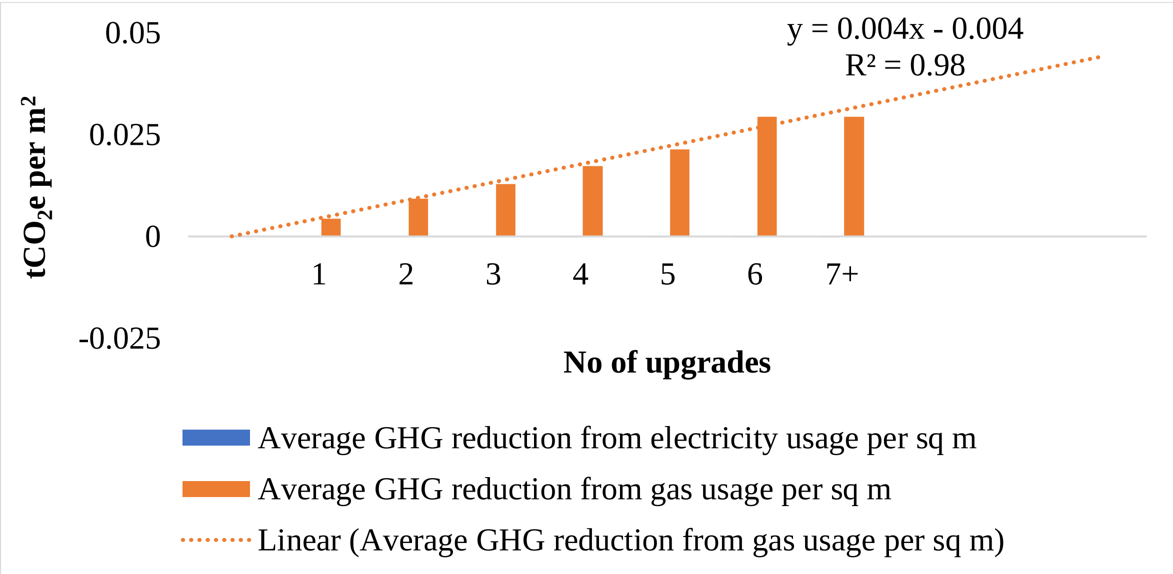

Figure E2. Average GHG emission reduction from electricity and gas usage in tCO_2e per m^2 in zone 6

After normalizing based on the HDD and CDD values across all zones, the relationships between different retrofit types and average energy savings were analyzed. This process helped identify patterns in energy performance improvements associated with each type of retrofit. The relationships between various retrofit types and their average GHG reduction potential were analyzed as well. The analysis reveals that GHG reductions from natural gas savings are significantly higher compared to those from electricity savings. Interestingly, when air sealing and heat pump installations are combined, the GHG reductions from electricity usage can become negative. This is due to the increased electricity consumption from heat pumps, which offsets the overall GHG reduction.

After calculating the total GHG reduction potentials from electricity and natural gas usage, the number of houses that would need to be retrofitted with various upgrades and/or combinations of upgrades was determined, factoring in the 2030 emissions reduction targets for both BC and Pemberton. This analysis helps identify the scale of retrofitting required to meet these targets, offering insights into how different retrofit strategies contribute to achieving the desired GHG reductions by 2030. By assessing the retrofit combinations and their respective GHG reduction potentials, planners can prioritize the most effective interventions for maximizing emission reductions across the housing sector. For instance, in Pemberton, 674 (HDD-corrected) houses need to perform air sealing, or 426 (HDD-corrected) houses need to perform air sealing and install heat pumps, to achieve their 2030 GHG reductions target from existing buildings.

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List of Acronyms

CEA	Community Energy Association
NRCan	Natural Resources Canada
HDD	Heating Degree Days
CDD	Cooling Degree Days
ACH	Air Changes per Hour

1. Introduction

1.1 Background

The Community Energy Association (CEA) assists several communities in British Columbia in achieving their IPCC 1.5°C targets, which aim to reduce emissions by approximately 50% from 2010 levels by 2030 and a complete elimination by 2050. To meet these goals, emissions must decrease in transportation, buildings, and solid waste, with reductions in all areas being crucial.

There is growing evidence that reducing emissions from existing buildings will pose significant challenges. Most buildings that will be in use by 2030 and 2050 are already standing today and retrofitting them will be essential to meet the CleanBC and Federal Green Building targets. Retrofitting half of the low-density residential buildings to achieve GHG neutrality by 2030 and all of them by 2050 is a monumental task. This translates to achieving retrofit rates of about 4% to 7% of the existing housing stock each year, ensuring that these buildings become zero or very low GHG emitters.

CEA is actively working with various BC communities on retrofit programs that could lead to significant GHG emission reductions if successfully implemented. A key focus is on transitioning buildings from fossil fuel heating and hot water systems to electric heat pumps. However, a challenge identified by CEA is the lack of analysis of the EnerGuide assessment data linked to housing archetypes, which hinders the understanding of retrofit potential within communities. Despite thousands of EnerGuide assessments conducted in BC and many ongoing residential retrofit initiatives, no one has performed this critical analysis.

CEA seeks research that explores this issue in greater depth and begins to develop solutions that will support residential retrofit feasibility studies. This research would create a foundation for effectively assisting communities in achieving deep GHG emission reductions in this sector. Specifically, CEA aims to analyze pre- and post-EnerGuide evaluations to uncover correlations between housing archetypes and various retrofit factors, as well as to develop a tool for generating retrofit emission scenarios.

1.2 Goals of the Study

The goals of this project are –

i) to explore correlations between the types of retrofits completed and reductions in energy and GHGs by analyzing the EnerGuide assessment data for each climatic zone in BC; and

ii) to develop a basic retrofit emissions scenario to help CEA support municipalities with exploring and implementing residential retrofit programs.

1.3 Scope of the Study

The project will involve two main activities: analyzing EnerGuide evaluations and developing a basic retrofit emissions scenario. It consists of three phases:

Accessing EnerGuide Data: The initial phase focuses on obtaining the EnerGuide assessment data from CEA and Natural Resources Canada (NRCan).

Analyzing Evaluations: This phase involves analyzing pre- and post-EnerGuide evaluations to identify correlations between types of retrofits and reductions in energy and GHG emissions for climatic zones in BC.

Developing the Emission Scenario: Based on the analysis, a basic emission scenario will be created to estimate community-level emission reduction potential after normalizing the data based on Heating Degree Days (HDD) and Cooling Degree Days (CDD).

2. Literature Review

2.1 Heating Degree Days (HDD) and Cooling Degree Days (CDD)

Heating Degree Days (HDD) quantify the number of degrees Celsius that a day's average temperature falls below 18°C. For instance, if the daily mean temperature is 12°C, the HDD for that day is 6°C. If the mean temperature exceeds 18°C, the HDD value is recorded as zero. HDD serves as an indicator of the heating demand throughout the year. The 18°C threshold signifies the temperature below which heating is necessary to maintain comfortable indoor conditions. Locations with many days below this average or significantly lower mean temperatures will require more energy (and cost) for heating to ensure comfort and safety. A decrease in projected HDD values suggests that a location may experience shorter cold periods or less severe winter weather (Climate Atlas of Canada, 2024b).

Cooling Degree Days (CDD) measure the number of degrees Celsius that a day's average temperature exceeds 18°C. For example, if the daily mean temperature is 21°C, the CDD for that day would be 3°C. If the mean temperature is below 18°C, the CDD value is recorded as zero. CDD is commonly used to estimate the annual demand for air conditioning. An increase in projected CDD values indicates that a location is likely to experience hotter or longer summers. The 18°C threshold represents the temperature at which air conditioning becomes necessary to maintain comfort indoors. Areas with many days above this average temperature, or significantly higher mean temperatures, will require considerable energy (and costs) for cooling buildings to ensure comfort and safety (Climate Atlas of Canada, 2024b).

2.2 Climatic Zones in BC

Depending on the HDD, there are 6 climatic zones in BC (Figure 3), which were considered to analyze the EnerGuide data. The main municipalities of each climatic zone are listed in Table 1 (CleanBC Better Homes, 2022).

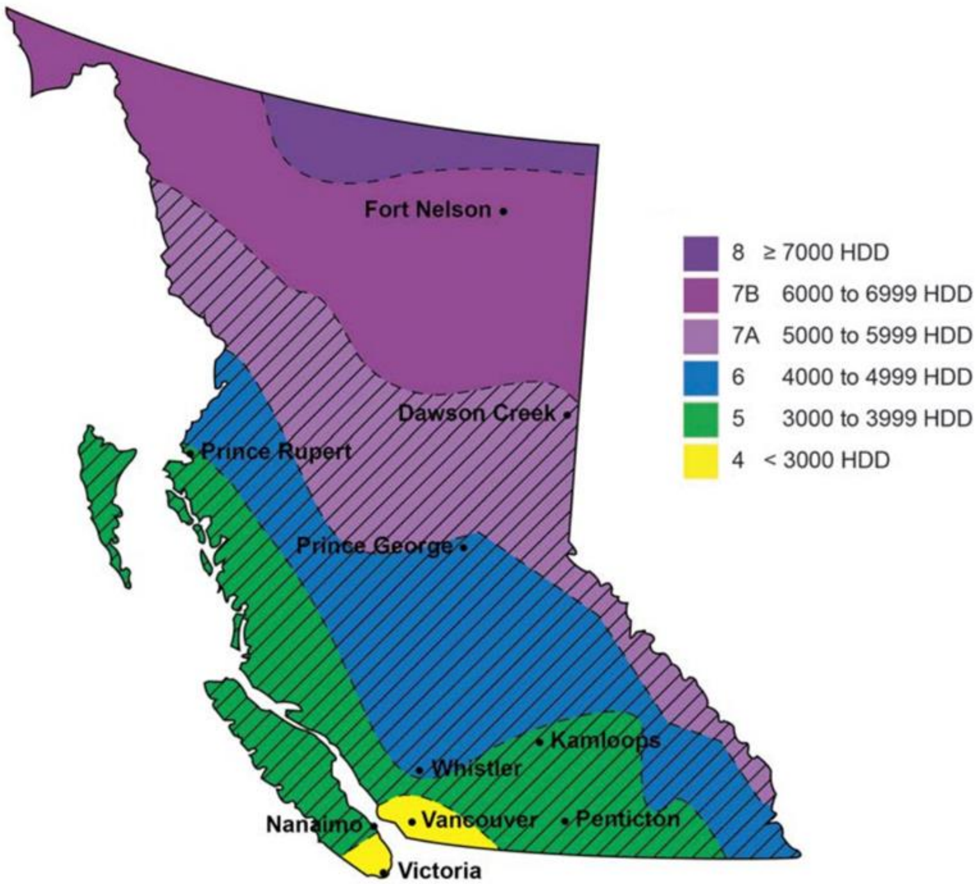

Figure 3. Climatic zones in British Columbia

Table 1. List of municipalities in different climatic zones in BC

Zones	Municipalities
Zone 4 < 3000 HDD	Abbotsford, Agassiz, Chilliwack, Cloverdale, Crofton, Duncan, Haney, Jordan River, Ladner, Langford, Langley, Mission City, New Westminster, North Vancouver, Port Renfrew, Richmond, Sechelt, Sidney, Sooke, Squamish, Surrey, Vancouver, Victoria, West Vancouver, White Rock
Zone 5 3000-3999 HDD	Alberni, Ashcroft, Bamfield, Bella Bella, Bella Coola, Burnaby, Cache Creek, Campbell River, Castlegar, Comox, Courtenay, Crescent Valley, Gold River, Grand Forks, Hope, Kamloops, Kaslo, Kelowna, Kitimat, Ladysmith, Lillooet, Lytton, Masset, Merritt, Montrose, Nakusp, Nanaimo, Nelson, Ocean Falls, Osoyoos, Parksville, Penticton, Port Alberni, Port Alice, Port Hardy, Port McNeill, Powell River, Prince

Zones	Municipalities
	Rupert, Qualicum Beach, Queen Charlotte City, Salmon Arm, Sandspit, Tahsis, Tofino, Trail, Ucluelet, Vernon, Youbou
Zone 6 4000-4999 HDD	Carmi, Cranbrook, Dog Creek, Elko, Fernie, Golden, Greenwood, Kimberley, McBride, Prince George, Princeton, Quesnel, Revelstoke, Stewart, Terrace, Whistler, Williams Lake
Zone 7A 5000-5999 HDD	100 Mile House, Burns Lake, Chetwynd, Dawson Creek, Fort St. John, Glacier, Mackenzie, McLeod Lake, Smithers, Taylor
Zones 7B & 8 ≥6000 HDD	Beatton River, Dease Lake, Fort Nelson, Smith River

2.3 EnerGuide Evaluation Data

A home energy audit, also known as an EnerGuide Home Evaluation, is the essential first step toward enhancing any home's efficiency. This audit helps identify opportunities to improve comfort and reduce utility bills. Conducted by a certified energy advisor, the evaluation assesses factors such as air leakage, insulation, and the condition of the furnace and ductwork. Following the audit, a personalized report outlining recommendations for upgrades that can significantly enhance the home's efficiency is prepared. The report also includes the home's efficiency rating, allowing it to compare it with similar homes in that area and assess improvements after upgrades (BC Hydro, 2024a).

During a pre-upgrade evaluation, the following steps are taken:

- Establish goals: Discussing on the homeowner's objectives and any efficiency or comfort issues.

- Measure the home size: Assessing the size and heated volume of the home.

- Inspect insulation: Documenting existing insulation levels throughout the property.

- Record heating systems: Noting the make and model of both space and water heating systems.

- Blower door test: Conducting a blower door test to identify air leakage, calculating air changes per hour (ACH) and the home's equivalent leakage area.

- Energy modelling: Using HOT2000 software to create an energy model for the home.

- Renovation upgrade report: Providing a customized report with recommendations for energy-saving upgrades and their expected savings.

- EnerGuide rating: Issuing an EnerGuide rating and label to demonstrate the home’s energy performance.

In the post-upgrade evaluation, the focus shifts to:

- Energy performance check: Evaluating the home’s energy performance after the upgrades and renovations.

- Document changes: Recording modifications made since the pre-upgrade evaluation and calculating the new EnerGuide rating.

- Updated label: Using the new data to create an updated EnerGuide label and a Homeowner Information Sheet.

2.4 Types of Retrofit Considered in the Analysis

The data acquired from NRCan was for both pre- and post-EnerGuide evaluation and from that dataset, 11 types of retrofits were identified. The following sections detail the types of retrofits and different recommendations for those in BC.

2.4.1 Air sealing

Air leakage occurs when outside air enters, and conditioned air escapes the home through cracks and openings. Relying on air leakage for natural ventilation is not advisable, as it can lead to excessive air infiltration during cold or windy weather, and insufficient airflow during warmer periods, potentially compromising indoor air quality. Additionally, air leakage can cause moisture issues that impact both occupant health and the structural integrity of the home. Sealing these cracks and openings minimizes drafts and cold spots, enhancing overall comfort.

Controlling air leakage is the most crucial retrofit activity and should be prioritized in any home upgrade strategy. It is vital to ensure that moisture does not infiltrate the insulation or building envelope whenever we insulate or enhance the air barrier system. Effective air leakage control involves systematically identifying and sealing as many air leakage paths as possible using materials like weather stripping, caulking, gaskets, and tapes (Government of Canada, 2024). Table 2 contains the recommended airtightness targets and insulation levels for homes in different climatic zones in BC (BC Housing, 2020).

Table 2. Recommended airtightness targets and insulation levels for homes in different climatic zones in BC

Wood-frame building enclosure assembly	**Zones 4 & 5**	**Zone 6**	**Zone 7A**	**Zone 7B & 8**
Attic Spaces	R-40	R-50	R-60	R-60
Cathedral or Flat Roofs	R-30	R-30	R-35	R-40
Above-grade Walls	R-20	R-25	R-25	R-30
Below-grade Walls	R-20	R-20	R-25	R-25
Suspended Floors	R-25	R-30	R-40	R-50
Slab-on-grade Floors	R-10	R-15	R-20	R-25
Airtightness (ACH50)	<5 ACH	<4 ACH	<3 ACH	<2 ACH

2.4.2 Attic insulation

Attic insulation is a critical component of retrofitting for improved energy efficiency and comfort in a home. Proper insulation helps regulate temperature, reduces heating and cooling costs, and prevents moisture issues. There are different types of attic insulation – batt insulation, blown-in insulation, rigid foam boards, etc. Batt insulation is made of fibreglass or mineral wool, and it comes in pre-cut panels that can be easily placed between joists. Loose-fill materials like cellulose or fibreglass can be blown into the attic space, filling gaps, and providing better coverage in hard-to-reach areas. Rigid foam boards can be installed on the underside of the roof or around the attic perimeter for added insulation. Colder climates necessitate higher R-value insulation. For instance, a home in Prince George needs an R-60 rating for the attic, whereas a home in Vancouver requires only an R-40.

2.4.3 Ventilation

Reducing drafts and improving ventilation are essential components of any retrofit. It is important to differentiate between drafts, which are unwanted air leaks that cause heat loss, and ventilation, which removes stale air and introduces fresh air. A balanced approach is necessary to enhance indoor air quality while addressing issues like mold and condensation. There are two main ventilation approaches - natural ventilation and mechanical ventilation. Natural ventilation relies on opening windows and doors for airflow, which can be energy-saving but less reliable due to weather conditions and potential drafts. Mechanical ventilation uses fans and ductwork for consistent airflow year-round. The BC Building Code (BCBC 2024) and Part 9 of the National Building Code (NBC) require all new homes in British Columbia to have a mechanical ventilation system to ensure adequate fresh air and good indoor air quality.

2.4.4 Ceiling insulation

Up to 35% of summer heat gains and winter heat losses can occur through the roof. This makes it the most critical area to insulate in the home. Ceiling insulation can be added to existing homes and is relatively easy to install if there's enough space in the roof area. The best time for installation is during renovations when the plaster is removed. Proper ceiling insulation not only enhances energy efficiency but also helps with weatherproofing and reduces moisture problems like condensation.

2.4.5 Foundation insulation

The foundation or basement area can be insulated in different ways. Rigid foam boards or spray foam can be applied to the outside of the foundation walls. This exterior insulation method is effective for both new and existing homes, providing continuous insulation that reduces thermal bridging. Foam board or fibreglass batts can be installed on the interior side of the foundation walls. This option is often used in basements and can be more manageable in terms of space but may require additional moisture barriers. Insulating the walls of crawl spaces with rigid foam or fibreglass batts can significantly improve energy efficiency. It is also important to ensure proper ventilation in the crawl space to prevent moisture issues.

2.4.6 Header insulation

Header insulation involves insulating the headers, or the horizontal framing members that support the walls and ceilings in a building. There are different types of headers to insulate including exterior wall headers, floor headers, roof headers, etc. Exterior wall headers are located at the top of exterior walls, typically above windows and doors. Floor headers are found in floor systems, insulating these can reduce drafts and enhance comfort, particularly in homes with unconditioned spaces below. Roof headers are used in roof framing.

2.4.7 Wall insulation

Walls can contribute to approximately 20% of heat loss in homes. Beyond this loss, various cracks and penetrations can lead to uncontrolled air leakage, allowing outside air to enter and conditioned air to escape. Walls can be insulated during major repairs or renovations. Interior work typically involves wall repairs, upgrading electrical wiring, installing insulation and vapour barriers, and finishing with drywall. On the exterior, insulation can be integrated with re-siding projects for enhanced efficiency. Table 3 contains the recommended R-values for different insulation types for different climatic zones in BC (The Home Depot, 2024).

Table 3. Recommended insulation levels for different climatic zones in BC

	Good	**Better**	**Best**
	Zone 4		
Ceiling Below Attics	R-40 Batt or Blown Insulation	R-50 Batt or Blown Insulation	R-60 Batt or Blown Insulation
Cathedral Ceilings & Flat Roofs	R-31 Batt Insulation	R-31 Batt Insulation + R-5 CodeBord®	R-31 Batt Insulation + R-10 CodeBord®
Floors Over Unheated Spaces	R-31 Batt Insulation	R-31 Batt Insulation + R-5 CodeBord®	R-31 Batt Insulation + R-10 CodeBord®
Walls Above Grade	R-19 Batt Insulation	R-22 Batt Insulation + R-5 CodeBord®	R-24 Batt Insulation + R-5 CodeBord®
Foundation Walls	R-12/14 Batt Insulation	R-14 Batt Insulation + R-5 CodeBord®	R-14 Batt Insulation + R-10 CodeBord®

	Good	Better	Best
Zone 5			
Ceiling Below Attics	R-40 Batt or Blown Insulation	R-50 Batt or Blown Insulation	R-60 Batt or Blown Insulation
Cathedral Ceilings & Flat Roofs	R-31 Batt Insulation	R-31 Batt Insulation + R-5 CodeBord®	R-31 Batt Insulation + R-10 CodeBord®
Floors Over Unheated Spaces	R-31 Batt Insulation	R-31 Batt Insulation + R-5 CodeBord®	R-31 Batt Insulation + R-10 CodeBord®
Walls Above Grade	R-19 Batt Insulation + R-5 CodeBord®	R-19 Batt Insulation + R-7.5 CodeBord®	R-24 Batt Insulation + R-10 CodeBord®
Foundation Walls	R-14 Batt Insulation + R-7.5 CodeBord®	R-14 Batt Insulation + R-10 CodeBord®	R-22 Batt Insulation + R-10 CodeBord®
Zone 6			
Ceiling Below Attics	R-50 Batt or Blown Insulation	R-50 Batt or Blown Insulation	R-60 Batt or Blown Insulation
Cathedral Ceilings & Flat Roofs	R-31 Batt Insulation	R-31 Batt Insulation +	R-31 Batt Insulation +

	Good	Better	Best
		R-5 CodeBord®	R-10 CodeBord®
Floors Over Unheated Spaces	R-31 Batt Insulation	R-31 Batt Insulation + R-5 CodeBord®	R-31 Batt Insulation + R-10 CodeBord®
Walls Above Grade	R-19 Batt Insulation + R-5 CodeBord®	R-19 Batt Insulation + R-7.5 CodeBord®	R-24 Batt Insulation + R-10 CodeBord®
Foundation Walls	R-14 Batt Insulation + R-7.5 CodeBord®	R-14 Batt Insulation + R-10 CodeBord®	R-22 Batt Insulation + R-10 CodeBord®
		Zone 7A	
Ceiling Below Attics	R-50 Batt or Blown Insulation	R-60 Batt or Blown Insulation	R-60 Batt or Blown Insulation
Cathedral Ceilings & Flat Roofs	R-31 Batt Insulation	R-31 Batt Insulation + R-7.5 CodeBord®	R-31 Batt Insulation + R-15 CodeBord®
Floors Over Unheated Spaces	R-31 Batt Insulation	R-31 Batt Insulation + R-7.5 CodeBord®	R-31 Batt Insulation + R-15 CodeBord®

	Good	Better	Best
Walls Above Grade	R-19 Batt Insulation + R-5 CodeBord®	R-19 Batt Insulation + R-7.5 CodeBord®	R-24 Batt Insulation + R-10 CodeBord®
Foundation Walls	R-14 Batt Insulation + R-7.5 CodeBord®	R-14 Batt Insulation + R-10 CodeBord®	R-22 Batt Insulation + R-10 CodeBord®

2.4.8 Natural gas furnace

To keep the heating costs manageable during winter, it is crucial to ensure the heating system operates efficiently. If the gas furnace is older, it may be consuming more energy than necessary, leading to higher utility bills compared to newer, more efficient models. To enhance the furnace's energy efficiency, there are two main options: upgrade to a newer furnace or retrofit the existing unit. As BC's electricity grid is considered clean, it is more recommended to switch to electric heat pumps from natural gas-based furnaces.

2.4.9 Air conditioning

Retrofitting air conditioning involves upgrading or installing new systems in existing buildings to improve comfort and energy efficiency. This is particularly important as climate change leads to hotter summers and increased demand for cooling. If there is no air conditioning system installed and it is required to upgrade the natural gas-based heating system, it is advisable to install a heat pump which will serve both.

2.4.10 Domestic hot water system

Retrofitting a hot water system involves upgrading or modifying existing water heating systems to improve efficiency, reduce energy consumption, and enhance performance. This is especially important for older systems that may be costly to operate. Tankless water heaters provide hot water on demand, eliminating standby heat loss associated with traditional tanks. Heat pump water heaters use electricity to move heat from the air or ground to heat water, offering significant energy savings. Adding insulation to older hot water tanks can reduce heat loss, improving efficiency and lowering energy bills. Implementing timers on traditional tank heaters can help control heating schedules, reducing energy usage during non-peak times. Insulating hot water pipes minimizes heat loss as water travels from the heater to the tap, improving efficiency and reducing waiting time for hot water. Installing a hot water recirculation system can provide immediate access to hot water, reducing water waste, and improving comfort.

2.4.11 Heat pump

Heat pumps offer an energy-efficient alternative to conventional heating systems, such as natural gas furnaces and electric baseboards. They also provide cooling capabilities, reducing reliance on traditional air conditioners, and ensuring year-round comfort. By transferring heat rather than generating it, heat pumps are highly efficient and low carbon, especially in BC where 97% of electricity comes from clean hydroelectric sources. This results in a significant reduction in greenhouse gas emissions - around two tons of CO_2e per year per home - comparable to driving a gas-powered car 8,000 kilometers. Heat pumps are about 300% more efficient than electric baseboards and natural gas furnaces, and approximately 50% more efficient than typical window air conditioners. Currently, operating an electric heat pump is about 12% cheaper than running a natural gas furnace, with savings increasing as carbon pricing rises (BC Hydro, 2024b; Government of Canada, 2022). Transitioning from electric baseboard heating to a heat pump can lead to substantial savings; for instance, a townhouse in Burnaby experienced a 40% reduction in utility bills after switching to a heat pump from an electric baseboard (The Canadian Press, 2022).

3. Methodology

3.1 Literature Review and Background Research

Literature review and background research were conducted to understand relevant terms, BC's climatic zones, EnerGuide assessment, types of retrofits, etc., which guided the data analysis phase.

3.2 Data Assemblage

The pre-and post-evaluation EnerGuide assessment for houses in BC was collected from NRCan. Datasets from both 0-100 rating and GJ rating systems were compiled. For analyzing the EnerGuide evaluation data, 4 climatic zones were considered – zone 4, zone 5, zone 6, and zones 7 and 8 together, as there are fewer records for zones 7 and 8. There are thousands of records for zones 4 and 5. For time constraints, representative municipalities were taken from zones 4 and 5. For instance, North Vancouver was picked from zone 4 and Kelowna was picked from zone 5. For other zones, all the records were considered. The EnerGuide assessment record has around 300 data fields but for this report, the following data fields were used (Table 4).

Table 4. Data fields used for the analysis

Data Fields	Description
CLIENTCITY	City (where property is located)
EGHFCONELEC	Consumption of electricity in kWh
EGHFCONNGAS	Consumption of gas in m^3
EGHFCONTOTAL	Total energy consumption in MJ
EVALUATIONSID	Evaluation ID
EVALTYPE	Type of evaluation (D or E)
ENTRYDATE	Date of data entry (when electronic file was created)
FLOORAREA	Floor area of the house (m^2)
AIR50P	Air leakage at 50 pascals
UGRAIR50PA	Proposed air leakage at 50 Pa
ATTICCEILINGDEF	Description of attic insulation (displays percentage of attic area, followed by the nominal R-value)

Data Fields	Description
UATTCEILINGDEF	Proposed description of attic insulation (displays percentage of attic area, followed by the nominal R-value)
ERSVENTILATIONENERGY	Ventilation energy consumption in MJ
UGRERSVENTILATIONENERGY	Upgrade Ventilation energy consumption in MJ
CAFLACEILINGDEF	Description of cathedral or flat roof insulation (displays percentage of attic area, followed by the nominal R-value)
UCAFLCEILINGDEF	Proposed description of cathedral or flat roof insulation (displays percentage of attic area, followed by the nominal R-value)
FNDDEF	Description of foundation insulation (displays percentage of foundation area, followed by the nominal R-value)
UGRFNDDEF	Proposed description of foundation insulation (displays percentage of foundation area, followed by the nominal R-value)
FNDHDR	Header insulation value (RSI) – basement
UGRFNDHDR	Upgrade header insulation value (RSI) – basement
WALLDEF	Description of wall insulation (displays percentage of wall area, followed by the nominal R-value)
UGRWALLDEF	Proposed description of wall insulation (displays percentage of wall area, followed by the nominal R-value)
FURSSEFF	Primary heating equipment efficiency (Steady State efficiency)
UGRFURNACEEFF	Proposed primary heating equipment efficiency
AIRCOP	Co-efficient of performance for the A/C system
UGRAIRCOP	Proposed efficiency of A/C system
PDHWEF	Domestic hot water equipment efficiency
UGRDHWSYSEF	Proposed domestic hot water equipment efficiency
COP	Heat pump co-efficient of performance

Data Fields	Description
UGRHPTYPE	Proposed heat pump type
UGRNUMDOORESTAR	Number of ESTAR doors (installed + recommended)
NUMDOORESTAR	Number of installed ESTAR doors
UGRNUMWINESTAR	Number of ESTAR windows (installed + recommended)
NUMWINESTAR	Number of installed ESTAR windows

3.3 Data Analysis

3.3.1 Identifying whether any specific type of retrofit was recommended and/or completed

After compiling data from both 0-100 rating and GJ rating systems, different Excel sheets were created for different zones by filtering the CLIENTCITY field. In total, 11 types of retrofits were considered, excluding the installation of Energy Star doors and windows. .

Table 5 contains the details of calculating whether each type of retrofit was recommended and/or completed or not for each house. Here, D means pre-EnerGuide evaluation and E means post-EnerGuide evaluation. Moroever, the descriptions of data fields were provided in Table 4. After that, summary tables for each zone were prepared to list the number of houses where an upgrade was recommended, the number of houses where upgrades were done, the number of houses which upgraded based on recommendation, the number of upgraded houses in different years, and the total number of retrofits and types of retrofits done in those houses.

Table 5. Details of calculating whether any specific type of retrofit was recommended and/or completed or not

Type of Retrofit	Data Fields	Upgrade Recommended	Upgrade Completed
Air Sealing	AIR50P (1)	If 2D<1D	If 1D<1E
	UGRAIR50PA (2)		

Type of Retrofit	Data Fields	Upgrade Recommended	Upgrade Completed
Attic Insulation	ATTICCEILINGDEF (3) UATTCEILINGDEF (4)	If 4D≠3D	If 3D≠3E
Ventilation	ERSVENTILATIONENERGY (5) UGRERSVENTILATIONENERGY (6)	If 6D≠5D	If 5D≠5E
Ceiling Insulation	CAFLACEILINGDEF (7) UCAFLCEILINGDEF (8)	If 8D≠7D	If 7D≠7E
Foundation Insulation	FNDDEF (9) UGRFNDDEF (10)	If 10D≠9D	If 9D≠9E
Header Insulation	FNDHDR (11) UGRFNDHDR (12)	If 12D≠11D	If 11D≠11E
Wall Insulation	WALLDEF (13) UGRWALLDEF (14)	If 14D≠13D	If 13D≠13E
Natural Gas Furnace	FURSSEFF (15) UGRFURNACEEFF (16)	If 16D>15D	If 15E>15D
Air Conditioning	AIRCOP (17) UGRAIRCOP (18)	If 18D>17D	If 17E>17D
Domestic Hot Water System	PDHWEF (19) UGRDHWSYSEF (20)	If 20D>19D	If 19E>19D
Heat Pump	COP (21) UGRHPTYPE (22)	If 22D = “Air”	If 21E>21D

3.3.2 Calculating energy saving

For calculating energy saving, energy saving from electricity consumption (using the EGHFCONELEC field), energy saving from natural gas consumption (using the EGHFCONNGAS field), and total energy saving (using the EGHFCONTOTAL field) were considered. Values of these fields for ‘D’ evaluations are consumption before retrofit, and values for ‘E’ evaluations are consumption after retrofit. The difference between these two is the energy saving after completing upgrades. Moreover, energy saving per sq m (divided by the FLOORAREA field) was calculated. Following are the equations for calculating energy saving per sq m.

i. $$Energy\ saving\ per\ sq\ m\ from\ electricity\ consumption\ (kWh\ per\ sq\ m) = \frac{\text{EGHFCONELEC for D evaluation} - \text{EGHFCONELEC for E evaluation}}{\text{FLOORAREA}}$$

ii. $$Energy\ saving\ per\ sq\ m\ from\ natural\ gas\ consumption\ (m^3\ per\ sq\ m) = \frac{\text{EGHFCONNGAS for D evaluation} - \text{EGHFCONNGAS for E evaluation}}{\text{FLOORAREA}}$$

iii. $$Total\ energy\ saving\ per\ sq\ m\ (MJ\ per\ sq\ m) = \frac{\text{EGHFCONTOTAL for D evaluation} - \text{EGHFCONTOTAL for E evaluation}}{\text{FLOORAREA}}$$

3.3.3 Calculating GHG emissions reduction

For calculating GHG emissions reduction, emission factors for electricity and natural gas consumption were multiplied by energy savings from electricity and natural gas consumption, respectively. The emission factor for electricity consumption was 0.0000113 to calculate GHG emission in tCO_2e (Government of British Columbia, 2024b). Besides, the emission factor for natural gas consumption was 0.001937 to calculate GHG emission in tCO_2e (Ministry of Environment and Climate Change Strategy, 2021). The following equations detail the calculation of emission factors.

Emission factor for electricity consumption:

1 GWh electricity consumption = 11.3 tCO_2e GHG emission

1 kWh electricity consumption = **0.0000113** tCO_2e GHG emission

Emission factor for natural gas consumption:

0.03885 GJ/m^3 natural gas consumption = 49.87 $kgCO_2e/GJ$ GHG emission

1 m^3 natural gas consumption = **0.001937** tCO_2e GHG emission

3.3.4 Calculating average energy saving and GHG reduction potential for BC and Pemberton

Energy saving and GHG emission reduction values were normalized based on HDD and CDD for each zone and they were multiplied by the HDD and CDD of BC and Pemberton. Following that the average energy saving and GHG reduction potentials were calculated for BC and Pemberton. Table 6 contains the values of HDD and CDD of different municipalities considered in the normalization analysis. The HDD and CDD values are mostly taken from the

Climate Atlas of Canada website, and it provides the average HDD and CDD for the period 1976-2005.

Table 6. Heating degree days (HDD) and cooling degree days (CDD) for different zones and municipalities considered in the analysis

Zone	**City**	**HDD**	**CDD**	**References for HDD**	**References for CDD**
Zone 4	North Vancouver	2776	71.4	(Climate Atlas of Canada, 2024c)	(Climate Atlas of Canada, 2024a)
Zone 5	Kelowna	3627	194.4		
Zone 6	All	4500	30.2	Average of HDD range was taken.	CDD for Prince George was taken (Climate Atlas of Canada, 2024a)
	Pemberton	5116	10.3	(Climate Atlas of Canada, 2024c)	(Climate Atlas of Canada, 2024a)
Zone 7 and 8	All	6000	21.5	Average of HDD range was taken.	CDD for Fort St. John was taken (Climate Atlas of Canada, 2024a)
British Columbia	All	3000	100	Assumed average considering majority of population live in southwest side.	

Following equations explain how the energy saving and GHG emissions reduction values were normalized based on HDD and CDD for BC and Pemberton.

i. $$Average\ energy\ saving\ potential\ from\ electricity\ usage\ (kWh\ per\ sq\ m)\ for\ BC = \sum\left(\frac{Energy\ saving\ per\ sq\ m\ from\ electricity\ consumption}{HDD\ or\ CDD\ of\ specific\ zones} \times HDD\ or\ CDD\ of\ BC\right)/n$$

ii. $$Average\ energy\ saving\ potential\ from\ electricity\ usage\ (kWh\ per\ sq\ m)\ for\ Pemberton = \sum\left(\frac{Energy\ saving\ per\ sq\ m\ from\ electricity\ consumption}{HDD\ or\ CDD\ of\ specific\ zones} \times HDD\ or\ CDD\ of\ Pemberton\right)/n$$

iii. $Average\ energy\ saving\ potential\ from\ natural\ gas\ usage\ (m^3\ per\ sq\ m)\ for$

$$BC = \sum(\frac{Energy\ saving\ per\ sq\ m\ from\ natural\ gas\ consumption}{HDD\ or\ CDD\ of\ specific\ zones} \times HDD\ or\ CDD\ of\ BC)\ /n$$

iv. $Average\ energy\ saving\ potential\ from\ natural\ gas\ usage\ (m^3\ per\ sq\ m)\ for$

$$Pemberton = \sum(\frac{Energy\ saving\ per\ sq\ m\ from\ natural\ gas\ consumption}{HDD\ or\ CDD\ of\ specific\ zones} \times HDD\ or\ CDD\ of\ Pemberton)\ /n$$

v. $Average\ of\ total\ energy\ saving\ potential\ (MJ\ per\ sq\ m)\ for\ BC =$

$$\sum(\frac{Total\ energy\ saving\ per\ sq\ m}{HDD\ or\ CDD\ of\ specific\ zones} \times HDD\ or\ CDD\ of\ BC)\ /n$$

vi. $Average\ of\ total\ energy\ saving\ potential\ (MJ\ per\ sq\ m)\ for\ Pemberton =$

$$\sum(\frac{Total\ energy\ saving\ per\ sq\ m}{HDD\ or\ CDD\ of\ specific\ zones} \times HDD\ or\ CDD\ of\ Pemberton)\ /n$$

vii. $Average\ GHG\ reduction\ potential\ from\ electricity\ usage\ (tCO_2e\ per\ sq\ m)\ for$

$$BC = \sum(\frac{GHG\ reduction\ per\ sq\ m\ from\ electricity\ consumption}{HDD\ or\ CDD\ of\ specific\ zones} \times HDD\ or\ CDD\ of\ BC)\ /n$$

viii. $Average\ GHG\ reduction\ potential\ from\ electricity\ usage\ (tCO_2e\ \ per\ sq\ m)\ for$

$$Pemberton\ = \sum(\frac{GHG\ reduction\ per\ sq\ m\ from\ electricity\ consumption}{HDD\ or\ CDD\ of\ specific\ zones} \times HDD\ or\ CDD\ of\ Pemberton)\ /n$$

ix. $Average\ GHG\ reduction\ potential\ from\ natural\ gas\ usage\ (tCO_2e\ per\ sq\ m)\ for$

$$BC = \sum(\frac{GHG\ reduction\ per\ sq\ m\ from\ natural\ gas\ consumption}{HDD\ or\ CDD\ of\ specific\ zones} \times HDD\ or\ CDD\ of\ BC)\ /n$$

x. $Average\ GHG\ reduction\ potential\ from\ natural\ gas\ usage\ (tCO_2e\ per\ sq\ m)\ for$

$$Pemberton = \sum(\frac{GHG\ reduction\ per\ sq\ m\ from\ natural\ gas\ consumption}{HDD\ or\ CDD\ of\ specific\ zones} \times HDD\ or\ CDD\ of\ Pemberton)\ /n$$

All these measures were calculated for different types of retrofits and also combinations of retrofit types. For instance, houses where only air sealing was done, were identified and these values were calculated for those houses to identify the relationship between air sealing and energy saving and GHG reduction potentials. This has been done for most of the retrofit types and some combination of retrofits (i.e., air sealing + heat pump, air sealing + ventilation, etc.).

3.3.5 Developing emission reduction scenarios for BC and Pemberton to achieve 2030 targets

After calculating average energy saving and GHG reduction potentials per sq m for BC and Pemberton for specific types of retrofit and/or combination of retrofits, the number of houses needed to be retrofitted to achieve the 2030 emission reduction targets of BC and Pemberton were calculated.

GHG emission reduction target of BC by 2030 from existing buildings:

GHG emissions in BC were reported to be 64.76 million tons in 2007 (The Canadian Press, 2019). In BC, buildings account for about 12% of provincial GHG emissions (BC Climate Action Toolkit, n.d.). Besides, BC has established legislated targets to cut GHG emissions as part of its CleanBC climate strategy, including a 40% reduction in GHG emissions from 2007 levels by 2030 (Government of British Columbia, 2024a). So, the total annual GHG emissions reductions from the existing buildings for BC should be (64.76*0.12*0.4) or 3.10848 million tons or **3108480 tCO_2e in 2030**.

GHG emission reduction target of Pemberton by 2030 from existing buildings:

According to the Community Climate Action Plan for Pemberton, the total annual GHG emissions reductions from the existing buildings have been set to **448 tCO_2e in 2030** (Community Energy Association, 2022).

The calculated average GHG reduction potential (both from electricity and natural gas savings) is per sq m. For calculation, the average floor area of houses in BC and Pemberton was taken as 1430 sq ft or **133 sq m** (Statistics Canada, 2019). So, after the analysis, we will get the number of houses to be retrofitted with different types of upgrades to achieve the GHG reduction targets of BC and Pemberton by 2030. For that, GHG reduction potentials from electricity saving and natural gas saving were added first. Following are the equations for calculating the number of houses to be retrofitted with different types of upgrades to achieve the GHG reduction targets of BC and Pemberton by 2030.

i. $No\ of\ houses\ to\ be\ retrofitted\ in\ BC =$

$$\frac{2030\ target\ for\ GHG\ reduction\ of\ BC}{Average\ GHG\ reduction\ potentials\ from\ electricity\ and\ natural\ gas\ savings * Average\ floor\ area}$$

ii. $No\ of\ houses\ to\ be\ retrofitted\ in\ Pemberton =$

$$\frac{2030\ target\ for\ GHG\ reduction\ of\ Pemberton}{Average\ GHG\ reduction\ potentials\ from\ electricity\ and\ natural\ gas\ savings * Average\ floor\ area}$$

4. Results

4.1 Analysis of Pre- and Post-EnerGuide Evaluation Data

Total DE evaluations in zone 4 (North Vancouver), zone 5 (Kelowna), zone 6, and zones 7 and 8 together were 4237, 4264, 6199, and 1374, respectively. Summary tables for each zone were prepared to list the number of houses where an upgrade was recommended, the number of houses where upgrades were done, the percent uptake, and the number of houses which upgraded based on recommendation (Table 7). Moreover, the number of upgraded houses in different years (

Table 8) and the total number of retrofits done in those houses (Table 9) were also summarized for each zone. Most of the houses were retrofitted between 2008 and 2013, and there is also an increase in 2022 and 2023 (

Table 8). The number of houses with 2 types of retrofits is the highest. Besides, houses with 3, 4, and 5 types of retrofits are also higher in number (Table 9).

Table 10 represents the number of houses with different types of retrofits in different climatic zones. Air sealing is the most common type of retrofit done in every climatic zone. The houses which had done air sealing and changed their natural gas furnaces is the highest in number. Changing natural gas furnaces is the second most common retrofit type. Besides, other insulations were coupled with air sealing in a significant number of houses (

Table 10).

Table 7. Summary of retrofits done in climatic zone 4 (North Vancouver)

Type of retrofit	Upgrade recommended	%	Actual upgrade	%	% uptake	Upgraded based on recommendation
Zone 4 (North Vancouver)						
Air Sealing	3808	90	3778	89	99	3394
Attic Insulation	2645	62	960	23	36	892
Ventilation	228	5	29	1	13	4
Ceiling Insulation	311	7	106	3	34	51

Type of retrofit	Upgrade recommended	%	Actual upgrade	%	% uptake	Upgraded based on recommendation
Foundation Insulation	1327	31	502	12	38	316
Header insulation	514	12	210	5	41	90
Wall Insulation	856	20	298	7	35	154
NG Furnace	3422	81	2902	68	85	2679
Air Conditioning	2193	52	842	20	38	754
Domestic Hot Water	2774	65	468	11	17	375
Heat Pump	2456	58	833	20	34	790
EnergyStar Doors	11863		1182		10	
EnergyStar Windows	99518		23228		23	
Zone 5 (Kelowna)						
Air Sealing	2209	52	3513	82	159	1849
Attic Insulation	1601	38	974	23	61	876
Ventilation	186	4	19	0	10	4
Ceiling Insulation	83	2	60	1	72	33
Foundation Insulation	969	23	590	14	61	422
Header insulation	286	7	196	5	69	109
Wall Insulation	296	7	170	4	57	105
NG Furnace	2483	58	2249	53	91	2074
Air Conditioning	1927	45	1085	25	56	929

Type of retrofit	Upgrade recommended	%	Actual upgrade	%	% uptake	Upgraded based on recommendation
Domestic Hot Water	888	21	215	5	24	136
Heat Pump	1918	45	995	23	52	844
EnergyStar Doors	5276		1487		28	
EnergyStar Windows	50313		17875		36	
Zone 6						
Air Sealing	4675	75	5244	85	112	4088
Attic Insulation	3113	50	1581	26	51	1466
Ventilation	173	3	24	0	14	10
Ceiling Insulation	326	5	147	2	45	97
Foundation Insulation	2419	39	1037	17	43	794
Header insulation	1005	16	607	10	60	384
Wall Insulation	1425	23	683	11	48	518
NG Furnace	4738	76	3978	64	84	3869
Air Conditioning	1277	21	755	12	59	543
Domestic Hot Water	3427	55	650	10	19	527
Heat Pump	1477	24	770	12	52	603
EnergyStar Doors	11791		2613		22	
EnergyStar Windows	93344		28972		31	
Zones 7 and 8						
Air Sealing	953	69	1121	82	118	829

Type of retrofit	Upgrade recommended	%	Actual upgrade	%	% uptake	Upgraded based on recommendation
Attic Insulation	727	53	346	25	48	326
Ventilation	29	2	2	0	7	0
Ceiling Insulation	56	4	28	2	50	14
Foundation Insulation	550	40	284	21	52	208
Header insulation	215	16	106	8	49	68
Wall Insulation	503	37	202	15	40	155
NG Furnace	1025	75	846	62	83	814
Air Conditioning	224	16	130	9	58	89
Domestic Hot Water	867	63	187	14	22	169
Heat Pump	245	18	134	10	55	93
EnergyStar Doors	2483		728		29	
EnergyStar Windows	17336		5539		32	

Table 8. The number of upgraded houses in different years in different climatic zones

Year of evaluation	No of upgraded houses			
	Zone 4 (North Vancouver)	Zone 5 (Kelowna)	Zone 6	Zones 7 and 8
2007	50	35	68	16
2008	340	511	849	216
2009	865	1165	1695	417
2010	659	520	952	248
2011	772	620	1057	201

Year of evaluation	No of upgraded houses			
	Zone 4 (North Vancouver)	Zone 5 (Kelowna)	Zone 6	Zones 7 and 8
2012	585	610	639	148
2013	217	163	179	29
2014	19	33	31	1
2015	6	19	18	0
2016	9	11	12	0
2017	7	8	7	0
2018	6	4	12	1
2019	3	3	8	0
2020	5	5	10	0
2021	76	37	71	11
2022	266	206	273	43
2023	350	309	317	44
2024*	5	9	7	2
Total	4237	4264	6199	1374

** The records for 2024 are only for January month.*

Table 9. Total number of retrofits done in the upgraded houses in different climatic zones

No of retrofits done	No of houses			
	Zone 4 (North Vancouver)	Zone 5 (Kelowna)	Zone 6	Zones 7 and 8
1	759	916	1107	251
2	1772	1642	2430	500
3	704	788	1339	323
4	578	471	683	183
5	228	156	294	63
6	73	77	120	16
7	40	32	56	1
8	21	10	13	2
9	15	8	6	0

No of retrofits done	No of houses			
	Zone 4 (North Vancouver)	Zone 5 (Kelowna)	Zone 6	Zones 7 and 8
10	4	0	2	0

Table 10. Number of houses with single or combination of retrofits in different climatic zones

Retrofit types	Zone 4 (North Vancouver)	Zone 5 (Kelowna)	Zone 6	Zones 7 and 8	Total
Air Sealing	583	580	629	135	**1927**
	13.8%	13.6%	10.2%	9.8%	
Attic Insulation	10	126	60	9	**205**
	0.2%	3.0%	1.0%	0.7%	
Ventilation	0	1	0	0	**1**
	0	0.02%	0	0	
Ceiling Insulation	2	2	1	1	**6**
	0.05%	0.05%	0.02%	0.07%	
Foundation Insulation	1	12	13	4	**30**
	0.02%	0.3%	0.2%	0.3%	
Header insulation	0	1	2	0	**3**
	0	0.02%	0.03%	0	
Wall Insulation	0	1	19	10	**30**
	0	0.02%	0.3%	0.7%	
NG Furnace	161	187	370	86	**804**
	3.8%	4.4%	6.0%	6.3%	
Air Conditioning	1	0	0	0	**1**
	0.02%	0	0	0	
Domestic Hot Water	1	5	7	5	**18**
	0.02%	0.1%	0.1%	0.4%	
Heat Pump	0	1	6	1	**8**
	0	0.02%	0.1%	0.1%	
	266	266	337	48	**917**

Retrofit types	Zone 4 (North Vancouver)	Zone 5 (Kelowna)	Zone 6	Zones 7 and 8	Total
Air Sealing + Attic Insulation	6.3%	6.2%	5.4%	3.5%	
Air Sealing + Ventilation	1	0	0	0	**1**
	0.02%	0	0	0	
Air Sealing + Ceiling Insulation	7	0	7	2	**16**
	0.2%	0	0.1%	0.1%	
Air Sealing + Foundation Insulation	50	83	74	28	**235**
	1.2%	1.9%	1.2%	2.0%	
Air Sealing + Header insulation	0	3	3	1	**7**
	0	0.1%	0.05%	0.1%	
Air Sealing + Wall Insulation	16	25	116	37	**194**
	0.4%	0.6%	1.9%	2.7%	
Air Sealing + NG Furnace	1330	1106	1698	311	**4445**
	31.4%	25.9%	27.4%	22.6%	
Air Sealing + Air Conditioning	0	5	0	1	**6**
	0	0.1%	0	0.1%	
Air Sealing + Domestic Hot Water	18	16	20	2	**56**
	0.4%	0.4%	0.3%	0.1%	
Air Sealing + Heat Pump	0	6	8	4	**18**
	0	0.1%	0.1%	0.3%	

4.2 Energy Saving in Different Climatic Zones

Average total energy saving, energy saving from electricity and natural gas consumptions (both total and per sq m) were plotted against the number of upgrades to identify the trend in different climatic zones. The equations of trendlines and r-square values are included in the graphs. Graphs for climatic zone 6 were presented here and graphs for other zones were given in Appendix. In general, the average total energy saving increases if the number of upgrades increases and they are very strongly related to each other in every climatic zone (Figure 4 and

Figure 5). Besides, the average total energy savings from natural gas consumption also increases if the number of upgrades increases and they are very strongly related to each other in every climatic zone (Figure 8 and Figure 9). Interestingly, the average total energy savings from electricity consumption is negatively correlated with the number of upgrades. It can be said that if the upgrades involve more electrification (i.e., changing natural gas-based furnaces to heat pumps), it will increase electricity consumption (Figure 6 and Figure 7).

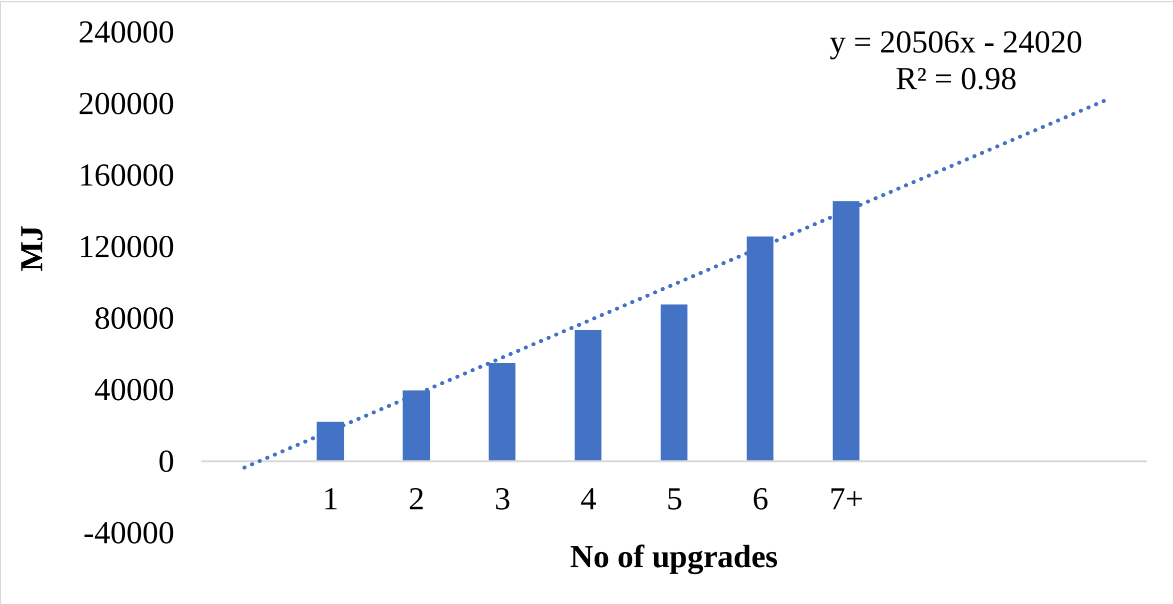

Figure 4. Average of total energy saving in MJ for different numbers of upgrades in zone 6

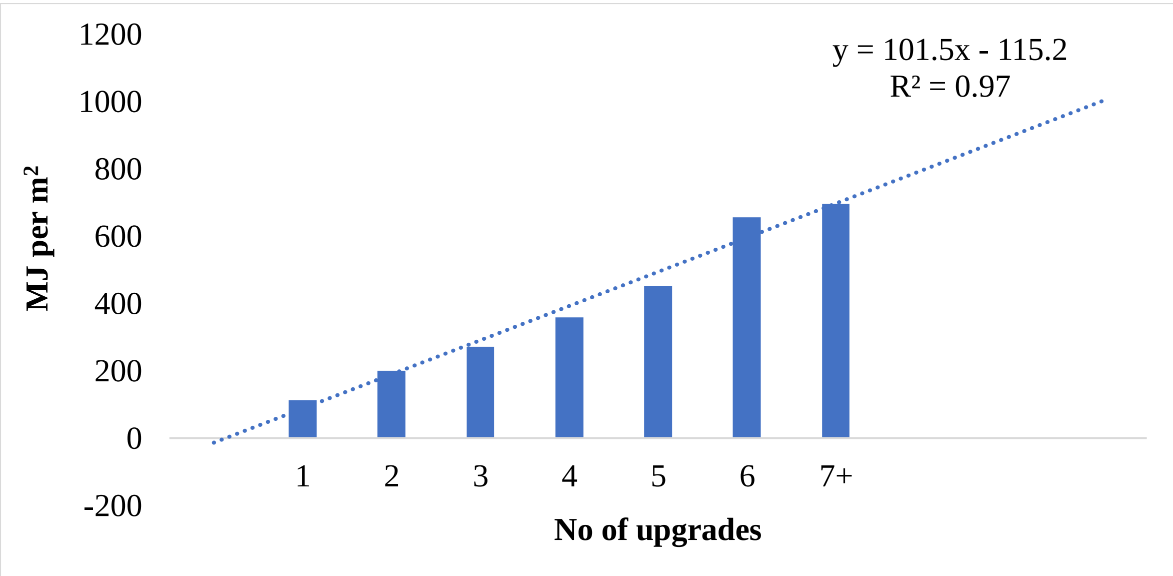

Figure 5. Average of total energy saving in MJ per m^2 for different numbers of upgrades in zone 6

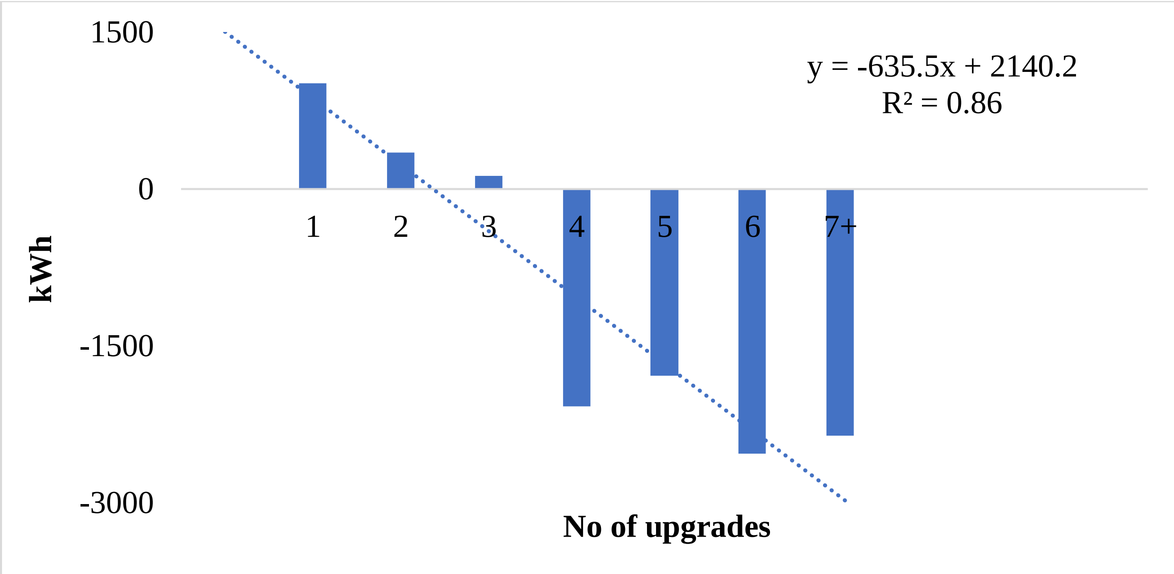

Figure 6. Average of total energy saving from electricity consumption in kWh for different numbers of upgrades in zone 6

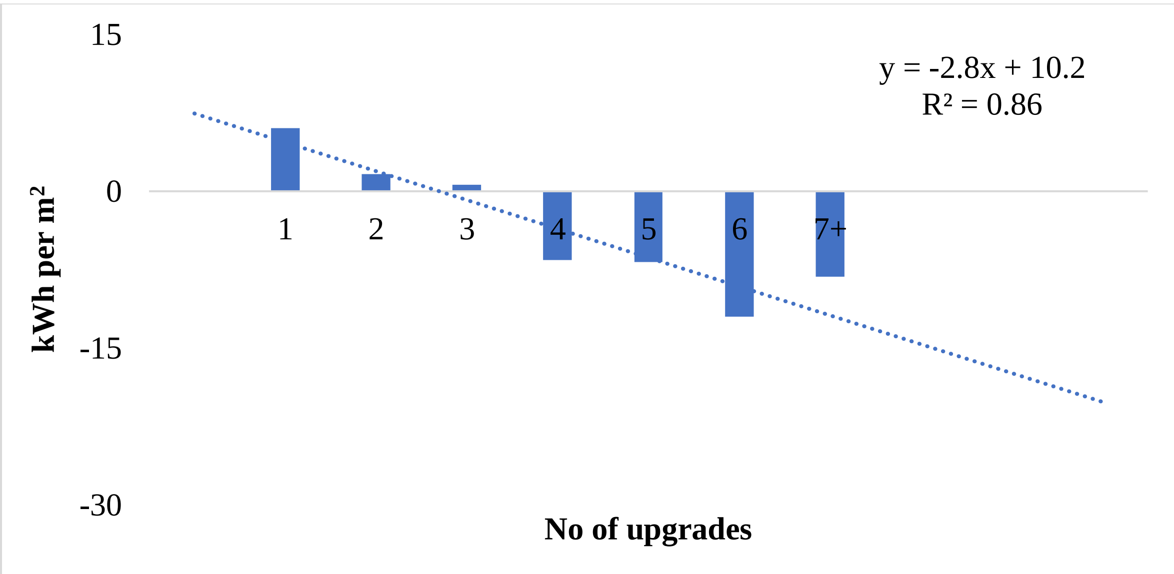

Figure 7. Average of total energy saving from electricity consumption in kWh per m^2 for different numbers of upgrades in zone 6

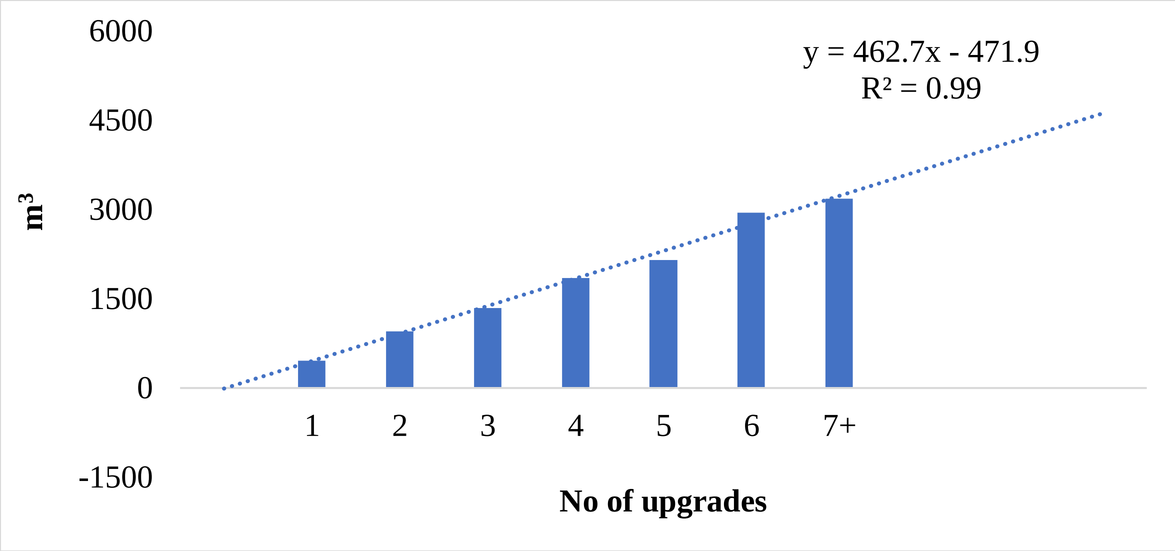

Figure 8. Average of total energy saving from gas consumption in m^3 for different numbers of upgrades in zone 6

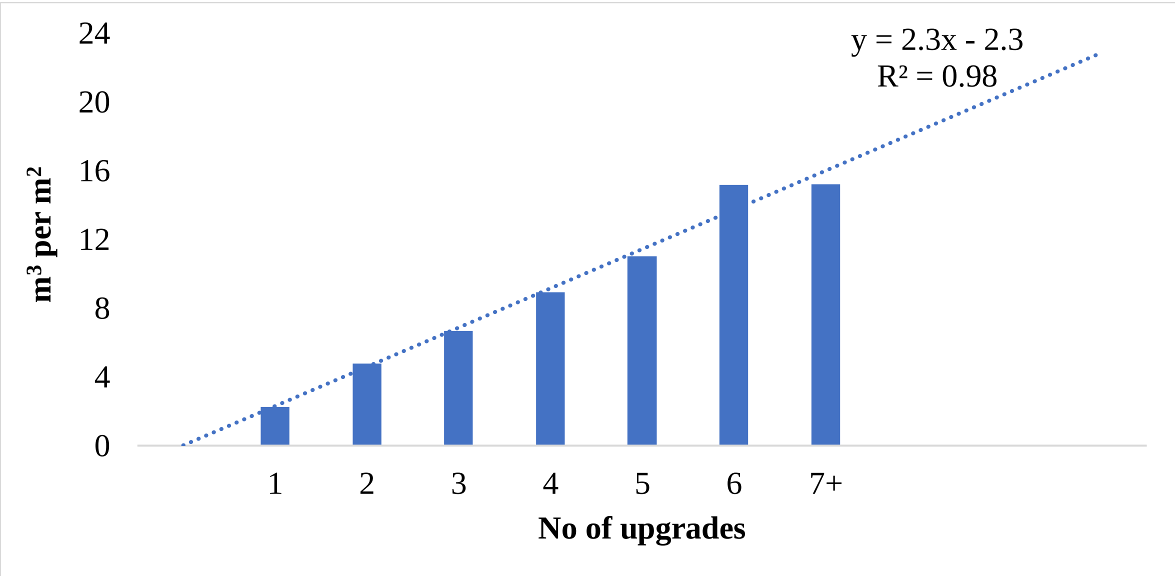

Figure 9. Average of total energy saving from gas consumption in m^3 per m^2 for different numbers of upgrades in zone 6

4.3 GHG Emissions Reduction in Different Climatic Zones

The average total GHG reduction from electricity and natural gas usage was plotted against the number of upgrades to identify the trend. Graphs for climatic zone 6 were presented here and graphs for other zones were given in Appendix. Like energy saving, GHG reduction is also positively and strongly correlated with the number of upgrades. In a word, if the number of upgrades increases, total GHG reduction will also increase. Notably, GHG reduction from electricity usage is negligible compared to reduction from natural gas usage. Because of more electrification after upgrades, increase the electricity consumption. So, GHG reduction from electricity saving is either very small or negative. However, GHG reduction from natural gas saving is substantial in every climatic zone (Figure 10 and Figure 11).

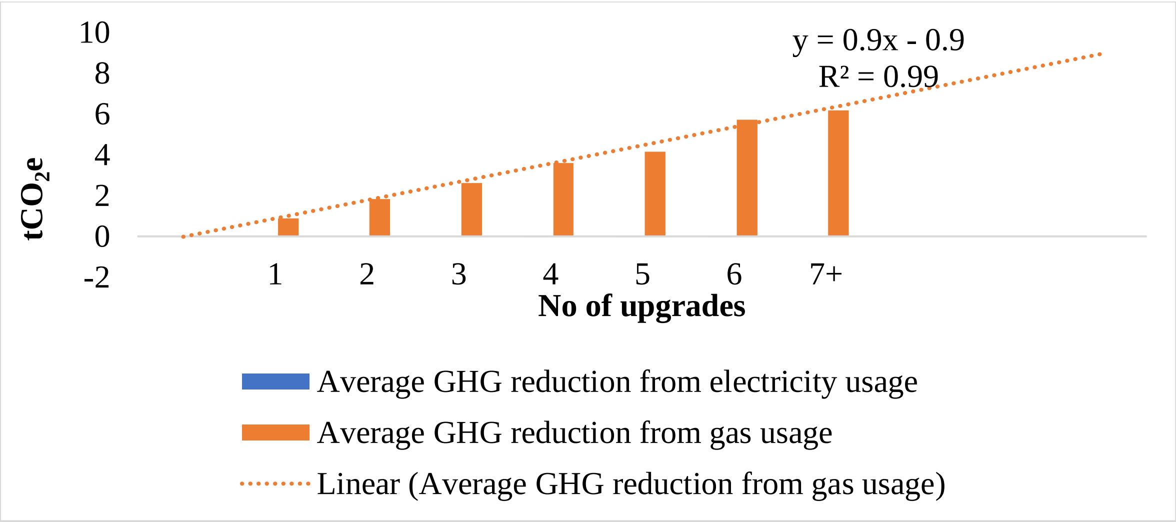

Figure 10. Average GHG emission reduction from electricity and gas usage in tCO_2e in zone 6

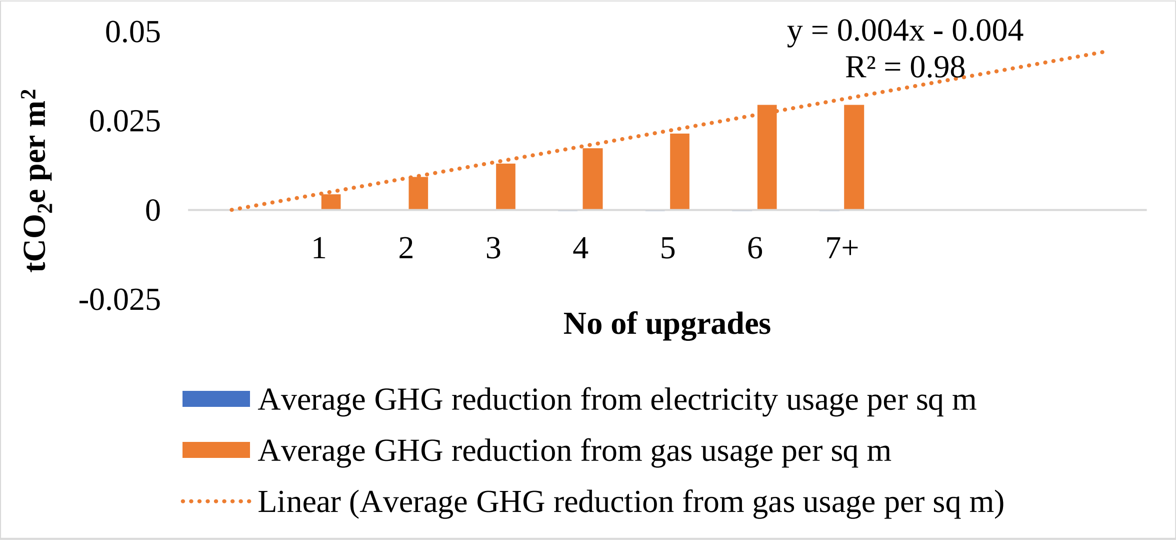

Figure 11. Average GHG emission reduction from electricity and gas usage in tCO_2e per m^2 in zone 6

4.4 Correlation between different retrofit types and energy-saving potential

Total energy saving and energy saving from electricity and natural gas usage were normalized based on HDD and CDD (provided in Table 6) and converted for BC and Pemberton scenarios. The relationships between different retrofit types and average energy saving were identified after combining all the HDD and CDD corrected values from all the zones. Average energy saving potentials for different types of retrofits and combinations of retrofits are given in Table 11. Interestingly, energy saving from electricity usage values are negative while doing air sealing and installing heat pumps together as heat pumps will increase electricity use more than before.

Table 11. Average energy saving potentials for different types of retrofits for BC and Pemberton

Retrofit types	For BC			For Pemberton			For BC			For Pemberton		
	Average energy saving potential from electricity usage	Average energy saving potential from natural gas usage	Average of total energy saving potential	Average energy saving potential from electricity usage	Average energy saving potential from natural gas usage	Average of total energy saving potential	Average energy saving potential from electricity usage	Average energy saving potential from natural gas usage	Average of total energy saving potential	Average energy saving potential from electricity usage	Average energy saving potential from natural gas usage	Average of total energy saving potential
	HDD Corrected						CDD Corrected					
Air Sealing	4.27	1.49	71.99	7.29	2.54	122.77	13.64	2.93	163.79	1.41	0.30	16.87
Attic Insulation	1.22	0.62	27.67	2.07	1.05	47.19	2.81	2.06	90.70	0.29	0.21	9.34
Foundation Insulation	4.75	1.37	75.69	8.10	2.34	129.08	12.31	4.60	241.06	1.27	0.47	24.83
Wall Insulation	2.36	1.36	59.89	4.03	2.32	102.13	13.07	8.23	359.40	1.35	0.85	37.02

Retrofit types	For BC			For Pemberton			For BC			For Pemberton		
	Average energy saving potential from electricity usage	Average energy saving potential from natural gas usage	Average of total energy saving potential	Average energy saving potential from electricity usage	Average energy saving potential from natural gas usage	Average of total energy saving potential	Average energy saving potential from electricity usage	Average energy saving potential from natural gas usage	Average of total energy saving potential	Average energy saving potential from electricity usage	Average energy saving potential from natural gas usage	Average of total energy saving potential
	HDD Corrected						CDD Corrected					
NG Furnace	0.44	3.37	132.39	0.76	5.75	225.76	1.41	10.68	432.56	0.15	1.10	44.55
Air Sealing + Attic Insulation	3.97	1.95	87.39	6.77	3.32	149.03	9.34	4.56	207.16	0.96	0.47	21.34
Air Sealing +Foundation Insulation	8.05	2.33	120.98	13.72	3.98	206.31	22.59	7.43	382.17	2.33	0.76	39.36
Air Sealing + Wall Insulation	3.75	2.45	116.72	6.40	4.19	199.04	19.28	10.28	534.37	1.99	1.06	55.04
Air Sealing + NG Furnace	0.43	4.29	168.02	0.74	7.32	286.53	1.10	11.84	471.60	0.11	1.22	48.57
Air Sealing +Domestic Hot Water	3.68	0.98	49.59	6.28	1.66	84.57	4.42	2.37	104.05	0.46	0.24	10.72
Air Sealing + Heat Pump	-2.07	2.40	135.18	-3.52	4.10	230.52	-8.29	10.37	703.29	-0.85	1.07	72.44

* Units: total energy saving = MJ per sq m, energy saving from electricity usage = kWh per sq m, and energy saving from natural gas usage = m^3 per sq m.

4.5 Correlation between different retrofit types and GHG reduction potential

GHG reductions from electricity and natural gas usage were also normalized based on HDD and CDD (provided in Table 6) and converted for BC and Pemberton scenarios. The relationships between different retrofit types and average GHG reduction potential were identified after combining all the HDD and CDD corrected values from all the zones. Average GHG reduction potentials for different types of retrofits and combinations of retrofits are given in Table 12. GHG reduction from natural gas savings is significant compared to GHG reduction from electricity savings. Interestingly, GHG reductions from electricity usage values are also negative while doing air sealing and installing heat pumps together as heat pumps will increase electricity use more than before.

Table 12. Average GHG reduction potentials for different types of retrofits for BC and Pemberton

	For BC		For Pemberton		For BC		For Pemberton	
Retrofit types	Average GHG reduction potential from electricity saving	Average GHG reduction potential from natural gas saving	Average GHG reduction potential from electricity saving	Average GHG reduction potential from natural gas saving	Average GHG reduction potential from electricity saving	Average GHG reduction potential from natural gas saving	Average GHG reduction potential from electricity saving	Average GHG reduction potential from natural gas saving
	HDD Corrected				CDD Corrected			
Air Sealing	4.83E-02	2.88	8.24E-02	4.92	1.54E-01	5.68	1.59E-02	0.58
Attic Insulation	1.46E-03	0.13	2.49E-03	0.22	3.38E-03	0.43	3.48E-04	0.04
Foundation Insulation	8.35E-04	0.04	1.42E-03	0.07	2.17E-03	0.14	2.23E-04	0.01
Wall Insulation	4.15E-04	0.04	7.08E-04	0.07	2.30E-03	0.25	2.37E-04	0.03
NG Furnace	2.10E-03	2.73	3.57E-03	4.65	6.64E-03	8.63	6.84E-04	0.89

Retrofit types	For BC		For Pemberton		For BC		For Pemberton	
	Average GHG reduction potential from electricity saving	Average GHG reduction potential from natural gas saving	Average GHG reduction potential from electricity saving	Average GHG reduction potential from natural gas saving	Average GHG reduction potential from electricity saving	Average GHG reduction potential from natural gas saving	Average GHG reduction potential from electricity saving	Average GHG reduction potential from natural gas saving
	HDD Corrected				CDD Corrected			
Air Sealing + Attic Insulation	2.13E-02	1.79	3.64E-02	3.06	5.03E-02	4.20	5.18E-03	0.43
Air Sealing + Foundation Insulation	1.11E-02	0.55	1.89E-02	0.94	3.11E-02	1.75	3.21E-03	0.18
Air Sealing + Wall Insulation	4.27E-03	0.48	7.28E-03	0.82	2.19E-02	2.00	2.26E-03	0.21
Air Sealing + NG Furnace	1.13E-02	19.19	1.93E-02	32.73	2.87E-02	52.88	2.96E-03	5.45
Air Sealing + Domestic Hot Water	1.21E-03	0.05	2.06E-03	0.09	1.45E-03	0.13	1.50E-04	0.01
Air Sealing + Heat Pump	-2.18E-04	0.04	-3.72E-04	0.07	-8.75E-04	0.19	-9.02E-05	0.02

* Units: GHG reduction from electricity saving = kgCO_2e per sq m and GHG reduction from natural gas saving = kgCO_2e per sq m.

4.6 GHG Reduction Scenarios for BC and Pemberton to Achieve 2030 Targets

After calculating the total GHG reduction potentials from electricity and natural gas usage, the numbers of houses needed to be retrofitted in total with different types of upgrades and/or combinations of upgrades were calculated considering the 2030 emissions reduction targets of BC and Pemberton (Table 13). The numbers of houses indicate the number of houses needed to perform a single retrofit or a combination of retrofits. For example, 674 houses in Pemberton need to perform air sealing to achieve the 2030 GHG reduction target, or 426 houses in Pemberton need to perform air sealing and install heat pumps to achieve the same target. According to the 2021 census, Pemberton only has 1,355 houses. So only attic insulation cannot achieve the target as 1,633 houses need to perform attic insulation to achieve the 2030 GHG reduction target. Notably, the CDD corrected values show higher number of houses for all types of retrofits.

Table 13. The number of houses needed to be retrofitted to achieve 2030 emissions reduction targets of BC and Pemberton

Retrofit types	**Total GHG reduction potential for BC (HDD Corrected)**	**Total GHG reduction potential for Pemberton (HDD Corrected)**	**Total GHG reduction potential for BC (CDD Corrected)**	**Total GHG reduction potential for Pemberton (CDD Corrected)**	**No of houses in BC (HDD corrected)**	**No of houses in BC (CDD corrected)**	**No of houses in Pemberton (HDD corrected)**	**No of houses in Pemberton (CDD corrected)**
Air Sealing	2.93	5.00	5.83	0.601	7.97E+06	4.01E+06	674	5606
Attic Insulation	1.21	2.06	4.03	0.415	1.93E+07	5.80E+06	1633	8114
Foundation Insulation	2.71	4.62	9.05	0.932	8.63E+06	2.58E+06	730	3615
Wall Insulation	2.67	4.55	16.1	1.66	8.76E+06	1.45E+06	741	2032
NG Furnace	6.54	11.1	20.7	2.13	3.58E+06	1.13E+06	302	1580

Retrofit types	Total GHG reduction potential for BC (HDD Corrected)	Total GHG reduction potential for Pemberton (HDD Corrected)	Total GHG reduction potential for BC (CDD Corrected)	Total GHG reduction potential for Pemberton (CDD Corrected)	No of houses in BC (HDD corrected)	No of houses in BC (CDD corrected)	No of houses in Pemberton (HDD corrected)	No of houses in Pemberton (CDD corrected)
Air Sealing + Attic Insulation	3.81	6.50	8.93	0.92	6.13E+06	2.62E+06	518	3661
Air Sealing + Foundation Insulation	4.61	7.87	14.6	1.51	5.07E+06	1.60E+06	428	2234
Air Sealing + Wall Insulation	4.80	8.18	20.1	2.07	4.87E+06	1.16E+06	412	1625
Air Sealing + Furnace	8.32	14.2	22.9	2.36	2.81E+06	1.02E+06	237	1426
Air Sealing + Domestic Hot Water	1.93	3.29	4.63	0.477	1.21E+07	5.04E+06	1023	7059
Air Sealing + Heat Pump	4.63	7.90	20.0	2.06	5.05E+06	1.17E+06	426	1636

* Units: Total GHG reduction potential = kgCO_2e per sq m.

5. Conclusion

The Community Energy Association (CEA) is working to support BC communities in aligning with the IPCC 1.5°C climate targets by focusing on key areas of emissions reduction: buildings, transportation, and solid waste. Specifically, the initiative aims to tackle the significant challenge of retrofitting existing homes to meet CleanBC and Federal Green Building standards. This research analyzes EnerGuide data from Natural Resources Canada (NRCan) to explore how various retrofit types affect energy consumption and GHG emissions reductions, to help municipalities develop more effective residential retrofit programs.

The analysis focuses on homes in four distinct climatic zones across BC, including areas like North Vancouver (zone 4) and Kelowna (zone 5). It examines the impact of 11 different retrofit types, including insulation upgrades, air sealing, and heat pump installations, on energy use (electricity and natural gas) and subsequent GHG emissions. The study looked at data from homes that had undergone energy evaluations, comparing consumption levels before and after retrofits to calculate energy savings and GHG reductions.

A key finding was that homes with more retrofit types (e.g., combining air sealing, insulation, and furnace replacements) showed the greatest reductions in natural gas consumption and GHG emissions. However, homes that moved toward electrification, such as by installing heat pumps, saw an increase in electricity consumption.

This study also calculated normalized energy savings and GHG reduction values for different climatic zones by adjusting for Heating Degree Days (HDD) and Cooling Degree Days (CDD). This provided a clearer picture of retrofit effectiveness across varied climate conditions. For instance, in colder regions like Pemberton, significant retrofitting efforts, such as air sealing or heat pump installation, would be needed to meet 2030 GHG reduction targets. The study estimated the number of homes needing upgrades to achieve these goals - such as retrofitting 674 homes with air sealing or 426 homes with air sealing and heat pump installation together to meet the 2030 targets in Pemberton.

This analysis provides critical insights for policymakers and planners, enabling them to prioritize specific retrofit strategies based on their potential for energy savings and GHG reductions, ultimately helping communities in BC transition toward a more sustainable, low-emission future by 2030 and 2050.

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Appendix

Energy Saving in Climatic Zones 4, 5, 7 and 8

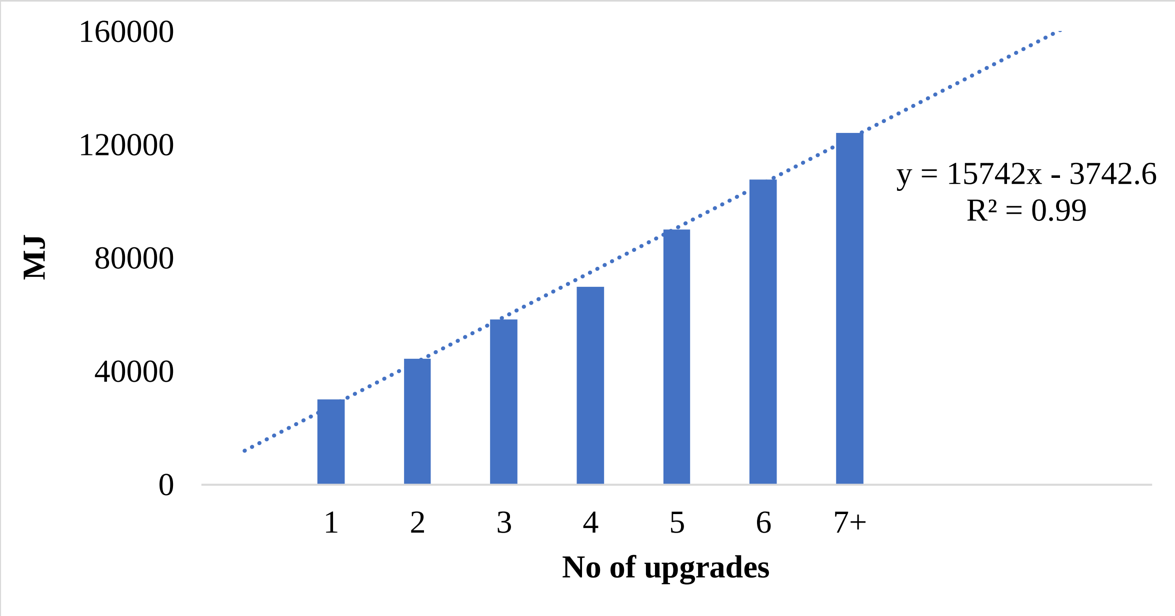

Figure A12. Average of total energy saving in MJ for different numbers of upgrades in zone 4 (North Vancouver)

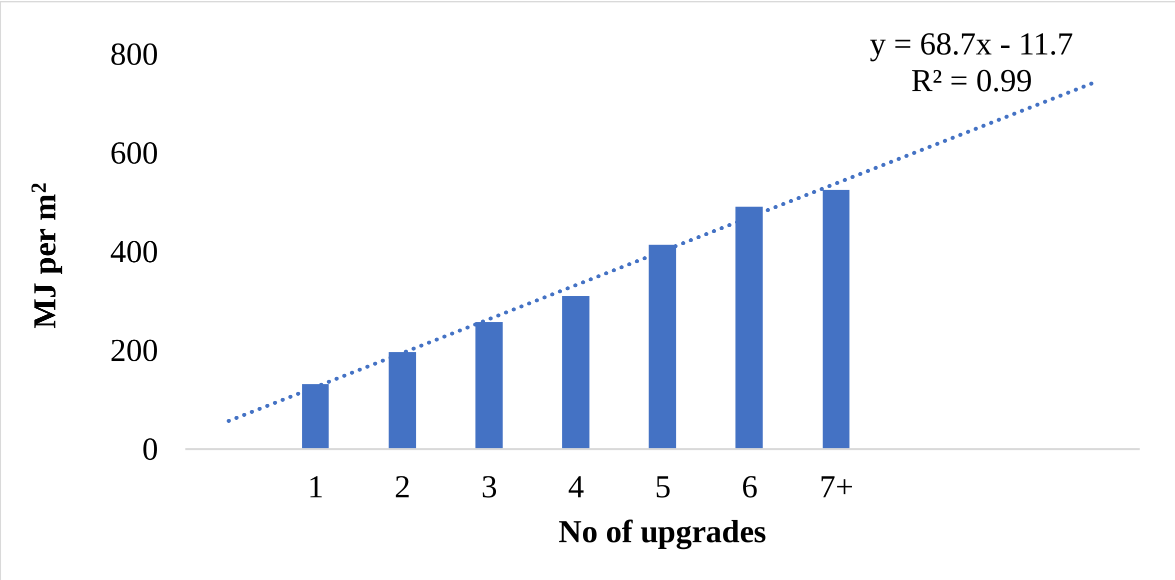

Figure A13. Average of total energy saving in MJ per m2 for different numbers of upgrades in zone 4 (North Vancouver)

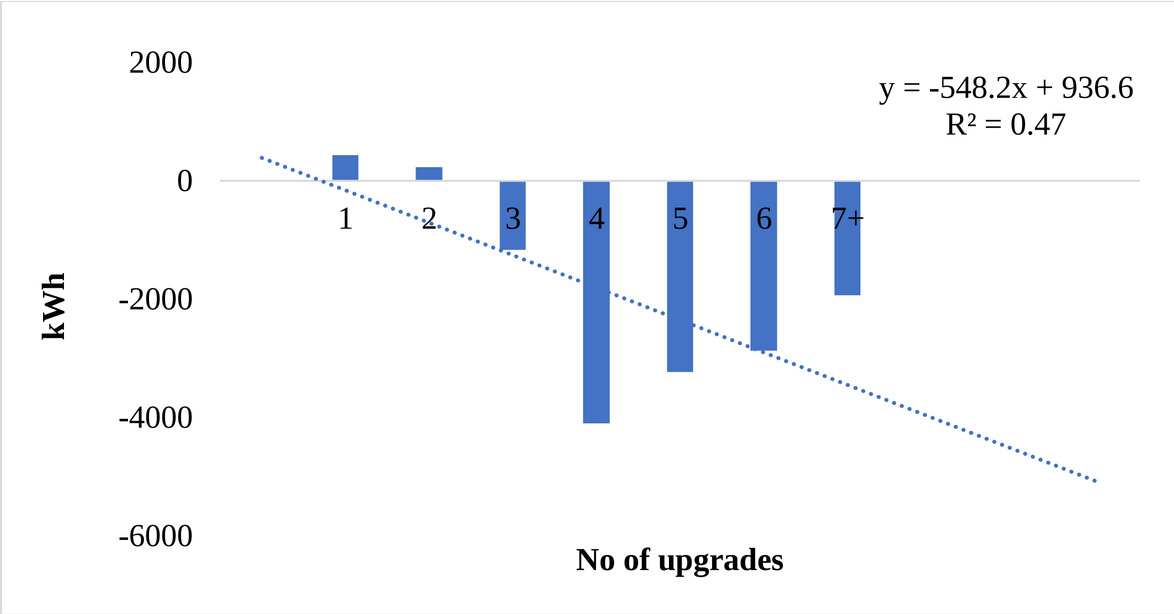

Figure A14. Average of total energy saving from electricity consumption in kWh for different numbers of upgrades in zone 4 (North Vancouver)

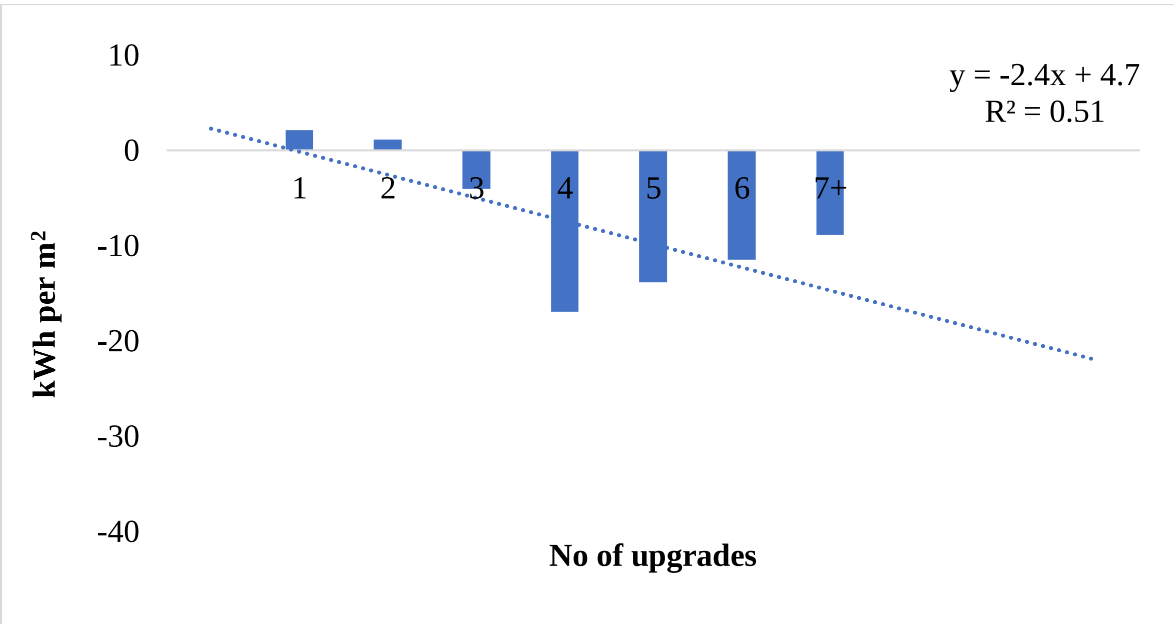

Figure A15. Average of total energy saving from electricity consumption in kWh per m2 for different numbers of upgrades in zone 4 (North Vancouver)

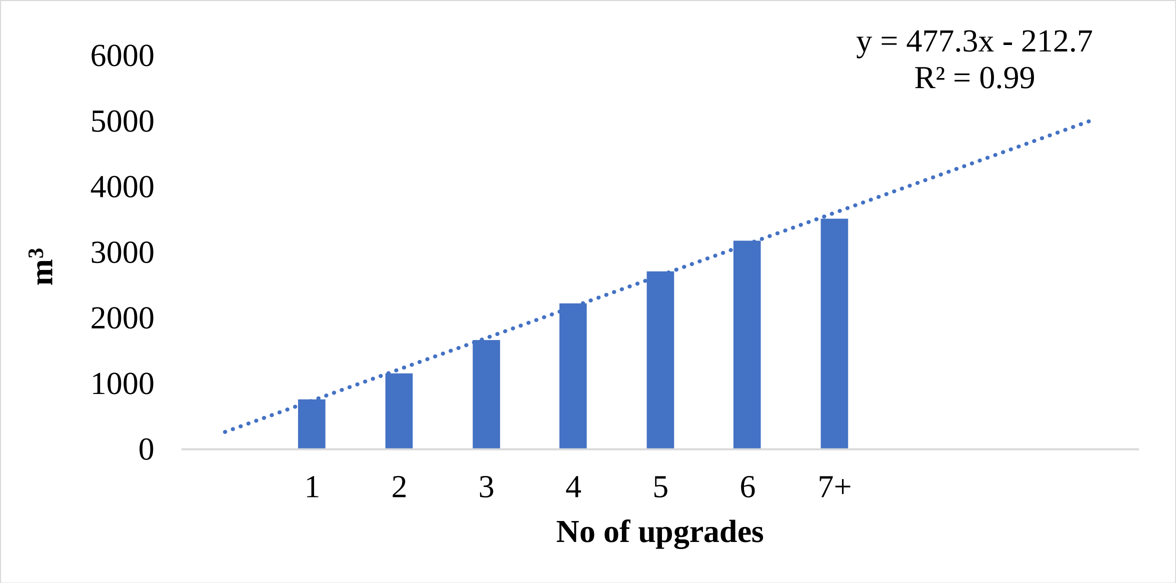

Figure A16. Average of total energy saving from gas consumption in m3 for different numbers of upgrades in zone 4 (North Vancouver)

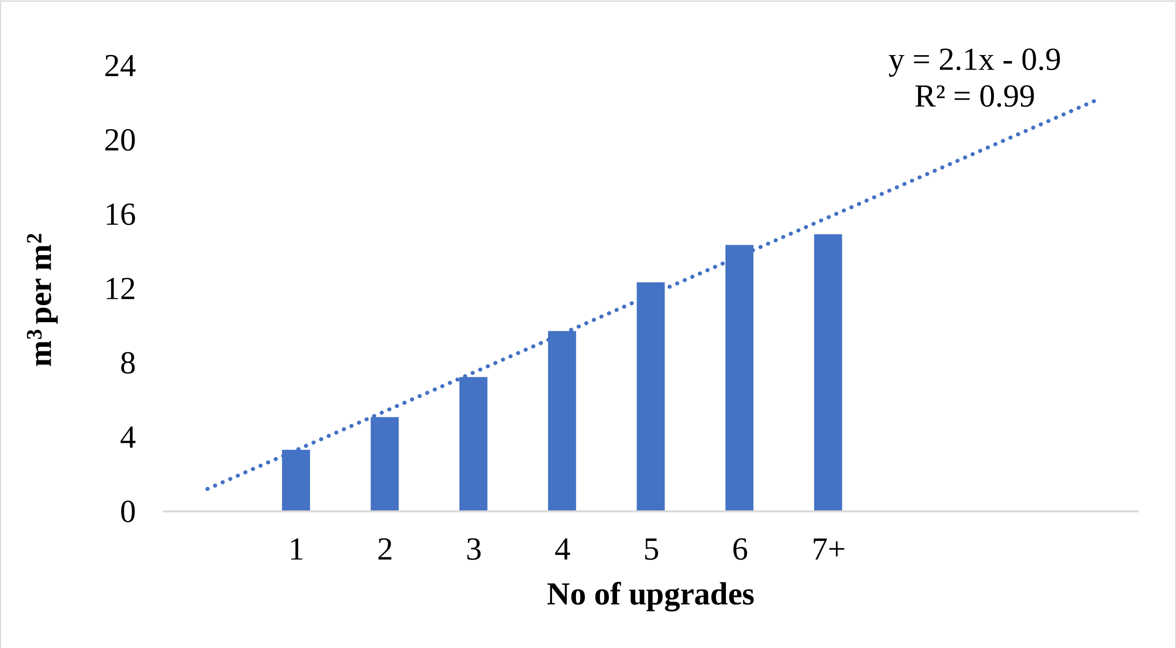

Figure A17. Average of total energy saving from gas consumption in m3 per m2 for different numbers of upgrades in zone 4 (North Vancouver)

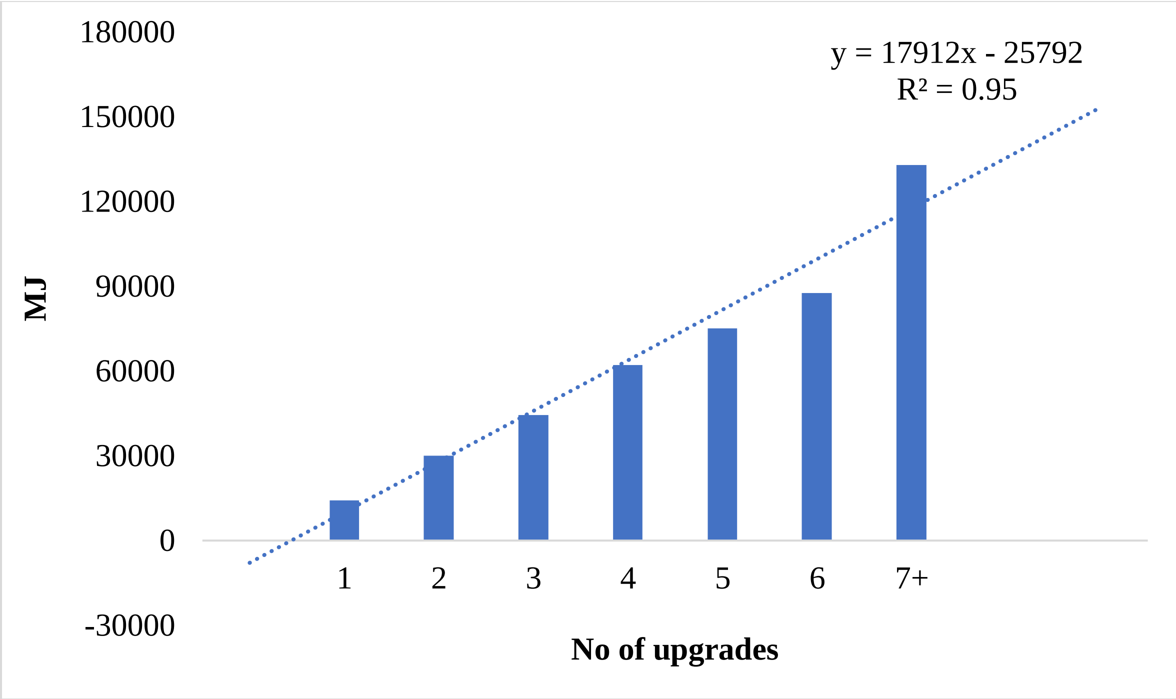

Figure A18. Average of total energy saving in MJ for different numbers of upgrades in zone 5 (Kelowna)

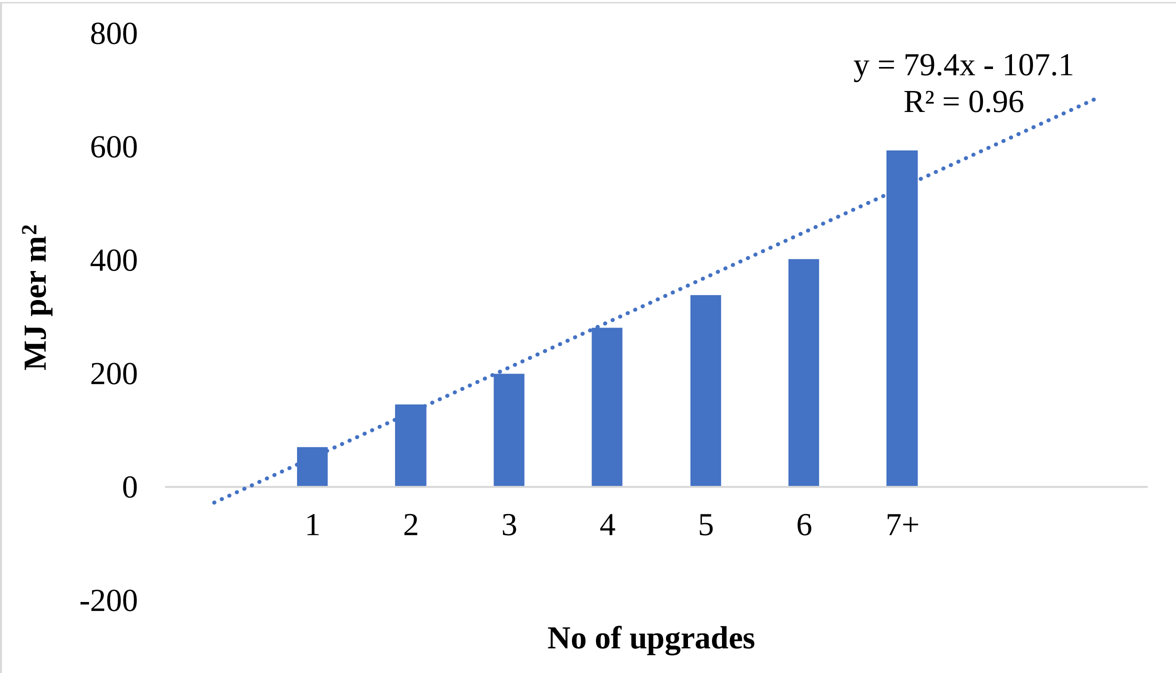

Figure A19. Average of total energy saving in MJ per m2 for different numbers of upgrades in zone 5 (Kelowna)

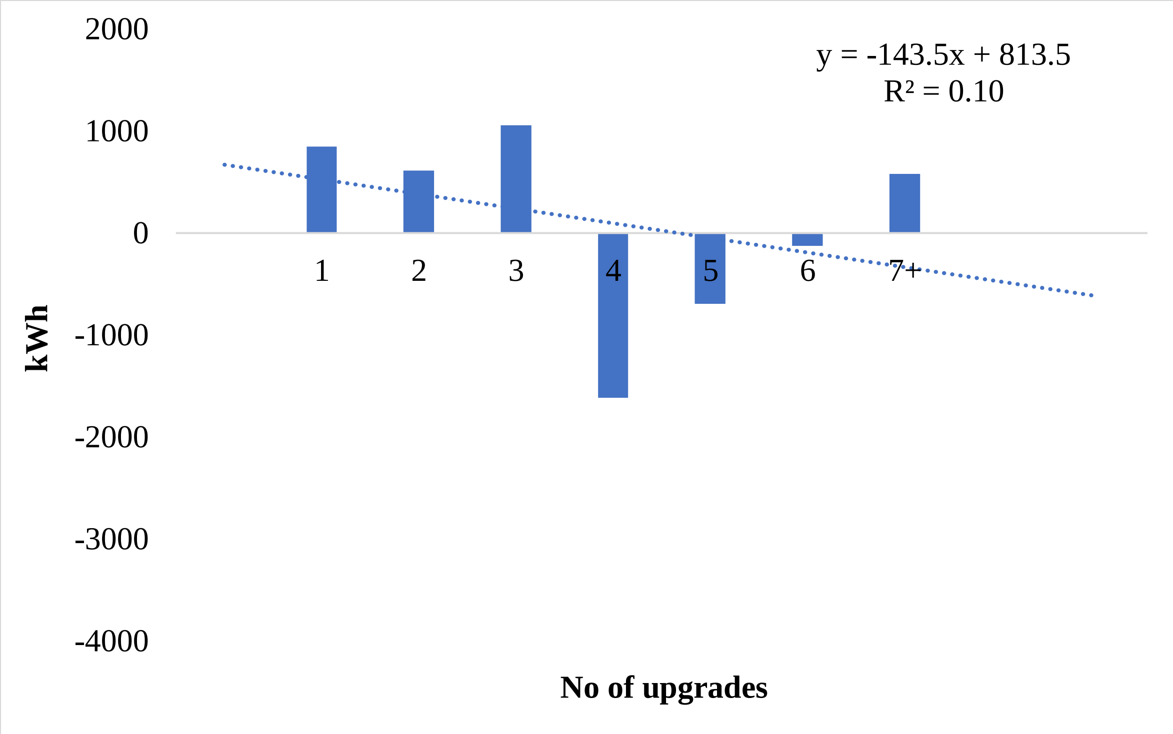

Figure A20. Average of total energy saving from electricity consumption in kWh for different numbers of upgrades in zone 5 (Kelowna)

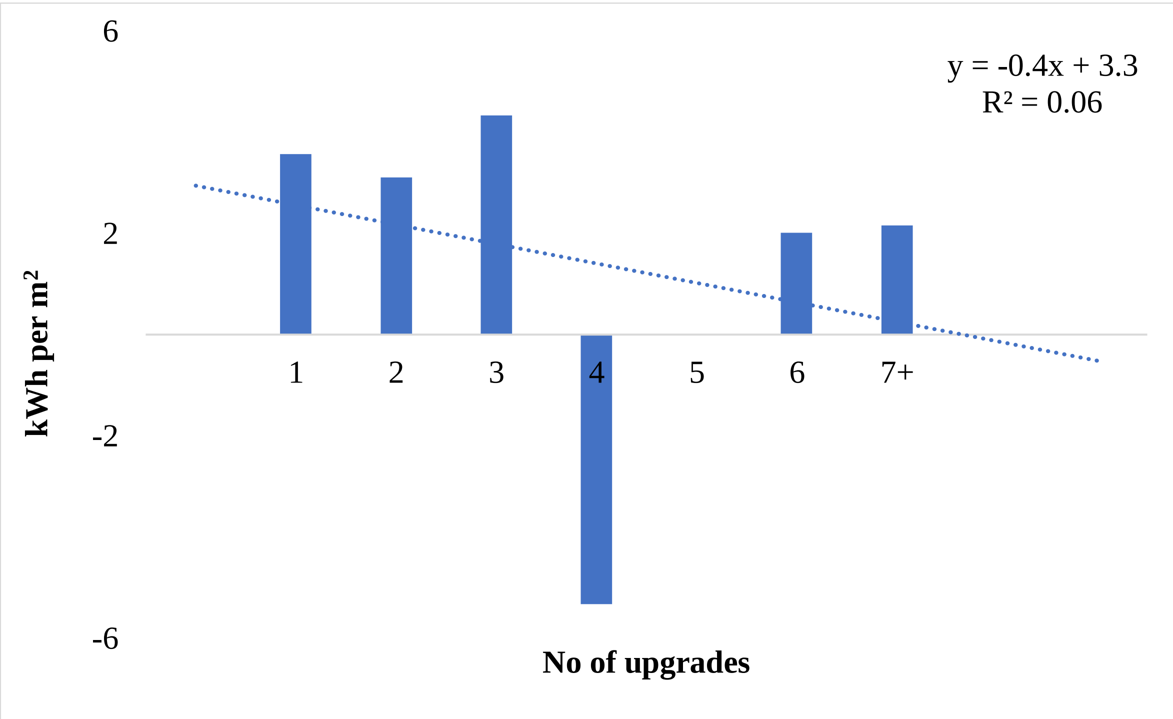

Figure A21. Average of total energy saving from electricity consumption in kWh per m^2 *for different numbers of upgrades in zone 5 (Kelowna)*

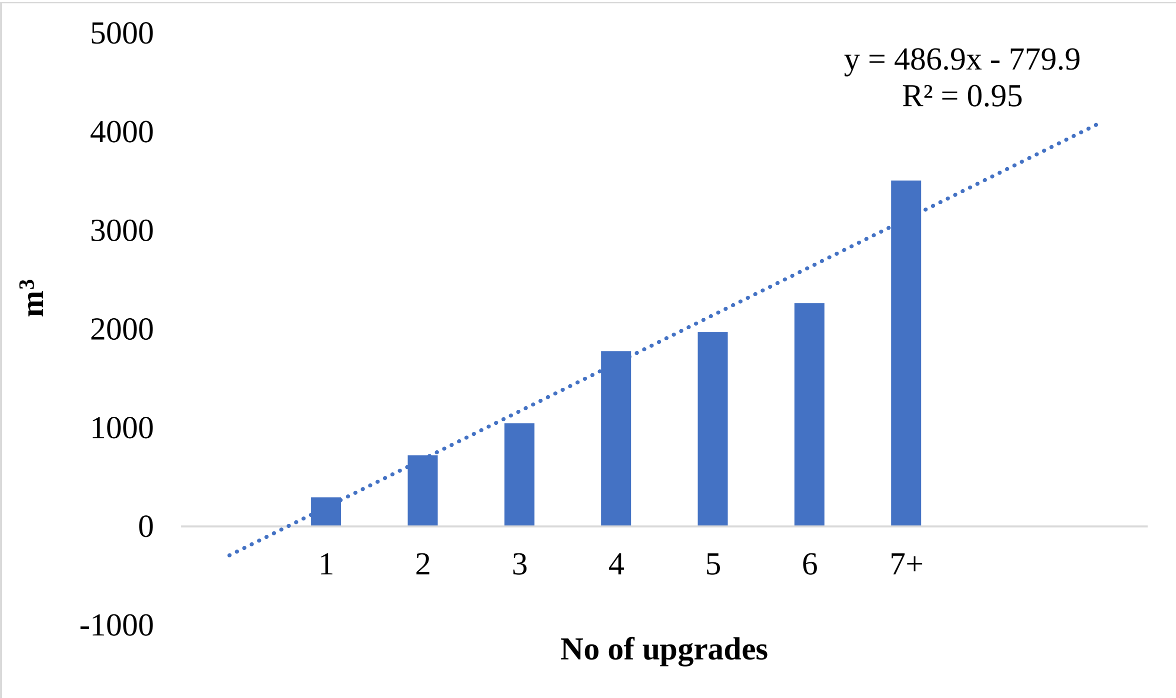

Figure A22. Average of total energy saving from gas consumption in m^3 for different numbers of upgrades in zone 5 (Kelowna)

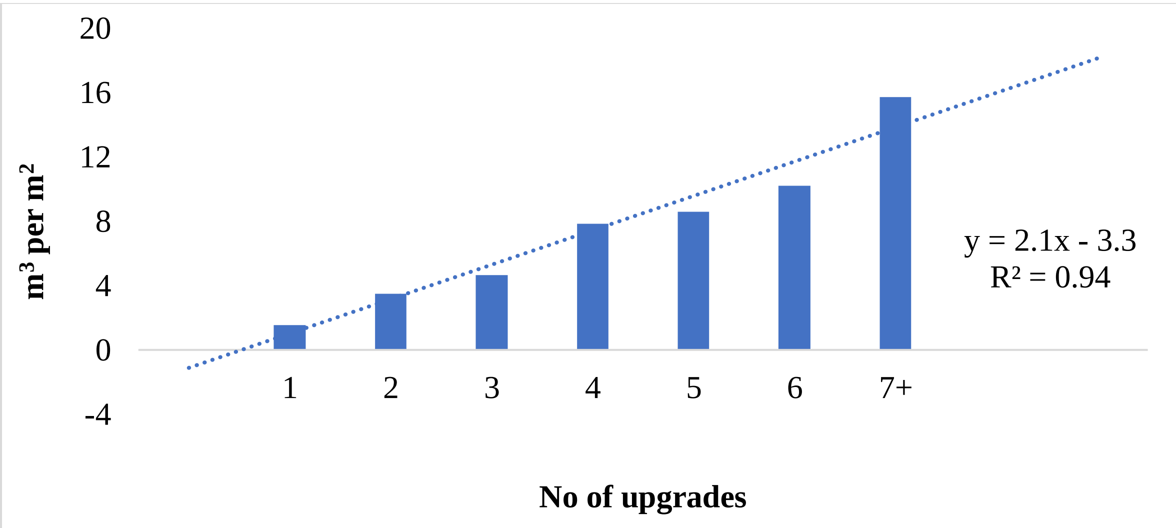

Figure A23. Average of total energy saving from gas consumption in m^3 per m^2 for different numbers of upgrades in zone 5 (Kelowna)

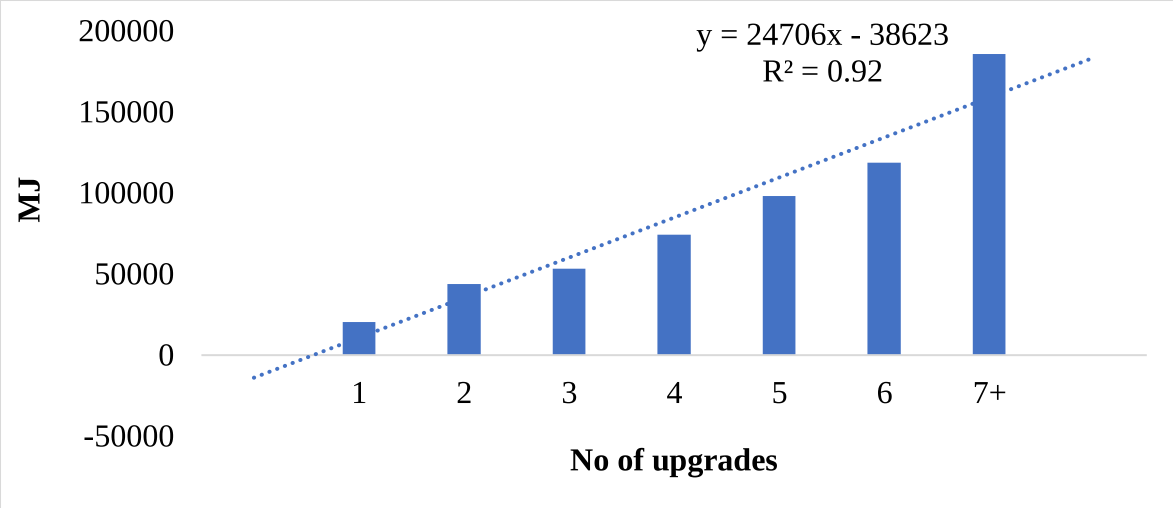

Figure A24. Average of total energy saving in MJ for different numbers of upgrades in zones 7 and 8

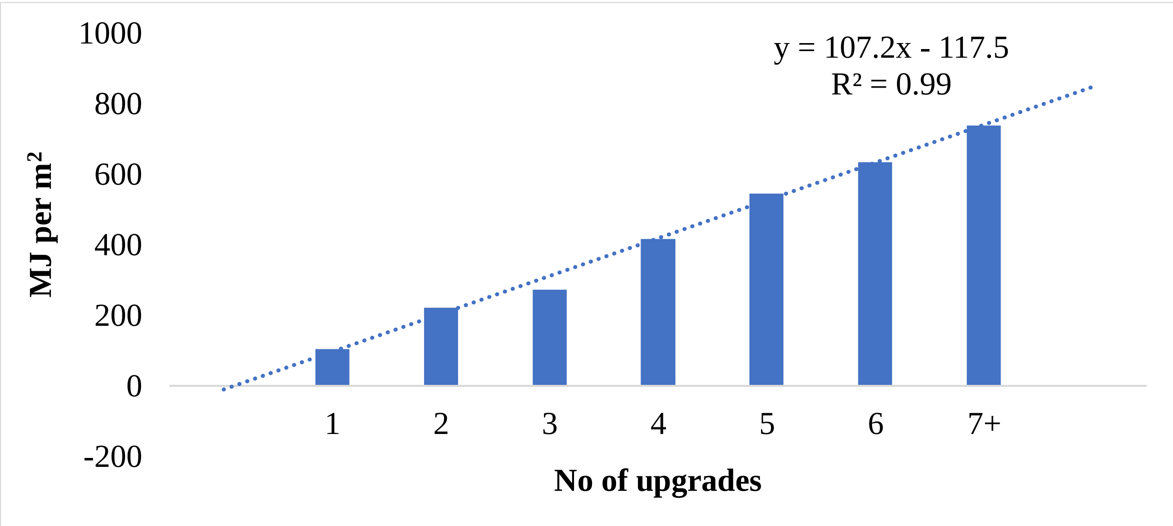

Figure A25. Average of total energy saving in MJ per m^2 for different numbers of upgrades in zones 7 and 8

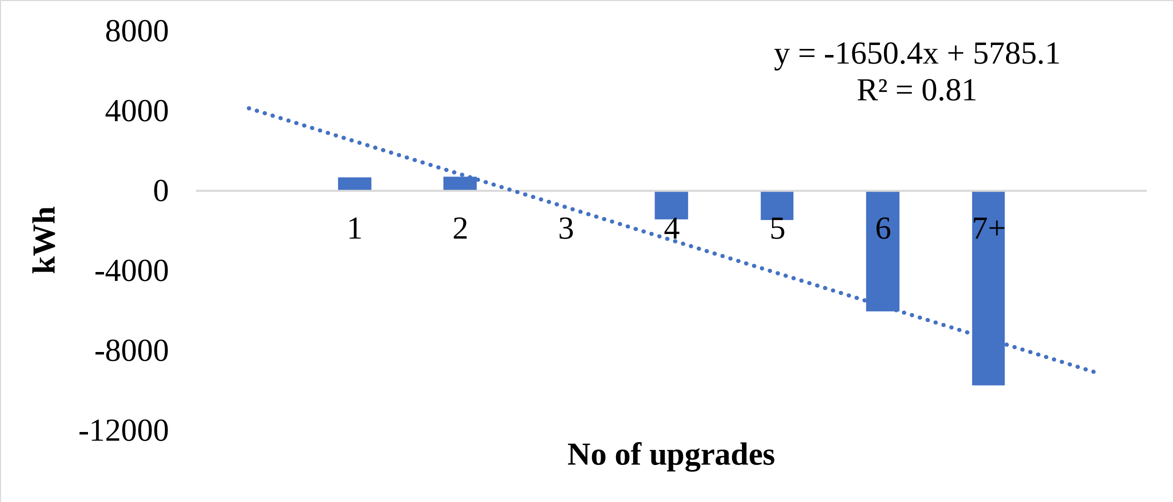

Figure A26. Average of total energy saving from electricity consumption in kWh for different numbers of upgrades in zones 7 and 8

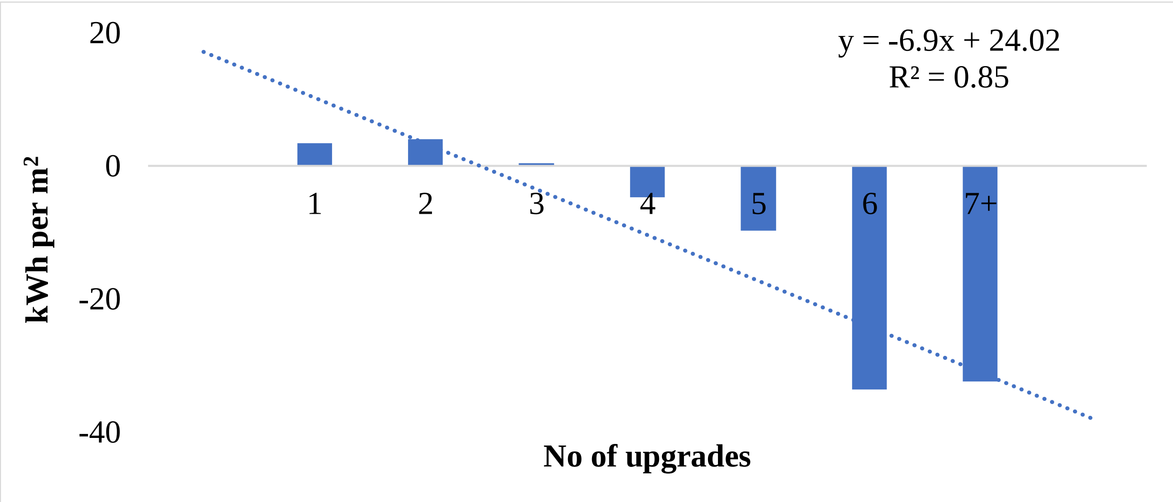

Figure A27. Average of total energy saving from electricity consumption in kWh per m^2 for different numbers of upgrades in zones 7 and 8

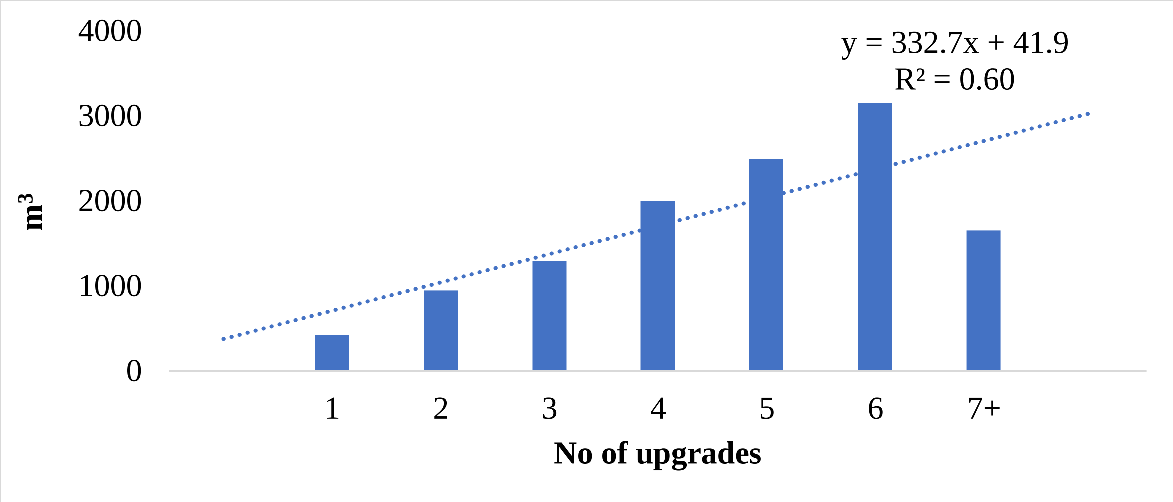

Figure A28. Average of total energy saving from gas consumption in m^3 for different numbers of upgrades in zones 7 and 8

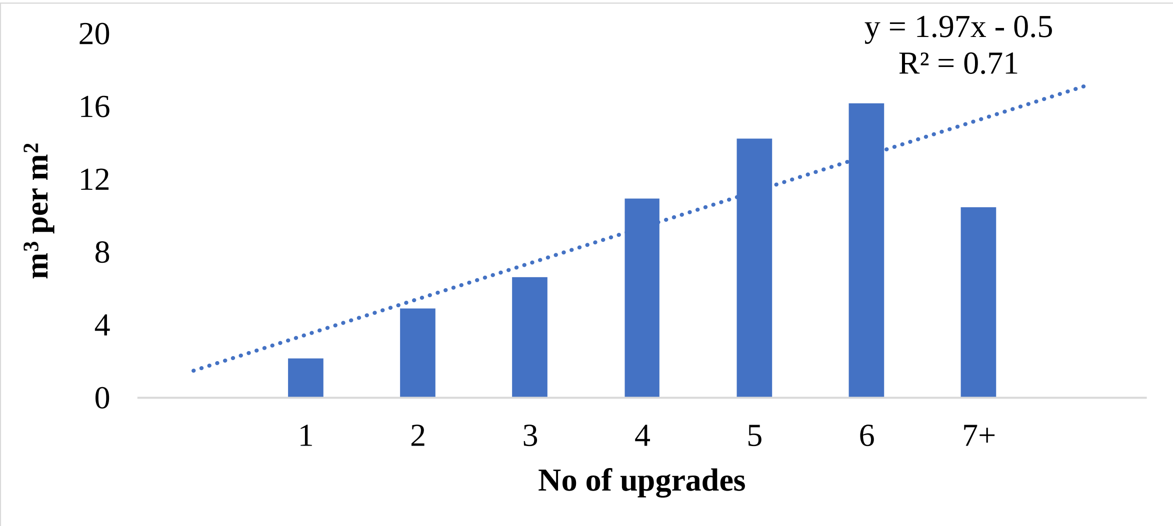

Figure A29. Average of total energy saving from gas consumption in m^3 per m^2 for different numbers of upgrades in zones 7 and 8

GHG Emissions Reduction in Climatic Zones 4, 5, 7 and 8

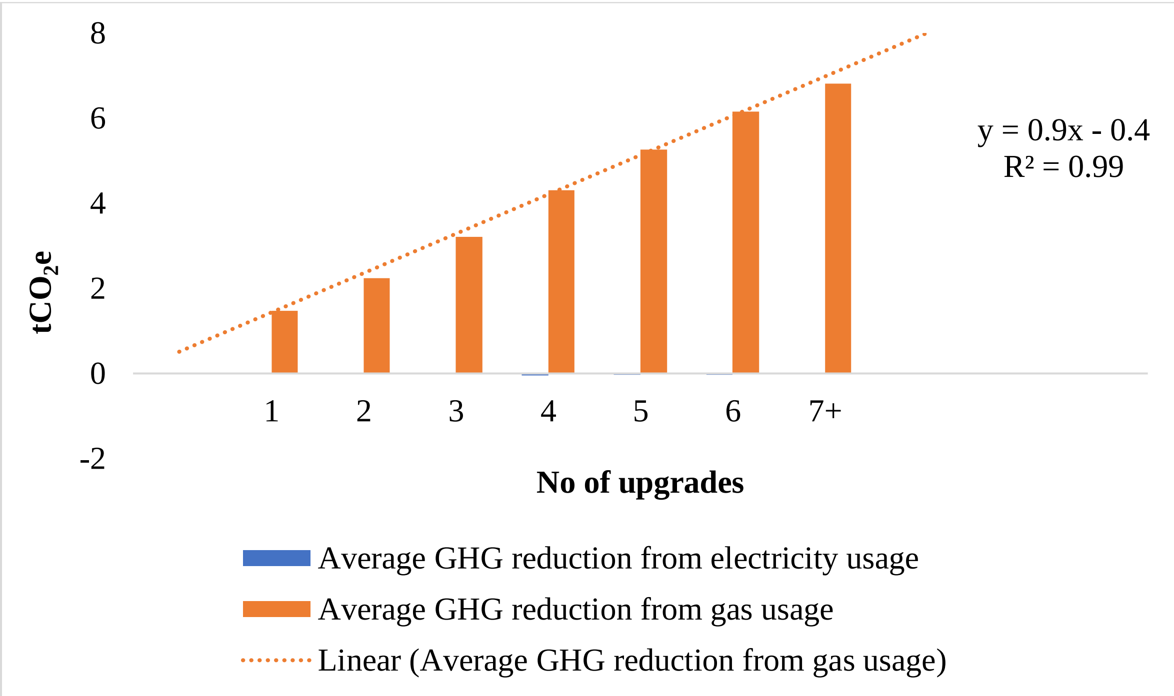

Figure A30. Average GHG emission reduction from electricity and gas usage in tCO_2e in zone 4 (North Vancouver)

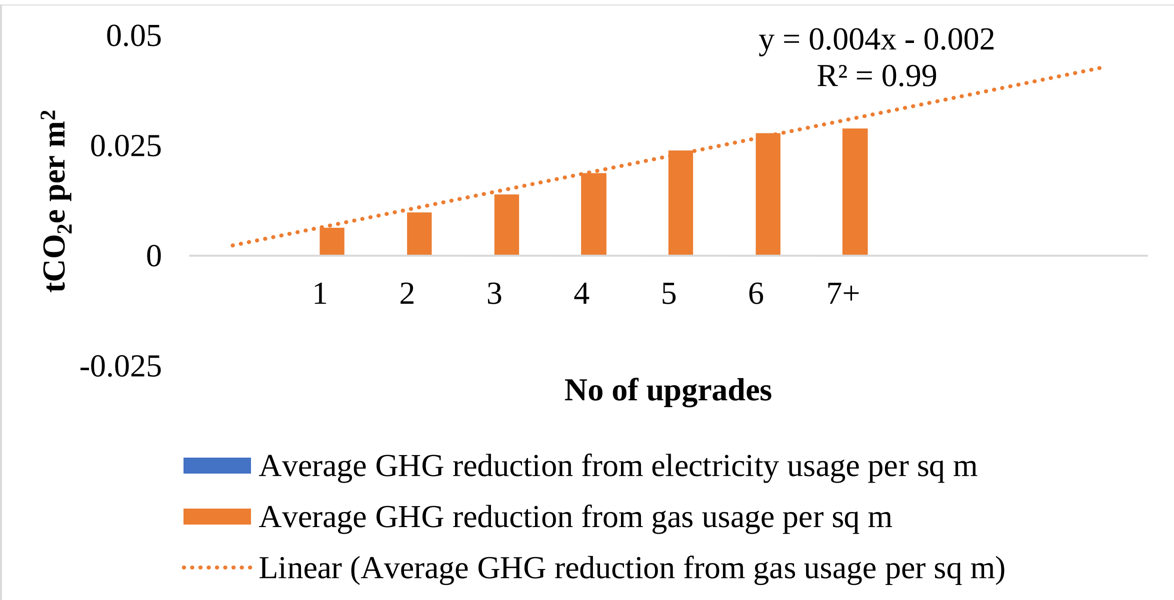

Figure A31. Average GHG emission reduction from electricity and gas usage in tCO_2e per m^2 in zone 4 (North Vancouver)

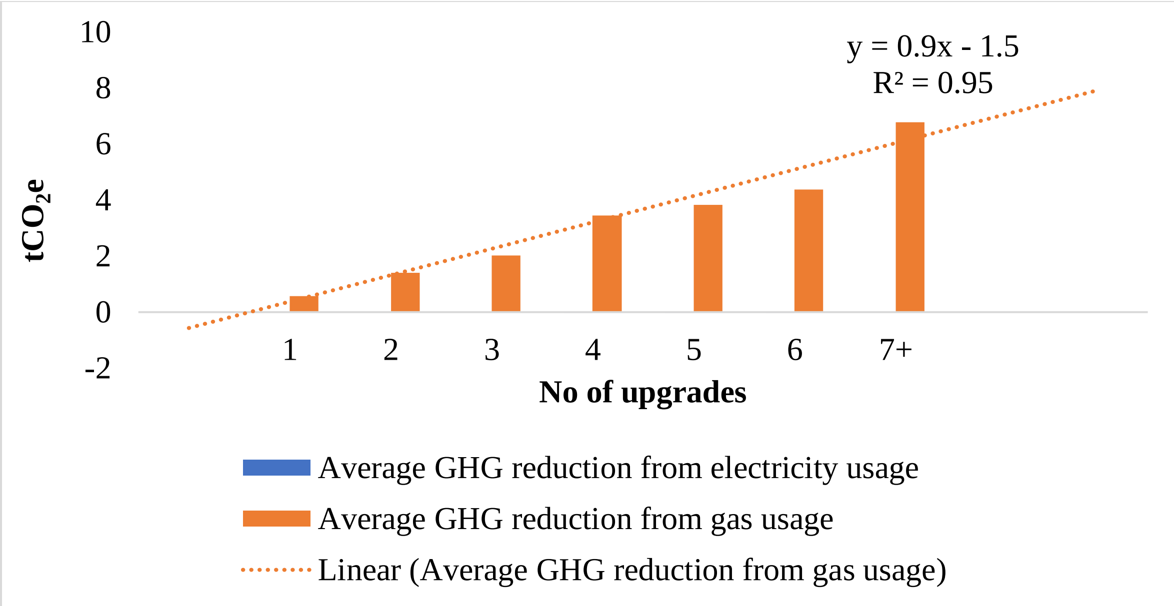

Figure A32. Average GHG emission reduction from electricity and gas usage in tCO_2e in zone 5 (Kelowna)

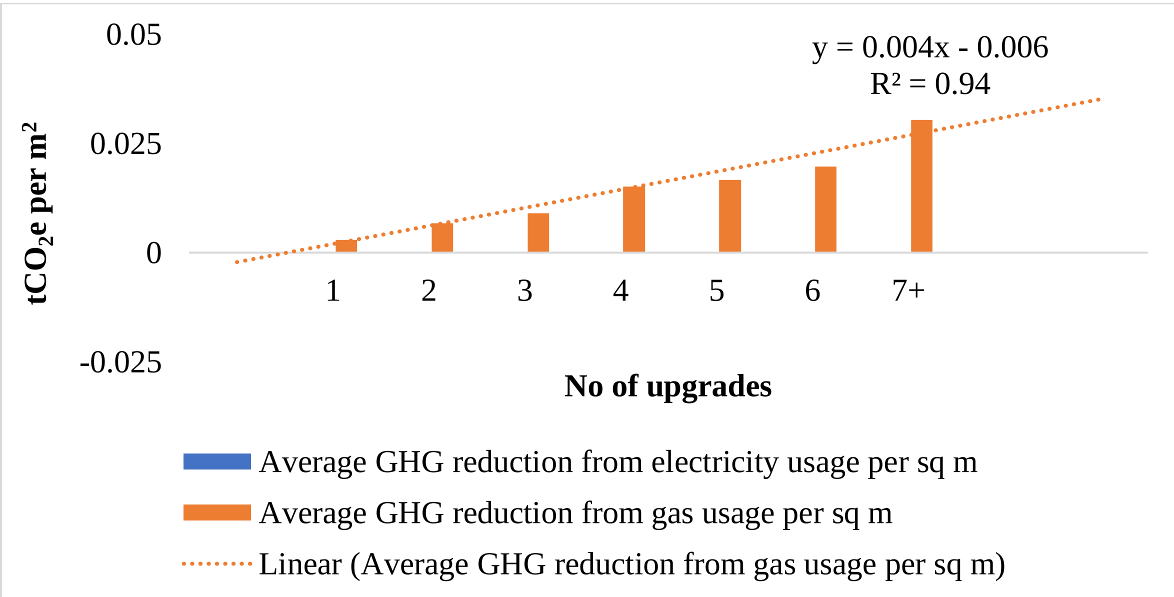

Figure A33. Average GHG emission reduction from electricity and gas usage in tCO_2e per m^2 in zone 5 (Kelowna)

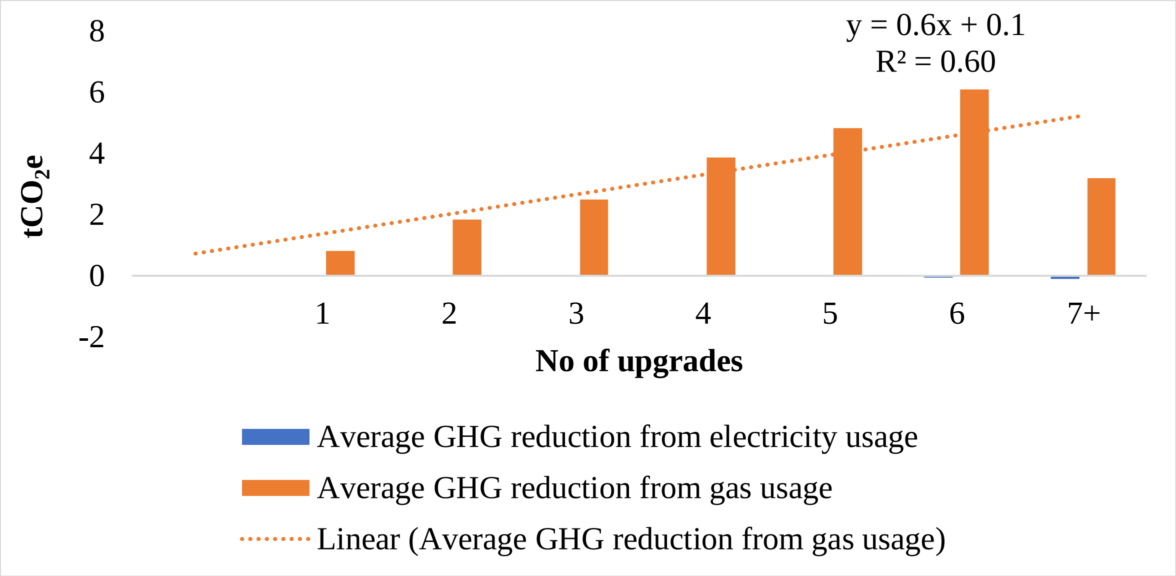

Figure A34. Average GHG emission reduction from electricity and gas usage in tCO_2e in zones 7 and 8

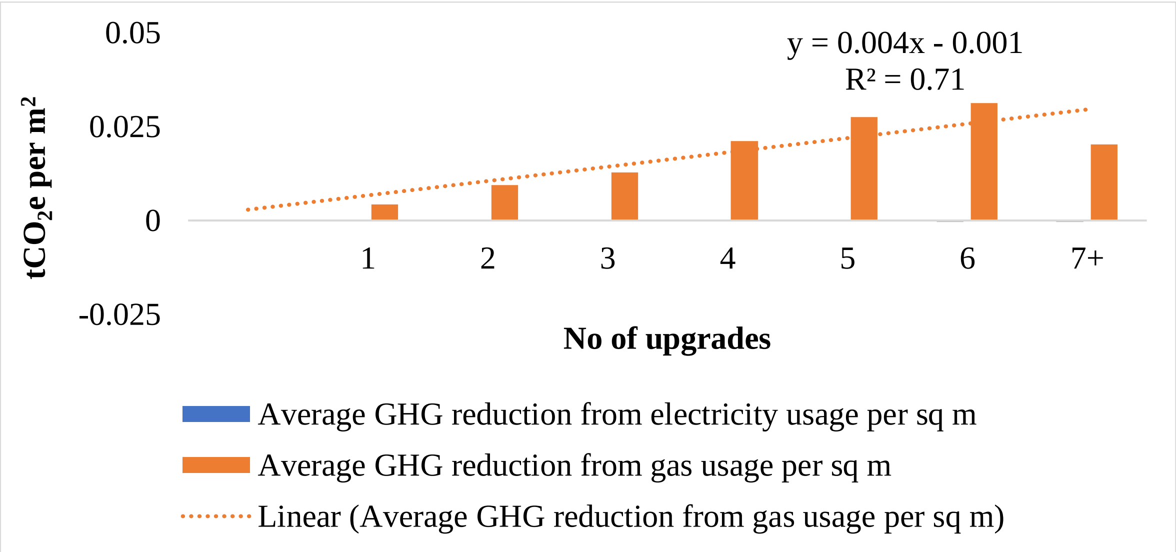

Figure A35. Average GHG emission reduction from electricity and gas usage in tCO_2e per m^2 in zones 7 and 8