developing energy efficient retrofit strategies to achieve greenhouse gas emission reductions in bc social housing

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DISCLAIMER

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This project was conducted under the mentorship of BC Housing Management Commission 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 BC Housing Management Commission or the University of British Columbia.

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content

executive summary

Building retrofit projects are restrained by an existing buildings' structure, organization, equipment, and system design. These parameters limit which retrofit strategies are feasible and cost effective for a retrofit project to achieve significant greenhouse gas (GHG) emissions.

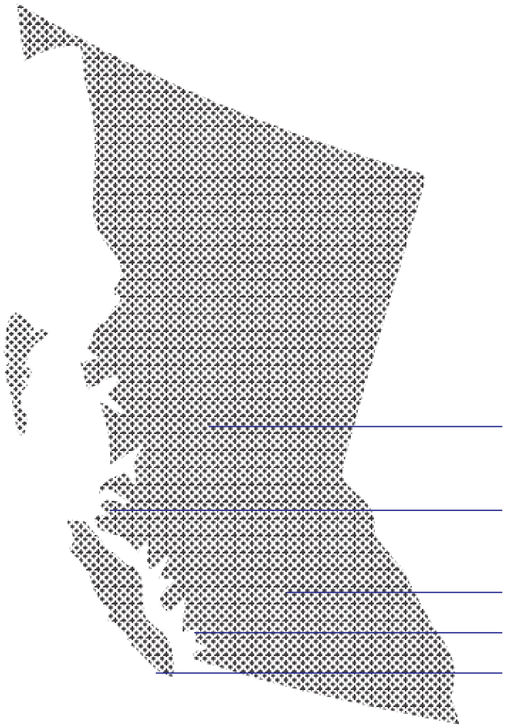
This report looks specifically at BC Housing Management Commission (BC Housing) buildings, primarily in the Lower Mainland Vancouver region. These buildings range in their housing typology, from mid or low-rise apartments, townhouses, to mixed-use residential buildings. The report excludes single family units, as the focus is on large scale projects with high energy use reduction potential. Most of BC Housing Management Commission buildings were constructed between the 1950s and 1980s, with a majority of the high-rise apartment buildings being built in the 1970's. They often have similar construction materials, mechanical, ventilation and electrical supply equipment. Since many of these buildings use the same building methods they often face the same maintenance issues, expected lifetime, and high energy use.

This report identifies the most effective strategies to reduce GHG emissions in BC Housing buildings. There are three high cost strategies that have been identified by BC Housing as effective strategies for radical change. This includes fuel switching to air source heat pumps, building envelope renovations, and ventilation system upgrades. These strategies have been applied to many BC Housing projects and were analyzed through case studies to identify the barriers that arise during retrofit projects. This report includes case studies for the Grandview Terrace, Sunnyside Manor, Chimo Terrace, Oppenheimer Lodge, and New Vista Apartment projects.

The case studies include a comparison study between the existing building's natural gas and electricity usage, the original American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) energy audits and the final renovation scope of work to determine the anticipated energy reduction potential of the applied energy conservation measures (ECMs) post construction. BC Housing's renovation projects are following the requirements and ECMs included in the *BC Housing Design Guidelines and Construction Standards* to make their building retrofit projects more energy efficient. The figures of the case studies are intended to determine the feasibility of reaching the current Clean BC GHG Emissions targets and the potential expansion of the BC Energy Step Code to include renovation projects. The BC Energy Step Code currently applies only to new construction projects. The barriers indicated in this report are intended to identify crucial areas where retrofit projects are limited in their capacity to reach these targets due to their complexity.

context

BC Housing owns and manages 729 social housing properties throughout the Province. This is in the form of either BC Housing, First Nation Group, or Non-profit Organization managed buildings. These buildings include a range of housing typologies including, low-rise apartments, high-rise apartments, townhouses, single family units, modular units and hotel - single resident occupancy (SRO) buildings.



CITY OF VANCOUVER GREEN CITY 2020 ACTION PLAN

The *City of Vancouver Green City Action Plan* is a comprehensive plan outlining the economic and employment structure of the city to identify areas of change to reach GHG emission reduction targets, originally estimated for 2020. This report discusses climate leadership and policy making action. The emissions data used in the report are a compilation of Vancouver's total GHG emissions and are not specific to social housing energy use. The targets in this action plan focus on new construction projects and are lower than BC Housings internal GHG emission reduction targets for renovation projects. The plans' major building industry goals include:

1 Require all buildings constructed onward to be carbon neutral in operations.
2 Reduce energy use and greenhouse gas emissions in existing buildings by 20% over 2007 levels.

BC HOUSING RESEARCH + ENERGY GOALS

BC Housing has a research team and publicly publishes a resource database for industry and independent home owners to use for educational purposes and advance their own practices in regard to new construction and renovation projects. These documents were used as resources for this report, including but not limited to, the *BC Energy Step Code Design Guidelines, Building Envelope Thermal Bridging Guide, Wall Air Barrier Reference Sheet, Achieving Airtight Buildings*, and the *Energy Consumption in Low-Rise Multi-Family Residential Buildings in British Columbia.*

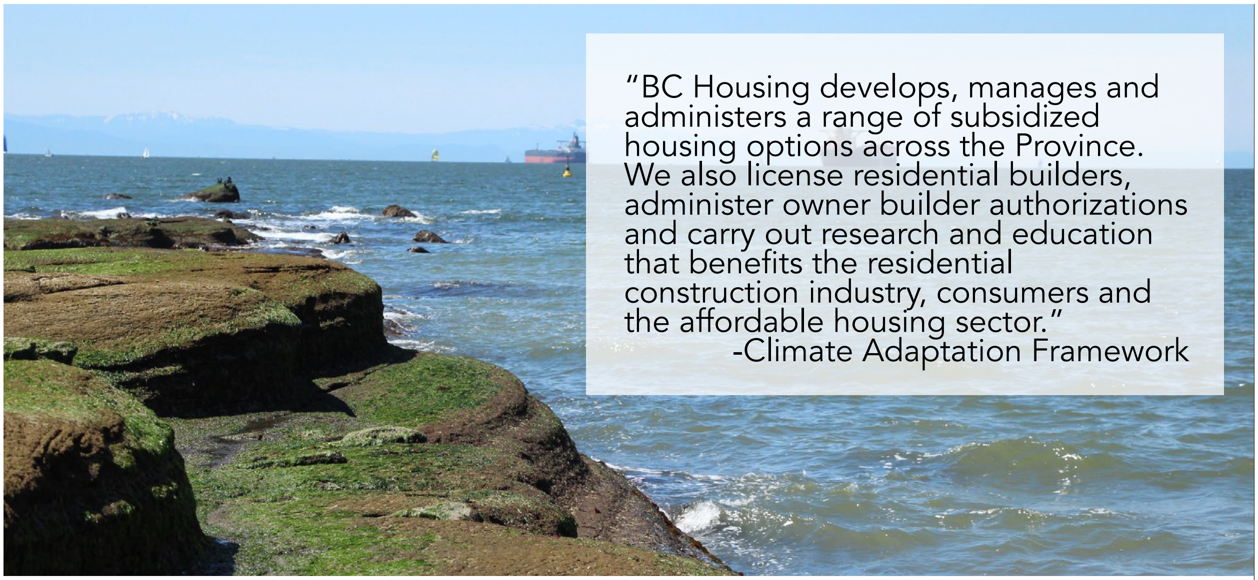


Figure 1. Photograph of ocean view at Stanley Park, Vancouver

CLEAN BC

This initiative identifies strategies for all sectors of the building industry to contribute to a cleaner Province. For BC Housing, this includes using cleaner and more efficient technologies and building upgrades such as fuel switching to electricity from natural gas for building equipment. The policy also includes funding to promote the adoption of efficiency measures: "Energy performance is a key part of B.C.'s work to improve public housing. The Province has launched a $1.1 billion, 10-year Capital Renewal Fund to support the improvement and preservation of existing, aging public housing stock in B.C. Of this, $400 million is targeted to energy performance improvements that will lead to greenhouse gas emission reductions." (Clean BC 2019 Report, page 31) The policy outlines targets for the building industry as follows:

1. Improve the BC Building Code in phases leading up to "net-zero energy ready" by 2032
2. Public buildings will reduce emissions by 50%, with all buildings reducing 40% by 2030
3. Adopt the model National Energy Code for existing buildings by 2024
4. Increase efficiency standards for heating equipment and windows
5. Encourage the development of innovative and cost-effective low-carbon building solutions

BC HOUSING'S CLIMATE ADAPTATION FRAMEWORK

This framework was developed by BC Housing in coordination with the Province of British Columbia and the BC Housing Livegreen Sustainability Plan. This framework acknowledges the increasing risk climate change poses to BC, and with it, increased damage to and deterioration of BC Housing buildings.

1. Integrate climate resilience considerations into our core business activities
2. Upgrade existing housing and design new developments to withstand climate change impacts
3. Make tenants safe and prepared by strengthening community resilience to the impacts of climate change

project methodology

1 Background Research

Researched and compiled information regarding BC Housing's energy initiatives and incentive programs.

2 BC Housing Interviews

Held interviews with project technicians in Development and Asset Strategies and members of the Energy and Sustainability team. This identified a range of scales of building retrofits and energy audits completed through BC Housing.

3 Site Visits

Visited construction sites of case study projects when possible.

4 Case Studies

Case studies identified the strategies and barriers of retrofit projects

5 BC Housing + Energy Step Code Resources

Compiled data from energy audit reports, utility bills and energy usage. Identified strategies that could be applied to building retrofits from the BC Housing Design Guides and Research library and Energy Step Code documents.

7 Summarize Barriers

Identified the barriers for retrofit projects in regards to achieving the 50% GHG emission reductions that the Province of BC is looking to achieve by 2030/31 (Clean BC.)

Buildings are identified for renovation based on either BC Housing's energy efficiency initiatives or are investigated when building operations staff identifying issues in the building.

The BC Energy Step Code currently only identifies requirements for new construction projects. Some strategies and methodologies in the *BC Step Code Design Guideline* are shared with *BC Housing's Design Guidelines and Construction Standards* that BC Housing is employing in their retrofit projects. Measures that are included in the project's final scope of work

1. Increasing Building R-Values
2. Reducing Thermal Bridging
3. Increasing Air Tightness
4. Recovering Heat During Ventilation
5. Separating Heating and Cooling from Ventilation

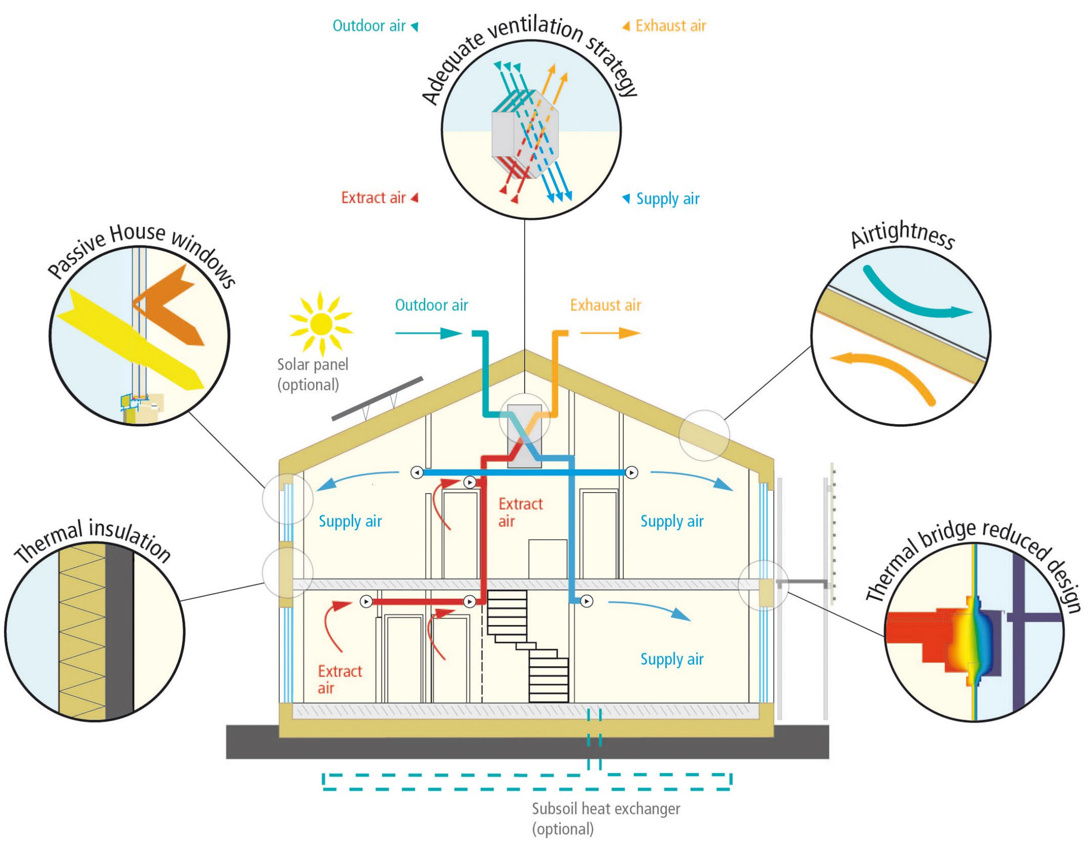


Figure 2. Passive House Institute, *Passive Haus 5 Basic Principles*, Passive House Requirements. This diagram summarizes the main approaches for architectural design and building construction that apply energy efficient building considerations.

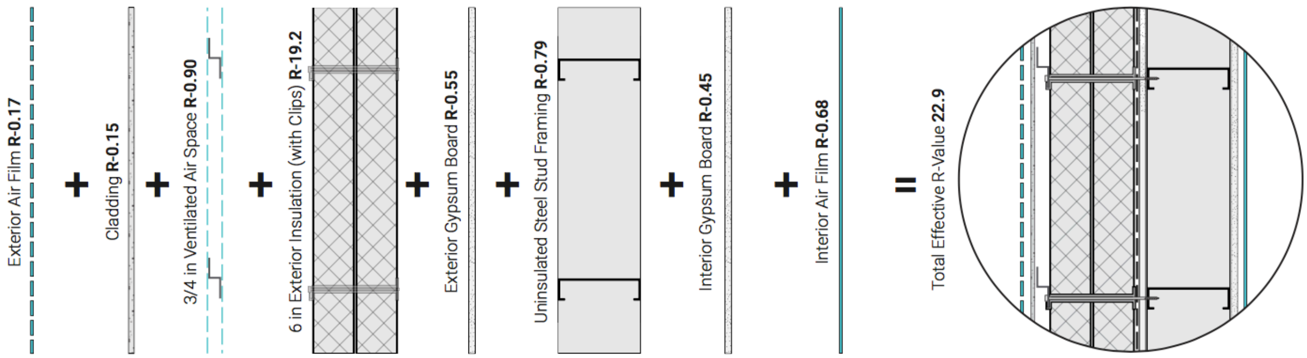


Figure 3. *Wall R-Values: High Rise MURB.* The annotated drawing shows an approach to insulating a light steel frame assembly to achieve effective R-20 wall envelope.

BUILDING ENVELOPE

The term *building envelope* in this report describes the exterior building walls, foundation, floors and roof that physically separate interior conditioned and exterior unconditioned space. This includes the separation between air, heat, water, and sound transfer.

Upgrading the building envelope in renovation projects has significant potential for GHG emission and energy use reductions. If a building envelope is inefficient, it increases heat loss and the combustion of natural gas (GJ) or use of electricity (kWh) in a buildings heating system. Reducing the loss of heat for ambient indoor air temperature will reduce the building's overall thermal energy demand intensity. There are four areas of the building envelope that can significantly improve the envelope's efficiency.

1. Additional Insulation
2. Increasing Airtightness
   Measured by Air changes/hour (ACH)
3. Reducing Thermal Bridging
4. Replacing Windows | Resealing with caulking to reduce air leakage, replacing single pane with double pane or triple pane windows, low U-value windows.

BUILDING ENVELOPE | INCREASING R-VALUES

The **R-value** of a building is defined as "an envelope's thermal resistance, or its ability to prevent heat from moving from one side to the other."[1] It has a direct impact on a building's **thermal energy demand intensity (TEDI)** and its **total energy use intensity (TEUI.)** Increasing the R-value in exterior walls reduces the heat loss through a building envelope. This includes constructing walls with more insulation and continuous air and vapour barriers.

1 British Columbia Province, BC Energy Step Code: Design Guide, 20.

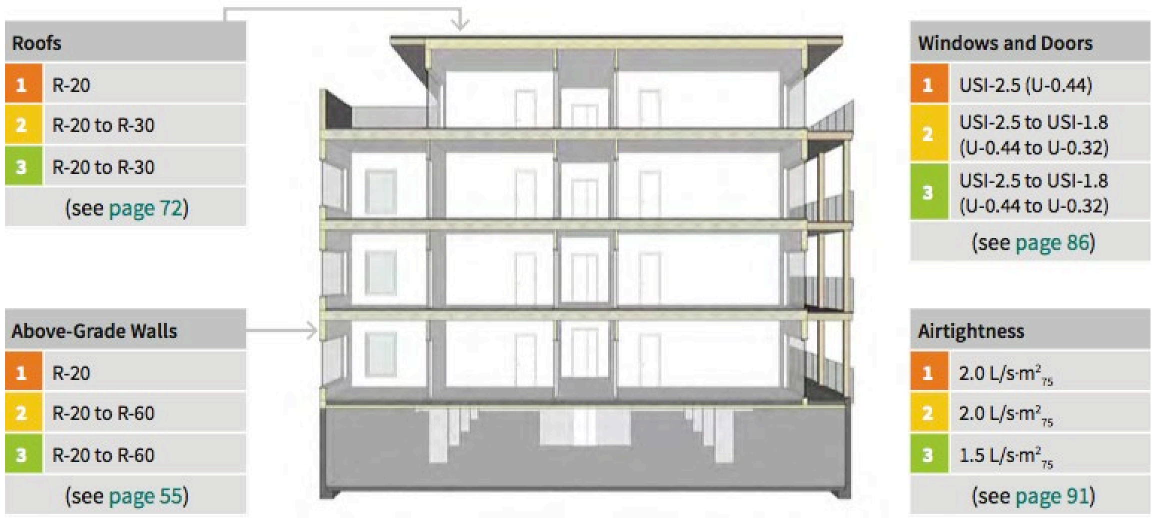


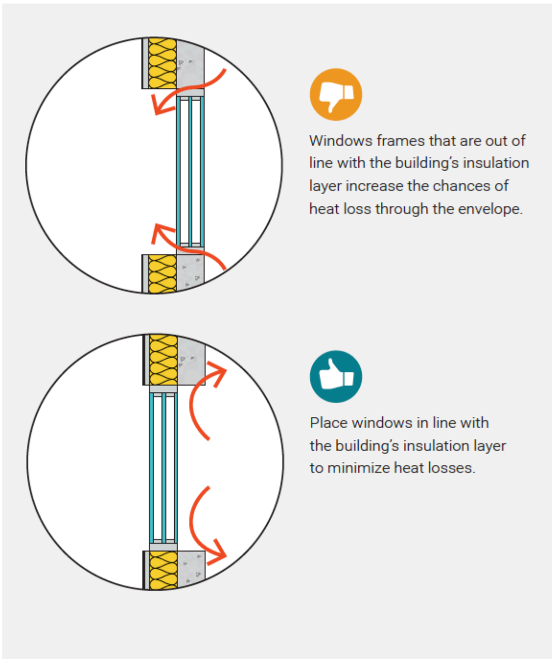
Figure 4. BC Energy Step Code Builder Guide, Part 3 Climate Zone 4 (Lower Mainland, Vancouver) Minimum R-Value Requirements for Building Envelope

BUILDING ENVELOPE | AIRTIGHTNESS

Air leakage from a building envelope has a large effect on a building's energy use and efficiency. Air can escape through punctured materials, unsealed windows and doors, or when original construction did not include air or vapour barriers.

The *BC Energy Step Code*'s definition for airtightness describes how "buildings designed for a compact shape, form and size not only improve thermal performance, but can improve air tightness as well. Complex forms with more corners have a greater overall potential for air leakage through the building envelope."[2] This definition does not align with the approach for increasing airtightness in retrofit projects. Existing building geometry defines the building face and structural members that can limit a building's ability to be airtight. For these projects, airtightness refers to the addition of a building membrane, caulking, and repairs to seal the building envelope, while working with existing geometry.

2 British Columbia Province, *BC Energy Step Code: Design Guide*, 21.



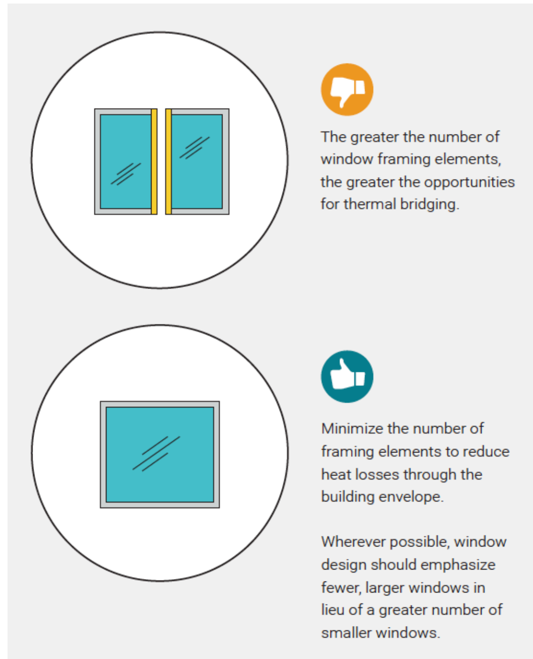


Figure 5. Align Windows with Insulation BC Energy Step Code Design Guidelines
Figure 6. Reduce Framing Elements by Having Fewer, Larger Windows. BC Energy Step Code Design Guidelines

BUILDING ENVELOPE | THERMAL BRIDGING

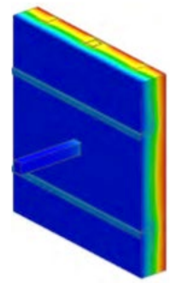
Thermal bridging is defined in the BC Energy Step Code as "an area in a building's envelope that interrupts the building's continuous insulation layer, causing heat to escape the interior of the building to the outside."[3] Thermal bridging significantly reduces the efficiency of a building envelope. Insulation and air barriers must be continuous. Areas that often cause air leakage and should be constructed with attention are basements headers and rim joists, roof to wall transitions, interior wall to exterior wall junctions, window and door jambs, and any penetrations through the building envelope.[4]

Interface details are areas that have a high potential for thermal loss through a building envelope. They are seen in, "slab edges opaque to glazing or wall transitions, parapets, corners and through wall penetrations."[5] Compared to **clear field assemblies** which are areas of thermal bridging where structural components intersect one another in wall, roof and floor assemblies. The transfer of heat flows through these two conditions determines an envelopes' thermal efficiency. The **point transmittance** is where heat flow through the envelope occurs at irregular locations.

3 British Columbia Province, *BC Energy Step Code: Design Guide*, 21.
4 BC Housing Managament Commission, *Design Guidelines and Construction Standards*, 148.
5 BC Housing Management Commission, *Building Envelope Thermal Bridging Guide*, 8.

BC Housing Building Envelope Thermal Bridging Guide: Thermal Resistance Testing Methods

1. Clear Field Transmittance
   Heat flow from the wall, floor or roof
2. Linear Transmittance
   The additional heat flow caused by details that are linear
3. Point Transmittance
   Heat flow caused by thermal bridges that occur only at single, infrequent locations.



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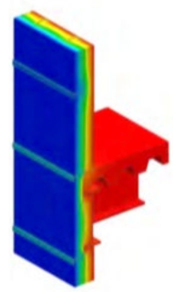

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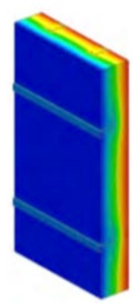

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Figure 7 (Above.) BCH *Building Envelope Thermal Bridging Guide*: Thermal Resistance Testing Methods. From left to right ; Point Transmittance, Linear Transmittance, Clear Field Transmittance

ASHRAE level standard testing is necessary to determine the effective thermal resistance (R-Value) of envelopes. To determine an envelopes' overall thermal performance, the BC Housing Building Envelope Thermal Bridging Guide identifies three approaches to calculate the U-value. This includes the clear field transmittance, linear transmittance and point transmittance.

BUILDING ENVELOPE | LIMITATIONS

Existing Building
The existing building structure and construction materials greatly define the parameters of a building envelope retrofit projects. The integrity of the building envelope varies depending on what constraints the existing building has to work within. If a building face has complex geometry, there may be large areas of thermal bridging. An example of this is seen in continuous floor slabs that project to the exterior, seen in concrete balconies. With complex building geometry the cost of the renovation increases, and the efficiency of the ECM decreases.

Development Permits
Another issue for building envelope projects are the bylaws put in place by the different authorities having jurisdiction throughout the Province. Some regulations restrict the changes that can be made to a building's image, typically in its exterior cladding. Development permits are controlled by these authorities and the design team must work with them to find a cladding system that fits their construction requirements for each neighbourhood. This can sometimes cause delays for the project in acquiring development permits.

High Initial Cost
Building Envelope upgrades have high initial costs and their payback period is often longer than the building's expected lifetime. They are included as an ECM for large scale building projects based on their GHG emission reduction potential alone.

HIGH-EFFICIENCY HEAT PUMPS

Air source heat pump outdoor unit
→ Control Valve / Hydro box
→ Domestic Hot Water Heaters (has heat exchangers)
→ pipes for hot water distribution
→ radiant heaters in units (often baseboard heaters) and plumbing (showers, sinks)

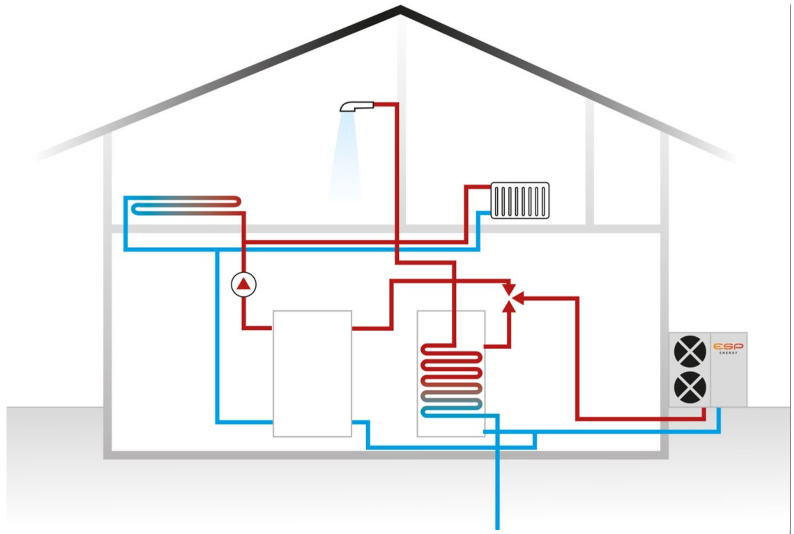


Figure 8. Air source heat pump unit in residential buildings.
"Air Source Heat Pumps." ESP Energy, www.espenergy.co.uk/products/air-source-heat-pumps.

Ground source heat pumps are not used for BC Housing renovation projects. This is because they require a large amount of excavation and site work to install, which makes them unfeasible for renovation projects. Air source heat pumps are the primary system used in BC Housing fuel switch retrofit projects. They are much more efficient systems as both a primary heating and domestic hot water (DHW) fuel source than natural gas. Their energy efficiency is measured through the Coefficient of Performance (COP.)[6] The COP for heat pumps is extremely high, some achieving up to a 300% increase in efficiency (COP of 3) compared to natural gas combustion heating systems that only have an efficiency of 80-90%. The *BC Energy Step Code Builder Guide* describes that "Air-source heat pumps extract heat from the outside air during the heating season, and extract heat from the indoor air in the cooling season. Ductless mini-split systems are air-source heat pumps which are commonly used to control temperatures in individual rooms or spaces by heating or cooling air (air-to-air system.) Larger heat pumps are generally used as part of a central heating or cooling system in larger buildings."[7] Air source heat pumps exchange air through a single unit connected through the exterior wall or are used in an existing forced-air duct system to bring preconditioned air into a building, and release air to the exterior.

The adoption of heat pumps increases the electrical use of an existing building. This can require upgrades to existing building electrical panels and/or services but is the preferred alternative to the combustion of natural gas, as it reduces the building's overall carbon emissions.

6 British Columbia Province, *BC Energy Step Code: Builder Guide*, 116.
7 Ibid.

Heat pumps are being increasingly used in renovation projects. They can be used, when sized appropriately, for different building scales. Through Clean BC, BC Housing can now access funding through their Retrofit Incentives[8]:

- Up to $200,000 is offered. The incentive amount is based on a rate of $70/ tCO_2e of lifetime greenhouse gas savings up to a maximum of 75% of a project's incremental cost.
- If a project is receiving an incentive or grant through another third-party program, the total amount of this other funding will be subtracted from the project's incremental cost before the eligible SHIP incentive is calculated.

DOMESTIC HOT WATER UPGRADE

BC Housing's initiatives include upgrading natural gas combustion boilers to condensing boilers for hydronic baseboard heating and DHW use. DHW can account between 30-50% of the total energy use in a building and it is usually used throughout the year, even during the summer when space heating may not be required.

The Government of Canada requires that DHW heaters achieve a minimum of 94% Annual Fuel Use Efficiency. They also state that "where possible and practical, utilize a concentric venting system (inner flue exhaust and outer combustion air intake) to increase efficiency by pre-heating intake air and reduce number of envelope penetrations."[9] Other ways to reduce energy consumption for commercial boilers is to ensure that the products used have fan-assisted combustion, motorized dampers, electric ignitions, and sealed combustion. These measures reduce heat escape from the building and limit the natural gas combustion required. The preferred fuel source for hydronic systems is an air source heat pump. Using this electric source system increases the electrical consumption of the building, although it is a cleaner fuel source than natural gas in BC due to the availability of low carbon hydroelectric power.

DHW heat pump technology: Chimo Terrace

Chimo Terrace's existing heating system uses an inefficient natural gas DHW heater. This system is active even during the warmer summer months, causing unnecessary fuel combustion. Air source heat pumps have been designed as the primary hot water heating source, with existing boilers being retained as a secondary back up system. The intention is to shut off the natural gas boilers completely during the summer months, with the DHW heat pump meeting demands for those months. A control bypass valve would be installed to automatically trigger the use of the existing Natural gas heating when the heating demands exceed the heat pump DHW capacity.

HEAT PUMPS | LIMITATIONS

Climate Region

Air source heat pumps operate well within an ambient outdoor temperature of 0°C to -5°C. Therefore, heat pumps are currently adopted primarily in Climate Zone 4 and 5. Heat pumps can be used in other climate zones but may require using it in combination with an existing back up heating system (usually gas.) BC Housing typically uses the Sanden Heat Pump equipment. This system uses CO_2 rather than a refrigerant and is specified to operate at temperatures as low as -15°C.[10] For single-family residential units or townhouses, a ductless heat pump system may be used as the primary heating system. They work more efficiently in colder climates, with temperatures as low as -5°C to -25°C.[11]

8 Clean BC, *CleanBC Social Housing Incentives.*
9 BC Housing Management Commission, *Design Guidelines and Construction Standards*, 289.
10 Sanden Water Heater, *Sanden SANCO2: Heat Pump Water Heater Technical Information*
11 BC Hydro, *Should You Get a Heat Pump*?

There are some cold climate heat pumps that work more efficiently past -25°C that are being developed and starting to be implemented.

In BC Housing's Chimo Terrace project the renovation included control valve upgrades to trigger the existing natural gas DHW boiler when temperatures drop below 0°C. Installing controls valves is key to ensure that natural gas combustion is not occurring when it is not necessary as a back-up. This was done to promote the adoption of the fuel switch, while allowing for a backup system so that the operations staff can see the potential of the new system and its capability to work independently of backup systems.

Electrical Upgrades
The integration of heat pumps increases the electrical load on a building. This can sometimes require significant upgrades to the electrical supply. This can add significant costs to the project and delay the project timeline since all electrical upgrades must be coordinated with BC Hydro.

Distance / Adjacency to Boilers
The adjacency of the heat pumps to the boilers is important to ensure the effectiveness of the system. In the Chimo Apartment project it was specified that the heat pumps were required to be within a 50' distance from the boilers. Available space within the existing site conditions and building dictate whether or not this minimum distance can be met. There are other models of heat pumps that can be installed at greater distances.

Structural Upgrades
Heat pumps may require additional structural support due to their weight and size depending on their location on site. When boiler rooms are located on the roof, a structural assessment must be completed early in the design stage of the project to ensure that the roof structure can support the heat pumps.

High Initial Costs
Air source heat pumps require exterior enclosed space to operate. This means they must be in an enclosed and secure space, while allowing air exchange. This may increase additional costs for supporting the heat pump system including the enclosure and structural foundation support. The initial cost for a heat pump fuel switch is high and has a typical payback period of 15-45 years with a COP of 3, as seen in the case study analysis based off energy audit results. A condensing boiler replacement has a payback period of approximately 20 years. Although it has a lower payback period, its efficiency is only 80-90% (a COP of less than 1.)

VENTILATION SYSTEM UPGRADES

Heat Recovery Ventilation (HRV) systems are effective for reducing the energy consumption of a building by recovering the heat from exhaust air to precondition the supply air in a building. It is effective in all residential building scales. **Compartmentalized Ventilation** is where forced air moves into each room (rather than entering a room through doors cracks, etc.) and exhaust air is moved from each room in a circuit. This system should be applied with an HRV unit.[12] **Centralized HRV** units are the most efficient because they limit the perforations of the building envelope that individual HRV units cause. Centralized HRV's can be used in combination with heat pumps to create a high efficiency mechanical system. Multiple central HRV's may be required for larger buildings that require additional fresh air with enlarged floor space.

Individual HRV Units are also referred to as In-suite HRV Units. This system is designed to have one unit per residential suite and is located at the exterior wall to recycle and supply fresh air as a closed loop system within the apartment. The bathroom and hood range exhaust are ducted directly to the exterior wall unit.

Makeup Air Units are ventilation units that supply fresh air, without recovering heat from the exhaust in the building. This keeps supply and exhaust completely separate. Rooftop makeup air units are standard within BC Housing projects. Natural Ventilation occurs with operable windows and corridor pressure created by a centralized air handling system. This system does not allow for units to be compartmentalized for air flow, although it encourages the use of a semi-passive system for cooling that can be applied to existing ventilation systems.

LIMITATIONS

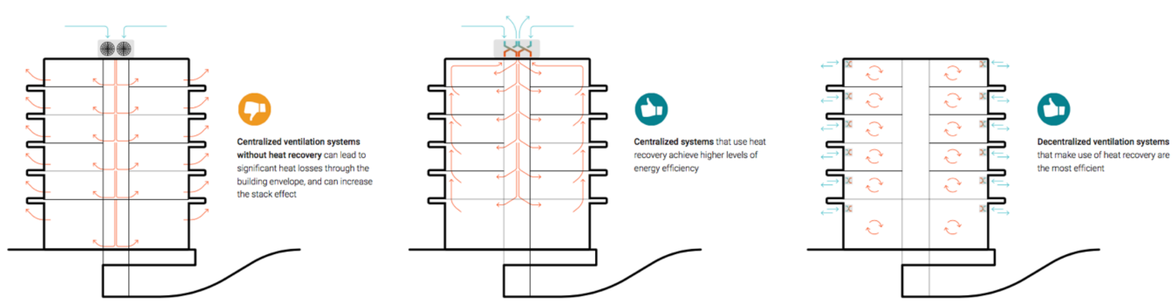


Figure 9. The BC Energy Step Code Design Guidelines, Recover Heat During Ventilation.

Control Upgrades

The *BC Step Code* identifies separate heating and cooling from ventilation as a strategy for creating efficient building systems. Separating the systems means that ventilation can continue as required for occupants, while heating / cooling can fluctuate or be turned off as needed. Using building automation systems and updating controls for ventilation is essential in monitoring and limiting the energy use of a building. Control updates are often included in retrofit projects and have low initial costs, with quick payback periods.

12 British Columbia Province, *BC Energy Step Code: Design Guide*, 22.

Existing Ventilation System

Existing ductwork defines the potential for heat recovery systems within a retrofit project. If existing ductwork in a building can allow for central or corridor heat recovery ventilation units, that is the preferred system. For many buildings this is not the case, or the existing ductwork does not meet the minimum ASHRAE requirements for fresh air supply and exhaust. Upgrading the ductwork is often outside the project's budget and scope and is not an option. Retrofit projects may require building bulkheads to support the ducts, reducing ceiling heights or adding cost to the project. Individual HRV's also require puncturing through the exterior wall, creating a large opening in the building envelope, an interface detail condition of heat escape. Any upgrades that require the demolition or removal of existing material risk disturbing hazardous and/or asbestos-containing material. This can incur high costs associated with creating a safe, contained work site and disposal method.

Tenants

An additional concern occurs when the noise caused by certain vents for bathroom exhaust cause tenants to disconnect the fan system. This interferes with the buildings ability to meet the fresh air requirements for the residence and can impact the energy efficiency. This is another reason why building automation systems are integral to maintaining the ventilation system.

Site Energy Use

Property GFA:
13199 m^2
Existing Building Site Energy Use
Natural Gas: 8,832 GJ
Electricity: 675,154 kWh
Total GHG Emissions:
448 Metric Tonnes CO2e

Projected Energy Savings

Site Energy Reduction:
Natural Gas: 2,093 GJ
Electricity: 36,808 kWh
GHG Savings:
105 Metric Tonnes CO2e (23%)
Notes:
- Existing Site Energy uses the 2012 Baseline determined by recorded utility bill information.
- Energy Savings Data acquired from Low-Cost of 2016 Energy Audit

Housing Type
1. High Rise Apartment (8 storeys) x 2
2. Duplexes (attached to high rise towers, 2 storeys) x 2 connected
3. Townhouses (3 storeys) x 6 separate buildings

Units: 154 Units
Floor Area: 13, 199 m^2

Site
The site is a block area that creates a complex and private exterior space, separated from street view. The site has a complex elevation change throughout and uneven terrain at grade.

Project Stage:
1. Building Envelope: Post Construction
2. Roof Replacement: Construction

Context
Location: 1441 Graveley Street, Vancouver, Climate Zone 4
Region: Lower Mainland
Housing Provider: BCH Managed
Year Built: 1969

Building Construction
The existing building was constructed with slab-on-grade foundations, with crawl spaces of uneven heights, that provide access from the exterior. Load-bearing walls are concrete masonry units (CMU) and infill walls are constructed of wood framed superstructures. Some load-bearing walls extend past the envelope of the building, and were originally constructed with uninsulated CMU and brick veneer. This was a large area of thermal bridging. The facade is a combination of brick veneer and stucco. All services for the buildings on site are centralized and equipment is located in the apartment buildings' mechanical room. Services are distributed through the ground to the other buildings, who have mechanical rooms below grade.

Past renovations on the project include a heat plant and direct digital control upgrade. The natural gas consumption decreased approximately 20% from the 2005 Benchmark Baseline from 10424 GJ to 7046 GJ in 2015.

Energy Audit Results | 01/04/2016

The ECMs that were selected have an estimated total energy savings potential of 2093 GJ of natural gas, with an electrical consumption savings of 36880 kWh, and GHG emission reduction of 104.8 tonnes of CO2e (23.4%.)

These capital upgrade measures include the replacement of windows (single to double glazed) and the addition of external insulation. "As shown for fuel, the envelope losses at Grandview Terrace, make up 50% of the building natural gas consumption. A significant portion of the building envelope is made up of operable windows in tenant spaces, contributing to these losses. Ventilation accounts specifically for the energy required to heat any outside air that is brought into the building by make-up air unit fan."[1] The ECM energy reduction calculations are based off additive individual measures reduction potential, and is not calculated as a cumulative set of measures.

Renovation Scope of Work

Building Envelope:
The building envelope was replaced and is now constructed of:
- Existing CMU structural Wall
- Additional insulation (4" Roxul external insulation), new air barrier insulated aluminum panels or Hardie Board exterior wall finish
- New weather stripping and air sealing the building
- Exterior Insulation on apartment, upgraded wall cavity and exterior insulation at townhouses

Roof Replacement
- Full roof replacement with additional insulation, new membrane, asphalt finish and parapet flashing
- Construction began in June 2019. Second phase of the project removed from original scope of work and brought back into the project when additional funding became available

Ventilation
- Replace existing Make-up Air Unit with Condensing unit
- Central Air Conditioning Unit Replacement
- Relocated to the mechanical room and connected to existing central air distribution system.
- Original location was above the elevator shaft, accessed from the laundry room on the top floor
- Bathroom and hood range fans replaced

Electrical
- Existing natural gas generator was replaced with diesel fuel generator and relocated from the mechanical room to the exterior
- Energy Efficient Lighting Upgrades for Common and Exterior areas, common area lighting controls

Retrofit Results + Barriers

1 Cost Outweighing Energy Performance
The original scope included 6"of exterior insulation to be added to all buildings. In the townhouse buildings, the team decided to reduce the insulation to 4"of exterior insulation to front and back of the exterior walls. In these buildings the desired R-value and energy performance did not outweigh the costs. They payback period for the energy savings for every inch after 4" of additional exterior insulation is insignificant.

2 Accessibility
Electrical supply to the building is required to be fully replaced and may trigger site accessibility concerns. With the excavation of the grade in certain points of construction, consultants must ensure they do not significantly change the grading condition, or it may require current National Building Code standards compliance.

3 Tenants
Completing the building envelope renovation required advanced notice to tenants that their units would be temporarily occupied to construct new wall partitions to the exterior, made of plywood and polycarbonate windows to allow for daylighting. Notice to tenants must be considered at the early planning stages of the project to ensure there are no delays. Many tenants are unhappy with their space and building being disturbed by the renovation process.

4 Asbestos
The crawl spaces in the buildings had asbestos materials that were soaked during a pipe leak in one building and created a hazardous environment that required additional costs to clean. This increased the cost and caused delays for the retrofit project.

1 Prism Engineering, *Detailed Energy Audit Report: Grandview Terrace*, 16.

Site Energy Use

Property GFA: 4816 m²
Existing Building Site Energy Use:
Natural Gas: 4,884 GJ
Electricity: 353,060 kWh
Total GHG Emissions:
247 Metric Tonnes CO2e

Projected Energy Savings

Site Energy Reduction:
Natural Gas: 2,156 GJ
Electricity: -63,662 kWh
GHG Savings:
107 Metric Tonnes CO2e (43%)

Notes:
- Existing Site Energy uses the 2005 Baseline determined by recorded utility bill information.
- Energy Savings Data acquired from Low-Cost of 2019 Energy Audit

Housing Type
Senior Residences

Mid-Rise Apartment Building, (10 storeys)
Units: 61 Units
Floor Area: 4,816 m²

Site
Located in West Vancouver. The building is in a residential neighborhood. It is adjacent to other mid and high rise apartment buildings.

Project Stage:
1. Fuel Switch: Design / Initiation
2. Building Envelope: Design

Context
Location: 1495 Esquimalt Ave, West Vancouver, Climate Zone 4
Region: Lower Mainland
Housing Provider: BCH Managed
Year Built: 1975

Building Construction
Concrete Structural Walls and floors, with cast in place concrete foundations. There are steel infill shear walls with exterior aluminum panels cladding. The concrete balconies have a upstand wall that is continuous with the floor slab. The tar and gravel roof membrane was replaced in 2000.

The building has a partial below grade basement in center portion housing mechanical and electrical service equipment. The building has natural gas boilers and hydronic baseboard heaters.

Energy Audit Results | 01/04/2019

ASHRAE Level II Energy Audit identified six Energy Conservation Measures that were selected for immediate research as part of the Energy Savings Plan. The total energy savings of the ECMs was estimated to be 2156 GJ of natural gas and 107.3 CO2e, with an increase in electrical use of 63,662 kWh.
- The fuel switch to an air-source heat pump for the domestic hot water heaters has an estimated reduction of 145 GJ (9%) of natural gas use in the building. This requires more electricity to operate, increasing the electricity demand on the building (-75894 kWh.)
- Envelope upgrade to R-40 walls was estimated to have a 1,178 GJ (28%) of natural gas reduction and 2224 kWh of electricity savings.
- Air source heat pump (ASHP) Corridor Ventilation system integration was estimated to have a savings of 109 GJ natural gas consumption and an increase of 15012 kWh of electricity consumption.
- Heating Plant Replacement was estimated to reduce natural gas consumption by 451 GJ (11%.)

These retrofits were used due to their capacity to significantly reduce the buildings energy consumption. Heat pumps were determined to be the best fuel switch option for this project, rather than switching to an electric boiler.

Renovation Scope of Work

Building Envelope:
The building envelope is being completely replaced and includes:
- A removal of balcony concrete up-stand walls to reduce the thermal bridging between balcony connection and allow the new building envelope to wrap around the structural walls. The loss of concrete is also intended to counteract the addition of weight to the building from the new envelope.
- Balcony waterproofing, drainage improvement, install glaze metal railings and canopies on top floor balcony.
- Additional Insulation and cladding to all walls, including structural concrete wall
- Replacement of exterior shear walls, the existing steel walls cannot support the weight of required cladding or reach R40 as specified in the energy audit. This was an added cost after the physical wall testing was completed.
- Window and glazed door replacement for the entire building.
- Full roof replacement with additional insulation and roof deck replacement

Mechanical
- Fuel switch to Domestic hot water heat pump
- Installation of new diesel emergency generator
- Installation of fire suppression system
- Hydronic heating system boiler plant, piping, and baseboard heating replacement

Retrofit Results + Barriers

1 Expanded Scope of Work
The scope of work was expanded after the primary consultant did more building inspections including an ASHRAE Energy Audit, Electrical, Mechanical, Building Envelope, and Seismic Assessments. The reports found additional areas of repair or upgrades in the building.

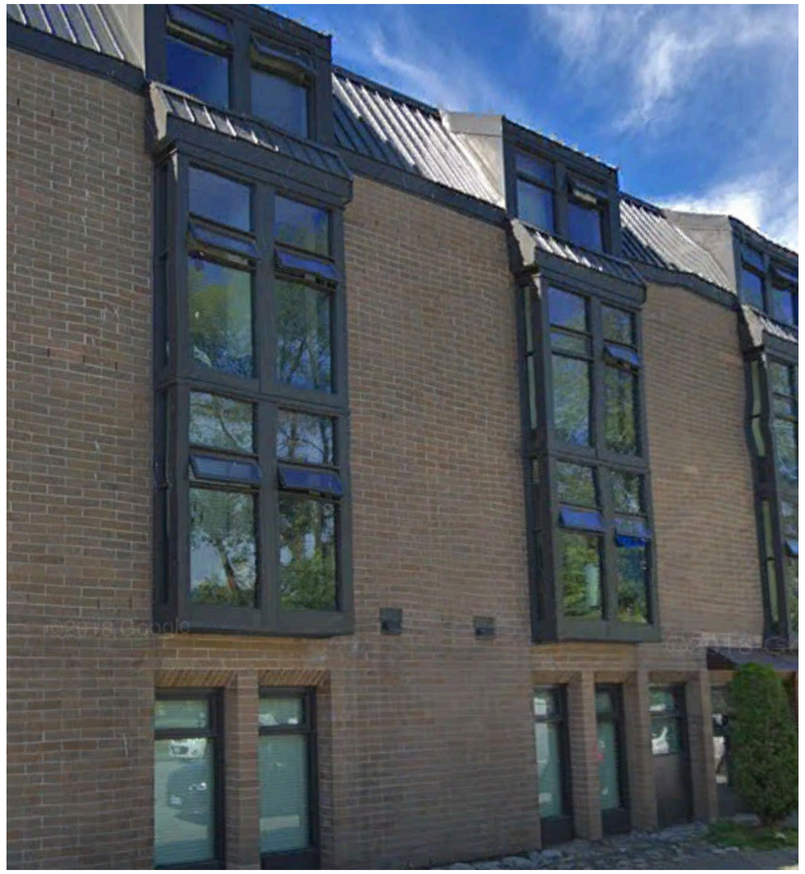
2 Development Permit
The project is currently delayed due to the application process for a development permit through the City of West Vancouver.

3 Window Opening
The Design Development Report identified that to replace the windows between the concrete shear walls (fixed), the window opening will be reduced 12". This is because of the building envelope scope of work that required additional cladding and exterior material on adjacent walls and the floor slab at the top of the window to increase thermal resistance.

4 Thermal Bridging at Balcony
The site-cast concrete floor slab extends to the exterior of the building at the balcony, allowing a significant amount of heat loss. Thermally breaking the balcony would have significant cost impacts and is not included in this projects' scope.

5 Seismic Upgrades
The unreinforced concrete masonry unit firewalls could be at risk of failure during an earthquake. Only the reinforcement of CMU fire exit stair is included in the project.

6 Electrical Upgrades
Electricity use will increase by 63,662 kWh but this is offset by the 2,047 GJ reduction of natural gas used in the building by switching to a heat pump fuel system.



Site Energy Use

Property GFA:
3,346 m²
Existing Building Site Energy Use:
Natural Gas: 3,387 GJ
Electricity: 43,354 kWh
Total GHG Emissions:
194 Metric Tonnes CO2e

Projected Energy Savings

Site Energy Reduction:
Natural Gas: 1,760 GJ
Electricity: 14,300 kWh
GHG Savings:
87.7 Metric Tonnes CO2e (45%)
Notes:

- Existing Site Energy uses the 2006 Baseline determined by recorded utility bill information.
- Energy Savings Data acquired from Low-Cost of 2016 Energy Audit

Housing Type

Mid-Rise Apartment Building, (4 storeys)
Units: 147 Units
Floor Area: 3,352 m²

Site

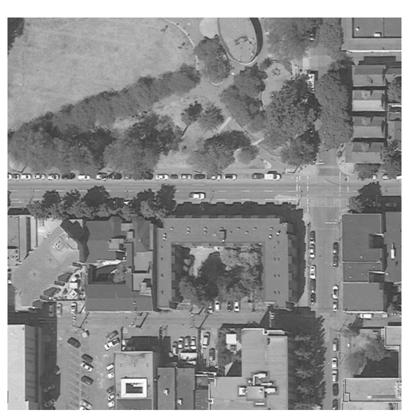
Located in Downtown East Side, Vancouver. The building is in a residential neighborhood. It is adjacent to other low /mid-rise apartment buildings. The building faces a park that has open green space and community gardens.

Project Stage:

1. Roof + Fenestration: Post Construction

Context

Location: 450 E Cordova Street, Vancouver, Climate Zone 4
Region: Lower Mainland
Housing Provider: NPO Managed
Year Built: 1974



Building Construction

The building has site-cast concrete foundations and the walls are combination of concrete and monolithic reinforced brick walls, with steel frame construction in some areas. The exterior walls are 14-16" thick masonry brick walls that are exposed in the interior and exterior. Some of the exterior walls were found with exploratory openings during Building Envelope Condition Assessment to have 2" of adhered rigid insulation. The existing roof was a gravel ballasted tar and gravel sloped roof. A sloped metal mansard roof ties to flat roof and the curtain wall glazing that extends from the building. The existing windows were single-glazed non-thermal broken aluminum frame windows.

The original boiler was replaced in 2002 with an energy efficient gas fired domestic hot water boiler. The building is heated by hot water baseboards. In 2018 the building also upgraded its fire alarm system, controls, and exterior lighting as independent projects.

Energy Audit Results | 01/04/2016

The report was based off the 2013 BEPI (ekWh/m2): Gas (298) + Sub Total (127.) The low cost energy conservation measures identified were a ventilation control upgrade, boiler control upgrade, BAS re-commissioning, heating control upgrade, window and roof replacement provide an estimated reduction of 1760 GJ in natural gas use, 14,300 kWh of electricity, and 88 tonnes of CO2e (45%) in the building.

In 2018 there was a separate project to update controls and lighting at Oppenheimer. This included a heating controls upgrade and ventilation control upgrade. BC Housing does not have the utility data at this time for 2018/2019 as it is obtained annually.

Renovation Scope of Work

Roof Replacement:
- The existing low sloped roof was replaced with new 2ply SBS roof and additional insulation.
- The project scope was reduced from an R40 (6.5" insulation) to have an R20 (4") thermal roof.

Building Envelope
- The original scope included providing insulated interior wall assembly at the existing uninsulated exterior walls if feasible. This was removed from the scope of work during the construction phase.
- The floor slab extends to support a curtain wall glazing system that is continuous with the full building height.
- All windows including the glazing wall system were to be replaced with double pane, energy efficient glazing.
- The existing aluminum frame exterior doors were to be replaced.

Exterior
- Repair cracks at brick masonry mass walls and re-point to improve water management and structural integrity
- Modify landscaping to building perimeter to improve water flow away from building perimeter
- The consultants designed a trench along the perimeter of the building to support drainage.

Mechanical
- Make-up air unit control upgrade
- Replace existing interior exhaust fans with programmable control

Retrofit Results + Barriers

1 Wall Envelope Remediation
The energy audit recommended a remediation of the exterior wall assembly with increased insulation on the interior to increase its thermal resistance. It is less effective than insulating the exterior. There are significant thermal breaks throughout every floor slab and the interior walls. The structure is completely site cast concrete or brick construction, there would be significant heat loss through the structural members, making an additional interior insulation approach ineffective for GHG energy reduction. Additional insulation in the interior would also reduce floor space and exit stair widths. Exterior insulation and re-cladding was not approved for the scope of work as the City of Vancouver would not allow for the exterior of the building to be changed and it would exceed the project budget.

2 Thermal Bridging
Due to the inability to affordably insulate the building, the building still suffers a large amount of energy loss through the envelope.

3 Roof Height
The roof replacement was original specified to have additional insulation to reach a thermal rating of R40. This required 6.5" of rigid insulation layer, which would require an increase in the roof parapet height to meet minimum code requirements. The roof was reduced to a R20 rating.

4 Asbestos
The tar material of the roof and the parapet curb board is asbestos containing.

5 Structural Repairs
The structural assessment of the existing building was completed and concluded that the building renovation should include repair or replacing all cracked brick columns, damaged lintels, minor cracks in masonry walls (with sealant), the corroded reinforcing steel and spall on 3rd floor slab.

Site Energy Use
Total Site (both buildings)

Property GFA:
5,948 m²
Existing Building Site Energy Use:
Natural Gas: 5732 GJ
Electricity: 271,720 kWh
Total GHG Emissions:
289 Metric Tonnes CO2e

Projected Energy Savings

Site Energy Reduction:
Natural Gas: 2,690 GJ
Electricity: -61,100 kWh
GHG Savings:
133 Metric Tonnes CO2e (46%)
Notes:
- Existing Site Energy uses the 2012 Baseline determined by recorded utility bill information.
- Energy Savings Data acquired from Low-Cost of 2019 Energy Audit

Housing Type
Low-Rise Apartment Building, (3 storeys)
Units: 82 Units
*Totals of both buildings

Site
Located in East Vancouver. The building is in a residential neighborhood. The buildings entry faces a community garden, beyond which is the Vancouver Harbour.

2140 Wall Street

2080 Wall Street

Project Stage:
Mechanical Upgrade: Construction

Context
Location: 2080, 2140 Wall Street, Vancouver, Climate Zone 4
Region: Lower Mainland
Housing Provider: BCH Managed
Year Built: 1970

Building Construction
The ground floor is partially below grade and is constructed of site-cast concrete. The second level has a concrete floor slab (including balcony), the rest of the building above is wood frame construction. The original exterior wall finish is painted concrete and face seal stucco.

The roof was replaced in 2012 and included a complete removal of previous roof system, repair to existing roof sheathing and desk, installation of new 2 ply SBS roofing system including a sloped insulation package, new scuppers and drains. In 2006 the domestic hot water tank was replaced. 2005 Benchmark baseline shows an annual 3220 GJ energy use for natural gas. The 2012 baseline for this project scope shows a natural gas reduction for both buildings of 1994 GJ (25%.) The roof replacement may also contribute to this reduction. The two buildings operate separately, the only shared service between them is the fiber-optic cable.

Energy Audit Results | 17/10/2016

Gas consumption in the building accounts for approximately 83% of the energy consumption in Chimo Terrace. Reducing gas consumption is the primary goal of the retrofit recommendations. "The buildings currently produce 227 tonnes of annual CO2 emissions based on the following energy consumption data." There is a significant fluctuation between winter and summer months of natural gas consumption – due to the gas fired boilers. The ECMs indicated in this report that were included in the project scope have an estimated reduction of 2,690 GJ of natural gas, an increased consumption of 61,100 kWh of electricity, with an overall GHG emission reduction of 133 tonnes of CO2e (46%.)

Renovation Scope of Work

Hallway Ventilation Units
- Replace with heating coils to pre-condition fresh air supply to corridors.

Domestic Hot Water Heat Pump
- The intention is to shut off the natural gas boilers completely during the summer months and the DHW heat pump could meet demands for those months. The existing natural gas boilers act as the backup heating system when temperatures drop below -10°C.
- A control bypass valve would be installed to automatically trigger the use of the existing DHW tank when the heating demands exceed the heat pump DHW capacity.

Exhaust Fan Replacement
- Two speed washrooms fan replacements to improve ventilation in all suites .

Seismic Upgrade
- There were multiple seismic improvements made to the buildings, including additional footings and steel columns at the ground level to support the overhangs at the second floor level. The new heat pump room in Building A required increased slab thickness to support the heat pumps and hot water tanks.

Windows and Sliding Doors Replacement
- All windows and sliding doors were replaced with double-glazed thermally broken vinyl window frames.

Lighting Upgrades in Common Area

Retrofit Results + Barriers

1 **Heat Pump Location**
The heat pumps must be within a 50ft distance to the domestic hot water boilers. The original design for Building A did not achieve this, therefore an extension at the ground level was built to house the hot water pumps. An additional concrete foundation pad was structurally required to support the heat pumps.

2 **Heat Recovery Units not Feasible**
The Energy Audit recommended implementing a Heat Recovery system for the exhaust fans. This was not possible due to the existing low ceiling heights and the numerous services concealed within asbestos-containing ceilings, which would be costly to relocate. New bulkheads would further reduce ceiling height clearances and have code implication. Central HRV units were also deemed unfeasible with the existing vertical ductwork and distance of the hallway ventilation units.

3 **Bathroom Exhaust Fans**
Noise concerns with the new bathroom fans. This is happening because of the existing ductwork having a small 3" diameter, not allowing air the air pressure to move easily through the ducts. The joints are also unsealed and ducts are uninsulated, causing increasing noise.

4 **Corridor Ventilation Fan Units**
The hallways height where the fan units are located are limited. The fan units require duct openings and air grills through the building envelope. On the ground floor of Building A there are floor joists and existing electrical conduit that run along the required opening area. This now requires an additional inspection from a structural engineer to ensure an opening will not cause a failure in the structural system. Consultants are in the process of determining a solution for this issue, including the potential to re-route and add a vertical duct on the second floor to avoid penetrating through floor joists.

5 **Building Envelope Upgrade**
This building renovation project did not include a building envelope upgrade because the physical spot tests in all assembly did not show degradation. This project was initiated prior to ECM initiatives influenced the project scope.

PROJECT RESULTS | CLEAN BC TARGETS

Clean BC targets require that all public buildings reduce emissions by 50% by 2030. The BC Housing residential buildings explored in this project's case studies range in their stage of the project. There is no utility data for the projects post construction to compare the final energy use of the buildings with the adoption of ECM.

- Grandview Terrace completed part of the construction phase in June 2019 and is continuing with the roof renovation project.
- Sunnyside Manor is in the design / project initiation stage
- Oppenheimer Lodge is post construction, the project was completed in 2018.
- Chimo Terrace is in the construction phase

The analysis (See Appendix) could only include the estimates included in the ASHRAE Energy Audits and the historical utility data collected for natural gas and electricity consumption. Only the measures that were included in the final scope of work were used to quantify an anticipated GHG emission reduction. The energy audits use an additive approach to quantify the energy use savings, not including the effects of packaged measures of ECMs. Therefore, the final GHG reduction results will likely differ since multiple measures are being completed for each building, and they will be working in combination to make the building more efficient. All projects included in the study show significant anticipated reductions in metric tonnes of CO_2e (GHG Emissions.) The effectiveness of the ECMs was quantified using the overall energy audit data for each retrofit project.

The **Grandview Terrace** retrofit project shows an estimated GHG reduction of **23% from a 2005 baseline.** This figure includes only what was identified in the

GHG Target / Energy Audit

Project	Grandview Terrace	Sunnyside Manor	Chimo Terrace	Oppenheimer Lodge
Location (Step Code Region)	4	4	4	4
Units	154	61	82	147
Property GFA - m2	13199	4816	5948	3346
Existing Building Site Energy Use Natural Gas (GJ)	8832	4883.7	5731.92	3887
KWh Electrical Use	675,154	353,060	271,720	43,354
Total GHG Emissions (Metric Tonnes CO2e)	447.9	247.5	288.9	194.4
Electrical Savings (kWh)	36880	-63662	-61100	14300
Energy Audit Projected Site Energy Reductions (GJ)	2093	2156	2690	1760
Project GHG Savings (Metric Tonnes of CO2e)	104.8	106.9	133.1	87.7

Figure 12. Case Study Energy Reduction and Clean BC Target Comparison: the projected energy savings and reduction of GHG emissions in the building post construction, with the use of the Energy Conservation Measures.

Note: These GHG reduction figures will likely change post construction, as they will show a total reduction based on the energy conservation measures working together.

energy audit to provide energy savings. Of all the ECMs that were identified to provide natural gas consumption reductions only the replacement of the windows, roof, building envelope, and installment of new shower fixtures were included in the project. The baseboard control valves, as well as the lighting and controls upgrades were the ECMs identified in the audit to provide electricity savings. Therefore, this figure does not include any potential natural gas or electricity savings for the MUA controls along with the bathroom and hood range fan upgrade with new in-suite HRV units that provide additional energy savings. This combination of measures will likely perform more efficiently than what the current anticipated GHG reduction is estimated at. The GHG reduction also includes other work done since 2005, including new boilers that were installed before the current project commenced.

Sunnyside Manor has an anticipated GHG reduction of **43%.** The audit did not include GHG emission reductions for certain ECMs including the interior lighting occupancy sensors, the heating plant replacement, or the new diesel generator.

Oppenheimer Lodge shows an estimated **45%** GHG emission reduction. The ECMs with the largest potential for natural gas savings were the window replacement, BAS re-commissioning, and the heating control upgrade. In 2018 there was a separate project to update the controls and lighting at Oppenheimer. This included a heating control upgrade and ventilation control upgrade. BC Housing does not have the utility data at this time for 2018/2019 as it is obtained annually.

Chimo Terrace's boiler was replaced in 2006, providing a natural gas consumption reduction of **90 GJ (1.6%) from a 2005 baseline**. The anticipated reduction of the ECMs for the current retrofit project shows an estimated GHG reduction of **46%** from the original 2005 baseline. The installation of DHW heat pumps and suite baseboard heating controls have the highest natural gas reduction potential.

barriers to retrofits

BC Housing has implemented many different strategies and combinations of technologies in their retrofit projects. These ECMs can be complicated to employ and have high costs associated due to the complexity of renovation projects. BC Housing renovation projects must occur with tenants still residing in the building. The team must post notices for noise that will occur and build temporary exterior walls for building envelope retrofit projects. This can impact the schedule of the project and the planning process. The case studies of the following projects define similar issues that arise during the energy audit, the development stage, and on site during the construction process. The ECM's that had common issues throughout the project were in regard to building envelope and heat pump fuel-switching retrofits.

BUILDING COMPLEXITY

The existing building system defines the boundaries and structure that all ECMs must work within. This includes the existing building construction materials, program arrangement, the interior floor level ceiling heights, corridor width, and site area used for preparation and material storage during construction.

BUILDING ENVELOPE

Some municipal government bylaws mandate the building image of a particular neighbourhood, this can limit the potential for re-cladding projects that drastically change the look of the building. It can also cause a delay in acquiring a building permit from the authority having jurisdiction.

The integrity of the building envelope varies depending on what constraints the existing building has to work within. Complex geometries limit the effectiveness and feasibility of a building envelope retrofit. The addition of insulation on the exterior may increase the weight of the wall assembly. Structural testing must be done to ensure that the existing wall assembly can support the additional weight, or else upgrades must be made. If so, there will be increased costs and the projects feasibility should be reconsidered.

Thermal bridging is a large concern for the efficiency of a building envelope. Many BC Housing high rise apartment buildings were built in a similar time period and are constructed of site cast concrete, with exposed concrete and continuous floor slabs and balconies. This is a difficult condition to retrofit and the renovation cost may not outweigh the GHG savings. For additional insulation projects, the exterior insulation should be continuous. Boards should be extended a minimum of 600mm below grade[13] and extend out from foundations. To achieve this the process would have to include the excavation of the surrounding ground to expose foundation walls and footings, having high associated costs. This approach is not often used.

Roofs do not pose as many issues, since they often follow a similar construction and have the structural capacity to support the additional weight of exterior insulation. Flat roofs are designed with parapets that follow the minimum height requirement of the national and provincial building codes. In some cases, increasing the exterior insulation on the roof level may reduce this height and require an increased height of the parapet. This would require re-cladding and flashing of the parapet wall and may not be cost effective. In these cases, less insulation is applied to the exterior, reducing the overall thermal resistance of the roof.

Heat Pump Fuel Switch

Typical commercial heat pumps require large amounts of energy and may require additional electrical upgrades to the services. For Part 3 buildings, multiple residential size heat pumps may be used as a primary measure with existing DHW supply to be used with increased heating demands. During the winter months or at temperatures below the specified product operation temperature, the control valves will trigger the use of the existing DHW system. This approach can also be applied for climate regions outside of the Lower Mainland. As stated earlier, the current heat pump technology can operate up to -5°C.

13 BC Housing Management Commission, *Design Guidelines and Construction Standards*, 155.

This limits the adaption of heat pump fuel switch projects in Northern climate regions within British Columbia. The geographic condition and climate of a site can dictate the feasibility of a heat pump fuel switch project.The sizing and location to put air or ground source heat pumps must be properly analyzed during the energy audit and design proposal stage of the project. Site sizes are restricted and may not allow for the required heat pump size and quantity within the maximum distance from the DHW tanks as required for certain models. The design team must ensure that all specifications for the heat pump model used in the design are met and considered early in the project.

Net Present Value → Payback from Energy Savings

Within retrofit projects, budgets increase with change orders and unexpected costs. Because of this, certain ECMs may be re-evaluated to determine their necessity in the project's scope or where costly strategies and materials can be minimized. For the ECMs to be identified as feasible for the project, the performance of the ECM must outweigh the cost of the measure.

Grandview Terrace Example:
The original scope includes 6" of exterior insulation to be added to all buildings. In the townhouse buildings, the team decided to reduce the exterior insulation to 4" in the front and back exterior walls. In these buildings the desired R-value and energy performance did not outweigh the costs. The thermal resistance and energy efficiency of the exterior wall does not significantly increase past 4" of added exterior insulation. The costs for additional insulation are higher than the potential energy savings.

Funding / Planning Process

BC Housing is constantly re-evaluating their process for renovation projects. That includes coordinating many departments to improve the success of all future projects. Projects would previously be identified for renovation if the physical building or its equipment required maintenance or replacement. The BC Housing Energy Team prioritizes the energy audits for retrofit projects that are identified to have a minimum GHG reduction potential of 25 tCO_2e. With the Clean BC requirement for all public buildings to reduce emissions by 50% by 2030, BC Housing is now initiating projects that require retrofitting existing technologies or building envelope replacements to reduce GHG emissions. This has caused the BC Housing Energy Team to have energy audits done for all proposed projects. This process is still ongoing. This is intended to occur prior to an RFP for any building renovation project, so that potential ECMs are identified and included in the initial scope of work and capital planning budget.

ECM SELECTION TOOL

The Energy Management Team has compiled data from previous projects and their Energy Incentive programs to create a list of ECMs with their anticipative costs that include the following:

1. Energy Audit | Based on an Estimated Average Cost / square ft, Total Cost
2. Cold Water Rinse Laundry | Based on an Estimated Average Cost per Suite , Total Cost
3. Low Flow water fixtures | Based on an Estimated Average Cost per Suite, Total Cost
4. DHW Heat Recovery | Based on an Estimated Average Cost per Suite, Total Cost
5. DHW preheat with Heat Pumps | Based on an Estimated Average Cost per Suite, Total Cost
6. Heating Plant Upgrade | Based on an Estimated Average Cost / square ft, Incremental Cost
7. Optimize Boiler Plant Control, Total Cost
8. Building Automation System | Based on an Estimated Average Cost per Suite, Total Cost
9. Weather Strip and Air Seal the Building | Based on an Estimated Average Cost per Suite, Total Cost
10. Increased Window Thermal Performance | Based on an Estimated Average Cost / square ft, Incremental Cost
11. External Insulation on Walls | Based on an Estimated Average Cost / square ft, Incremental Cost
12. External Insulation on Roof | Based on an Estimated Average Cost / square ft, Incremental Cost
13. Lighting and Controls | Based on an Estimated Average Cost / square ft, Total Cost

These measures are considered for each renovation project and approved by the Energy Management and Capital Planning departments. The costing for each measure is taken from previous retrofit projects. This uses an additive approach to budgeting and does not include all labour and site preparation costs required for the installation of measures.

CONSTRUCTION INDUSTRY

In many of the case studies seen, BC Housing depends on the integrity, timeline, and thoroughness of all consultants involved in the project. It is very easy for high cost issues to be overlooked. This can happen in many different ways, including inaccurate measuring of existing energy use to size or design of the mechanical system upgrades and consultants not being diligent in their initial physical building assessments / testing.

Example: Chimo Terrace
The ceiling physical test was not thorough on the ground floor. Even though consultants tested the ceiling construction, they did not account for the structural joists and conduit that could affect (and is affecting) the design approach for the hallway ventilation units.

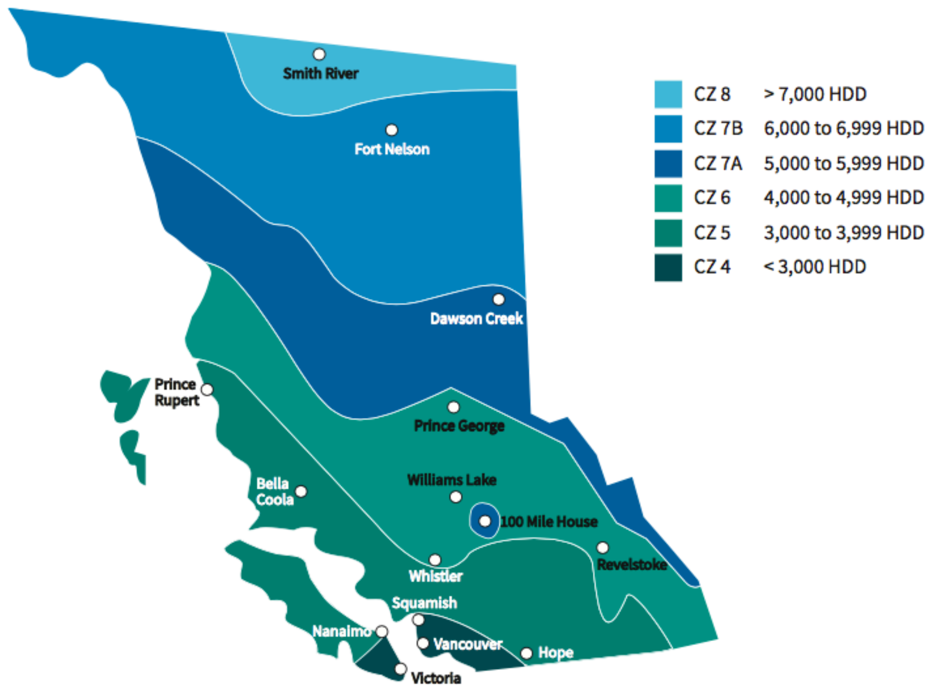


Figure 10. BC Housing Management Commission, Design Guidelines and Construction Standards, *British Columbia Climate Zones*

CLIMATE ADAPTABILITY

Retrofit projects are limited in their capacity to integrate passive design strategies. Since their position and primary construction materials are fixed, they can only respond to additive strategies. This can include the integration of natural ventilation, thermal mass and solar shading to limit the solar heat gain in the building and reduce cooling loads.

Reduce Solar Gains (South and West Façade)

Reducing the solar gains on a building façade and in the interior of the building can reduce the cooling demand of the space. This can be done by integrating shade devices on the building façade. The following approaches can be applied for retrofit projects.

1 Light shelf:
Reflects light into the space on the ceiling. Limits the thermal retention of solar heat on floor materials.

2 Horizontal + Vertical Fins:
The addition of exterior vertical (East / West facing facades) or horizontal fins as shading devices (South facing facades) help control the direct light entering the building.

3 Natural Ventilation:
In larger interior spaces that have multiple exterior walls, natural ventilation can be used to circulate cooler air into the space, reducing cooling loads. This is not feasible for apartment buildings, as there is limited open interior space and they primarily consist of private units.

4 Creating Obstructions
Planting trees or other vegetation strategically to block the sun's rays, can help promote cooler interior environments, as well as create more shaded exterior space. Deciduous trees will lose their leaves in the winter months, when cooling is not required, allowing the solar gains in the building and potential thermal mass for the concrete structures.

ENCOURAGE THERMAL MASS

Trombe Wall

It is a passive heat building method. A trombe wall is an outer layer of glazing or transparent material to create a cavity layer between that outer material and the existing exterior wall. The transparent material allows the sun to penetrate the cavity and heat the air and building material, utilizing thermal mass. The trombe wall should be applied to the winter sun building elevation.

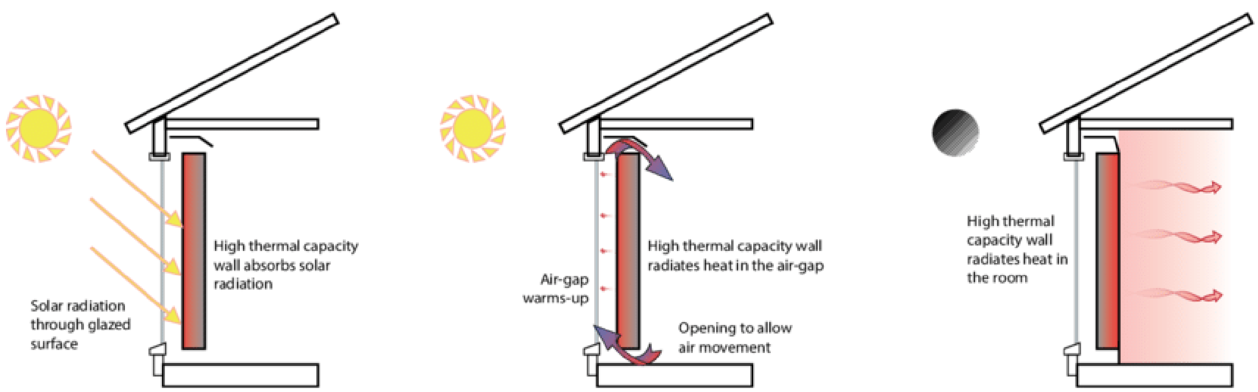


Figure 11. Trombe Wall concept diagram. The left image describes the absorption of solar heat on the interior concrete wall. The middle image shows how during the summer months, natural ventilation can be encouraged through the system. The right image is the nighttime condition where the thermal mass emits heat into the space.

SOLAR ENERGY

There may be potential for solar panels to be integrated into the building. Solar technology could be considered as part of the building envelope renovation projects and could be achieved by the addition of photo-voltaic panels or materials. Integrating solar technology could alleviate the increased electrical requirements of a building when fuel switching from natural gas boilers to electric domestic water heat pumps or when fuel switching to air source heat pumps. In the Vancouver Lower Mainland climate region this approach cannot provide a significant amount of solar energy during the winter season, when the heat pumps electricity demand is at its highest. Although, solar panels when active can contribute to the electrical supply for the building for lighting, ventilation and domestic use that occurs throughout the year.

Located across the electrical grid, "placed close to the loads for which they provide for"[14] This includes Solar PV, rooftop solar arrays, building integrated photovoltaic, on-site ground-mounted solar arrays, and community solar.

Nanogrids
These are often residential scale and for single-buildings. They are "local electrical grids that use distributed generation and include sophisticated controls and battery storage."[15] This includes Solar PV, rooftop solar arrays, building integrated photovoltaics, on-site ground-mounted solar arrays, and community solar. "Nanogrids and microgrids are connected to the larger electrical grid at a point of common coupling that maintains voltage at the same level as the main grid and aligns frequency unless there is a reason to disconnect (e.g., outage or need to control electricity flowing back onto the grid.) A switch can separate the nanogrid or microgrid from the main grid automatically or manually, and the smaller grid then functions independently as an island (called 'islanding'.)"[16]

MINIMIZED EMBODIED ENERGY

Embodied energy is the energy used for the operation and construction of a building. This includes the materials and processes used for construction and renovation. The use of recycled products in all construction projects reduces the overall embodied energy of a building. For retrofit projects, the material with the highest embodied energy is the rigid insulation used for building envelope retrofits and refrigerants in certain heat pump models. Design teams should use C02 heat pumps, when possible.

During construction the use of clean energy powered tools should be explored, rather than using a fossil fuel energy source. The potential for designing for disassembly to re-use building materials and products is limited within renovation projects. This is most applicable in building envelope projects, by using pre-fabricated or modular panel systems where possible that can be disassembled and re-used.

In reviewing this report, it is evident that building retrofit projects must navigate

14 ASHRAE, *Building Our New Energy Future*, 11.
15 Ibid.
16 Ibid.

complexity, innovation, and financial difficulties during every phase of the project. The exercise of compiling data used in this report reinforces the difficult nature of quantifying the energy savings potential for these renovation projects. Non-Profit Organization operated buildings often do not provide their utility data to BC Housing, therefore existing energy usage for those buildings is only acquired through the energy audit completed by a consultant. The way in which consultants quantify the energy savings may differ for each project and may reflect the overall savings for an individual building or an entire site, as seen in the Chimo Terrace project where two buildings expand over two separate lots and do not share any services. Grandview Terrace also shared an entire block site, but these six individual buildings shared services including their heating and electrical supply.

Not all ECMs may be economically feasible for a building. Once a project's retrofit costs exceed a certain dollar amount per residential unit, the project becomes unfeasible as a retrofit. Demolishing and new construction are then considered through a business case comparison. BC Housing is in the unique position where demolition and rebuild projects are not feasible, due to the Province's social housing crisis. They are currently being funded by new build programs such as the Building BC: Supportive Housing Fund and Community Housing Fund to build thousands of new residential units throughout the Province.[17] Therefore the displacement of current tenants, as well as the project design and construction time to rebuild a structure on the same lot is not an option. To meet their housing targets, BC Housing must improve every building possible, in addition to new build projects.

STEP CODE CONSIDERATIONS

The existing building creates many limitations to the ECMs that can be implemented in a building renovation project. Therefore, not every building is able to follow an optimal path to energy consumption reductions. The current BC Step Code requires a maximum equipment and systems **TEUI of 130 kWh/(m^2•year) for Part 3 New Construction** buildings in **Climate Zone 4**. This climate zone includes Vancouver and the Lower Mainland region, where the buildings explored in this projects case studies are located.

Requirements For Part 3 Residential Buildings Located In Climate Zone 4 (see page 37)
(Based on BCBC Table 10.2.3.3.A)

	Equipment & Systems TEUI (kWh/(m^2·year))	Building Enclosure TEDI (kWh/(m^2·year))
STEP 1	Conform to Part 8 of the NECB	
STEP 2	130	45
STEP 3	120	30
STEP 4*	100	15

* Solutions to the Upper Steps will be included in a later versions of this guide.

Figure 12.
BC Energy Step Code Design Guidelines, Part 3 New Construction Part 3 Buildings Requirements Table.

17 Municipal Affairs, *B.C. Government Addressing Housing Affordability Challenges.*

The results of the case studies comparison are quantified by comparing the existing building site energy usage (kWh) and the anticipated total reductions, with the application of ECMs to determine an anticipated TEUI (kWh/m^2*year) in each building post construction. These results are limited by the information provided through the energy audits, they do not include energy reductions for all of the ECMs included in the projects scope of work and the anticipated TEUI is used only as a comparative tool.

STEP CODE				
Project	Grandview Terrace	Sunnyside Manor	Oppenheimer Lodge	Chimo Terrace
Location (Step Code Region)	4	4	4	4
Units	154	61	147	82
Property GFA - m2	13199	4816	3346	5948
Building Tpye	Part 3	Part 3	Part 3	Part 3
Exsting Building Natural Gas Use (kWh)	3130452.4	1357668.6	1914169	1524337.9
Total Building Electricty Use (kWh)	675,579	352,980	430,835	271,720
Total Projected Energy Reductions	-581854	-489280	-747820	-489280
Total Projected Site Energy Use after Retrofits (kWh)	3224177.4	1221368.6	1597184	1306777.9
Project Site TEUI (kWh/m2 * year)	**244.3**	**253.6**	**477.3**	**219.7**

Figure 11. Case Study Energy Reduction Comparison, projected annual energy use, after ECM retrofits, compared to the Step Code requirements for Lower Mainland (Climate Zone 4)

None of the case studies are able to meet the current BC Energy Step Code new construction targets. The table below shows a range of **57-130 kWh/m^2*year higher TEUI than the maximum Step Code Level 2 building TEUI**. This shows that retrofit projects such as Grandview Terrace, that include substantial building envelope and ventilation upgrades may still using up to twice as much energy as the current targets. Therefore, if the Province of British Columbia includes renovation projects in the future editions of the BC Energy Step Code, they will have to significantly reduce the targets for Part 3 Building retrofit projects in the Lower Mainland. Projects in other climate zones were not included in this analysis, but it can be expected that those climates will have similar results and difficulty reaching the current new construction targets for their respective climate zones.

RECOMMENDATIONS

PLANNING PROCESS

Through this project it is evident that BC Housing is working diligently to incorporate ECMs into all renovation projects. They are working to find economical and effective strategies to achieve the 50% GHG reductions required by Clean BC. Part of this initiative has been to integrate energy audits into the early stages of the project. This must continue to result in reduced energy consumption in renovation projects.

It is stated in the *BC Housing Design Guidelines and Construction Standards* that an Energy Audit is required to be submitted prior to construction stage for all renovation and conservation projects. If the audit is only completed during this stage of the project, it limits the ability for the design team and BC Housing to respond to the issues identified in the energy audit if they go beyond the original project scope. It also allows for the design to be completed without thoroughly investigated potential ECMs that could be implemented in the building. The current efforts to have Energy Audits completed prior to the initial Capital Planning phase is important for the success of the renovation project.

The *BC Housing Design Guidelines and Construction Standards* may consider using the Energy team's approach as a model for the guidelines, to ensure that energy audits are submitted prior to the projects scope of work is defined or during the design stage. This way the audits can identify the primary Energy Conservation Measures that can be implemented in the building and their associated costs so they can be included in the budget capital planning prepares prior to the beginning of the project initiation.

The energy audits being completed for all existing buildings are currently ASHRAE Level I or Level II. For projects considered by Capital Planning for renovation, there should be an increased requirement prior to the budget approval process to minimum ASHRAE Level II (for low rise apartment projects) and Level III (for high rise apartment projects.) ASHRAE Level II Audits provide lots of information and more exploration of a building's existing architectural, mechanical, and ventilation systems. The measures and calculations created are limited in the fact that they are summarized as an additive sum of GHG reductions and energy consumption. They do not combine and measure the cumulative effects of measures as they work together (e.g. building envelope + DHW Heat Pump.) ASHRAE Level III Audits require a building model to be completed and apply measures to see more accurate computer-generated results that respond to the existing building form, member sizes, etc. There is a significant difference in the thoroughness of an energy audit due to the inclusion of digital modeling of the existing building and mechanical systems, that include direct environmental pressures and climate zones. This is more effective to properly plan and budget for the ECMs required.

BC Housing could consider more invasive physical testing during the same stage of the project. This would help to identify any discrepancies between existing systems, the proposed energy conservation measures and products. This will help limit project delays or additional scope of work to the renovation project during the design development and construction phases.

Passive Strategies

The potential to incorporate passive strategies is limited by the existing building design and building orientation. Additive options could be considered to reduce the heating and cooling loads on a building. BC Housing could consider including vegetation, solar reflective window coatings and solar shading to mitigate the cooling loads for the summer months.

There is also the potential to consider integrating the use of photovoltaic materials or panels for roof and building envelope retrofit projects. The building envelope projects could anticipate the advancement of photovoltaic technology and be designed for the potential of connecting photovoltaics to the cladding system in the future. Solar panels should be considered if there is an increase in electrical capacity on the building.

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BC HOUSING RESEARCH LIBRARY

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2. Energy Consumption in Low-Rise Multi-Family Residential Buildings in British Columbia | https://www.bchousing.org/research-centre/library/building-science-reports/low-rise-energy-study&sortType=sortByDate
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5. Greenhouse Gas Implications of HVAC Upgrades | https://www.bchousing.org/research-centre/library/technical/building-science-reports/greenhouse-gas-implications&sortType=sortByDate
6. Wall Air Barrier Reference Sheet | https://www.bchousing.org/research-centre/library/residential-design-construction/wall-air-barrier-reference-sheet&sortType=sortByDate

glossary of terms

Airtightness
Measured in Air changes/hour (ACH), or "the air leakage rate is measured per unit of envelope area and expressed as L/s·m2 at 75 Pascals pressure differential." (BC Energy Step Code Design Guide)

Coefficient of Performance
The output of heat relative to the electricity consumption of an equipment.

Energy Conservation Measures (ECM)
An ECM is any type of project conducted or technology applied to reduce to energy consumption in a building.

Fenestration
All areas (including the frames) in the building envelope that let in light, including windows, plastic panels, clerestories, skylights, doors that are more than one-half glass, and glass block walls.

GHGI - Greenhouse Gas Intensity
kg CO2/m2/year
"GHGI is a measure of the emissions intensity of a building's emissions, measured and expressed in tonnes or kilograms of carbon dioxide equivalent per unit area over the course of a year (kg CO2/m2/year.)"

Heating degree-days
A measure of the severity of the weather. One degree-day is counted for every degree that the average daily temperature is below the base temperature of 18°C. For example, if the average temperature on a particular day was 12°C, six degree-days would be credited to that day. The annual total is calculated by simply adding the daily totals.

Site Energy
Site Energy is the annual amount of all the energy your property consumes onsite, as reported on your utility bills. Use Site Energy to understand how the energy use for an individual property has changed over time.

Source Energy Use
The total amount of raw fuel that is required to operate your property. In addition to what the property consumes on-site, source energy includes losses that take place during generation, transmission, and distribution of the energy, thereby enabling a complete assessment of energy consumption resulting from building operations. For this reason, Source EUI is the best way to quantify the energy performance of commercial buildings

Source EUI
The Source Energy Use divided by the property square foot.
Water/Wastewater Source EUI – For Water and Wastewater treatment plants, this metric is the Source Energy Use divided by the total average flow through the plant.

TEDI - Thermal Energy Demand Intensity
kWh/M2-a
"Measure of the total heating energy necessary to maintain a comfortable indoor air temperature over the course of a year, measured and expressed in kWh/m2/year. The metric considers both passive gains (e.g. incoming solar radiation, heat generated by indoor appliances) and losses (e.g. heat losses through the building envelope), as well as any energy needed to mechanically heat a building or warm incoming ventilation air." (*BC Energy Step Code Design Guide*)

TEUI - Total energy Use Intensity
kWh/m2-a
"Measure of the total amount of energy a building uses over the course of a year, per unit of building area. The metric considers all energy used in a building, including plug loads (e.g. lighting, appliances) and process loads (e.g. elevators, mechanical systems, fans.) Like TEDI, TEUI is measured and expressed in kWh/m2/year." (*BC Energy Step Code Design Guide*)

Grandview			
Total GHG Emissions (Metric Tonnes CO2e)	**2012 Baseline (Portfolio Manager)**	**2012 Baseline (Portfolio Manager)**	GHG (tonnes)
Natural Gas	49.9 kg CO2e / GJ	8832	440716.8
Electricity	2.96 kg CO2e / GJ	2,431	7194.4
Total Metric Tonnes CO2e			447.9
Energy Conservation Measures	**Natural Gas Savings (GJ)**	**Electricty Savings (kWh)**	**GHG Savings (tonnes)**
Window Upgrade	1050		
Roof Replacement			
Building Envelope Upgrade	287		14
MUA Controls			
Bathroom + Hood Range Exhaust Fan Upgrades			
Heating Element Replacement			
Baseboard Heater + Control valve		10200	
In-suite HRV			
Install Low Flow Shower Heads	756		
Lighting Upgrade - Common Areas		26,400	0.3
Lighting Control Update		280	0
Total Annual Savings	2093	36,880	14.3
Total TEUI Savings kWh	581854		

Sunnyside			
Total GHG Emissions (Metric Tonnes CO2e)	**2005 Baseline (Portfolio Manager)**	**2005 Baseline (Portfolio Manager)**	GHG (tonnes)
Natural Gas	49.9 kg CO2e / GJ	4,884	243696.6
Electricity	2.96 kg CO2e / GJ	1,271	3762.2
Total Metric Tonnes CO2e			247.5
Energy Conservation Measures	**Natural Gas Savings (GJ)**	**Electricty Savings (kWh)**	**GHG Savings (tonnes)**
Building Envelope Upgrade	1178	2224	59.4
Air sourced Heat Pump	418	-75894	19.8
ASP Corridor Ventilation	109	-15012	5.2
Interior Lighting Occupancy Sensors		1668	
Common Area Lighting Upgrades		23074	0.3
Heating Plant Replacement	451	278	22.7
New Dieseil Generator			
Total Annual Savings	**2156**	**-63662**	**107.4**
Total TEUI Savings kWh	599368		

Chimo Terrace			
Total GHG Emissions (Metric Tonnes CO2e)	**2005 Baseline (Portfolio Manager)**	**2005 Baseline (Portfolio Manager)**	GHG (tonnes)
Natural Gas	49.9 kg CO2e / GJ	5731.9	286022.8
Electricity	2.96 kg CO2e / GJ	978	2895.4
Total Metric Tonnes CO2e			288.9
2006 Boiler Reduction I Chimo	Building A	Building B	
Natural Gas Consumption	3129.8	2512.1	**5641.9**
Reduction %		4506.7	**-1.57%**
Energy Conservation Measures	**Natural Gas Savings (GJ)**	**Electricty Savings (kWh)**	**GHG Savings (tonnes)**
Window Replacement			
Sliding Door Replacement			
DHW Heat Pumps	1270	-74700	62.4
Boiler Control Upgrade	270	100	13.4
Suite Baseboard Heating Controls	450		22.4
Hallway Ventilation upgrade	380	13500	19
Suite / Bathroom Fan Upgrades			
Exhuast Fan Timer (In Suite)	320		15.9
Total Annual Savings	**2690**	**-61100**	**133.1**
Total TEUI Savings kWh	747820		

Oppenheimer			
Total GHG Emissions (Metric Tonnes CO2e)	**2005 Baseline (Portfolio Manager)**	**2005 Baseline (Portfolio Manager)**	GHG (tonnes)
Natural Gas	49.9 kg CO2e / GJ	3,887	193961.3
Electricity	2.96 kg CO2e / GJ	156	462.0
Total Metric Tonnes CO2e			194.4
Energy Conservation Measures	**Natural Gas Savings (GJ)**	**Electricty Savings (kWh)**	**GHG Savings (tonnes)**
Window Replacement	610	10000	30.4
Roof Upgrade	50	800	2.5
2018			
Ventilation Control Upgrade	120	1500	6
BAS Re-Comissioning	490	2000	24.4
Heating Control Upgrade	490		24.4
Total Annual Savings	**1760**	**14300**	**87.7**
Total TEUI Savings kWh	489280		

The Energy Audit Measures show only the Energy Conservation Measures that are included In the project's final scope of work
Energy Audits re extimated for each building individually