Developing Low Cost Strategies to Achieve Step Code Compliance in Affordable Housing

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August 2019

This report was produced as part of the UBC Sustainability Scholars Program, a partnership between the University of British Columbia and various local governments and organizations in support of providing graduate students with opportunities to do applied research on projects that advance sustainability across the region.

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

Acknowledgments

The author would like to thank the following individuals for their contribution, feedback, and support throughout this project.

Bill MacKinnon | Senior Manager | Energy & Sustainability | BC Housing

Mercedes Lopez | Senior Manager | Construction Services | BC Housing

Sadia Afrin | Manager | Commissioning | BC Housing

Fabian Navarro | Energy Specialist | BC Housing

Kira Pederson | Project Technologist | Asset Strategies | BC Housing

Steven Chan | Senior Technical Officer | Development Strategies | BC Housing

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Cover photo: The Little Mountain Modular Home | Step Code level 3 Compliant | Vancouver, BC | BC Housing

Photo credit: Hamid Karimi

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Executive Summary

Finding the unique most cost-effective solution to meet the BC Energy Step Code requirements is not an easy or straight forward task as the standard is an open platform for design teams, builders and contractors to improvise, innovate and create systems which can perform well enough to meet the energy efficiency targets and successfully pass the energy modeling analysis.

But what is easy and straight forward is understanding the fact that no matter how much the compliance incremental cost is, it will not be more than 10% but will likely be less than 3% and will result in better quality, higher-performing, more durable, climate-resilient and more comfortable building. This is all about better engineering fighting against the routine status quo!

The 2018 cost Metric Research Report has identified the incremental cost of Energy Step Code compliance to be less than 3% for complying to step 3 and 4 in climate zone 4 and 5 in British Columbia and BC Housing's actual completed modular home project, complying to step code 3 shows a 7.2% incremental capital cost. A discrepancy between what it cost and what it should cost is possibly due to lack of experience, availability of material, inexperienced manpower and probable lack of direct financial motivation.

Implementation of the BC Energy Step Code standard will take reasonable amount of time to be adopted, adjusted and populated as the mainstream. Meanwhile, the champions, early adopters and innovators are volunteering to pilot the standard and trying hard to lower the incremental cost as the implementation process proceeds further.

BC Housing has been a leader in this regards by not only initiating multiple step code compliant projects, but also integrating the standard's requirements into their own Design Guideline and Construction Standards and has already completed a few projects and even taken a step further and initiated a few Passive House projects which are the ultimate target of BC Energy Step Code standard in the best performing case.

BC Housing's experience in designing step code compliant buildings has proved the possibility of achieving the stringent TEDI and TEUI targets through ambition, willpower, dedication, hard work and welcoming the newer technologies.

Their experience has also shed light on the path forward to complying with the step code requirements in a few important steps:

- Meeting the step code requirements in higher levels of the standard is not practical unless all of the passive measures such as building orientation, form, massing, continuous insulated envelope, high-quality windows, airtightness, thermal bridging prevention and heat recovery ventilation, are taken into account in a very early stage of the project design process.

- Implementing the envelope first policy will not only lower the long-term cost but also reduce the need for higher efficiency and more complex mechanical systems such as water source heat pump or VRF systems. BC Housing's record shows many projects have been meeting their TEUI targets using simpler systems such as electric baseboard heating, DX split units and even higher quality PTACs.
- Extra attention is needed to ensure that increasing insulation material does not unintentionally increase the embodied energy in the building and respectively raise the GHG emission indicators as BC Housing has specific targets on Green House Gas emission reduction.
- With the new requirement of maximum 20 hours of overheating in BC Housing projects, specific attention is required to implement passive and/or active cooling measures into the design in a very early stage to ensure the thermal comfort requirements of the building code and BC Housing are being met.

The purpose of this report is to initially provide enough background information about the BC Energy Step Code Standard as well as BC Housing's stance on the standard and sustainability in general. The report then continues further with three examples of BC Housing Energy Step Code compliant projects, their challenges and lessons learned. These projects are:

- 1st and Clark Residential and clinic project in Vancouver
- Rosewood Development project in the city of Surrey
- Little Mountain Modular affordable housing project in Vancouver

In conclusion, the report evaluates the energy conservation measures (ECMs) which can impact the energy efficiency of the building and support compliance with BC Energy Step Code and then cross-checks the ECMs with the associated incremental cost to help with prioritizing the available options to meet the Step Code requirements with the lowest cost.

Although the short history of the BC Energy Step Code standard and lack of mass information has obstructed the ability to have a precise breakdown of costing, an effort has been made to identify choose the measures which can improve TEDI and TEUI metrics while lowering the cost and maintaining the affordability.

Introduction

Scope of this report

For this report and since most of BC Housing projects are located within the southern part of the province and Vancouver Island, it was decided that the scope of this report will be limited to the new construction projects located in BC climate zone 4 and 5 only.

BC Energy Step Code

The Province of British Columbia has committed to take incremental steps to increase energy efficiency requirements in the BC Building Code to make buildings net-zero energy ready by 2032. The BC Energy Step Code which currently is a part of the BC Building Code has been developed to support that effort.

The BC Energy Step Code is a voluntary provincial standard enacted in April 2017 and provides an incremental and consistent approach to build higher energy-efficient buildings that go beyond the requirements of the base BC Building Code. It does so by establishing a series of measurable, performance-based energy-efficiency requirements for construction which designers, contractors, and builders can choose to build to. The Energy Step Code is a single provincial standard that replaces the patchwork of different green building standards which have been required or encouraged by local governments in the past. Communities and local governments may voluntarily choose to adopt the BC Energy Step Code Standard in bylaws and policies to improve energy efficiency and promote sustainability within their territories. At the time of this report, more than 40 local governments have already referenced this standard in their policies, bylaws or other formal procedures.[1]

Unlike previous standards, the BC Energy Step Code takes a performance-based approach rather than the traditional prescriptive approach. The BC Energy Step Code does not specify how to construct a building but identifies an energy-efficiency target that must be met and allows the designers and builders to decide on how to meet the requirements. To comply with the BC Energy Step Code, builders must use energy modeling software and on-site tests to demonstrate the compliance of both the design and the constructed building with the requirements of the BC

[1] Energy Step Code (n.d) Retrieved from https://energystepcode.ca/implementation_updates/

Energy Step Code. This approach allows the project team to pursue innovative, creative and cost-effective solutions and to incorporate leading-edge technologies as they become available.

BC Housing position on Energy Step Code

On a wider scope, BC Housing is committed to actively support the provincial government's actions leading to the creation of a low-carbon economy and a sustainable future. BC Housing is not only committed to meet the energy efficiency targets but also committed to reducing the greenhouse gas emissions from owned and leased buildings by 80% in 2050 relative to 2005 baseline. BC Housing's sustainability plan focuses on three strategic areas:

- Development of cutting-edge expertise in the delivery of sustainable social housing.
- Gaining recognition as a leader in sustainable social housing provision within the social housing sector and the construction industry.
- Establishing a best practice approach to integrate sustainability into all levels of decision making.

BC Housing's stance on the BC Energy Step Code is also very strong with a commitment defined in its Design Guideline's and Construction Standards for not only improving the energy performance targets of the buildings, but also improving indoor environmental quality, enhancing resource efficiency, reducing operation and maintenance costs as well as maintaining a sustainable procurement policy. In further advancing its sustainability leadership, BC Housing is requiring minimum energy performance targets for all its new projects to meet the Energy Step Code Standard based on the following order:

Part 3- Combustible Buildings Less than 7 Story

- Step 4 in climate zone 4
- Step 3 in climate zone 5
- Step 2 on climate zone 6,7 & 8

Part3- Non-Combustible Buildings 7 Story or Greater

- Step 3 in climate zone 4
- Step 2 in climate zone 5,6,7 & 8

Part 9

- Step 4 for all different climate zones in BC

Background and Literature Review

Multiple references have been used in this report. The following sections are an effort to provide sufficient background information to understand the report and the backbone behind it.

BC Energy Step Code metrics

TEDI & TEUI

As explained earlier, the BC Energy Step Code is a performance-based energy efficiency standard. This means the energy efficiency will be measured by a few metrics using energy modeling software for the proposed building. The two main metrics used by the Energy Step Code are known as TEDI and TEUI and they are defined in the Energy Step Code Standard website as following:

TEDI or "Thermal Energy Demand Intensity" is a metric of the annual heating required by the building for space conditioning and for conditioning of ventilation air, estimated by using an energy model, normalized per square metre of floor area of conditioned space and expressed in kWh/(m^2*year), taking into account all of the following:

- Thermal transmittance of above-ground walls and roof-ceiling assemblies
- Thermal transmittance of floors and walls in contact with the ground, or space that is not conditioned space
- Thermal transmittance and solar heat gain of windows, doors, and skylights
- Air leakage through the air barrier system
- Internal heat gains from occupants and equipment
- Heat recovery from exhaust ventilation

TEUI or "Total energy use intensity" is a metric of the energy used over a year by the building, estimated by using an energy model, normalized per square meter of the floor area of conditioned space and expressed in kWh/(m^2*year), for all of the followings combined:

- Space-heating equipment
- Space-cooling equipment
- Fans
- Interior and exterior lighting devices

- Service water heating equipment
- Pumps
- Auxiliary HVAC equipment
- Receptacle loads and miscellaneous equipment
- Appliances
- Elevators and escalators

Based on the BC Building Code, general book, here are the compliance requirements for TEDI and TEUI in different building applications:

10.2.3.3. Compliance Requirements: Buildings and major occupancies in Part 3 buildings conforming to the requirements of any of Steps 1 to 4 shall be designed and constructed to conform to the applicable energy performance requirements in Tables 10.2.3.3.A & 10.2.3.3.B[2]

Table 10.2.3.3.-A
Energy Performance Requirements for Residential Occupancies
Forming part of Sentences 10.2.3.3.(1) and (2)

Step	Hotels and Motels	Other Group C *Occupancies*	Hotels and Motels	Other Group C *Occupancies*
	Equipment and Systems – Maximum Total Energy Use Intensity, kWh/(m²•year)		*Building* Envelope – Maximum Thermal Energy Demand Intensity, kWh/(m²•year)	
1	Conform to Part 8 of the NECB			
2	170	130	30	45
3	140	120	20	30
4	120	100	15	15

Table 10.2.3.3.-B
Energy Performance Requirements for Business and Personal Services or Mercantile Occupancies
Forming part of Sentences 10.2.3.3.(1) and (2)

Step	Offices	Other Group D and E *Occupancies*	Offices	Other Group D and E *Occupancies*
	Equipment and Systems – Maximum Total Energy Use Intensity, kWh/(m²•year)		*Building* Envelope – Maximum Thermal Energy Demand Intensity, kWh/(m²•year)	
1	Conform to Part 8 of the NECB			
2	130	170	30	30
3	100	120	20	20

[2] Order of the Minister of Municipal Affairs and Housing, (2018), Building Act, Ministerial Order No. BA 2018 2

Airtightness in the building

Airtightness is an additional metric to TEDI and TEUI which needs to be met specifically in part 9 buildings complying with the Energy Step Code standard. Based on the BC Building Code, airtightness must be tested per Article 10.2.3.5 and comply with the following specific required measures in all part 9 buildings for Step Code 1 to 5.

Energy Step Code level	Airtightness Requirements for Buildings Located in climate zone 4* (Air Changes per Hour at 50 Pa Pressure Differential)	Airtightness Requirements for Buildings Located in climate zone 5** (Air Changes per Hour at 50 Pa Pressure Differential)
1	N/A	N/A
2	≤ 3.0	≤ 3.0
3	≤ 2.5	≤ 2.5
4	≤ 1.5	≤ 1.5
5	≤ 1.0	≤ 1.0

*Where the Degree-Days Below 18°C Value is less than 3000

**Where the Degree-Days Below 18°C Value is between 3000 to 3999

BC Housing Design Guidelines and Construction standards- Section 2

New construction energy performance requirements:

BC Housing's Design Guidelines and Construction Standards is a comprehensive document to define BC Housing's requirements for new construction and renovation projects. Section 2 of this guideline focuses on Energy and Environmental Design which specifically sets the path forward for energy step code compliance in new construction.
Based on this guideline, the building's energy and performance is required to comply with six main elements:

- ❖ All new BC Housing projects shall comply with different levels of energy step code based on type and climate zone to meet the defined minimum performance.
- ❖ The use of an energy modeling software and building envelope thermal bridging guide is mandatory to verify all energy targets.
- ❖ A thermal comfort evaluation is required for all passively cooled buildings as all BC Housing buildings are to be considered occupied by "Vulnerable Groups" and must adhere to the overheating hours limit specified in the City of Vancouver Energy Modeling Guidelines.

- It is required that the actual Envelope Air Leakage Rate shall be confirmed through mandatory testing performed following the requirements of the Provincial Energy Step Code.
- Interior Partitions Air Leakage Rate should be tested and reported demonstrating its compliance.
- Certified Passive House projects are encouraged as they exceed the above energy and airtightness targets, however it would still need to comply with the “vulnerable group” thermal comfort evaluation.

BC Housing’s Design Guidelines and Construction Standards have further requirements concerning energy efficiency:

Utilizing Passive Design Strategies

Passive design is an approach to building design that uses the building architecture to minimize energy consumption and improves thermal comfort. The building form and thermal performance of building elements including architectural, structural, envelope and mechanical elements are carefully considered and optimized for interaction with the local micro-climate.

In common practice, this is usually achieved through the optimization of the following aspects wherever and as much as its initially possible:

- Site and orientation
- Building shape and geometry
- Landscape
- Space planning
- Buffer spaces
- Solar shading
- Thermal resisting windows
- Continuous thermal insulation
- Air and moisture tightness
- Passive cooling

Using Energy Efficient Products

BC Housing is committed to achieving optimal energy performance on equipment and materials that are specified for new developments. BC Housing requires selecting energy-using equipment in consideration of its effect on the Energy Performance Target.

This must be considered specifically in the following aspects:

- Energy-efficient systems including Heating, Ventilation and Air conditioning
- Lighting system and fixtures
- Energy-efficient appliances

Intellectual Property

Developing this report was not possible without the valuable resources developed and made publicly available by multiple organizations. Their effort has significantly supported the implementation and popularity of the Energy Step Code Standard.

This report has used information in part and some in particular from the following resources:

- British Columbia Energy Step Code standard/ Government of BC website
- ORDER OF THE MINISTER OF MUNICIPAL AFFAIRS AND HOUSING, Building Act, Ministerial Order No. BA 2018 2
- BC Housing Design Guidelines and Construction Standards/ Section 2/ Sustainability
- BC Energy Step Code Design Guide
- BC Housing Energy Step Code Metric Research report/ 2018 Edition
- The Circular Economy in the build environment/ ARUP

Research Approach

The core of this report has been mostly defined by qualitative research using available records and information. The following steps have been taken to understand the problem and find the best possible solution. Although this list is not completely exhaustive and other actions have been taken as deemed necessary.

- Understanding the requirements of the BC Energy Step Code
- Understanding the requirements of BC housing for sustainability
- Researching the Cost Metric report
- Interviewing experts to get an independent third-party opinion
- Defining ARUP 7 S Model in a building
- Defining a list of energy conservation measures applied in design for new construction
- Evaluating the level of effectiveness for each energy conservation measure
- Evaluating the cost incremental of each measure
- Analyzing the simplicity, availability and passive functioning of these measures
- Cross-checking the effectiveness and cost increment of each measure on a priority table
- Proposing to draft a strategy to set the priorities on how to comply with energy step code on the lowest cost

Using the 7 S Model in listing the required actions

What is the 7 S Model?

"The concept of building in layers was first proposed by architect Frank Duffy in the 1970s and developed by Stuart Brand in the 1990s. Buildings, they said, are made of separate and interlinking layers, each with a different lifespan. Brand's widely-known model includes six layers: Site, Structure, Skin, Services, Space, and Stuff.

Figure 1 below illustrates how the layers model would function in the built environment context. An additional layer -System- has also been added to show how this approach would be applied beyond the scope of a building, for example in the context of a district or a city. Building in layers means that each element may easily be separated and removed. This facilitates reuse, remanufacture and recycling. For example, facades or heating systems may be designed and fitted as independent entities, integrated with other building systems but not entwined with the fabric of the building. This also avoids large scale wastage of assets, lowers resource use and other environmental impacts, and obviates the need to construct entirely new buildings and assets.

Building in separate layers, with different lifespan, also allows each element to be repaired, replaced, moved or adapted at different times without affecting the wider entity.” [3]

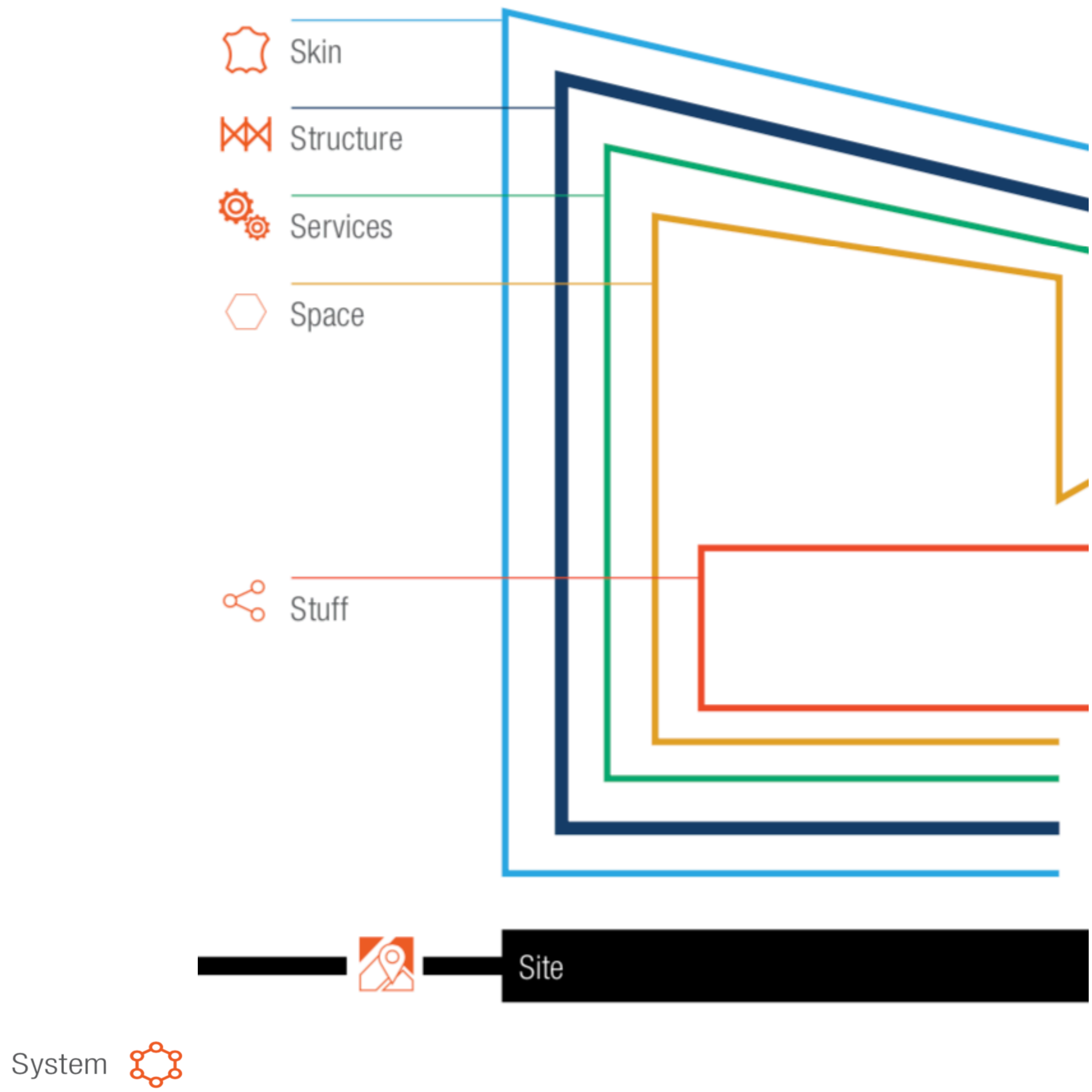


Figure 1- showing the schematic Layers of the building based on the ARUP 7 S Model

[3] ARUP Circular Economy Build Environment (2016) (p.62)

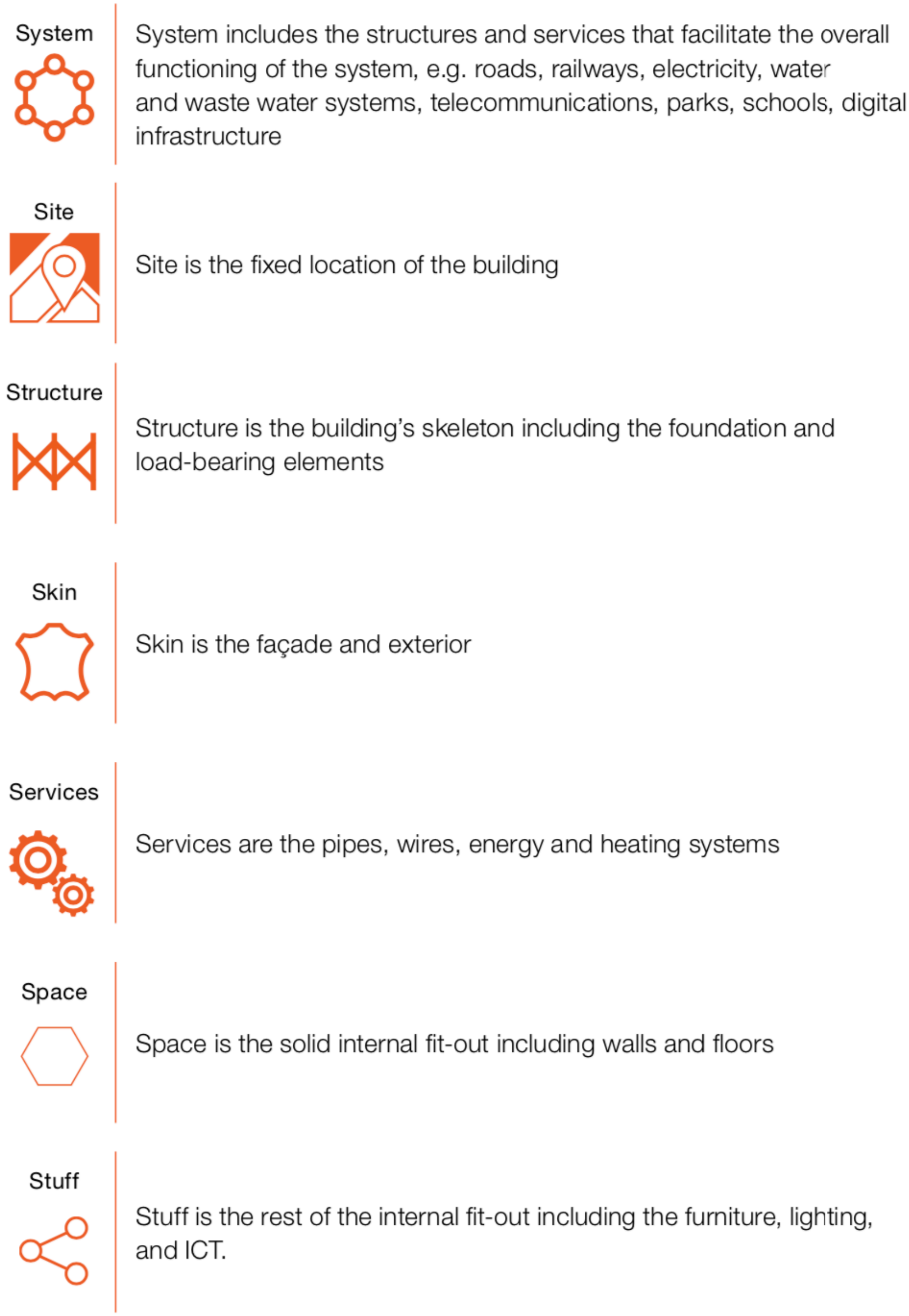


Figure 2- showing the definition of ARUP 7 S Model

Measures to be taken for complying with the BC Energy Step Code

The 7 S model is a very clean and clear way of looking at a building in multiple independent yet integrated layers and can be used as a lens for different applications. Although the Energy Step Code is a performance-based compliance standard and not a prescriptive one, but in reality and underlying the compliance, there are certain aspects of the building design and construction which helps improve the energy efficiency and building performance and their impact does affect the value of TEDI and TEUI and in some cases the airtightness.

Here we are trying to segregate such aspects based on the 7 S Model and analyze each impact as we go through the report:

1- **System** Although the system is considered as services and utilities ending to the building and not within the building, there are solutions that can directly impact the energy status of the building; A community based solar power plant is a good example of such solution. Theoretically a large portion of electrical energy is wasted in power transfer within the scale of the electrical grid. However, a local renewable-based power plant can cope with this problem by providing the possibility of connecting to a local microgrid and creating a power pool utilizing all the connected neighboring power generations. The produced energy in this method can be used in the building to offset any other non-renewable based source of power and support achieving the net-zero energy targets.

2- **Site** There are many effective energy conservation measures which can be taken on the site level:

2-1 Building orientation towards the sun: Building orientation can impact the solar gain in winter as well as summer and therefore affect the energy consumption of the building and the comfort level of the occupants. In general, south and west facing walls have a higher tendency of solar gain and proper orientation can benefit the sunlight during the heating season and avoid overheating during the summer.

2-2 Simple form, shape and unit density: Building sites are usually constrained by existing site conditions, setback requirements, lot size, and the existing street grid. However, limiting the building form to simple and less exposed vertical walls can lower the TEDI and affect meeting the step code targets.

A building with a lower vertical surface to floor area ratio (VFAR) has a lower overall potential for heat loss through the building envelope. On the other hand, the unit density can also affect energy efficiency as dense units will prevent exposing the external wall to unconditioned ambient and therefore improve energy efficiency.

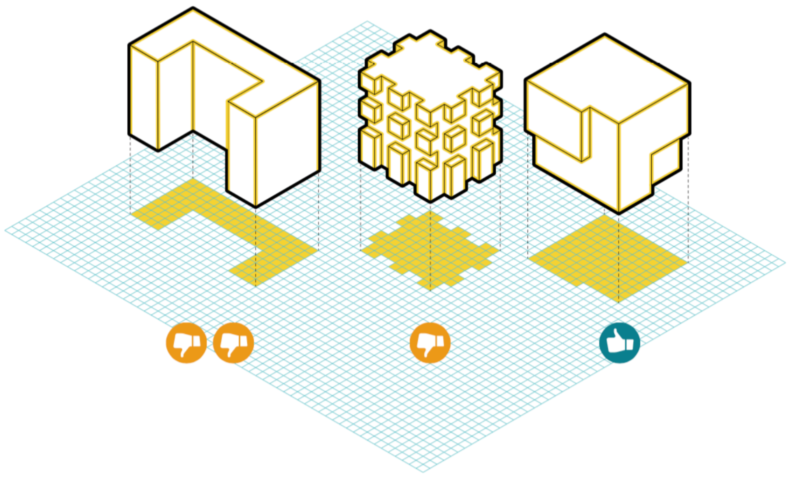


Figure 3- showing the importance of using lower VFAR in achieving TEDI targets, BC Energy Step Code Design Guide (Mar 2018) (p.29)

2-3 Landscaping as a thermal layer: Every building is generally located on its surrounding microclimate. Sun-facing walls, flat roofs, concrete material, other buildings' mass, and asphalt surfaces are examples of how the surroundings can contribute to heating or cooling a building. From avoiding the cold wind in winter to providing a cool breeze in summer, there are preventive actions that can passively improve the building energy consumption and support meeting Step Code metrics. Landscaping is an important part of this microclimate and building designers and landscape architects provide tall trees and shrubs on the south and west side of the building for shading and cooling the air for better natural ventilation during summer. Greening the roofs, walls and other surfaces will also help in absorbing the heat from sunlight and preventing the overheating hours in the building.

2-4 Energy oriented building layout: The layout of the building can also affect the energy consumption and meeting the Energy Step Code requirements in a building. Planning and locating spaces with specific requirements in their ideal thermal location in the building can reduce mechanical heating and cooling energy by taking advantage of the building's natural thermal response. Locating spaces with large internal heat gains such as commercial kitchens and administrative offices on the North or East facing side of the building is an example of such mindful layout.

3- Structure

3-1 Wood structure first: The materials used to design and build the main structure of a building has a fundamental impact on how much energy the building will use. Significant enough for BC Housing Design Guidelines and Construction Standards to define different desired Step Code levels for different structured buildings. Wood structure buildings in general, have a better thermal performance as opposed to concrete structures as wood has a lower thermal transmittance factor in comparison to concrete. British Columbia is a rich source of forestry and lumber and therefore a wood first envelope policy has been popular for a few years. Within the past few years wood structure technology has advanced in quality, the maximum number of floors, fire protection, and durability. Using wood will also impact the Green House Gas reduction as wood has a higher level of sequestrated carbon in comparison to concrete which has a high level of embodied carbon.

3-2 Enclosed balconies and space buffers: Enclosed balconies are a good example of buffer spaces. Integrating occupied buffer spaces such as corridors and entryways as transition space is beneficial as they can accept a wider thermal comfort range compared to the fully occupied spaces.

4- Skin

4-1 Continuous external insulation to prevent thermal bridging: Thermal bridging is an important source of heat loss in buildings and it is very difficult to meet the higher steps of the Energy Step Code if they are not eliminated. Although compact massing is the preliminary step in minimizing the number of junctions and articulations in the building façade, it is not the total solution to eliminate them. Therefore, designing continuous external insulation around the entire envelope and creating a barrier between the structural material and the building exterior is essential in meeting the Step Code requirements and must not be compromised.

4-2 Mounted Balconies: Balconies are another source of thermal bridging through connecting the load barrier slab of the balcony to the main floor of the building. This is an important matter and if the owners insist on having them, the designers must avoid thermal bridging by any of the common mounting systems to insulate the balcony floor from the rest of the building structural material.

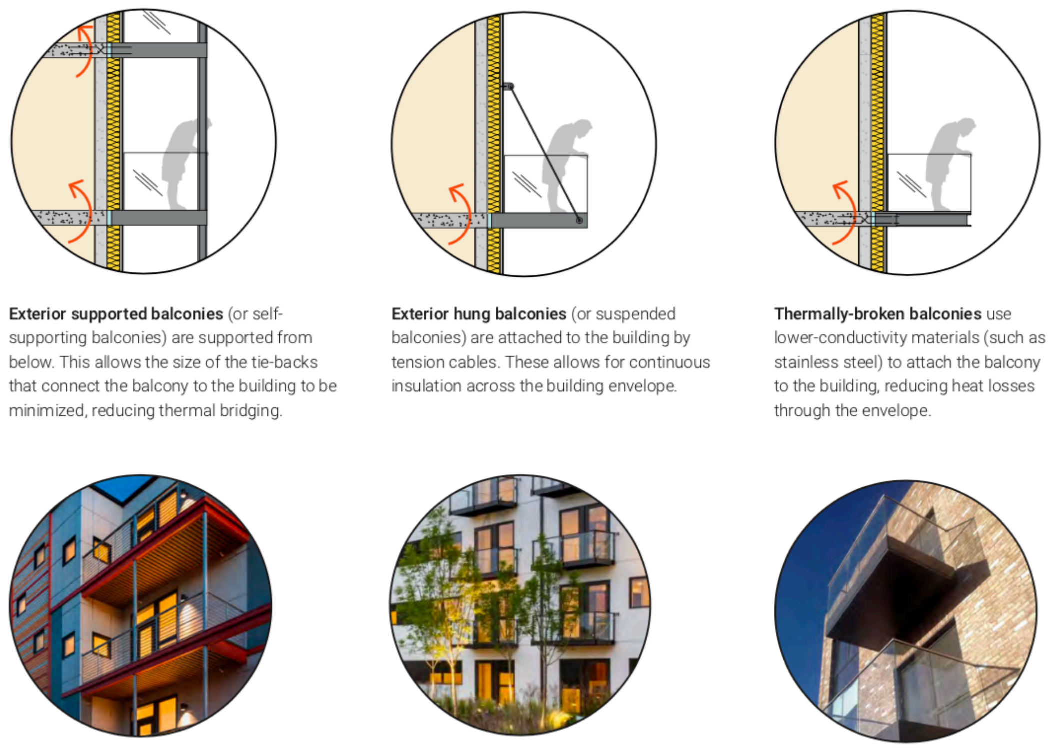


Figure 4- showing different mounted balcony system BC Energy Step Code Design Guide (Mar 2018) (p.34)

4-3 Higher thermal resisting roof and floor: Envelope first is a very important approach when it comes to improving the energy efficiency of the building and exposed floor and the roof assemblies are two of the main components of that matter. Having a higher R-value roof as well as insulated floor will largely prevent the heat transfer from the building and the unconditioned surrounding.

4-4 Higher thermal resisting windows and window covering: The U-value of the glazing selected for use in a building does have a significant impact on the ability of the building to achieve the performance targets of the BC Energy Step Code as windows are the weakest thermal component of the building envelope. Therefore, using a high-quality double or triple glazed window plays a very crucial role in meeting the Step Code requirements. The importance of using the right window does not stop at the U-value level and enough attention must also be paid to choosing the appropriate glass solar gain heat coefficient (SHGC), the material and assembly of the frame. The thermal bridging in mounting a window frame on the envelope also plays a key role in heat loss and attention to this matter is very important. Sometimes minimizing the number of large windows by combining them together can lower the amount of thermal bridging.

4-5 Lower window to wall ratio: It is important to remember that the highest thermal quality window will still perform like a lower thermal quality wall and therefore the number of windows in a building has a major role in meeting the Step Code requirements. This metric is usually measured by the window to wall ratio (WWR) and a common practice in climate zone 4 and 5 has proved that it will be very difficult to meet the step code requirements if the WWR is anything higher then 40% and therefore it is strongly suggested to consider lower WWR if the step code 4 is targeted for the building. The North facing windows are better in smaller sizes to prevent heat loss during the winter where the East facing windows are suggested to be larger to gain better daylight and reduce the lighting load.
As previously mentioned, the provision of solar heat gain on the South and West façade windows is more important. However, this needs to be adjusted and controlled by appropriate window coverings, blinds or external shading to adjust the glare and the amount of solar radiation.

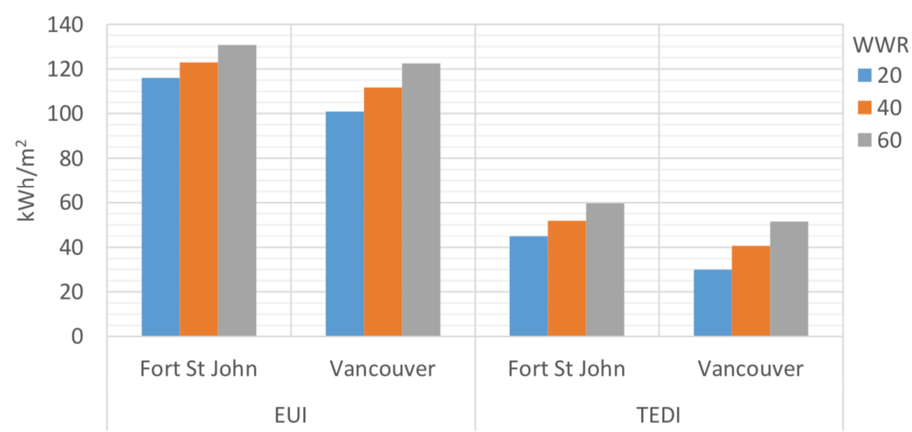


Figure 5- showing the average impact of WWR on TEDI and TEUI, Metric Research Report, (2018), (p.9)

4-6 Air and Moisture tightness: Although airtightness is not a direct requirement of the Energy Step Code standard for any of the part 3 buildings, the cost metric research analysis published by BC Housing defines that air and moisture tightness is one of the most cost-effective measures to improve the energy efficiency as well as improving the indoor environmental quality for the occupants. Tighter envelope prevents air, odor and moisture leak and prevents forming fungus and mildew in the building. Even though airtightness is required to be tested for the entire envelope, it is strongly advised to be measured and tested on every individual suit level as well. This is called compartmentalization and is a necessary step to make sure air quality and pest issues are not transferred from suite to suite. It also helps with ventilation system balancing.

4-7 Thoughtfully designed solar shading systems: The building orientation and windows have an important effect on how much solar heat gain and lighting the building will receive from the sunlight. The solar heat gain and the sunlight are both useful sources of energy and they reduce the energy consumption measures both for TEDI and TEUI, but the overheating and the glare can cause comfort problems during the summer and increase the load for cooling demand. Therefore, having a thoughtfully designed external solar shading system can minimize the negative effects while letting the benefits to continue.

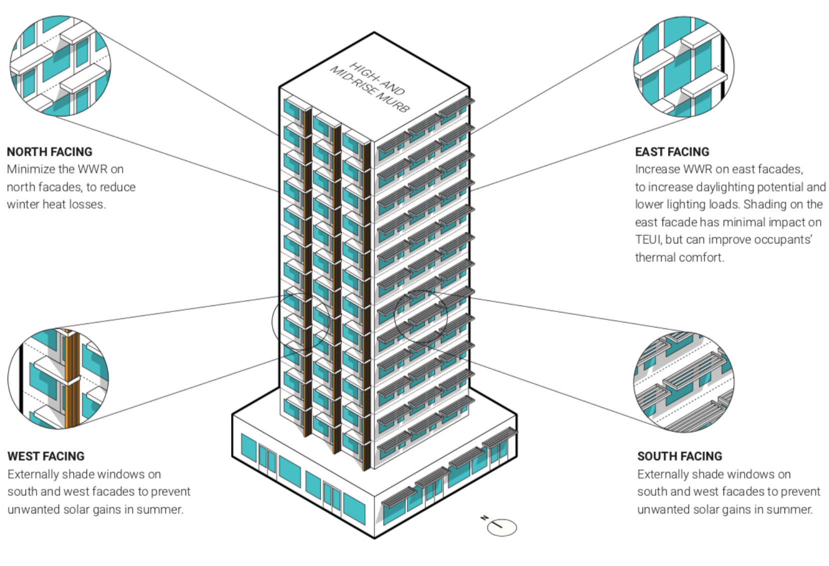


Figure 6- showing how different shading systems can impact energy efficiency, BC Energy Step Code Design Guide (Mar 2018) (p.29)

5- Services

5-1 Natural Ventilation: Natural ventilation is allowing the unconditioned outdoor air to ventilate the building to reduce the temperature, provide fresh air and generally improve the thermal comfort condition. This will consecutively reduce energy consumption and may make meeting the Energy Step Code requirements easier. Considering operable windows will allow the outdoor air inside through a full swing or tilt open window. Designing a larger opening window can allow more air to come in for enhanced ventilation if the building code requirement can be met. There are several other design features which can also improve the effectiveness of natural ventilation using:

- Creating cross-ventilation by designing windows in two opposite directions of the building.
- Using the buoyancy and stratification effect in design to direct warmer air outside the building from higher positions while letting the cooler air in from the lower positions.
- Using mechanical systems to flush out the warmer air during the night time when the outdoor air temperature is lower.
- Landscaping design next to the building is another way to make sure the intake air has a cooler temperature.

5-2 Heat Recovery Ventilation (HRV) with an economizer: Heat escaping through the exhaust air has a significant contribution to lowering the energy efficiency in the building. This is more important during the very cold or very hot months of the year when the building is conditioned as the temperature difference between indoor air of the conditioned building and outdoor air is quite noticeable. Achieving the higher levels of Energy Step Code in heating seasons is very difficult if the heat loss through the ventilation system is not accounted for. Therefore, having a heat/energy recovery ventilation system (HRV/ERV) is a huge support for compliance to the Energy Step Code.

If the building has been designed with passive cooling and natural ventilation only without an active mechanical cooling system, it will be necessary to choose an HRV with an economizer to be able to bypass the system during summer months to get the maximum cooling from the outdoor air. Designing the HRV system can be done on a suite level, floor level or the whole building depending on the balance between the airtightness, extra ducting and the cost and maintenance of multiple equipment.

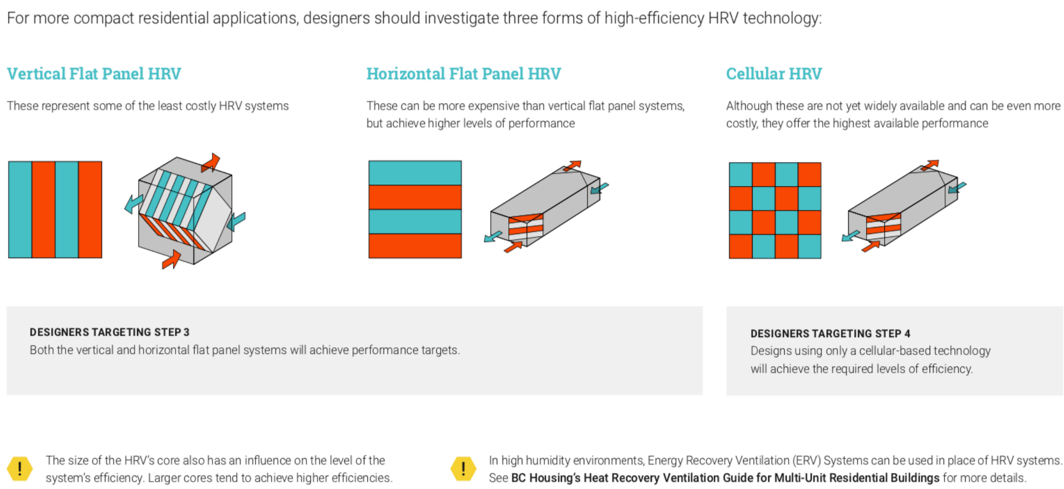


Figure 7- showing multiple HRV technologies to reduce TEDI value in MURB, BC Energy Step Code Design Guide (Mar2018) (p.36)

5-3 Make-up air cooling: As all BC Housing buildings are considered occupied by "Vulnerable Groups", they all must adhere to the overheating hours limit specified in the City of Vancouver Energy Modelling Guideline which limits the number of overheating hours to 20 hours exceeding the 80% acceptability level per year. Considering the hot temperature pattern in the lower mainland in the past few years and as buildings are better sealed and insulated, it is not very easy to achieve such targets in buildings with passive cooling and ventilation design only. Adding a full load cooling system might not be the priority solution as it will increase the energy consumption and TEUI and will consequently contribute to embodied GHG emissions as well. Therefore, designing a system to cool down the incoming make-up fresh air during summer can be a moderate approach to shave off the peak hot hours while not adding much to the energy consumption or the GHG indicators. This can be achieved by adding a cooling coil and a heat pump inside the central ventilation air handling units.

5-4 Using Heat pumps for heating, cooling, and DHW: Heat pumps have been taking traction in British Columbia for a while now as they are very energy efficient in comparison to other conventional HVAC systems. Although the term "Heat Pump" has been used alternatively between devices which either provide cooling, heating or both, it is important to mention that a heat pump is an electric device based on a refrigeration cycle which uses different forms of gases as the refrigerant medium and is capable of producing heat and cold either separately or simultaneously. Therefore, it is important to make sure we are clear about the type of system we are talking about when we are discussing a heat pump application.

Using a heat pump as part of the HVAC system can significantly reduce energy consumption as well as lowering the GHG emission intensity if they are replacing a natural gas system in the building. Although heat pump efficiency will drop in colder temperatures, they have proven quite efficient in climate zone 4 and 5 in British Columbia and therefore their use is highly advised to achieve the higher level of energy Step Code Standard.

Heat pumps come in forms of air, water and ground source or a combination and choosing the right system will depend on the different technical specifications of each project. Heat pumps can be used for space heating, space cooling as well as domestic hot water supply (DHW).

The availability of low temperature operating heat pumps for space heating and CO_2 heat pumps for domestic hot water supply has increased the popularity and application of these systems in British Columbia's building industry within the past few years.

5-5 Wastewater heat recovery system: Wastewater heat recovery system is simply a heat exchanging device placed on the wastewater drain line to absorb the heat from the wastewater before getting discharged to the sewage system.

This heat is used for preheating the cold water before entering either the domestic hot water system or hydronic space heating system depending on what kind of heating system is being used.

The discharging wastewater typically contains around 80% of the energy used to heat water in a building and a drain water heat recovery system can capture this energy before being wasted reducing the energy consumption of the building for water heating purposes. This could be done either through an individual heat exchanger or by adding a heat pump to the system for higher efficiency.

5-6 Higher efficiency HVAC and auxiliary equipment: Electrification is an objective for BC Housing to target GHG reduction in all of the new construction projects, but as the Energy Step Code does not limit the source of energy, there are possibilities to use natural gas devices and in that case it is very crucial to consider their energy efficiency. Apart from the heat pumps which usually come with a higher coefficient of

performance (COP), there are other equipment within the HVAC system that have been improved in recent years. BC Housing has a comprehensive list of requirements on how to choose a higher efficient system to meet the requirements of the Building and Energy Performance and Construction Standards. The BC Housing Design Guidelines and Construction Standards require all furnaces to be ENERGY STAR® rated and high efficiency condensing appliances with a minimum 95% Annual Fuel Utilization Efficiency (AFUE).
All major ventilation systems shall include heat recovery with a minimum sensible heat recovery effectiveness of 75%.
All boilers shall be high-efficiency appliances with minimum Annual Fuel Utilization Efficiency (AFUE) of 94% and ENERGY STAR® rated for 299 MBH and less and 94% and listed on Fortis BC Eligible Commercial Boiler List for condensing boiler with 300 MBH and greater.
The energy efficiency will also apply to all other auxiliary equipment such as pumps, fans or any other energy-consuming equipment within the HVAC system.

5-7 Alternative solar thermal or PV application: The ultimate objective of the Energy Step Code standard is to have all newly constructed buildings in British Columbia to be Net Zero ready by 2032. A Net Zero building is a building that can produce its annual energy consumption on-site and through a renewable source of energy. Solar energy is one of the most practical renewable sources of energy production and is used in two general forms of solar thermal and solar photovoltaic to either use either thermal radiation of the sunlight or generating electricity from the sunlight using the photovoltaic process. Utilizing solar energy is important in GHG reduction as it can replace a carbon-based energy source with a renewable source of energy.

5-8 Using higher efficiency PTAC: A typical Packaged Terminal Air Conditioner often abbreviated as PTAC, is a type of self-contained heating and air conditioning system commonly found in hotels, motels, senior housing facilities, hospitals, condominiums, apartment buildings, add-on rooms, and sunrooms. Many are designed to go through a wall, having vents and heat sinks both inside and outside. These devices are traditionally installed using an opening sometimes as big as 42×16 inches which are against the principals of airtightness and thermal bridging and has become one of the largest sources of the energy loss in many buildings on top of the fact that they are often not very energy efficient.

However, the concept of a self-contained individual electrical heating and cooling system with no ducting cost is very appealing when we talk about the GHG reduction and low-cost energy efficiency measures. Using a PTAC must be carefully studied and evaluated if meeting the Step Code is a target. There are a few companies who have been working to improve this technology by improving the energy efficiency and noise level of the system as well as replacing the large opening in the wall with two carefully sealed exhaust pipe eliminating the risk of air leakage and thermal bridging to the minimum possible.

Figure 8- showing an example of the modified PTAC unit Innova Air Conditioner 2.0, Innova Renewing Energy, (n.d), Retrieved from https://www.innovaenergie.com/en/products

5-9 Building Resilience/Provision for the future: The need for a cooling system seems to become more and more necessary as we go through the new warmer climate pattern. Buildings are now being built to operate for years into the future and they need to be resilient to climate change. Although a cooling system might not seem to be an immediate need at the moment for many projects, it does not mean that they might not be needed in the future. Therefore, it seems a good idea to design extra space, ducting, electrical panels and any other necessary provisions in the newly constructed buildings for the future if in case the need for a cooling system become viable. This will make the installation much easier and will prevent any extra cost of demolition and modification for the installation. The provision for the future can also be applied for other parts of the mechanical system such as additional space for a water heating system, heat recovery system and heat pump installation.

6- Space

6-1 Energy Efficient Lighting System: Lighting systems are another source of energy consumption and can have a noticeable impact on meeting the Energy Step Code standard. Traditional lighting systems are inefficient and produce a lot of heat in the process. Although the heat is sometimes considered to lower the heating load, but it is not the best way of heating nor justifiable concerning the amount of electrical energy they consume. Therefore, it is strongly suggested to use LED fixtures in designing all new construction projects. The LED technology has been around for a while and has dramatically improved in terms of performance, appearance, and cosmetics within the last few years. LED lighting systems consume a fraction of the energy that a conventional lighting system would use and generate much less side heat with much longer operating life which also reduces the operation and maintenance costs in a long term perspective.

6-2 Automated temperature and lighting control system: Most heating and cooling systems have a threshold of operating temperatures which they tend to operate more efficiently and some systems such as radiant floor heating or chilled beams have even a delay buffer time to bring the ambient temperature to the desired level. Cranking the thermostat up and down, rapidly and drastically with a wider temperature difference does not provide better comfort and has a higher chance of interrupting the energy efficiency of the system by either overloading or wasting the extra generated heat or cold.

Many buildings that are designed to meet the Step Code have been modeled based on strict operating schedules and sudden and often changes to that will result in much higher energy consumption and possibly dissatisfaction of the occupants. Therefore, designing a simple, low range and robust automated control system is an important step to ensure that consistent operation of the system is achieved at optimum energy consumption and comfort level. The occupants' culture has a big role in how the energy systems work and proper consideration of this matter in design is the key to success.

The same automated concept should also be applied to all lighting fixture operation based on the priority of required lighting density as well as the occupancy.

6-3 Interior design for better air movement: Air motion is an important part of thermal comfort along with mean radiant temperature, relative humidity, and some other additional factors. As we move on with implementing the aspects of Energy Step Code, we also need to remember the limitation they create along the way. Designing buildings to be more airtight and better insulated can significantly affect the air movement inside the building. Air can become stagnant inside the building and cause problems for natural ventilation, especially if passive cooling has been considered for the building. Excessive attention is required in the design stage to make sure the air can move effectively between different interior parts of the building for not only providing the fresh air but also creating a consistent temperature and improving the thermal comfort for the occupants. Better thermal comfort means less operating ours of the HVAC system resulting in lower energy consumption of the system and meeting the TEUI targets for Energy Step Code purposes.

7- Stuff

7-1 Higher efficiency appliances: Receptacle load and appliances are part of calculating TEUI in energy modeling for Step Code compliance and enough attention must be paid to ensure they are selected with the best available efficiency in the market. BC Housing has strict requirements on selecting the appliances and requires all refrigerators, freezers, dishwasher, clothes washers and any other appliances to be ENERGY STAR® rated. The Design Guidelines and Construction Standards also require the selected cooking appliances and microwaves are energy efficient, and at the lower end of the current EnerGuide rating scale.

The Cost Impact of Complying with the BC Energy Step Code

Like any other new standard, the implementation and popularity of the BC Energy step Code depend on the champions, early adopters, innovators and the main players of the industry.

Even though the standard has been only in effect since April 2017, there are tens of different municipalities and local governments who engaged with the Step Code in one way or another. From rezoning requirements to higher density incentives, each municipality is trying to promote and comply with the new construction projects with the different levels of the Energy Step Code standard. While all of these efforts have led to multiple new projects complying with the Step Code standard, there is not enough comprehensive information to define the real-time incremental cost of compliance in comparison to the BCBC baseline.

To cover the lack of information, the research department of BC Housing initiated a very valuable research in 2017 in collaboration with some of the building energy experts and developed a report of Metric Research including the cost metrics of complying with BC Energy Step Code Standard.

Energy Step Code Metric Research Report, Edition 2018

In 2017, BC Housing launched a research project for evaluation of the BC Energy Step Code metrics and republished the report in 2018 with further updated details. A part of the Metric Research report is focused on costing of different archetype buildings and measuring the cost increment of buildings to meet the Step Code in comparison to BC Building Code baseline in different climate zones.

The research result shows in fact, the incremental cost of constructing a building based on Step Code in comparison to the base code is very minimal. The report indicates that in summary, in Climate Zones 4 to 6, where the majority of BC's population resides, all of the buildings modelled within the range of the step level 4 will have an estimated incremental capital cost of less than a 3% and achieving step level 3 is estimated on an even lower incremental capital cost of less than 2.4% which seems quite feasible. Based on the report larger public spaces such as hotels have slightly higher TEUI values than the performance target for Step 3 in climate zone 7b, but capital costs for that solution were still less than 2.4%. Although these numbers have been thoughtfully researched and calculated, they are different from what happens on projects.

BC Housing for example, has completed a modular building complying with step level 3 with an average incremental cost of 7.29%. The difference seems to be due to the fact that both designers and contractors are new to the modifications required to meet the Energy Step Code and some additional cost has been occurring for providing the specific materials, gaining experience with trades and learning from the process. Despite these numbers, there is optimism to get closer to the Metric Research Report figures as the standard becomes more and more popular with designers and contractors and as the experience builds up.

The table in Figure 9 shows some examples of the lowest percentage change of incremental cost for a few different Part 3 building types and multiple heating sources in different climate zones in British Columbia.[4]

Archetype	Step	CZ4	CZ5	CZ6	CZ7a	CZ7b	CZ8
High-Rise MURB *Electric BB Mid Occupancy 0.6 VFAR 62-2001*	1	0.0%	0.0%	0.0%	0.0%	--	--
	2	0.4%	1.0%	1.3%	2.0%	--	--
	3	0.8%	2.3%	1.8%	2.3%	--	--
	4	2.4%	3.2%	2.7%	2.7%*	--	--
Low-Rise MURB *Electric BB Mid Occupancy 0.6 VFAR 62-2001*	1	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	2	0.5%	0.5%	0.4%	1.4%	2.7%	3.3%
	3	0.6%	2.2%	1.0%	1.6%	3.3%	3.3%*
	4	2.6%	3.3%	2.2%	4.1%	--	--
Hotel *50% WWR Common Area Fan Coils Heat Pump DHW Electric Laundry Load*	1	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	2	-0.2%	-0.1%	1.1%	0.7%	0.9%	1.9%*
	3	0.0%	1.2%	2.3%	2.2%	2.3%*	--
	4	1.2%	2.1%	2.8%	2.7%*	--	--
Commercial Office *No IT Load Default Occupancy with ASHP*	1	0.0%	0.0%	0.0%	0.0%	--	--
	2	-0.2%	-0.1%	0.4%	1.6%	--	--
	3	0.0%	0.2%	1.4%	1.8%	--	--
Other Commercial *No IT Load Default Occupancy with ASHP*	1	0.0%	0.0%	0.0%	0.0%	--	--
	2	-0.2%	-0.1%	0.4%	1.6%	--	--
	3	0.0%	0.2%	1.4%	1.8%	--	--
Retail *Big Box with FC*	1	0.0%	0.0%	0.0%	0.0%	--	--
	2	0.8%	1.3%	2.8%	4.6%	--	--
	3	2.0%	3.7%	5.5%	6.6%	--	--

Figure 9- Incremental Costs for different building archetypes across British Columbia Metric Research Report, (2018)

[4] BC Energy Step Code, Metric Research report, edition 2018

The Metric Research report also has a comprehensive analysis of how different HVAC systems have performed in energy modeling to achieve different levels of Step Code and can be used as a benchmark to evaluate the possibility of achieving Step Code on a reasonable cost increment and without affecting the affordability of the project.

Figure 10 below shows an example of the Step Code Solution for MURBs with alternative HVAC Solution:

Scenario			Measures								Outcome						
Climate	Step	HVAC	WWR	Wall R-Value (effective)	Roof R-Value (effective)	Window USI-Value	Infiltration	Vent. Heat Recovery (%)	Heating Efficiency	DHW Savings	TEUI (kWh/m^2)	TEDI (kWh/m^2)	ncrementa Capital Cos (%)	ncrementa Capital Cos ($/$m^2$)	NPV LCC Savings ($)	NPV LLC Savings ($/$m^2$)	COC ($/ton$CO_2e$)
CZ4	2	BB	40%	10	20	2.5	Code	60%	Condensing	20%	111.7	40.6	0.4%	11.8	$266,000	14.8	-222.9
		FC									128.4	33.8	0.4%	12.4	-$669,000	-37.2	204.6
	3	BB	40%	10	20	2.5	Improved	80%	Condensing	20%	100.8	29.7	0.8%	24.9	$371,000	20.6	-299.5
		FC						60%		40%	116.7	28.8	0.6%	18.5	-$673,000	-37.4	165.1
	4	BB	40%	10	20	1.6	PH	80%	Condensing	20%	85.8	14.8	2.4%	74.3	-$55,000	-3.0	41.6
		FC								40%	98.8	9.8	2.6%	78.0	-$1,664,000	-92.4	305.8
CZ7	2	BB	20%	20	40	1.2	Code	60%	Condensing	20%	116.0	44.9	2.0%	92.5	-$817,000	-45.4	638.2
		FC			20	1.6		80%		40%	130.0	39.8	2.3%	104.3	-$669,000	-109.6	481.4
	3	BB	20%	20	20	0.8	Improved	60%	Condensing	20%	100.3	29.2	2.3%	104.6	-$544,000	-30.2	401.5
		FC			40	1.2				40%	119.8	29.8	2.3%	102.7	-$1,864,000	-103.5	386.8
	4*	BB	20%	20	40	0.8	PH	80%	Condensing	20%	88.7	17.6	2.7%	123.3	-$520,000	-28.9	368.4
		FC								40%	106.5	15.3	2.8%	128.9	-$2,289,000	-127.2	390.6

Figure 10- showing an example of the Step Code Solution for MURBs with alternative envelope and HVAC solutions. Metric Research Report, (2018)

BC Housing Experience on Step Code Projects

BC Housing has been a prime leader in implementing the Energy Step Code Standard in the province of British Columbia and has already completed a few modular projects complying with step level 3 and is in the design process of multiple additional projects targeting step level 3 and step level 4 of the BC Energy Step Code.

For this report, three projects have been selected to learn more about their approach, effectiveness, challenges, barriers and cost increments of these projects.

- Residence and Clinic project on 1st & Clark Drive in Vancouver, BC (Design Stage)
- Rosewood Development by Elizabeth Fry Foundation in Surrey, BC (Design Stage)
- Little Mountain Modular home on 37th & Main street in Vancouver, BC (Completed)

Residence & Health Clinic project at 1st & Clark Dr. in Vancouver, BC

Figure 11- showing the building schematic, Curtesy of HDR Inc, hdrinc.com

The project is a mixed-use building for residential occupancy and a health clinic developed by BC Housing and Vancouver Coastal Health. The building is a combination of a 4-story concrete podium and parking floors which are partially underground plus two residential towers on top of it. The total built-up area is 20,208 m^2 which 14,716 m^2 of that is considered conditioned and modeled.

The building is located at 1st Avenue and Clark Drive in Vancouver BC and it is designed to accommodate some transitional housing, the health clinic and low-income residentials in the two towers named Clark and McLean. Clark tower will be a concrete construction whereas Mclean tower will be wood-framed.

The building is designed to target a combination of both the BC Energy Step Code as well as the city of Vancouver rezoning energy requirements. Based on the Energy Step Code, the building is designed to meet a combination of step level 3 and step level 4 level as per the following calculation of an average area-weighting of each construction type's total floor area:

- Step 3 Targets: Concrete Structure (excluding parkade) (68% of total floor area)
- Step 4 Targets: Wood Structure (32% of total floor area)

The same concept has also been adopted for defining the energy requirements for Vancouver Rezoning bylaw based on each space type total floor area percentage as per the followings:

- Retail Targets: Used for Social Enterprise (1% of total floor area)
- Residential 7+ Storey- no DES Targets: Used for Clinic, Transitional & Residential housing (99% of total floor area)

The table below shows the energy targets for both Step Code level as well as the City of Vancouver Rezoning bylaw.

Energy Targets	TEDI kWh/ m^2*Year	TEDI kWh/ m^2*Year	GHGI $KgCo_2$ e/ m^2	Overheating limits (hours)
Step Code level	25.2	113.6	N/A	200
Vancouver-Rezoning	29.9	120.7	6.0	200

Building Form and Orientation:

Figure 12- showing the building schematic stretched from East to West on Clark Dr., Curtesy of HDR Inc, hdrinc.com

The building has been designed on a sloped area stretched from East to West on Clark Drive. The initial intention of BC Housing and the designers has been on developing a simple form on a higher massing and higher number of floors to achieve the required TEDI and TEUI of the step 4 level. However, this has been modified by the City of Vancouver's requirements of limiting the number of floors and dividing the project into two towers at the two ends of the lot with a green space in between. The designers also wanted to avoid balconies to prevent thermal loss and improve step 4 TEDI, but the city has enforced changes into the form of the building by adding balconies to meet their development requirements which can negatively affect the possibility of meeting targeted TEDI and TEUI.

Building Envelope Properties

Glazing percentage:

To meet the required TEDI, the designers have managed to maintain a very low window to wall ratio in this project. The following glazing percentage was calculated for each of the towers and the podium and includes external walls adjacent to parkade spaces but does not account for the above-grade portion of the walls that are partially below-grade due to sloping ground. A U-value of 0.352 Btu/h. ft^2 F has been considered for all the windows to improve the thermal resistance of the envelope and increase the chance of meeting TEDI for steps 3 and 4.

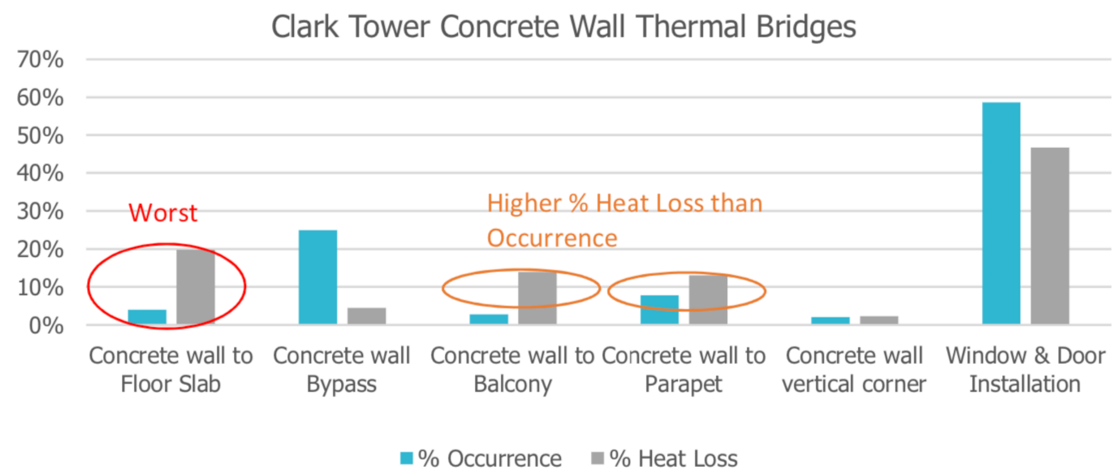
Glazing percentage	Clark Tower	McLean Tower	Podium
Per Tower/Podium	19%	19%	11%
Total	16%		

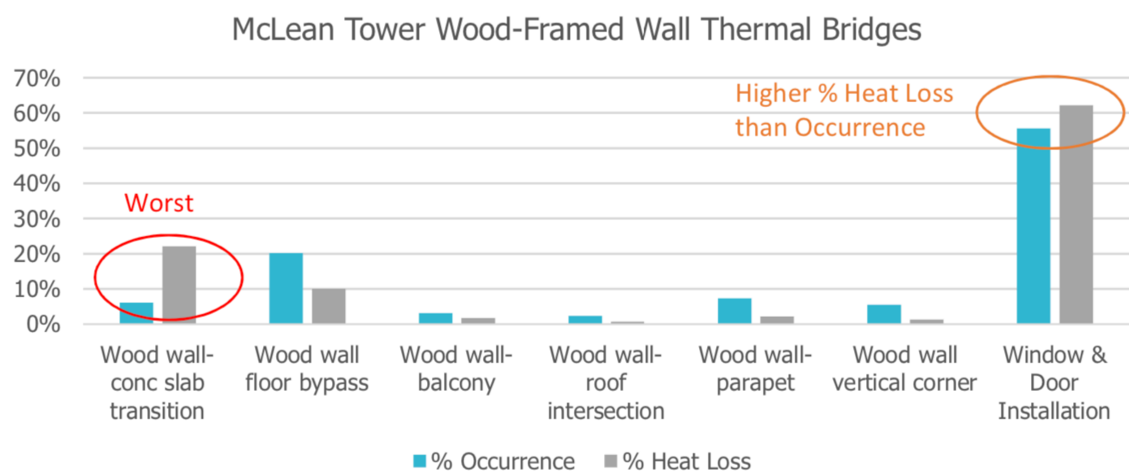
External Walls R-Value

Preliminary external wall areas have been considered for the energy modeling of this project, also taking the BC Hydro Thermal Bridging Guide into the consideration for each of the wood-framed walls at McLean tower, the concrete walls at Clark tower and the concrete podium walls. The clear wall R-values before thermal bridging and effective R-values after thermal bridging are shown in the table below.

Wall R-Value	Clark Tower- Concrete	McLean Tower- Wood	Podium-Concrete
Clear Wall before thermal bridging	19.6	31.5	19.6
Effective wall after thermal bridging	13.4	16.2	13.0

Thermal bridging has an important impact on TEDI and preventing that is an important key to achieving thermal targets in higher step code levels.





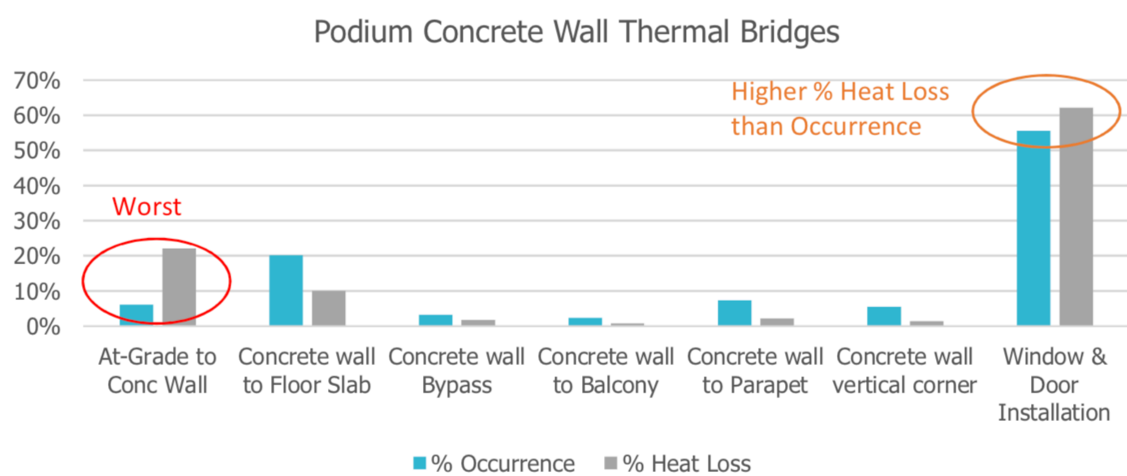


Figure 13- Showing an analysis highlighting which thermal bridges are most critical as well as which have a higher than average linear transmittance for each of the wood and concrete walls. Focal Engineering, (Aug 2018)

Mechanical Systems

This table describes the mechanical systems that were used in the energy modeling analysis. It is important to remember that as this project has been initiated in 2018, there had not yet been a requirement for a maximum of 20 overheating hours required by BC Housing Design Guidelines and Construction Standards. The groups described in the table include the following:

- Residential: Clark tower and McLean tower residential suites and Transitional spaces.
- Residential - Amenity: Lounges, offices, dining room and retail spaces.
- Clinic: Levels 2 and 3 clinic spaces including the overnight rooms within the clinic.

Since the design is in the early stages, all heating and cooling equipment were auto-sized, using a safety factor of 1.25 and 1.15, respectively.

HVAC System	Residential	Residential - Amenity	Clinic
Primary Spaces HVAC	Electric BB Heating, Cooling via operable windows and In-suite HRVs	Variable Refrigerant Flow heating & cooling system, Central HRV	Variable Refrigerant Flow heating & cooling system, Central HRV
Support Spaces HVAC	Corridors: Outdoor air tempered to 18°C, continuous, condensing MUA unit Mech & Storage: Heat to 10°C or 18°C by electric baseboard, Transfer/Exhaust fans Parkade: Exhaust fans Stairs: No HVAC system		

Lighting Power Density

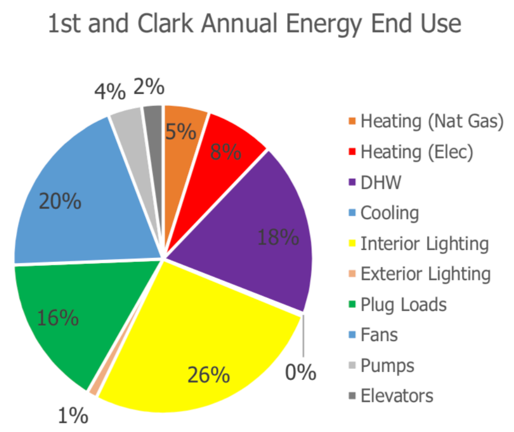
Since the project is in early design stages, rough estimates have been used by the designers and verified with the energy modeling analysis.

In the residential spaces, it has been roughly estimated that BC Housing's requirement of all-LED lighting will result in a lighting power density (LPD) of ~5 W/ m^2 which is very important in meeting TEUI targets. Although in the clinic, the LPD has been estimated to be higher at ~10 W/m^2.

Annual Energy use breakdown:

The following is a list of the main contributors to each of the end-use energy breakdown components in this project. This is essential in calculating the TEUI for both step level 3 and 4 targets in complying with BC Energy Step Code:

- Heating (natural gas): residential corridor make-up air unit
- Heating (electric): electric baseboard and VRF heating
- DHW (natural gas): domestic hot water throughout the building
- Cooling: cooling in clinic and amenity spaces with VRF
- Interior lighting: building lighting including parkade
- Exterior lighting: lighting primarily at the main entrances and walkways on the podium
- Plug loads: all the receptacles and building plug loads
- Fans: in-suite and central HRV supply and exhaust, make-up air unit, VRF and exhaust and transfer air fans
- Pumps: building pumps
- Elevators: building elevators



Building performance results based on energy modeling:

After the consideration of the design features and modeling the building, the following results have been achieved presented in this table next to the blended Step Code targets. The City of Vancouver Rezoning targets is also shown in the below table.

Energy results	TEDI	TEUI	GHGI	Overheating
Blended Step code Target	25.2	113.6	N/A	200
Base Simulation; After Adjustment	23.7	111.6	5.6	106

The results are presented for after the Corridor Pressurization Adjustment of Energy Modelling Guidelines v2.0 has been applied to the system. As can be seen in the above table, the project will meet the Step Code targets, although it is still far away from 20 hours overheating limit. This clearly shows that despite the limitations on building form and shape, meeting the Step Code level is possible, but the building will have excessive overheating hours beyond BC Housing Design Guidelines and Construction Standards and close attention to this matter is mandatory to meet the requirements.

Figure 14- showing the East-facing side of the building and the McLean tower., Curtesy of HDR Inc, hdrinc.com

The Risk on missing the targets and maintaining the compliance:

Apart from the overheating hours, the initial design of this project model meets the requirements of the Energy Step Code, but many of the result values are very close to the targets and it is very important for the team to keep energy efficiency in mind as the design advances. The following table is the recommendations by the energy modelers of this project to help to remain on target as the project progresses. With the new requirements for cooling and reducing the overheating hours, it is also recommended to enhance these parameters wherever it is needed and remodel the building to ensure of meeting all BC Housing Design Guidelines and Construction Standards on top of the BC Energy Step Code.

Recommendations	Target Value	Impact	Description
HRVs	75% Sensible	**TEDI**	Minimum recommended efficiency for HRVs.
MUA Units	Heat Pumps	**TEUI**	Optional replacement of the gas-fired make-up air units with a heat pump provides a buffer on the TEUI and GHGI.
Wood Wall	R-16	**TEDI**	These values include thermal bridging and any improvement will help the TEDI value.
Concrete Wall	R-13	**TEDI**	
Airtightness	0.9- 1.8 L/s.m2 Tested @ 75 Pa	**TEDI**	Savings from improvements from 1.8 down to 0.9 will benefit the TEDI and TEUI
Lighting	N/A	**TEDI**	While low lighting values are recommended, their impact on TEDI should be considered.
Fan power	N/A	**TEDI**	Small changes in ventilation and fan energy can significantly impact TEDI, so thoughtful ventilation design is very important.
Operable windows	N/A	**Overheating**	The operable portion of the windows matter in natural ventilation, so it is better to oversize the window opening than undersize it.
Make-up air cooling	20 hours overheating	**TEUI Overheating**	Addition of a cooling coil into central make-up air unit will help to reduce the overheating hours, but increasing TEUI

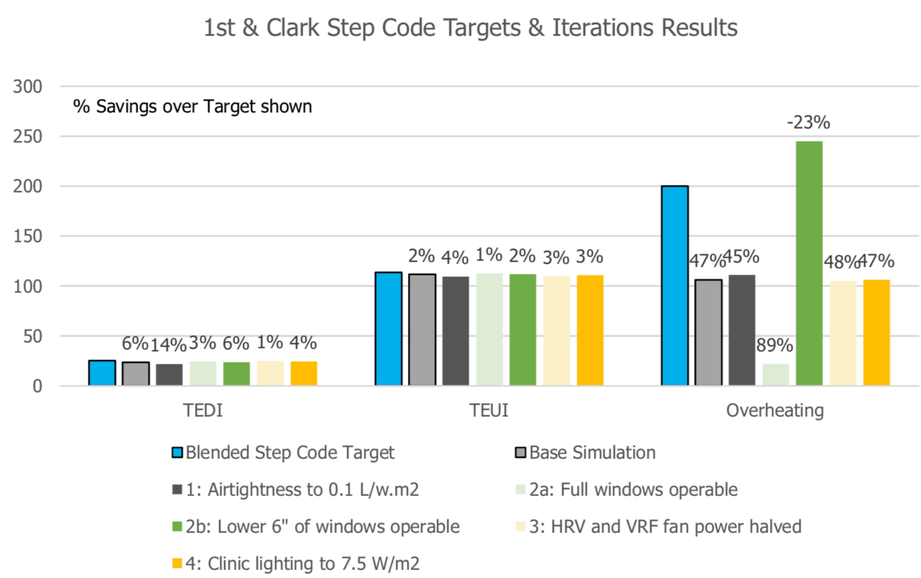


Figure 15- showing the impact of such changes on TEDI, TEUI and Overheating, Focal Engineering (Aug 2018)

Challenges and barriers:

Building Form:

The building form and shape has been challenged by the City of Vancouver requirements which has resulted in relatively higher TEDI and TEUI and increased the overheating hours beyond the acceptable level. These changes are resulting in the necessity of a central cooling system that will impact the internal layout of the residential towers by cropping the living spaces to add more ducting. This will also stress the budget by increasing the cost and affecting the affordability of the project.

Overheating hours:

Although this design meets the limit of overheating hours based on City of Vancouver requirements, it does not meet BC Housing's maximum overheating hour limit of 20 hours which has come into effect since 2019. This means the building will be challenged in hot months of summer and overheating hours leaving no choice but to be reduced. The current overheating hours of 106 demand for some type of cooling system which will bring its own set of challenges. A full load cooling system will add to TEUI and GHG values where the additional cost will also impact the affordability of the project.

Therefore, BC Housing and the designers are opting for a more moderate solution for this project by adding a cooling coil into the central make-up air unit to cool down the ventilation air hoping to and shave off the maximum overheating hours down to 20 hours in residential towers. This means the designers have to remove the suite level Heat Recovery Ventilators and go for a central HRV system which will again bring a new set of challenges.

A central HRV means adding a noticeable amount of ducting network to the building which will be limited by the available ceiling height in the corridors and leave no choice but to add multiple utility shafts in the tower cropping out into the residential footprint in order to make room for all of the new ducting which will again impact the cost and affordability of the project.

Facing this problem highlights the importance of considering passive measures in shape, form, and orientation of the building and prevention of thermal bridging (balconies) in design and permit stage as achieving the higher levels of Energy Step Code becomes quite difficult without them. This also hints the importance of using wood-frame structures versus concrete as that will generally improve the TEDI value and makes step code compliance more feasible.

Rosewood Development at 137th Street in Surrey, BC

Figure 16- showing the schematic design of Rosewood Development. Morrison Hershfield (Nov 2018)

Rosewood development is a mixed-use building developed by BC Housing, Elizabeth Fry Society of Greater Vancouver and Fraser Valley Aboriginal Friendship Centres Association to support women and children affected by the justice system located in the City of Surrey.

The building consists of five floors and a total area of 5,245 m^2 plus an additional 960 m^2 of parking which is considered unconditioned for energy modeling purposes. The floors are primarily residential units, corridors, some office space, common areas, and utility rooms. The building is being designed by Morrison Hershfield to meet step level 4 of the Energy Step Code as well as BC Housing's energy efficiency requirements. According to the preliminary design parameters and the assumptions made, the project meets its TEDI and TEUI targets as summarised in the following table:

Requirements	Electricity (GJ)	District (GJ)	Annual Energy (GJ)	TEDI kWh/ m^2 *Year	TEUI kWh/ m^2 *Year
BC Housing target	-	-	-	15	100
Preliminary Design	934.8	720.7	1,655.5	14.7	89.7

Based on the design of this project, a few major energy conservation measures impacting the overall performance of the building and meeting the step code 4 requirements:

- High-performance building envelope with high insulating value.
- High-efficiency lighting (LED) in parking and common areas.
- High efficiency (85%) Heat Recovery Ventilation for all suites, amenity, and office areas.

Building form, orientation, and density:

Meeting the step code 4 level is not an easy task as the metric limits are quite stringent and need many preliminary considerations in the early stage of design to make the compliance happen.

As it is seen in Figure 16, this building has quite a simple and dense form with the right orientation towards the sun. The overall shape and form of the building, as well as the massing, has an essential role in achieving TEDI and compliance with the Energy Step Code standard and the design of this building has a major contribution in achieving step code 4.

The more complex a building shape is, the greater opportunities for heat loss through the enclosure. A building with several complex junctions, balconies, and corners will lose far more heat through the enclosure than a building that has been designed as a simple, solid form.

Lower WWR and VFAR:

The energy efficiency and the form factor can also be evaluated through a building's vertical surface area to floor area ratio (VFAR) as well as the window to wall ratio (WWR).

The design of this building is considering a low 22% window to wall ratio as well as a 0.5 VFAR. This for sure has been supporting the design to meet the TEDI and the step code 4 level. A lower VFAR and WWR provides less opportunity for heat loss through the vertical surfaces, especially for windows which by default have lower R-value in comparison to the external walls and other horizontal surfaces.

Building envelope performance:

Designing higher R-values walls, floor and roof with continuous external insulation in combination with lower WWR and low U-value, high-quality, double-glazed windows has made it possible for Rosewood Development project to meet TEDI and step code 4 based on the following details:

External Walls: Effective Wall R-Value of R-11.6 based on an exterior-insulated stud wall with clips and panel system with consideration for thermal bridges such as slab edges, bypasses, shelf angles, shading attachments, window-to-wall transitions, transitions between wall types and parapets.

Roof: Effective R-Value of R-30

Floor: Effective R-Value of R-15.6 between parking and interior spaces.

Window U-Value: Double glazing (Main level) U-0.42 & SHGC-0.38, Double glazing (Upper levels) U-0.37 & SHGC-0.32

Solar shading systems:

It will be very difficult to meet the 20 hours overheating hours and provide the acceptable thermal comfort level in a building with no or minimal cooling system. This will be even harder without a thoughtful solar shading design to prevent excessive solar gain. The excessive solar gain will increase the temperature indoors and using a shading system design is necessary. It has been considered in this building in the form of overhangs and other shading systems.

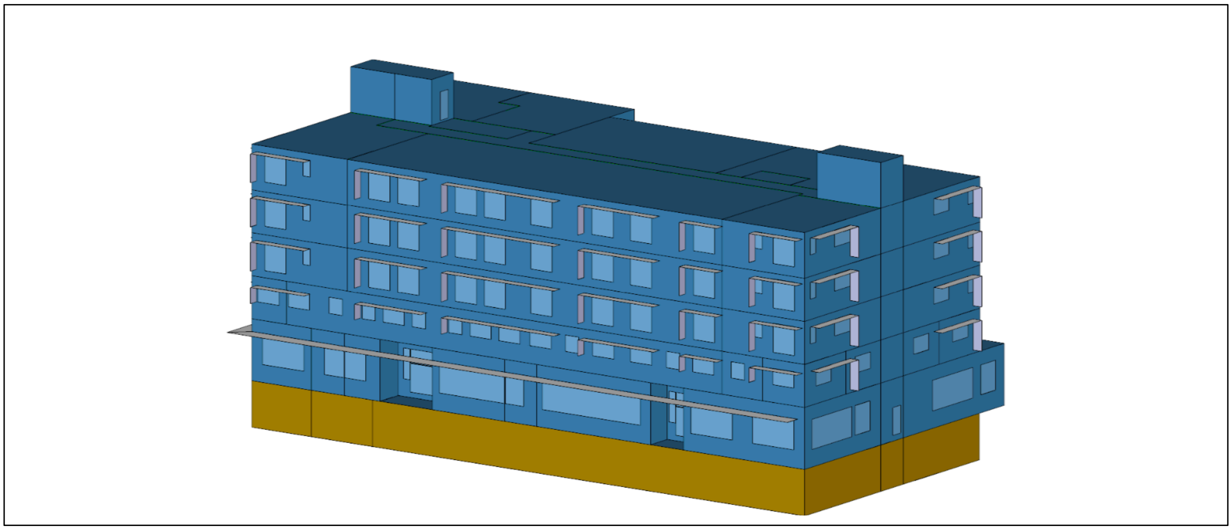


Figure 17- showing the schematic 3D design and solar shading of Rosewood Development for energy modeling. Morrison Hershfield (Nov 2018)

Mechanical Systems:

Heat Recovery Ventilation system: To meet the step level 4 TEDI, the use of 85% effective (SRE) heat recovery on outdoor air has been required for most areas of the building except the kitchen exhaust.

Space Heating and DHW: Hydronic baseboard heating has been designed for suites, offices, kitchen and lounge spaces. The energy required for space heating and Domestic hot water service is provided by the district heating system in this project. Additional low flow fixtures are assumed for approximately 20% reduction from the code requirement.

Space cooling: There is no full load mechanical cooling system designed for the suites in this project. However, tempered Make-Up Air Unit MUA using a split DX cooling system is provided through the central make-up air system in the building in order to shave the peak off the maximum overheating hours and meet the 20 hours limit of BC Housing's requirement.

Energy use breakdown:

The following tables and graphs summarize the Energy End-use Breakdown of this project:

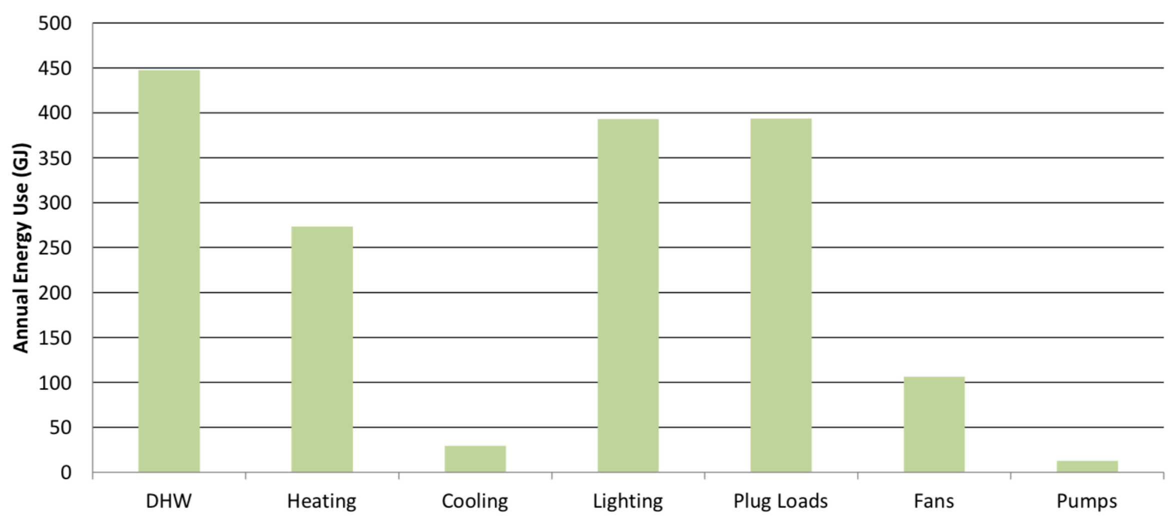


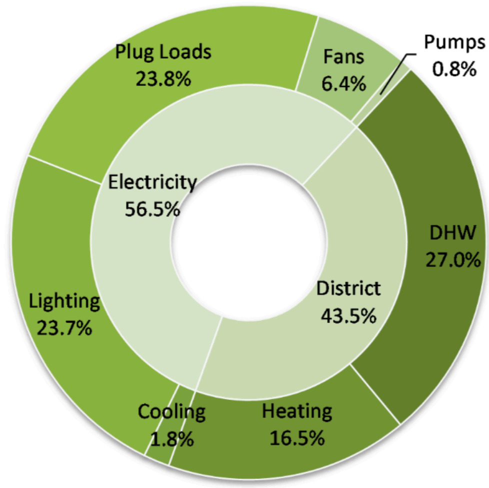
Figure 18- showing the energy use breakdown for Rosewood Development project, Morrison Hershfield (Nov 2018)

Figure 19-

At it is shown in this graph, DHW, lighting and plug loads are the three major contributors to TEUI and therefore close attention to the opportunities to reduce TEUI is important.

Utilizing LED lighting systems, Energy star appliances and possibly replacing the DHW with a heat pump can increase the assurance in achieving lower TEUI in step code 4 projects.

Courtesy of Morrison Hershfield (Nov 2018)



The Risk on missing the targets and maintaining the compliance:

Here are the necessary steps to ensure the current building performance will not be compromised as the design process advances:

- Maximizing the use of proper orientation and massing.
- Assuring the close cooperation between “Energy Modeller” and “Envelope Consultant” in designing a high performing envelope to meet the TEDI target.
- Attention to thermal bridging based on BC Hydro Thermal bridging guidelines.
- Ensuring to maintain an equivalent wall R-value of 11.6 (RSI 2.0)
- Ensuring to maintain an equivalent roof R-value of 30 (RSI 5.3)
- Preferably use a high-quality window (USI-1.8) based on BC Housing requirements.
- Maintaining the infiltration to 0.2 L/s/ m^2
- Designing the Heat recovery ventilation with summertime bypass (Economizer)

Challenges and barriers:

Over Heating problem:

The design team in this project has considered the shading and ventilation strategy carefully with the intent to reduce overheating. Another potential option considered to help mitigate the overheating problem is incorporating a mechanical cooling coil into the central outdoor air system intending to allow a smaller amount of cooling without increasing the design outdoor air ratio. Ventilation for suites is sized as per BCBC Part9 requirements and Part3 requirements have been used for other areas.

Given the assumptions above, the results indicate that all spaces will be within the allowable range of overheated hours. Although as the project progresses it will be important to ensure that the key design features with influence on overheating are carried forward as designed. The factors that most affect overheating in this building are:

- Building orientation and form
- Building Envelope
- Exterior shading
- Window solar heat gain coefficient (SHGC) and U-Factor
- Operable windows and window opening size
- Adding a cooling coil in the central outdoor air system
- The appropriate setpoint of supply air temperature
- Bypassing the heat recovery when conditioning is not required

The figure below shows the number of overheated hours by modeled thermal zone. It can be seen that no zone has greater than 14 overheated hours.

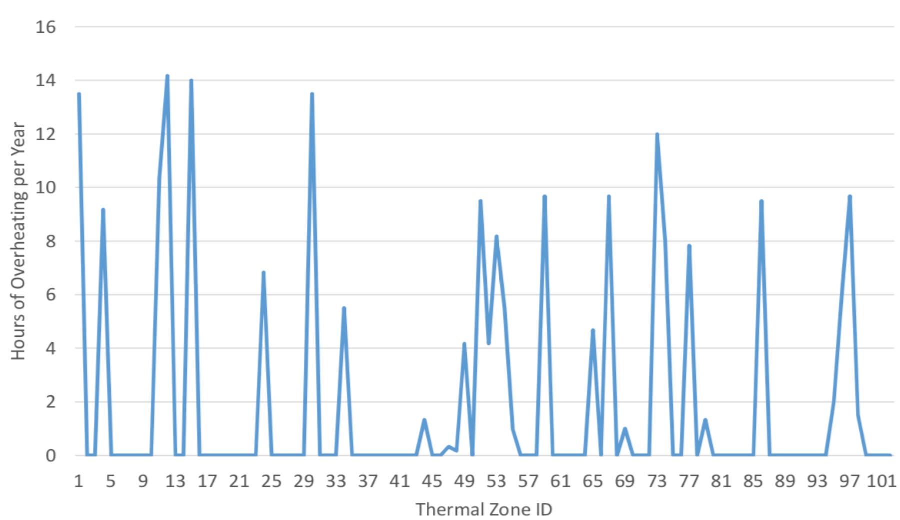


Figure 20- showing the number of overheating hours for Rosewood project, Morrison Hershfield (Nov 2018)

Little Mountain Modular Home Project at 37th & Main Street in Vancouver, BC

Figure 21- showing the Schematic Design of Little Mountain Modular Home, Horizon North, (Mar 2018)

The Little Mountain Project is a new construction prefabricated affordable housing project installed at Main Street and East 37th Avenue in Vancouver, British Columbia. This project is one of the few which has been already constructed and completed based on the Energy Step Code standard by BC Housing development.

The building consists of 3 stories of wood-framed single room occupancy with a portion of the main level dedicated to amenity spaces which include office, meeting room, staff room, laundry, lounge, dining room, and a commercial kitchen. The balance of the main level and all of the levels 2 and 3 are dedicated to 46 affordable housing suites. The building has a total floor area of 2,129 m^2 and a footprint of 716 m^2 with a cosmetic butterfly roof installed.

BC Housing energy performance requirements for this project are based on the BC Energy Step Code, with area-weighted requirements for amenity and residential areas as it is shown in the following table.

Area use category	Area (m^2)	Step Code level	TEDI (kWh/ m^2*Year)	TEUI (kWh/ m^2*Year)
Residential, Part 3, Combustible, Climate Zone 4 (HDD18<3000)	1,868	Step 3	30	120
Amenity Area (Business and Personal Services or Mercantile)	264	Step 2	30	170
Total	2,132	Combined	30	126.2

Additional Energy Conservation Measures taken to meet the Step Code level 3:

There have been several considerations in this project to support achieving the Step Code level 3 and following are the highlights:

- External insulation – Increased insulation values by providing a layer of rigid insulation on the exterior of the building.
- HRV's – Utilizing energy-efficient HRV units to provide passive cooling and employ heat recovery to minimize energy usage.
- LED Lighting Fixtures – LED lighting fixtures provide low energy consumption and lowers the TEUI value.
- Energy Modelling – Energy modeling and reporting has been performed before construction to allow planning for efficient and effective methods of meeting energy efficiency targets.
- Building Air Tightness – Air Tightness testing has been performed to ensure the building maintains efficient heat and cooling retention.
- Acoustic Seal – Penetrations are sealed, a benefit to be a modular project, the contractors can test more frequently in the plant and able to seal any penetrations in a controlled environment inside the factory.
- Window Testing – Water ingress testing has been performed on windows to ensure there is no leakage and proper envelope seal and airtightness are in place.
- Energy star appliances – Utilizing the Energy Star Appliances throughout the building for further efficiency and lower the TEUI and energy consumption.
- Thermal Bridging – Extensive work with Envelope consultants and energy consultants has been performed to apply BC Hydro Thermal Bridging Guideline to the envelope performance supporting the overall gross wall thermal performance.

- Occupancy Sensors – Extensive use of occupancy sensors on non-suite lighting allows to further reduce energy consumption and lower TEUI.

Envelope performance:

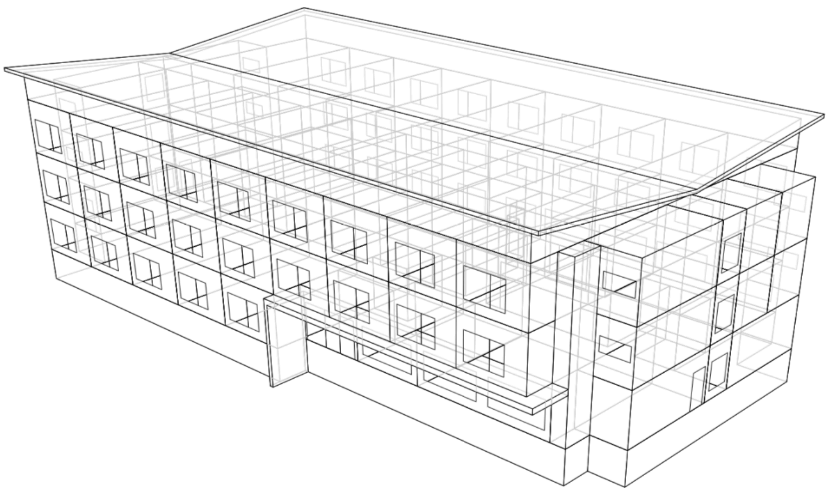


Figure 22- showing the Schematic Design form of Little Mountain Modular Home, Focal Engineering, (Mar 2018)

The building envelope performance is a key to achieve TEDI and comply with the Step Code requirement. The Little Mountain Modular Home Project has used the following specification for building the envelope:

Roof: An R-value of 40.6 has been designed for the roof of this building.

External Walls: A wall average R-value of 17.6 including the thermal bridging effect has been designed for this project.

Windows and WWR: Windows with a U-value of 0.22 and a 20% WWR has been designed for this project.

Floor: The exposed floor (Clearfield) of R-34 has been designed for this project.

Infiltration: An infiltration ratio of 0.2 L/s/ m^2

Mechanical systems:

HVAC systems:

This Modular Home project has been designed before BC Housing's mandate of meeting the maximum 20 hours overheating limit. Therefore, there is no cooling system assigned to this project and the building relies on natural ventilation for cooling purposes.

The following table shows the assignment of different mechanical systems in Little Mountain affordable housing project.

Application	Solution
Suit Ventilation	80% effective in-suite HRVs
Suit and support space heating	Electric baseboard
Amenity HVAC	Constant volume AHU with Air Source Heat Pump for Heating and Cooling
Commercial kitchen exhaust	Demand controlled exhaust hood and variable speed make-up air
Domestic hot water heating	In-suite electric resistance DHW tanks

Lighting Systems:

The use of LED lighting fixtures throughout the building and utilizing controlling sensors in public spaces has dramatically improved the overall lighting energy consumption to an average of 3.2 W/m^2 of the total building. This has an important role in achieving TEUI and complying with the energy step code requirements.

Compliance result:

With the design features considered in this project, the building is meeting the Step Code requirements and the energy modeling results have been shown in the following table. It is important to mention that the nature of off-site manufacturing for this project has facilitated an easier path to achieve TEDI and TEUI due to the higher manufacturing and assembly precision in a controlled environment.

Compliance Metric	TEDI	TEUI
Target	30	126
Result	28.4	82.8

Challenges and barriers:

Building dimension:

Due to the nature of Modular Home construction, there is a height limitation on the finished products to be able to ship across the province and comply with the logistics and transportation rules. However, this brings on a set of challenges on designing any central ventilation system for the building as there is in not enough room to accommodate the necessary ducting within the available ceiling height.

A combination of several zone ventilation can potentially reduce duct sizing and make it possible for the designers to fit the required ducting into the existing available ceiling height of the building.

Meeting the project budget:

The Little Mountain project is one of the few projects which has been constructed and completed based on the Energy Step Code requirements under BC Housing development.

Based on BC Housing information, the incremental cost of the building to be built based on step 3 has been about 7.2% more than what a similar building would cost based on the BCBC baseline.

This additional cost is slightly higher than what has been reported in cost metric analysis report since the contractors are just learning and gaining experienced and this can cause an additional cost to the project. There is a higher chance that the incremental cost will be reduced and will meet the cost metric report targets as Step Code compliance practice gets more traction and the standard gets more popular.

Another observation in this project is the use of an offsite manufacturing process. As the Step Code requirements get more stringent in higher levels, it becomes more beneficial to utilize offsite manufacturing due to the controlled environment and higher precision. These factors are very critical in providing the necessary insulation and airtightness and achieving the TEDI targets and therefore the use of offsite manufacturing plays a key role in achieving the higher levels of BC Energy Step Code at a reasonable cost.

Lack of skilled tradesmen who are familiar with the Energy Step Code requirements has played a role in cost increment and this is another good reason to choose offsite manufacturing as it is easier to train the staff and improve the manufacturing time in such facilities.

Overheating problem:

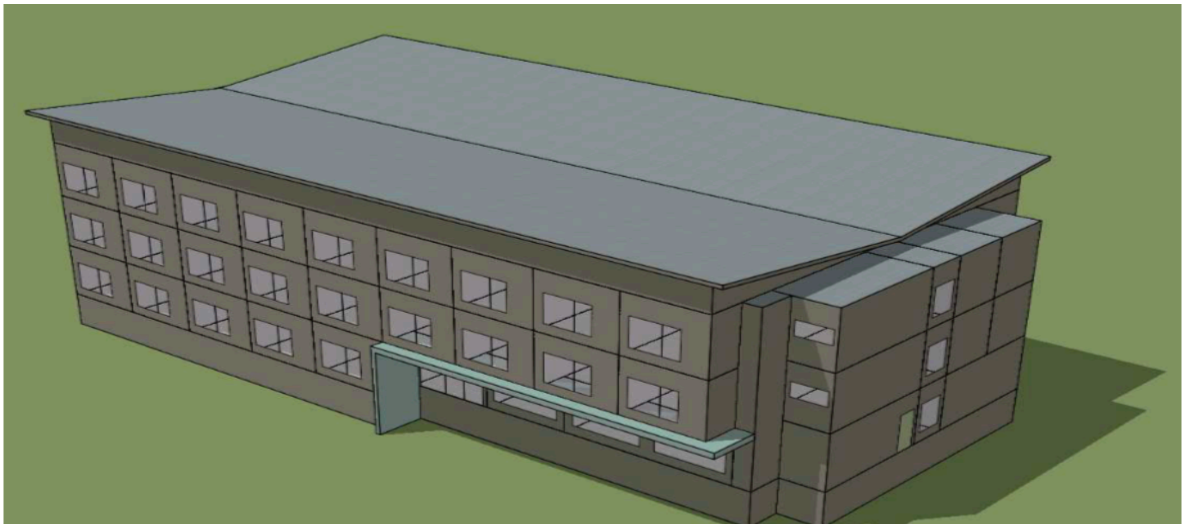


Figure 23- showing the Schematic Design on South-facing wall and small solar shading overhang on the entrance Focal Engineering, (Mar 2018)

This building has been designed and installed before the 2019 BC Housing requirement of 20 hours limit for overheating hours, and subsequently, the building does not currently meet the new thermal comfort requirement.

Although there are some trees on the South-facing wall, but apart from a very small overhang on the entrance there is no other solar shading system in place, and this is possibly contributing to the overheating hours by an excessive solar gain in July and August. Based on the energy modeling analysis, the building has slightly higher overheating hours at 28 and is experiencing some warmer days during the summer.

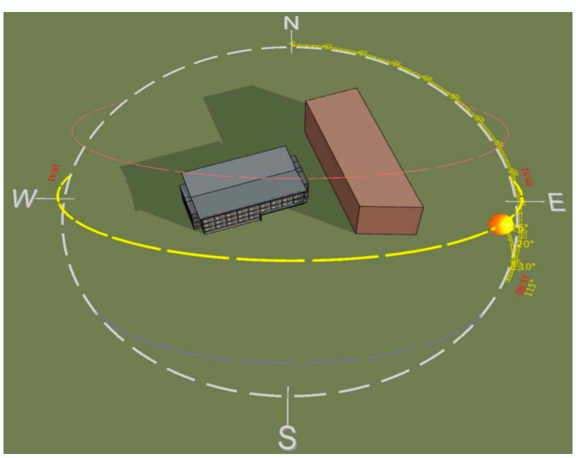


Figure 24-

Showing the building orientation towards the sun. As it is seen here, the South-facing wall gets a partial shadow from the neighboring building and mostly direct sun exposure and extra solar gain contributing to overheating hours,

Focal Engineering, (Mar 2018)

Conclusion

Paying attention to passive measures:

It is very important to pay attention to the fact that achieving the higher levels of Step Code is not practical if the initial passive design measures such as building orientation, form, massing, envelope, and thermal bridging are not first explored during the principal recommendations and initial project design stages. These passive measures along with Heat Recovery Ventilation are imperative to achieving TEDI and TEUI targets.

It is equally important to bring your attention to overheating problems and thermal comfort issues. Based on BC Housing's requirement to cap the maximum overheating hours at 20 while considering the warming climate pattern, paying attention to thermal comfort is necessary. An immediate solution or a future provision, considering a passive or active cooling system in all BC Housing's new construction projects seems unavoidable.

Paying attention to active measures:

With the improvement of technology and availability of higher-performing heat pumps, HRVs, ERVs, LEDs, control systems, solar systems, and many other building equipment types, lowering the energy consumption of the building is now easier than ever before.

However, it is very critical to ensure that packing all these technologies into the building does not increase the complexity of the operation and the main design core will always stay on keeping the simplicity and durability as the key performance factors in all BC Housing's new construction projects.

Paying attention to unintentional increasing of GHG emissions

As the industry accommodates new technologies and creates better insulation measures, improved airtightness and efficient equipment, the need to address the potential unintended outcomes associated with these new metrics cannot be overlooked.

Either through placement of higher efficiency, natural gas equipment or the accumulation of embodied carbon in construction materials such as insulation material and concrete, there is a need to ensure that the GHG emission reduction targets are not being sacrificed by the efforts to meet the higher level of Energy Step Code targets and always try to keep a reasonable balance of all measures.

Energy efficiency and cost evaluation table

There is currently no precise and realistic cost breakdown analysis on the incremental capital cost of Energy Step Code compliance. This report has tried to put together a cross-examination table combining all of the expertise from third party professionals interviewed for this project, along with the existing experience of BC Housing's staff and projects. Additional theoretical research on energy conservation measures in buildings was used to create a simple tool for prioritizing the steps to take to meet the Step Code keeping cost impact in mind with affordability as the highest priority.

The following table is the result of this effort and although it is not very precise, it is intended to be used as a practical and helpful tool in setting the strategy to move forward with Step Code Compliance.

The following is a list of energy conservation measures effectiveness on meeting the Energy Step Code requirements along with the associated incremental capital cost of each measure:

The impact on energy conservation measures Basic 💡 Medium 💡💡 High 💡💡💡	**List of possible improvements to meet the Energy Step Code requirements**	**The associated incremental cost** Basic $ Medium $$ High $$$
💡💡	Building orientation	$
💡💡	Form and density	$
💡	Landscaping	$
💡💡	Building layout	$
💡💡	Wood structure first	$
💡	Space buffers	$
💡💡💡	External insulation	$$
💡💡💡	Mounted balconies	$$$
💡💡💡	Better wall	$

💡💡💡	Insulated Roof and Floor	$
💡💡💡	Better windows	$ $ $
💡💡	Window covering	$
💡💡	WWR	$
💡💡	Solar shading	$
💡💡	Airtightness	$ $
💡💡	Natural ventilation	$
💡💡	HRV/ERV	$ $
💡💡	Make-Up air conditioning	$ $
💡💡	Heat pump (Space Heating)	$ $
💡💡	Heat pump (Space Cooling)	$ $
💡	Heat pump (DHW)	$ $ $
💡	Waste Water Heat Recovery	$
💡💡	Condensing Boiler	$
💡	Electric baseboard	$
💡	Higher Efficiency Pumps	$
💡	Higher Efficiency Fans	$
💡💡	Higher Efficiency PTAC	$
💡💡	LED lighting	$ $
💡💡	Automated Thermostat	$
💡	Automated Lighting	$
💡💡	Higher Efficiency Appliances	$
💡💡	Solar PV power	$ $
💡	Solar water heater	$ $

Based on the findings of this report the current incremental capital cost of complying with BC Energy Step Code 3 and 4 in climate zone 4 and 5 is an average between 7% to 10% in comparison to BCBC baseline which is in discrepancy with BC Housing cost Metric Research

Report published in 2017 and editioned in 2018 defining the incremental cost for the same compliance level to be less than 3%.

Perhaps the cause of this difference partially lies in the fact that the Step Code compliant construction has not yet become a common practice in British Columbia and the cost surveying companies do not have enough reliable information to estimate the cost and the contractors do not have enough experience in building the Step Code compliant buildings and this all together results in inflated cost in comparison with the cost Metric Research Report. Lack of specific material and shortage of trained and experienced trades might also have an impact on increasing the cost as well.

Based on the findings of this report, building in compliance with the BC Energy Step Code is feasible and more importantly is the right way forward. As the incremental capital cost trends lower and towards the 3%, building sin British Columbia can be built to BC Energy Step Code targets without affecting the affordability.

Building the high-performance buildings will not only improve the energy efficiency of the building and lower the GHG emissions but also creates a resilient, durable and comfortable home for future generations to come.

Recommendations

It is recommended for BC Housing to develop a new procedure to ensure that the passive measures of energy efficiency are not negotiated, compromised or value-engineered for projects targeting the higher levels of Energy Step Code, GHG reduction and thermal comfort requirements. It is necessary to ensure that the incremental cost of compliance will not exceed the project budget and will improve the affordability in general.

This could be achieved through a new approach to allocating the land, applying for a permit or designing the building on a very early stage.

A new procedure could also be developed to promote Energy Step Code compliance by recognizing the designers, contractors, suppliers, and builders who are the champions in supporting BC Housing to advancing their sustainability targets.

The author sincerely hopes that the content of this report will be useful in providing information for all interested parties and stakeholders concerning the BC Energy Step Code and can open a dialogue on the actual cost impact on improving the affordability of Energy Step Code compliance in future projects.