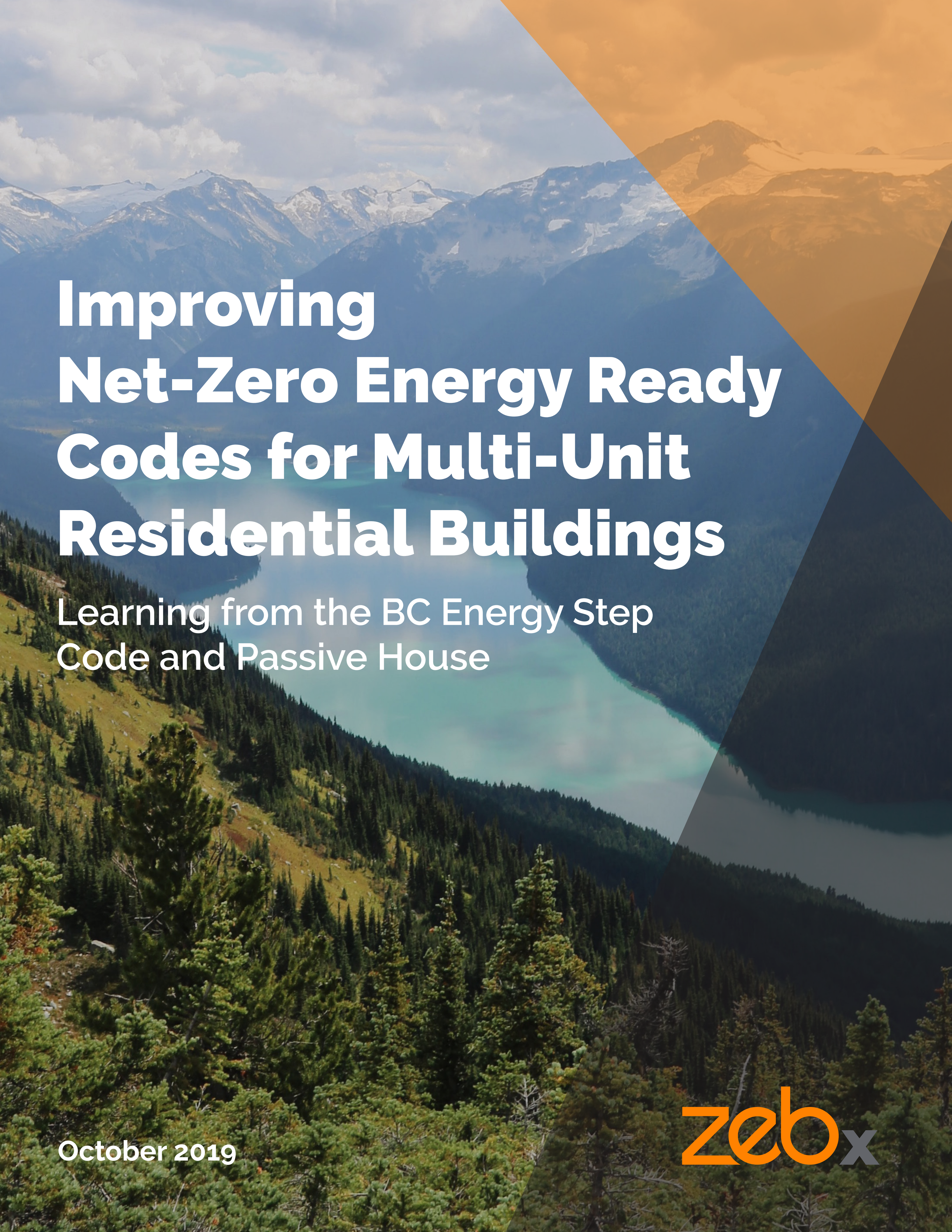


Improving Net-Zero Energy Ready Codes for Multi-Unit Residential Buildings

Learning from the BC Energy Step Code and Passive House

October 2019

zebx

REPORT SUMMARY AND CONTEXT

Lessons Learned from Leading Jurisdictions

In 2016, the City of Vancouver forged a new way forward to tackle greenhouse gas (GHG) emissions in buildings by establishing the Zero Emissions Building Plan (ZEBP). The first of its kind in Canada, the ZEBP set performance limits on buildings for heat loss, energy, and GHG emissions. Vancouver also recognized the value of capacity building, providing industry support tools, including funding the creation of ZEBx, Canada's first Zero Emissions Building Centre of Excellence. Early industry support of the ZEBP gave confidence to the Province of BC to develop a similar code framework, now known as the BC Energy Step Code. These new energy codes that use absolute building performance metrics have now been under implementation for over 2 years in BC."Thermal Bridging" and "Low TEDI" are now common terms in the BC building industry, shifting the focus towards foundational principles of designing and constructing good building envelopes. However, lessons from early projects have also shed light on where the Step Code needs to improve to ensure building performance outcomes are achieved for both today and into the future.

At the same time the Step Code was being implemented, Passive House was also increasing in popularity in the region. Passive House is a voluntary building performance standard regarded as one of the most stringent globally. Project teams pursuing this high level of performance, which is about 50% better than the highest level of the Step Code, have strengthened our understanding of how far multi-unit residential building (MURB) performance can go.

Insights from early Step Code and Passive House projects are identified and studied in this report, leading to initial recommendations on areas where the Step Code can improve and where more research may be needed. This report focuses predominantly on recommended energy efficiency improvements of the Step Code. The Step Code does not currently regulate greenhouse gas (GHG) emissions like its City of Vancouver counterpart policy, the Zero Emissions Building Plan. GHG targets are a notable omission from the Step Code, especially in a province where fuel choice is a significantly larger driver of GHG emissions in buildings than energy efficiency[1]. However, energy efficiency is often a prerequisite to practical and cost-effective electrification, a strategy recognized globally as the critical pathway to decarbonization in buildings.

REPORT SUMMARY AND CONTEXT

The Future of Net Zero Energy Ready Codes in Canada

The federal government is developing a Net Zero Energy Ready (NZER) building code for adoption by the provinces by 2030[2]. The Province of BC is ahead of schedule, having developed the Step Code in 2017, a tiered code with performance levels varying from current code to a NZER level, with any “step” available for voluntary adoption by local governments. The foundation for the development of the above policies and standards can be traced back to comparable standards in Europe that incorporate absolute energy metrics[3], many of them clearly influenced by the Passive House Standard, its first iteration developed in the 1990’s by the Passive House Institute in Germany. The Passive House standard promotes concepts of high energy performance, thermal comfort and indoor air quality by focusing on a high-performance building envelope and efficient and effective ventilation systems.

METRICS OF THE STEP CODE

TEDI

Thermal Energy Demand Intensity

The annual amount of heat in kWh/m2 of floor area that is required to maintain a building's space temperature, primarily reflective of building envelope and ventilation system performance. This metric is independent of heating system efficiency. This metric is often referred to as the building's annual heating load.

TEUI

Total Energy Use Intensity

The annual amount of total energy use in kWh/m2 of floor area. TEUI ensures that even when energy provided to a building is renewable, it is being used efficiently and not being wasted unnecessarily.

OTHER METRICS

GHGI

Greenhouse Gas Emissions Intensity

The annual amount of operational greenhouse gas emissions, measured in kg of CO2e/m2 of floor area. This metric is not currently part of the BC Energy Step Code, but does apply to City of Vancouver developments that are regulated under the ZEBP. Many BC municipalities are looking to incorporate GHG emissions alongside Step Code requirements in the near future.

Why is TEDI So Important?

1. It minimizes the load in the building which has historically been the largest in Canada and is most often served by a GHG intensive fuel (i.e. natural gas). In the absence of a GHG metric for buildings, minimization of heating loads is critical to reducing building GHG emissions.

2. A low heating load results in higher thermal and acoustical comfort. Higher performing building envelopes maintain higher surface temperatures and reduce drafts, improving comfort. One area where Passive House excels in thermal comfort over the Step Code is with regards to minimum window thermal performance. The window is the weakest link with regards to thermal comfort, both in terms of radiative and downdraft. A minimum window performance that maintains a suitable surface temperature minimizes both of these conditions and is a recommended addition to the Step Code. Payette has designed an online tool illustrating the relationship between thermal comfort and façade performance, considering both the radiative and downdraft impacts[4].

3. Heating load reduction strategies have been shown to be more operationally robust[5]. While they require more careful attention to detail in design and construction, such as air tightness and thermal bridge detailing, they are not as sensitive to high variations in operating performance when compared to mechanical and electrical interventions.

WHAT ABOUT COOLING LOADS?

The Step Code does not consider cooling loads as a standalone metric; however, there is strong evidence to support that it should. Passive cooling and cooling load reduction strategies are difficult to implement in Canadian MURBs and are often ignored.

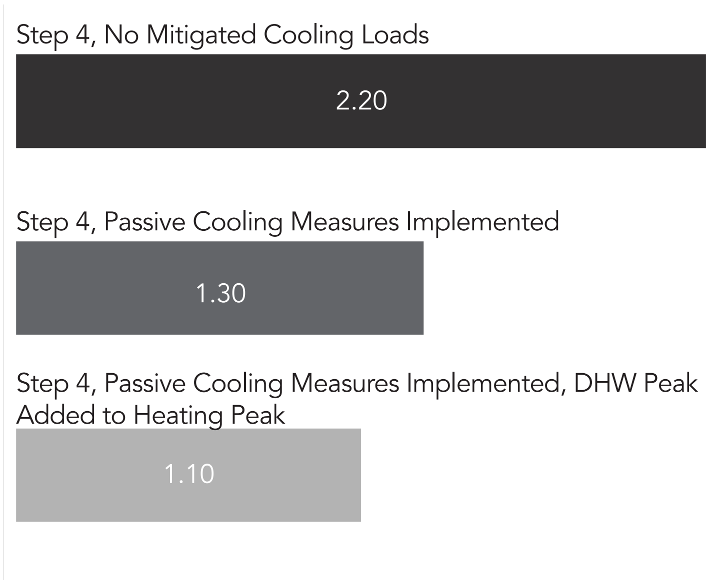
> The common use of large areas of glass, no exterior shading, and suites with single sided exposure that diminish natural ventilation potential are all barriers to effective cooling load mitigation.

The Vancouver market has broadly experienced overheating in MURBs due to a lack of installed air conditioning and passive cooling strategies, and a warming climate. Even well designed, early Passive House projects that have not installed air conditioning have experienced overheating[6] issues. For projects that have installed air conditioning, the cooling energy is often not large enough to incent reductions due to its small impact on TEUI. While not a large energy penalty, unmitigated peak cooling loads can be more than two times higher than peak heating loads for a Step 4 MURB (Figure 1).

Balancing Peak Cooling and Heating Capacity

A TEDI metric for cooling would directly require cooling load reduction strategies. This could bring cooling loads (both peak and annual) of high performance buildings in line with heating loads, creating opportunities for efficient infrastructure (i.e. properly sized heat pumps that can serve both heating and cooling loads).

Figure 1 - Ratio of Peak Cooling to Peak Heating Loads



WHAT IS THE PERFORMANCE POTENTIAL OF THE STEP CODE?

There is a wide range in modelled performance outcomes between various energy standards, as noted in Figures 2 and 3. The highest level of the Step Code has an energy target that is more than twice that of Passive House. Although the TEDI values are the same between the two standards, the different methodology used by Passive House results in approximately a 50% reduction in heating load when compared to the Step Code[7]. Should and could the Step Code be more aggressive in its targets? In order to gain a greater understanding of the performance potential of the Step Code when comparing it to standards like Passive House, it is necessary to understand which areas fall short due to differences in performance expectations versus those related to differences in methodology or assumptions. Through a review of the existing studies and reports on the different standards, four quick observations can be made about the current performance of the Step Code:

Point 1

The TEUI decrease between Step 2 and Step 4 of the Step Code is equal to the TEDI decrease between Step 2 and Step 4. This implies there are no expectations for energy reductions other than those impacting the heating load (i.e. building envelope and ventilation systems).

Point 2

Under typical scenarios, where the lowest first cost solutions are implemented, DHW and suite electrical consumption become the largest end uses in a Step 4 building.

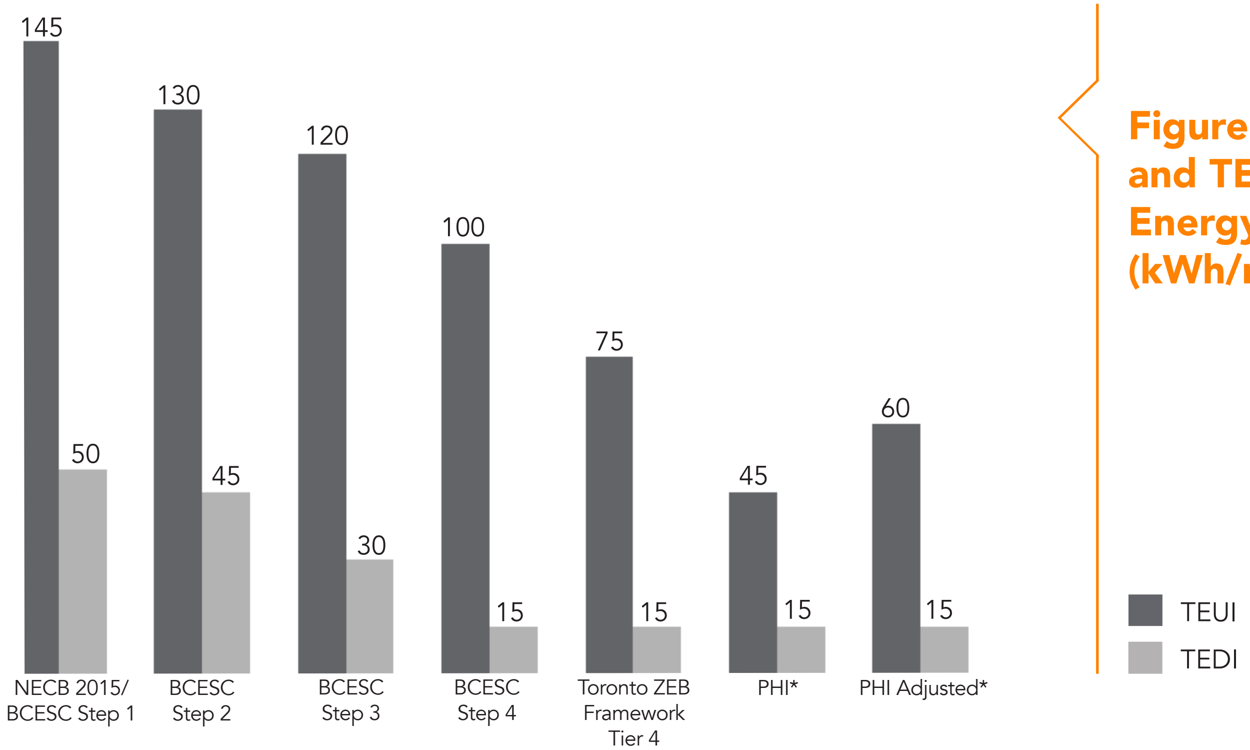


Figure 2 - TEUI and TEDI Across Energy Standards (kWh/m2/year)

*Passive House Institute has a Primary Energy Renewable (PER) target of 60 kWh/m2, with a project specific adjustment for density that translates to an average of 80 kWh/m2 for typical high rise developments; these values translate to site TEUIs of approximately 45 and 60 kWh/m2, respectively (varies by project).

Point 3

In the Step Code, less aggressive TEUI targets were pursued, recognizing that if and when fully electrified, these buildings in BC's clean electricity grid would be near zero emissions. This is in contrast to standards which apply more broadly, like Passive House, where aggressive energy efficiency is integral for achieving levels of GHG reductions in the range of 80%, as required by the Paris Agreement. For example, Step 4 TEUI targets of the Step Code can be met with electric baseboards or gas fired equipment[1], whereas heat pumps are required to meet the more stringent TEUI of Passive House[9].

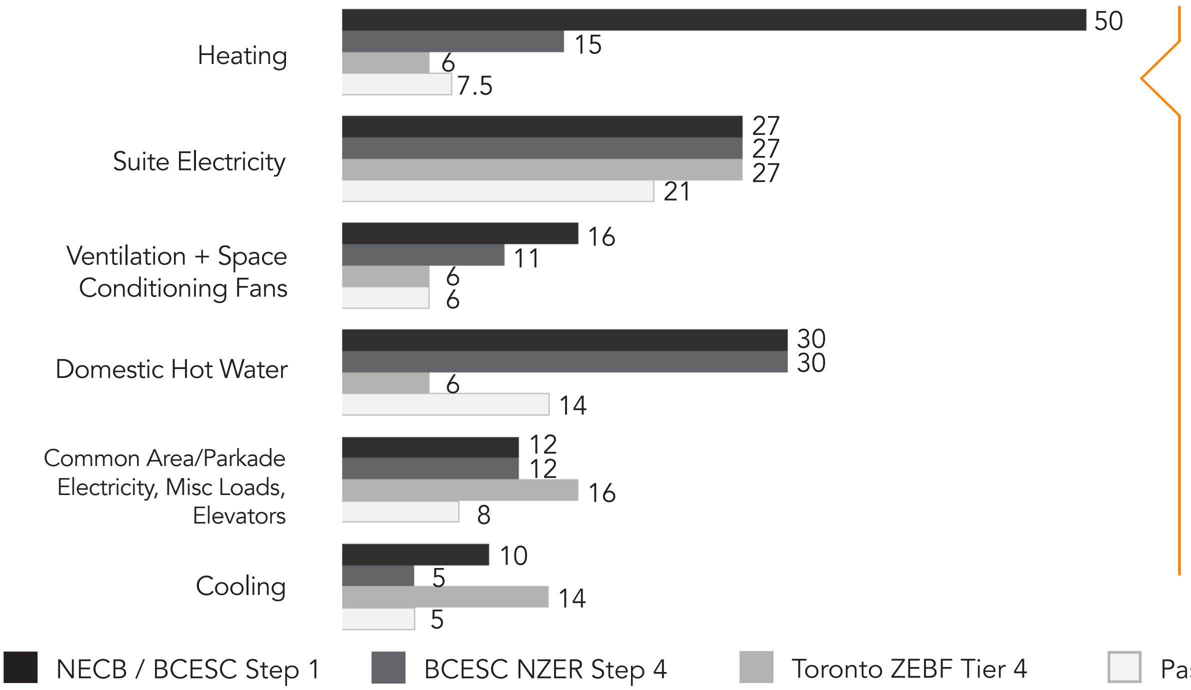
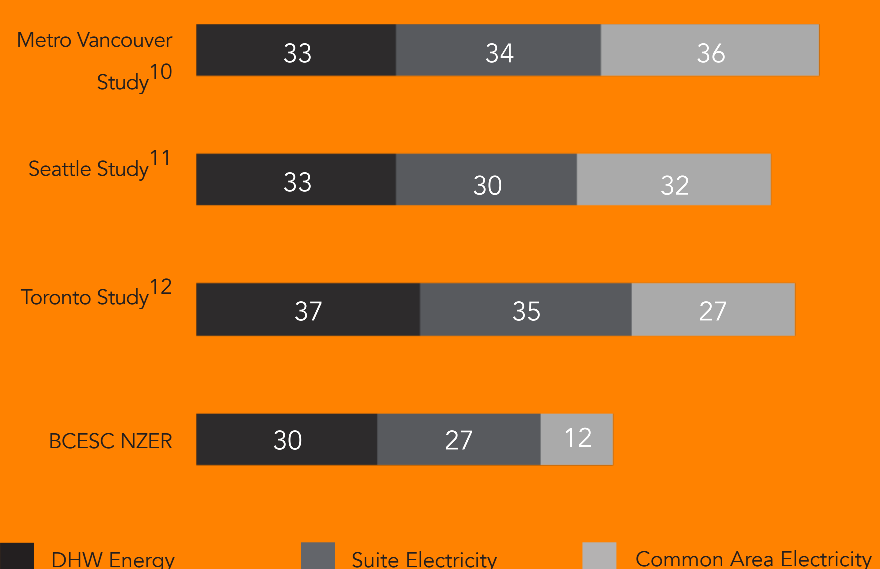


Figure 3 - Energy End Use Comparison Across Energy Standards (kWh/m2/year)

Point 4

While code compliance modelling needs to be standardized to avoid inconsistent approaches between projects, there should always be a continuous drive to align standardized code assumptions with actual operating expectation using past measured data. On average, suite electrical consumption and DHW energy usage are comparing fairly well between modelled assumptions and measured data (Figure 3). However, common area energy usage is significantly higher in practice. This is an area that is not well understood and requires further study.

Figure 4 - Energy End Use Comparison Across Energy Codes and Standards (kWh/m2/year)



A QUICK **SUMMARY** **SO FAR**

The Step Code could immediately make improvements to Net Zero Energy Ready MURBs by lowering the TEUI target to drive heat pumps for heating and DHW. A separate TEDI for cooling would also be a welcome addition to improve comfort and reduce HVAC infrastructure. Once heating and cooling energy is minimized, attention shifts to the remaining end uses, of which the largest include suite electrical consumption and domestic hot water.

DENSITY MATTERS!

The Step Code uses standardized assumptions for building characteristics typically outside the scope of energy codes. This includes things like frequency of appliance usage, hot water use, or the number of hours that the lights are on. The Step Code largely follows performance modelling procedures used in the National Energy Code for Buildings (NECB), with some modifications. The Passive House standard uses a whole set of different standardized assumptions.

Project teams working with both Step Code and Passive House have identified differences in methodologies:

Passive House suite electricity (appliances, plug loads, lighting) and DHW consumption are determined on a per occupant basis. The number of occupants in a building is based on both the number of suites and the size of those suites (approximately 1 person per 25m2 suite, 2 people per 75m2 suite, 3 people per 165m2 suite). Therefore, more smaller suites versus less larger suites over the same building area will result in more occupants and subsequently, higher suite electricity and DHW loads.

In the NECB and Step Code, suite electricity loads are only tied to the building area and not to the number of suites or occupants. The same is true for DHW loads in the NECB. The Step Code deviates from the NECB on DWH by using a usage per occupant[13], which is in turn based on the number of bedrooms per suite (1 person for a studio, 2 for 1-bedroom, 3 for 2-bedroom, 4 for 3-bedroom).

The correlation between building density and overall suite electricity and DHW contribution to TEUI is shown in Figure 5. While the graph represents two approaches in modelled assumptions, actual data has shown that usage of appliances and DHW are in fact linked to the number of suites and/or number of occupants[12, 14].

The strong correlation between density and overall TEUI has led the Passive House Institute (PHI) to update their energy use targets (PER) for MURB projects. PHI's analysis was funded as part of this study, which was seeking to better understand the main challenges related to North American high rise MURBs meeting the stringent energy performance requirements of Passive House. Density was determined to be the only factor which warranted a modification in the energy targets set by the Passive House standard, though all other end uses were studied and are documented in Appendix A (available through info@zebx.org).

Figure 5a - Suite and DHW Loads as a Function of Occupant Density: Using the Passive House Methodology

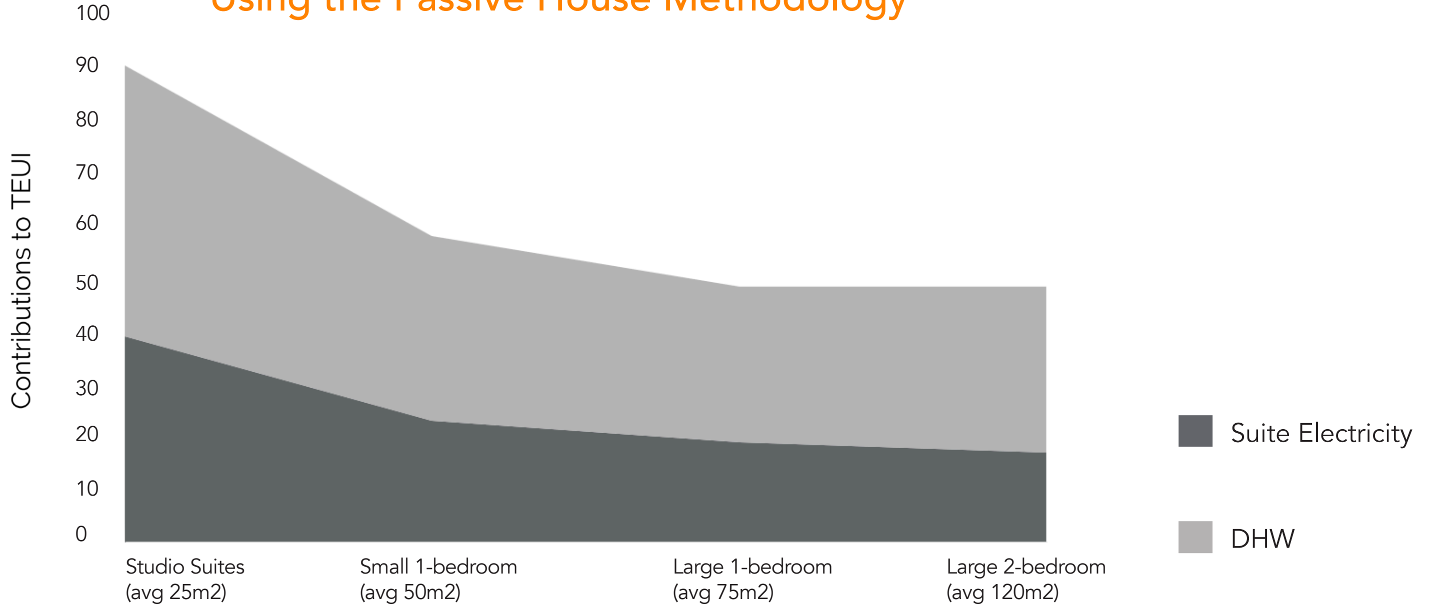
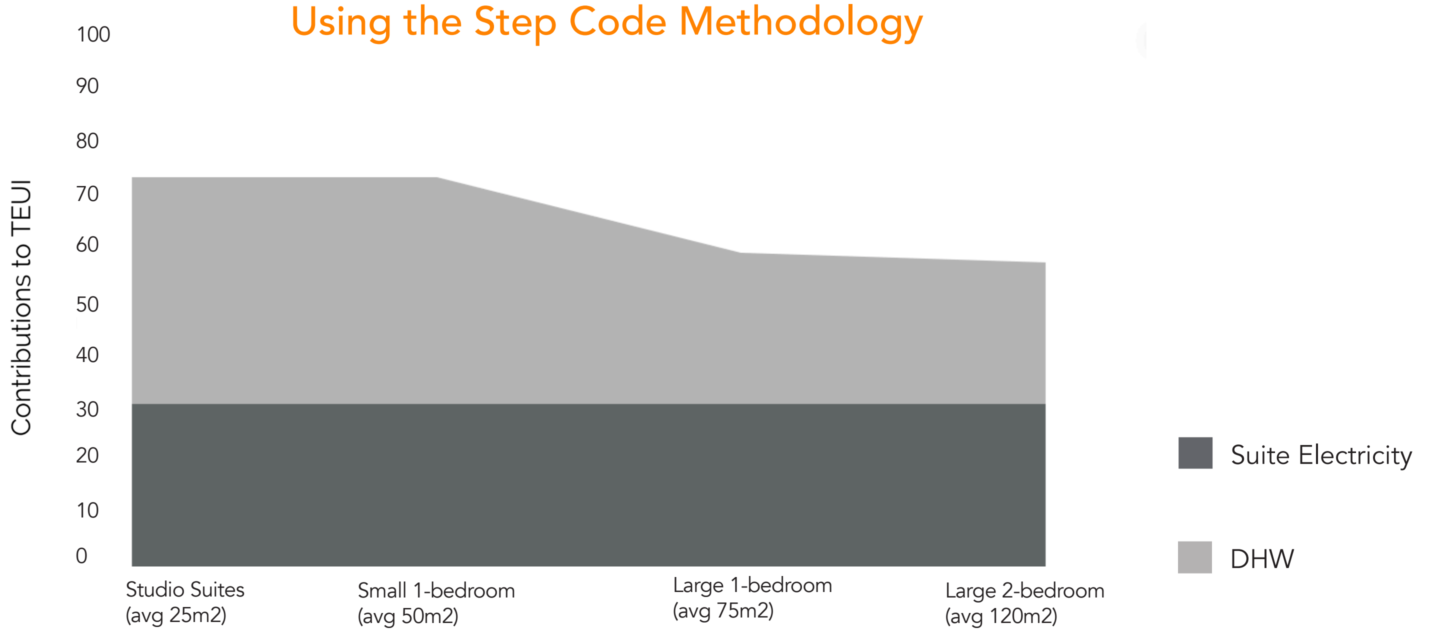


Figure 5b - Suite and DHW Loads as a Function of Occupant Density: Using the Step Code Methodology



*DHW contribution to TEUI is based on an equipment efficiency of 100% to normalize the data between the two methodologies

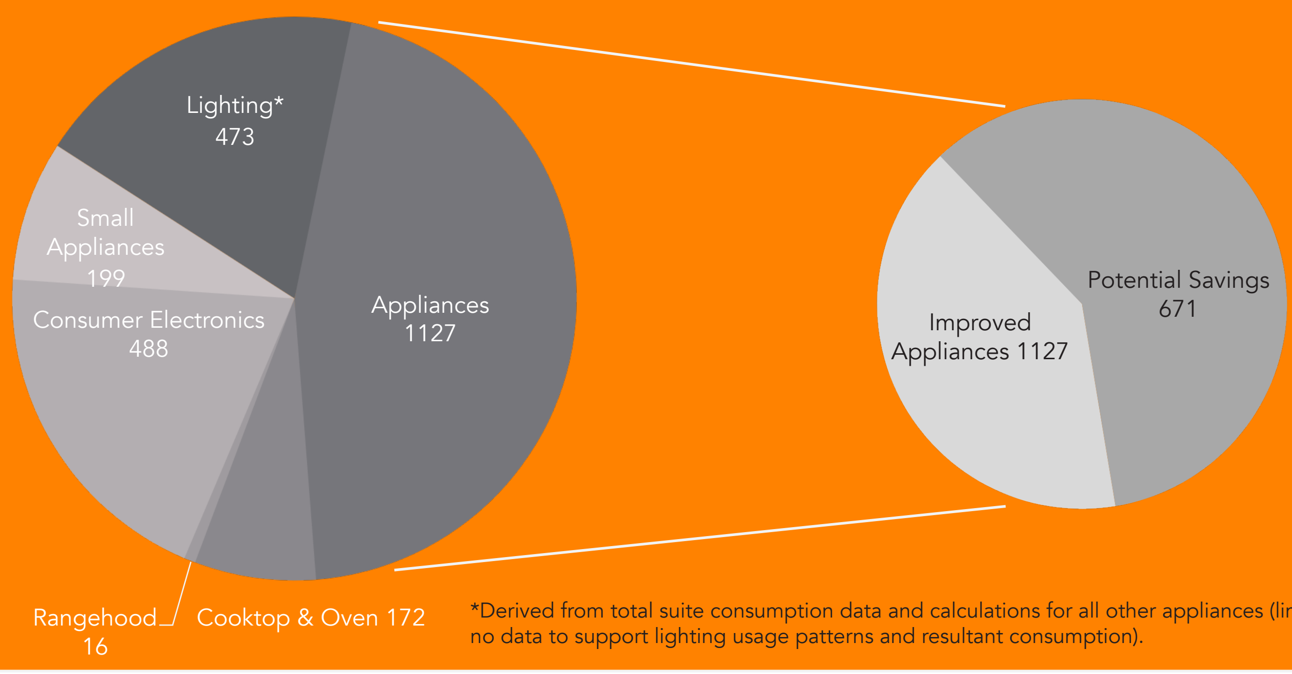
A QUICK **SUMMARY SO FAR**

Now that it has become clear that density is a major driver of energy consumption, particularly for suite electricity and DHW, how can we begin to bring that consumption down? Due to a lack of understanding of which design strategies correlate to which reductions in consumption and how to calculate those reductions, project teams often ignore these loads and leave them as fixed, according to the standardized default assumptions. The first step is to gain a better understanding of how these loads are made up to identify the major drivers of consumption, and ultimately reduction.

A DEEPER DIVE INTO THE SUITE

The Passive House standard uses a very granular approach to deriving suite electricity consumption, though limited meter data is available to validate actual consumption at the appliance level. Most of the measured data available for suite electricity consumption is limited to the whole suite, with little known about the specific energy usage of individual appliances, plug loads or lighting. A ground-up estimate of suite electricity was calculated using the Passive House methodology, using statistical data from Natural Resources Canada on appliance usage[15] and the likely performance of those appliances based on Canadian appliance shipments[16]. A proposed estimated suite breakdown is shown in Figure 6.

Figure 6 - Estimated Breakdown and Energy Savings Potential of Suite Electricity Usage



*Derived from total suite consumption data and calculations for all other appliances (limited to no data to support lighting usage patterns and resultant consumption).

Nearly 50% of suite electricity consumption is estimated to come from appliances.

A deep dive into available appliances in North America has shown that a 60% reduction in appliance energy consumption is possible with available products and over 70% reduction when expanding product selection to Europe (Appendix A). While lighting and equipment efficiencies can be quantified and improved upon, factors and strategies for reducing lighting and plug load usage needs further study.

Lighting energy consumption between Step Code assumptions, Passive House assumptions and estimated from usage data shows a large discrepancy – up to 90%. While there is good data on overall suite consumption, the discrepancy within the specific components leads to large uncertainty of those components. Are lighting energy and plug loads higher or lower than currently used assumptions?

BREAKING DOWN THE DHW LOAD

Similar to suite electricity consumption, there is a wide variation in DHW loads when comparing assumptions between standards and/or actual DHW consumption in MURBs.

The Step Code assumes an average hot water consumption of approximately 40L/person/day. Passive House assumes only 25 L/person/day. Actual measured consumption from different data sources have shown usage closer to 60 L/person/day[14, 17].

Although Passive House assumes less hot water consumption, it does separately account for distribution losses. These can amount up to 50% of the total DHW load when using the Passive House Planning Package (PHPP), the calculation engine and methodology required by the standard. The Step Code, like many energy codes, does not account for distribution losses directly. It's more typical for energy codes like the NECB or ASHRAE 90.1 to require insulation on piping as a prescriptive requirement rather than incorporating losses in the energy calculations.

Previous North American studies have shown distribution losses to be between 30% to 40% of the total DHW load [11, 12].

According to the calculation methodology in PHPP, length of pipe and insulation of pipe fittings has a significant impact on distribution losses (Figure 7). Careful consideration of efficient pipe runs, and insulation of pipe fittings are not currently common practices in Canadian MURB construction, though could be incentivized by updating standard modelling guidelines to account for these factors.

DHW loads are still predominantly served by GHG intensive fuel sources (i.e. natural gas). Therefore, reducing DHW loads is critical for reducing overall building GHG emissions.

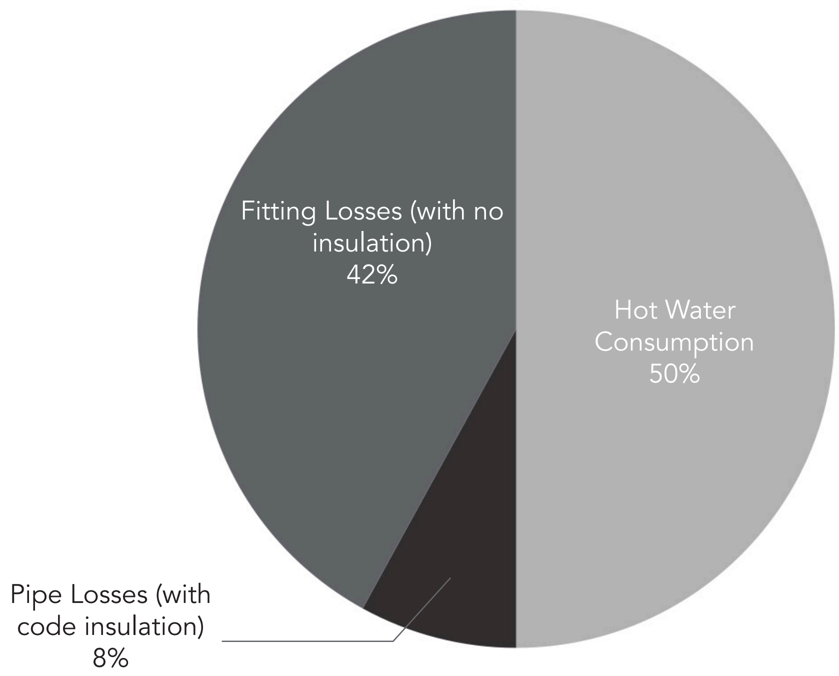


Figure 7 - Example Breakdown of DHW Loads

IMPROVED NET-ZERO ENERGY ROADMAP:
SUMMARY AND RECOMMENDATIONS

In order to better address high levels of energy usage in high density buildings, standardized assumptions in building codes must first properly account for increased density by recognizing direct links between occupancy and consumption.

A more granular approach to estimating suite electricity and DHW loads is required (e.g. breakdown by appliances, inclusion of DHW distribution losses) and should be coupled with more accurate modelling methodologies that recognize robust energy saving strategies in these areas.

Undertake additional studies directed at understanding the energy consumption of suites at the individual appliance and lighting level, as well as a greater understanding of major factors impacting common area energy consumption – one of the largest gaps noted between modelled and measured data.

Overall TEUI targets in the Step Code should be set to more aggressive levels to encourage the use of more energy efficient equipment for heating and DHW (i.e. heat pumps); and consideration by project teams to reduce energy consumption in typically ignored areas, such as suites, DHW, and common areas. Use of heat pumps for heating and DHW and modest load reductions in DHW and suite electricity could bring Step Code TEUI targets in line with Passive House at 60 kWh/m2/year.

The Step Code should consider adding a TEDI metric for cooling. It could also consider a minimum window performance at the NZER level to better ensure thermal comfort outcomes.

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IMPROVING NET-ZERO ENERGY READY CODES FOR MULTI-UNIT RESIDENTIAL BUILDINGS

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