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A Proposed Alternative to the BC Energy Step Code Targets

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Abstract: *The British Columbia (BC) government has introduced an Energy Step Code that will help the BC Building Code (BCBC) transition from current energy requirements to near net-zero energy requirements by 2032. The idea is to show a clear path to all stakeholders as to how the BCBC will transition in the next 15 years. An analysis was done using the Housing Technology Assessment Platform, an optimization tool developed by Natural Resources Canada, to find the most cost effective design strategies to achieve the different Step requirements in British Columbia's different climate zones. The analysis identified that the current targets could be challenging to achieve for certain archetypes and climates. This paper proposes to follow a reference house approach for both Mechanical Systems and the Building Envelope. The proposed approach is applied to two of the most challenging archetypes and climates to show that most of the identified issues were resolved.*

Keywords: *Step Code, optimisation, Building Code, British Columbia, high performance*

INTRODUCTION

The British Columbia (BC) government introduced the Step Code to help transition the BC Building Code (BCBC) from current energy requirements to near net-zero energy requirements by 2032. The idea is to advise all stakeholders how the BCBC will transition in the next 15 years. This target is in line with the federal government that is developing a "net-zero energy ready" model building code, with the goal that provinces and territories adopt it by 2030 (Canada, 2016). It is also a recommendation of the International Energy Association, which recommends that Passive Houses and Zero Energy Buildings should be the building code targets no later than 2030 (IEA, 2008).

As of December 15, 2017, the only tool available to local governments in BC, with the exception of the City of Vancouver, that want to require higher energy efficiency standards for buildings is the BC Energy Step Code. The Step Code applies to any new construction of Part 9 residential buildings province-wide, with different performance requirements set for Climate Zones 4, 5, and 6/7a/7b/8. The Step Code also applies to Part 3 multi-unit residential and large commercial buildings (Group D & E) in Climate Zone 4 (BC Government, 2017). A climate zone map of British Columbia is show in Figure 1.

In early 2017, a large parametric study was commissioned by the BC government to evaluate the cost impact of meeting the Energy Step Code for various archetypes in BC's six different climate zones. Natural Resources Canada (NRCan) provided support to the project by making available their internal Housing Technology Assessment Platform (HTAP) tool. The results of the project, which have been published (Integral Group, et al. 2017), found that builders can achieve the majority of steps for less than a 2% capital cost premium above the cost of conventional construction.

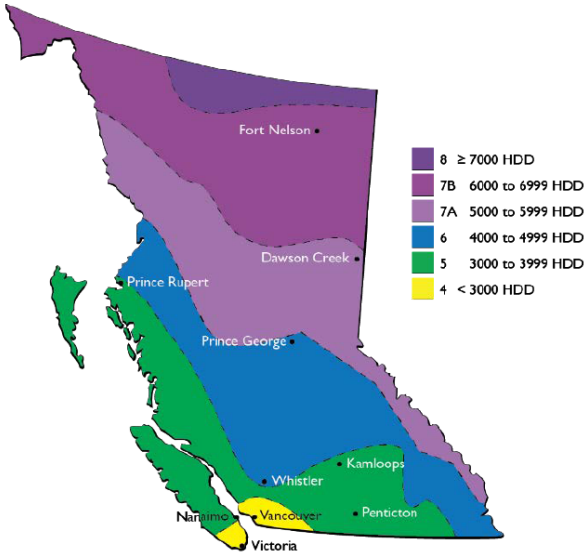

Figure 1: BC Climate Zones (Figure Credit: RDH Building Science Inc.)

There were some challenges identified with the current Step Code targets including having significant difference between the cost of meeting the targets between different archetypes and climate zones. A preliminary analysis was done to suggest ways that some of these issues could be addressed, however, this was not a main objective of the metrics project, and no changes were made to the targets.

With over two million separate HOT2000 (NRCan, 2018) energy models evaluated with different housing archetypes, in different climates, the results were further analyzed to help identify potential issues that could emerge with the BC Energy Step Code.

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This paper presents proposed modifications to the Energy Step Code targets for part 9 residential buildings and compares them to the current BC requirements.

ENERGY STEP CODE TARGETS

Step 1 of the Step Code is set at the current BCBC requirements but adds an EnerGuide evaluation with a blower door test. Table 2 provides the requirements for Mechanical Systems and the building envelope for Steps 2 to 5. Steps 2 to 4 have different targets for Climate Zone 4 (CZ 4), Climate Zone 5 (CZ 5) and all other climate zones have the same requirements. There is also an airtightness requirement that starts as 3.0 ACH at 50 Pa at Step 2 and decreases by 0.5 ACH per step to 1.0 ACH, for Step 5.

Table 2: BC Energy Step Code Requirements

Step	Mechanical Systems	Envelope
2	ERS[1] 10% better than reference house **OR:**	Either TEDI[2] or PTL[3]
CZ 4	MEUI[4] – 60 kWh/m^2	TEDI 45, PTL 35
CZ 5	MEUI – 90 kWh/m^2	TEDI 60, PTL 55
Colder	MEUI – 100 kWh/m^2	TEDI 70, PTL 55
3	ERS 20% better than reference house **OR:**:	Either TEDI or PTL
CZ 4	MEUI – 45 kWh/m^2	TEDI 40, PTL 30
CZ 5	MEUI – 75 kWh/m^2	TEDI 50, PTL 45
Colder	MEUI – 85 kWh/m^2	TEDI 60, PTL 50
4	ERS 40% better than reference house **OR:**	Either TEDI or PTL
CZ 4	MEUI – 35 kWh/m^2	TEDI 25, PTL 25
CZ 5	MEUI – 45 kWh/m^2	TEDI 40, PTL 40
Colder	MEUI – 55 kWh/m^2	TEDI 50, PTL 45
5	MEUI – 25 kWh/m^2	TEDI 15, PTL 10

1. *ERS: EnerGuide Rating System energy rating excluding base loads.*
2. *TEDI: Thermal Energy Demand Intensity is the modelled auxiliary energy required per unit area.*
3. *PTL: Peak Thermal Load is the modelled design heat loss per unit area.*
4. *MEUI: Mechanical Energy Use Intensity is the sum of the modelled heating, ventilation and air conditioning plus the domestic hot water energy use per unit area.*

MODELLED DATA

To evaluate the impact of the BC Energy Step Code, six base building archetypes were modelled in HOT2000 using HTAP to automate the process. Each archetype was evaluated with various combinations of energy conservation measures (ECM), which resulted in over 43 million possible design combinations for each archetype. Each archetype was modelled across BC's six climate zones (Fig. 1).

Archetypes evaluated

Six base housing archetypes were modelled in the BC Step Code parametric study. The study also modified some of the archetypes to verify architectural impacts, such as changing the exterior wall area of the medium single family house to reflect more complicated architectural features as well as changing building and window orientation. The archetypes modelled in the study were the following:

- Small single family (102.2 m^2 [1,100 ft^2], single storey on heated crawlspace)
- Medium single family (236.9 m^2 [2,550 ft^2], 2 storey with basement)
- Large single family (511.0 m^2 [5,500 ft^2], 2 storey with basement)
- Quadplex (128.4 m^2/unit [1,382 ft^2/unit], 3 storey over underground parkade)
- 6-unit row house (168 m^2/unit [1,808 ft^2/unit], 3 storey over underground parkade)
- 10 unit multi-unit residential building (MURB) (165.4 m^2/unit [1,780 ft^2/unit], 3 storey over underground parkade)

Each of the archetypes was modelled with a series of different building envelopes and mechanical systems as outlined in Table 1.

Energy conservation measures considered

Table 1 lists the energy conservation measures that were considered in the BC Step Code parametric study. The lowest efficiency option generally reflects the code minimum performance requirement for Climate Zone 4 (<3,000 Heating Degree Days [HDD]) in the National Energy Code of Canada for Buildings (NECB) section 9.36. HTAP utilises GenOpt (Lawrence Berkeley Labs, 2018) for its optimization algorithms. The default optimisation technique used in HTAP is GenOpt's particle swarm inertial weight (PSOIW) algorithm with the von Neumann neighbourhood topology. For each archetype and climate, between 10 and 20 thousand separate combinations of ECMs were modelled in HOT2000.

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Table 1: Energy conservation measures evaluated

Component	Options	#
Walls	R16, R18, R22, R24, R30, R40, R50, R60	8
Windows	3 double, 4 triple (U-1.8 to U-0.8)	7
Foundation	R11.3, R17, R20, R25	4
Under-slab	R0, R11, R15, R20	4
Exposed	R26.5, R29, R35, R40	4
Attic	R40, R50, R60, R70, R80, R100	6
Air sealing target, 50 Pa	3.5 ACH, 2.5 ACH, 1.5 ACH, 1.0 ACH, 0.6 ACH	5
DHW heating	Electric & gas tank, 2 x tankless, heat pump	5
Space heating	92% & 95% AFUE, combo, CCASHP	4
Drain water	None, 30%, 42%, 55%	4
HRV	None, 60%, 70%, 75% & 84% SRE	5
Total number of combinations > 43million		

CHALLENGES WITH CURRENT TARGETS

One of the major drawbacks to an energy intensity target approach is the difficulty in setting an appropriate and fair target over a range of building types (Rosenberg, et al., 2015). As other jurisdictions have experienced, changes to building codes aimed at reducing energy consumption, if not fully examined, can result in an increase in energy consumption (Allard et al., 2013). In the BC Step Code, this could occur for certain archetypes and climate zones.

Many factors can impact the energy performance of different archetypes with the most obvious being dwelling size given that we are considering energy use per square meter. Figure 2 shows the range of TEDI achieved for Step 1 (i.e. current code requirements) for different climates and archetypes. If we look at Summerland (HDD 3,350) the TEDI ranges from 41 kWh/m^2 to 56 kWh/m^2 for the different archetypes. With current code minimum requirements, the rowhouse is almost at Step 4, the medium single family dwelling and quadplex meet Step 3, and the other three archetypes meet Step 2. With the same energy conservation measures, there is a spread of close to 3 steps between archetypes. Figure 3 shows that the MEUI for the small single family house is roughly 60% higher than for the other archetypes.

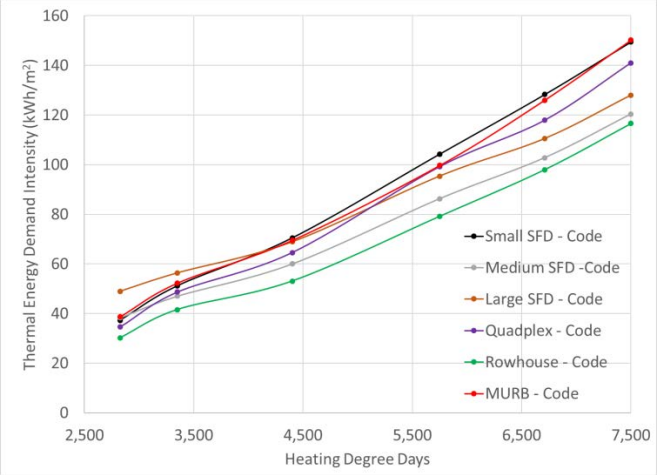

Figure 2: TEDI for different archetypes meeting code minimum requirements in different climate zones

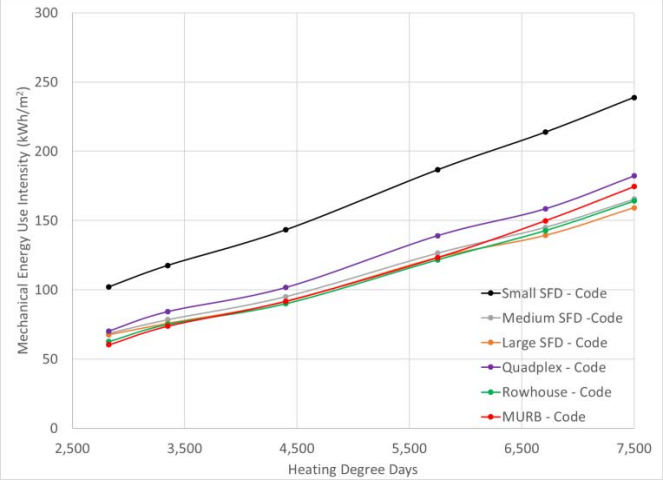

Figure 3: MEUI for different archetypes meeting code minimum requirements in different climate zone

The use of intensity-based metrics (on their own) results in a much higher energy budget permitted for larger homes. This results in it being easier and less expensive for larger homes to meet the Step Code (Integral, et al. 2017). This in turn could result in larger homes to lag rather than to lead in the adoption of energy efficient technologies and practices. This could result in entry-level market builders needing to push changes to their supply chain ahead of the higher-end builders, when the former are often much less adept in doing so. Alternatively, builders may be forced to move away from small detached single family architecture towards more compact and efficient multi-unit dwellings. This is a significant departure from the prescriptive or reference house approach that the market is used to, where homes of all sizes are expected to be using approximately the same envelope and similar technologies. This was not a

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planned outcome of the Step Code, and it should be reviewed on a policy basis whether the code should be inherently favouring certain archetypes. The promotion of compact small multi-unit dwellings might be beneficial, whereas the benefits to large dwellings may not.

Climate zones 4 and 5 each have their own requirements for a relatively small HDD band compared to climate zones 6 to 8 that are lumped together. Figure 2 shows the range from the lowest to the highest TEDI for climate zones 6 to 8 goes from 53.1 to 150 kWh/m^2, yet they all have the same target. All but the large single family house meet Step 3 for the TEDI with current code requirements for climate zone 4, whereas for climate zone 8, meeting Step 3 requires a reduction in TEDI from 48.5% to 60% depending on the archetype.

With the exception of Step 5, both the Mechanical Systems and the Building Envelop requirements have two potential targets, both of which could lead to very different levels of performance. For example, the large single family house can meet the climate zone 5, Step 2 requirement for MEUI and PTL using the minimum code requirements for climate zone 4. Even though the resulting MEUI is 16% below the Step 2 target, the design is 21.7% above the ERS reference house, or 35.2% above the MEUI that would be required if following the ERS reference house path. Similarly, the PTL is 35% below the Step 2 target, whereas the TEDI just missed the target. The targets would have to be adjusted such that they lead to similar levels of performance. The PTL values in general need adjustments. Figure 4 shows that for the lower steps, that code minimum values meet the PTL requirements, especially in the warmer climates. On the other end of the spectrum, only the best PTL results of the MURB archetype in climate zone 4 was able to meet the Step 5 PTL requirements, as shows in Figure 7.

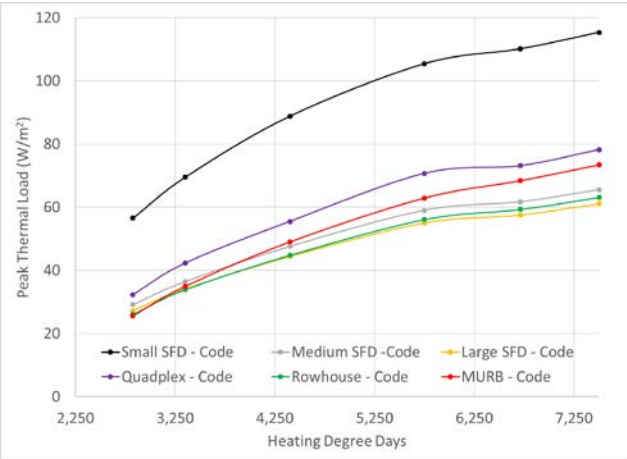

Figure 4: PTL for different archetypes meeting code minimum requirements in different climate zone

The biggest challenge with the way the current BC Energy Step code targets are laid out is that all climate zones need to achieve the same target for Step 5. Figure 5 shows the lowest TEDI achieved in the HTAP modelling for each archetype and climate zone. Figure 6 shows the lowest MEUI achieved in the HTAP modelling for each archetype and climate zone.

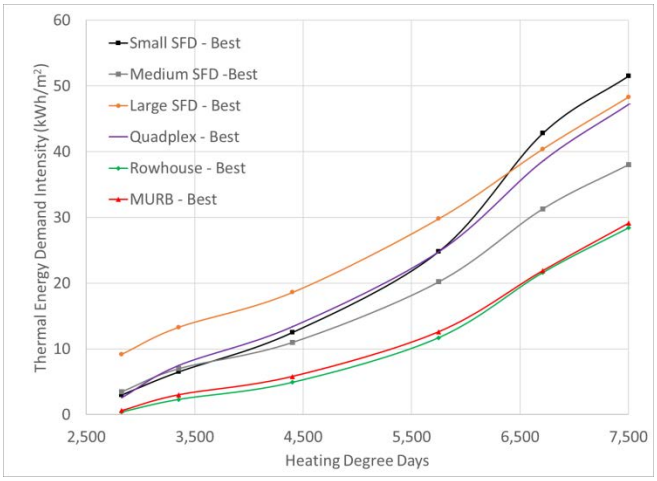

Figure 5: TEDI for different archetypes achieving the best performance in the HTAP modelling

All archetypes could meet the 15 kWh/m^2 TEDI for climate zones 4 and 5. However, even the best performing archetype in climate zone 8 is 100% over the target. Figure 6 shows similar results for the MEUI.

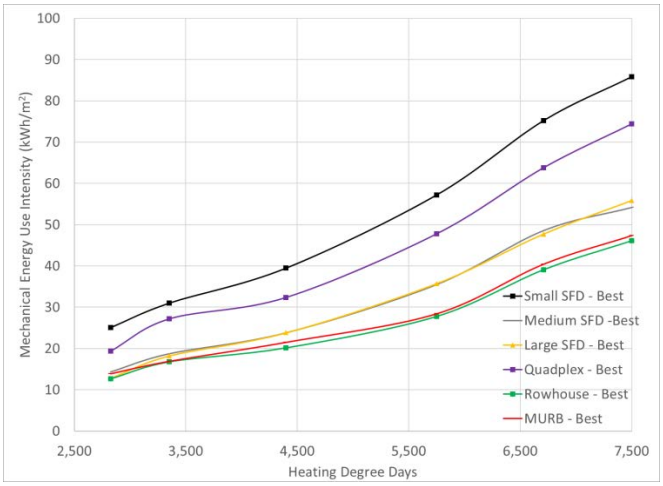

Figure 6: MEUI for different archetypes achieving the best performance in the HTAP modelling

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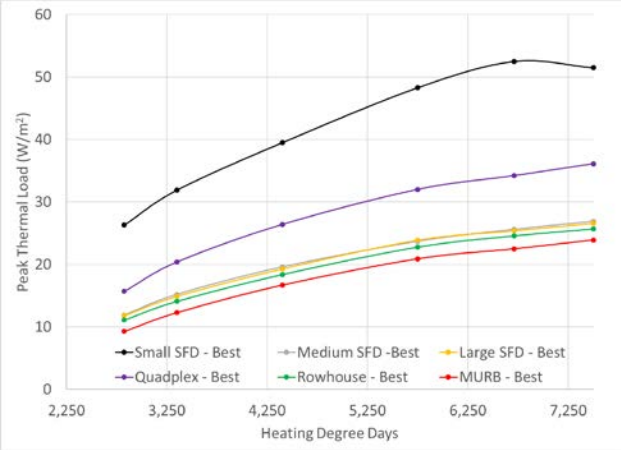

Figure 7: PTL for different archetypes achieving the best performance in the HTAP modelling

The Cost Efficient Passive Houses as European Standards (CEPHEUS) project in Europe tested and proved the viability of the Passive House concept, but concluded that targets need to be adapted to different climatic conditions. The Finnish and Norwegian participants demonstrated that the 15 kWh/m^2 was not readily achievable in their countries (Sun, 2013). Several other studies have been conducted regarding the performance of Passive Houses in various climates. The main finding is that under extreme climatic conditions, Passive Houses fail to meet the targets (Fokaides, et al., 2016).

The Passive House Institute (PHI) has subsequently done an analysis on the achievability of the Passive House standard in six different climates (Schnieders, Feista, Rongen, 2015). The coldest climate modelled was Yekaterinburg, Russia, which has humid continental climate with severe winters, no dry season, warm summers and strong seasonality (Yekaterinburg, 2018). The average temperature in the winter is 4ºC to 5ºC colder in Fort Neslon, BC, than in Yekaterinburg with average January temperatures of -21.2ºC compared to -16ºC (Environment Canada, 2018).

The PHI study modelled two archetypes in Yekaterinburg. A small, two-storey, end-of-terrace house with 120 m^2 of living area and a footprint of 6m by 11 m, and a larger multi-family residence with shops on the ground floor. South orientation on a nearly unshaded plot was assumed. The small house was optimized to the following performance parameters:

- Wall R-value: RSI-16.7 (R-95)
- Ceiling R-value: RSI-25 (R-142)
- Window U-value: U-0.51 (U-0.09)
- Airtightness: 0.3 at 50 Pa
- HRV efficiency: 92%.

Using a more efficient architecture (row-house on two levels), a warmer winter climate, favourable orientation, and much more aggressive ECM's, the resulting TEDI for the small unit was 22.4 kWh/m^2. The larger multi-unit building was able to meet the 15 kWh/m^2, using large south facing windows to boost passive solar gains.

One of the limitations of the BC parametric study, was that they started with specific archetypes and tried to have them meet more stringent energy efficiency requirements by layering on additional ECMs. As was seen in the PHI study (Schnieders, Feista, Rongen, 2015), developing a design that is specific for Northern climates, and additional ECMs would be needed to meet Step 5 in colder climates. However, the BC parametric study did attempt to modify some of the archetypes and try to increase the ECMs in an attempt to see if the archetypes could be made to achieve Step 5. Neither the small nor large single family dwelling or the quadplex were able to achieve Step 5 even with those additional measures (Integral Group, et al. 2017). As seen in Figure 6, the small single family house struggles to meet the MEUI requirement given that it has similar base loads as the larger buildings distributed over a much smaller area. However, this same issue can help it achieve the TEDI, as the base loads contribute to a greater share of the heating load compared to the large house, which struggles to achieve the TEDI, as seen in Figure 5.

Potential alternative requirements

One of the major challenges in developing energy efficiency requirements is to balance flexibility against complexity and this requires careful consideration of the compliance process and the proficiency of the local building industry (Hui, 2002). Most of the codes in use today have a mix of performance and prescriptive language with performance-based provisions being coupled with some prescriptive requirements. Adding a set of minimum prescriptive requirements would ensure that no archetype could perform worse than current requirements.

If the broad objective for jurisdictions to implement energy efficiency requirements is to address climate change, energy intensity metrics alone might not be enough. Although reducing energy intensity is good, jurisdictions need to reduce their overall greenhouse gas emissions. In the City of Vancouver, this was partially addressed by including both a greenhouse gas intensity metric to their requirements, as well as capping the total emissions for large homes over 3500 square feet, which must demonstrate a greenhouse gas (GHG) footprint at or below that of a 3500 square foot home (VBBL, 2017).

In 2014, the Passive House Institute US (PHIUS) departed from the International Passive House Institute (PHI, 2018)

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Passive House standard, which closely resembles Step 5 of the Step Code, and released their own set of passive house requirements (Wright & Klingenberg, 2014). PHIUS stated that the PHI standard was not responsive to the wide diversity of climate and energy market conditions in North America and that using European energy metrics for North American climates had forced solar-driven designs that tend to overheat and have very high cost envelopes. Instead of having a single TEDI metric for all buildings and climates, the PHIUS approach uses equations developed based on optimisation results from a 193 m^2 (2,080 ft^2) single-family detached house modelled in climates across North America. The PHIUS standard has four main performance requirements in the form equations:

1. TEDI is a function of Heating Degree Days (HDD), global solar radiation, and electricity price.
2. Cooling demand intensity based on Cooling Degree Days (CDD) and dehumidification design humidity ratio.
3. PTL is a function of heating design dry bulb temperature, HDD, and electricity price.
4. Peak cooling load is a function of peak cooling design temperature, CDD, and dehumidification design humidity ratio.

Since costs are a moving target over time, they plan to revise the standard every 3–5 years as utility costs change. Assuming $0.11/kWh, the PHIUS requirements for Vancouver results in a TEDI of 17.4 kWh/m^2 and PTL of 17.9 W/m^2, whereas Fort St John has a TEDI of 30.5 kWh/m^2 and PTL of 25.7 W/m^2. Figure 5 shows that only the rowhouse and MURB could reach the PHI target (or Step 5) for Fort St John, but that all of the archetypes could reach the PHIUS targets. There are now practitioners in Canada and the US that follow either the PHIUS requirements or the PHI requirements.

Given the cold climates experienced in Scandinavian countries, their high performance building codes could also serve as relevant examples. Allard, et. al. (2013) described the code requirements for Sweden, Norway and Finland:

Sweden: Three climate zones with different requirements; a PTL requirement ranging from 15 to 17 W/m^2, total energy use 63 to 73 kWh/m^2, supplied energy 25 to 29 kWh/m^2 (if electrically heated) or 50-58 kWh/m^2 if heated with no electricity. Buildings smaller than 400 m^2 get an additional 5 kWh/m^2 of total energy use.

Norway: The Norwegian regulations focus on energy for space heating. The requirements on space heating are adapted for colder climates and for buildings smaller than 250 m^2. Small building have an allowable net-energy consumption of 120+1600/m^2 kWh/m^2 instead of 115 kWh/m^2. The TEDI for buildings over 250 m^2, where average temperature is above 6.3ºC is 15 kWh/m^2. For lower temperatures, TEDI is adjusted by using the average outdoor temperature: $15+2.1\cdot(6.3-T_{o,avg})$. For small houses where the temperature is above 6.3, TEDI is adjusted by floor area: $15+5.4\cdot(250-A_{fl})/100$. For small houses in cold climates, additional adjustment for floor area and climate: $+(2.1+0.59 \text{ x } ((250- A_{fl})/100)) \text{ x } (6.3- T_{o,avg})$.

Finland: There are two different specifications in Finland with new independent passive house specification-alternatives being created and the existing ones expected to be adapted in the near future. The three climate zones are for the South, Middle, and Lapland. The Finnish VTT passive house specification ranges from TEDI of 20, 25, and 30 kWh/m^2, and primary energy from 130, 135, and 140 kWh/m^2.

Closer to home and on a National level, the Canadian Home Builder Association (CHBA) has launched a net-zero ready label (CHBA, 2017). If the intention of the federal and provincial government is to truly build net-zero and net-zero energy ready buildings, the CHBA approach is the only one that can ensure this target is met. Their label requires that the EnerGuide rating for the home, in GJ, be zero with the on-site renewables modelled, and any difference in the EnerGuide rating from 0 GJ needs to match the on-site renewables that are planned for future installation. The label puts an emphasis on the building envelope by requiring that the annual space heating energy consumption (MJ) of the proposed house be at least 33% lower than the corresponding reference house modelled with standard mechanical equipment in addition to having minimum effective thermal resistance of opaque assemblies.

Given that the CHBA label is targeting net-zero energy consumption, it specifies the use of the net-zero EnerGuide base loads. The reduced base-load is more realistic for net-zero buildings with a reduced daily lighting load from 3 kWh down to 1 kWh (provided that 75% of fixtures are compact fluorescents [CFL] or light-emitting diodes [LED]), and major appliances from 6.3 kWh/day to a value corresponding to the appliances' EnerGuide rating (if lower than the standard values). Another advantage of the CHBA approach is that they consider over-heating. Where over-heating is predicted, their methodology provides incentive for the builder to include more efficient cooling technologies at the time of construction compared to less efficient technologies added as a retrofit by making the renewable energy system design account for cooling, whether it is installed or not.

As with the standards developed in Norway and PHIUS, a regression analysis can be performed on either the BC Step Code parametric analysis data, or other modelling, to come up with an equation based set of requirements. These equations could provide allowances for building area and

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climate as well as other potential factors like utility costs. It could include a greenhouse gas (GHG) intensity metric, and a potential GHG limit – similar to what Vancouver introduced. If the goal is to achieve a net-zero energy ready target, the total energy use could be capped to what can be generated on the building. An analysis would be need to determine if that is feasible for all archetypes and climates. Clearer policy objectives would be required before developing a set of equations. The current Canadian Commission on Building and Fire Codes (CCBFC) policy is that until all levels of government agree on an approach for a national carbon-free economy, the long-term performance goal for buildings should focus on energy – not carbon (NRC, 2016).

PROPOSED REQUIREMENTS

When the Pacific Northwest National Laboratory developed a roadmap for Commercial Energy Codes in the US, they found that a performance based approach that requires energy efficiency improvement over a modelled reference building provides the best accuracy and potential for a highly automated approach that could eventually be applied to most buildings (Rosenberg, et al., 2015). They note that reference building should be an independent baseline that does not change over time. Only the percent improvement over time should change.

Comparing a proposed building design to the same building built to a set of reference requirements eliminates all of the challenges outlined with the current Energy Step Code. That is the current approach of the 2015 NBC. Sentence 9.36.5.4 (8) requires that (NBC, 2015):

> *If a computer program is used to carry out the compliance calculations, the calculation methods employed in the energy model shall*
>
> *a) be used for both the reference and proposed houses*

The Mechanical Systems requirements of the Step Code does have an option to use a percent savings relative to the EnerGuide Rating reference house for Steps 2 to 4. This study proposes to use the same approach for all Steps for both the Mechanical Systems requirements as well as the Building Envelope requirements.

There are some drawbacks of using a reference building approach, with one of the main ones being that it has often not promoted energy efficient architecture. If the proposed building is inherently inefficient due to a sub-optimal building form, no thought given to proper orientation, excessive amounts of North facing windows, etc., there is often no penalty associated with this given that the reference building generally has the same inefficient architectural features. This can be addressed fully, or in-part, by adjusting how the reference house is defined. For example, if the proposed building has 60% window-to-wall ratio on the North façade, the reference can be modelled with a specified maximum window ratio. This article does not specify how the reference building could be defined to address inefficient architecture, but it should be examined before launching a Code based on a reference approach.

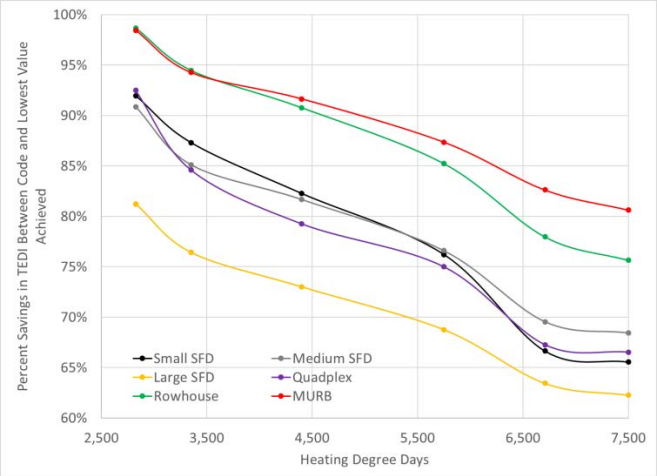

Figure 8: Percent savings achieved in TEDI between code built archetype and best achieved performance

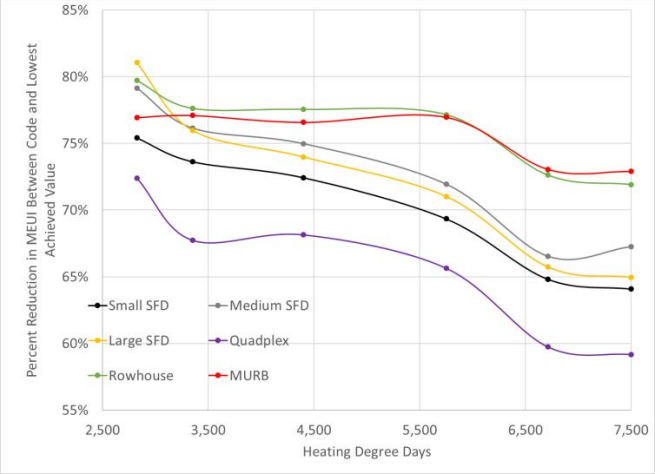

Figure 9: Percent savings achieved in MEUI between code built archetype and best achieved performance

Figures 8 and 9 show that it is easier to achieve a higher percent reduction in the warmer climate zones, whereas the current BC Energy Step Code demands higher percent energy savings in colder climate zones. If different targets were to be assigned to different climate zones, there should be higher savings required of the warmer climate zones compared to the current code requirements. If we were to have three sets of requirements, it would be less problematic to group climates zones 4 and 5, 6 and 7a, and 7b and 8 together. However, for simplicity, it is proposed to use one set of targets for all climate zones.

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With the exception of the MEUI for the large single family dwelling, we can see that all other archetypes can meet a 60% reduction in TEDI and MEUI. Achieving higher MEUI reduction could be achieved relatively easily with the large single family house by selecting more efficient mechanicals. It is thus proposed that a 60% reduction be targeted for Step 5, starting at 15% for Step 2 and increasing by 15% each step. The BC Energy Step Code was targeting a slower increase in requirements for the first steps (10% and 20% for Steps 2 and 3), which could facilitate the industry to start-off at a familiar pace and ensure that the fundamentals are implemented properly. However, the incremental cost of achieving higher energy savings increases substantially as performance increases, and weighting the steps to be larger for the later steps would compound the cost increases for the higher steps. If the goal was to have the same cost increase for each step, the opposite of the current approach could be implemented, with higher jumps in savings for the earlier steps, slowing down as steps increase. Having the same step increments is a compromise between the two approaches. Having the same overall targets for both equipment and envelopes for all climate zones results in a very simple code, as outlined in Table 3. .

Table 3: Proposed Energy Step Code Requirements

Step	Mechanical Systems	Envelope
2	MEUI 15% better than reference house	TEDI 15% better than reference house
3	MEUI 30% better than reference house	TEDI 30% better than reference house
4	MEUI 45% better than reference house	TEDI 45% better than reference house
5	MEUI 60% better than reference house	TEDI 60% better than reference house

COMPARISON OF PROPOSED AND CURRENT REQUIREMENTS

Tables 4 through 7 provide the proposed targets and the resulting lowest incremental cost design for Steps 1 through 5 for the small and large single family houses for climate zone 4 (Vancouver) and climate zone 7b (Fort Nelson) using the same incremental costs as those used in the BC parametric study (Integral Group, et al. 2017).

The proposed targets do seem to help address some of the identified challenges. The small single family house has relaxed targets for MEUI and more stringent targets for TEDI in Vancouver. In Fort Nelson, all MEUI and TEDI targets for both archetypes are less stringent than in the current BC Energy Step Code. No small single family house could meet the combination of proposed MEUI and TEDI targets. To achieve the MEUI, designs made use of a heat pump water heater. However, the modelled units has the evaporator on the tank, which robs heat from the house making the TEDI higher. This could be resolved by having heat pumps with the evaporator unit outside the house.

Table 4: Results using proposed requirements for small single family house in climate zone 4 (Vancouver)

Component	Step 1	Step 2	Step 3	Step 4	Step 5
MEUI target	102.1	86.8	71.5	56.2	40.8
TEDI target	37.3	31.7	26.1	20.5	14.9
Cost ($/m^2)	0	17.0	38.3	73.8	165.5
Walls	R16	R16	R16	R24	R40
Windows	U1.8	U1.8	U1.6	U1.2	U1.2
Attic	R40	R70	R70	R100	R100
ACH_{50}	3.5	1.0	2.5	2.5	0.6
DHW	.67 EF	.67 EF	Elec.	.94 EF	HPWH
Heating	92%	Elec.	Elec.	Elec.	92%
HRV	0%	0%	70%	60%	70%

Table 5: Results using proposed requirements for small single family house in climate zone 7b (Fort Nelson)

Component	Step 1	Step 2	Step 3	Step 4	Step 5
MEUI target	213.8	181.7	149.7	117.6	85.5
TEDI target	128.3	109.1	89.8	70.6	51.3
Cost ($/m^2)	0	-1.3	26.7	72.7	256.9
Walls	R22	R18	R18	R40	R60
Windows	U1.4	U1.2	U0.8	U1.2	U0.8
Attic	R60	R100	R60	R80	R100
ACH_{50}	3.5	1.5	0.6	0.6	0.6
DHW	.67 EF	Elec.	Elec.	Elec.	HPWH
Heating	92%	Elec.	Elec.	Elec.	Elec.
HRV	0%	60%	60%	60%	84%

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Table 6: Results using proposed requirements for large single family house in climate zone 4 (Vancouver)

Component	Step 1	Step 2	Step 3	Step 4	Step 5
MEUI target	67.6	57.5	47.3	37.2	27.0
TEDI target	49.0	41.7	34.3	27.0	19.6
Cost ($/m^2)	0	8.5	18.3	34.1	64.9
Walls	16	16	18	18	24
Windows	1.8	1.8	1.6	1.2	1.2
Attic	40	40	40	40	50
ACH_{50}	3.5	0.6	1	0.6	0.6
DHW	.67 EF	.67 EF	.8 EF	HPWH	.94 EF
Heating	92%	92%	95%	92%	ASHP
HRV	0%	60%	60%	70%	70%

Table 7: Results using proposed requirements for large single family house in climate zone 7b (Fort Nelson)

Component	Step 1	Step 2	Step 3	Step 4	Step 5
MEUI target	139.2	118.3	97.4	76.6	55.7
TEDI target	110.5	93.9	77.3	60.8	44.2
Cost ($/m^2)	0	3.3	5.7	39.5	122.1
Walls	22	22	22	40	50
Windows	1.4	1.6	1.6	1.2	0.8
Attic	60	60	60	40	100
ACH_{50}	3.5	1	0.6	0.6	0.6
DHW	.67 EF	.8 EF	.94 EF	.8 EF	Combo
Heating	92%	92%	95%	95%	Combo
HRV	0%	60%	60%	75%	70%

One observation from looking at the Tables 5 and 7 for Fort Nelson is the middle steps have some lower than code R-values for the insulation, which are countered with better airtightness levels. This would likely happen in Vancouver as well, however, the lowest R-values in the energy conservation measures matched the minimum code values for climate zone 4. Counting on tighter houses can be a challenging design path for builders to take as they could struggle to achieve the minimum TEDI requirements if they do not manage to achieve their airtightness target. Given the recent introduction of minimum airtightness targets, it is not yet clear what Authorities Having Jurisdictions will require of builders that do not achieve their target.

DISCUSSION

Given that the BC Energy Step Code has only recently been implemented, it may be difficult to apply a completely different strategy as proposed in this paper. However, there is a need for some changes if it is to be implemented in the province's colder climates and to Step 5 for some archetypes. One simple fix that would address some of the issues outlined in this paper would be to add the option of having the TEDI to be 10%, 20%, 40% and 60% (Steps 2, 3, 4 and 5, respectively) lower than the ERS reference house TEDI. Step 5 for the Mechanical Systems could simply extend the ERS percent better than reference house.

One potential barrier to the proposed code is that there is some confusion in the industry with regards to the percent better than reference house. Both the Step Code and the CHBA use a percent better than ERS that excludes the baseloads, which essentially provides a percent better than the reference house MEUI. HOT2000 provides results including base loads, requiring an extra calculation step. The definition of the heating system used in the reference house also changes. The Code defines in sentence 2 of 9.36.5.11.that "*The energy model calculations for the reference house shall include the same features as those used for the proposed house with regard to the principal heating and cooling energy sources, which are gas, electricity, oil, propane, wood or a heat pump*" (NBC, 2015). However, ERS does not model the reference house with a heat pump. Instead, it defaults to a heating system with the same fuel choice of the back-up heater. Thus following 9.36.5., modelling guidelines would lead to a lower percent savings than when modelling using ERS.

For other jurisdictions that are looking to establish a Step Code, the approach proposed in this paper could prove to be a simpler path. More analysis would be needed to ensure that the targets match overall policy objectives, such as:

- maximizing carbon reduction by minimizing the marginal cost of each extra unit of carbon reduction for each archetype and climate zone;
- supporting implementation strategies that streamline market and supply chain transformation, and maximize affordability of low-footprint entry market housing, taking into consideration GHG emission per occupant or household;
- promoting solutions that align with other code objectives such as increasing resilience given the anticipated demands of weather extremes (i.e. consider cooling), climate change, etc..

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In order to achieve these policy objectives using a reference building approach, the methodology of establishing a reference house would need to be reviewed.

CONCLUSION

The BC Energy Step Code just became available for jurisdictions to implement in December of 2017. As more jurisdictions begin to require builders to achieve minimum Steps, there could be potential challenges encountered for certain building archetypes, and for most archetypes in colder regions of the province. Some building archetypes will likely not be able to achieve higher steps in some parts of the province, whereas other archetypes could achieve these steps without improvement from their current performance levels in milder regions of the province.

A solution was proposed in this paper, which would make all steps compare the proposed house performance to a reference house standard. This is already an option for the Mechanical Systems for Steps 2 to 4. The proposed changes would extend it to Step 5, and for the TEDI as well.

The proposed changes would still make it more affordable to achieve Step 5 for more efficient archetypes like the rowhouse compared to the small single family house. However, it would ensure that targets could be met for all house archetypes throughout the province.

There could be other approaches to modifying the Step Code targets to address issues with certain archetypes (e.g. floor area adjustments to the targets) and for colder regions (e.g. relaxation of targets relative to HDD). However, it would add complexity to the targets, where builders are already having to learn new concepts (TEDI and MEUI), and could be more challenging to find a solution that works for all archetypes in all climate zones.

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