Energy Codes Performance Assessment of ASHRAE 90.1 and the NECB

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Abstract

A modelling study was completed to assess the relative energy efficiency of ANSI/ASHRAE/IESNA Standard 90.1 (ASHRAE 90.1) and the National Energy Code of Canada for Buildings (NECB) for British Columbia (BC). This involved applying the prescriptive requirements for ASHRAE 90.1-2010 and 2016, and the NECB 2011, 2015 and 2017 to eight archetype models across three main regions, representing the large majority of the BC commercial market. Of these Standards, the NECB 2017 proved the most efficient based on energy use across the overall Part 3 BC market. All versions of the NECB provided for higher green¬house gas savings than any version of ASHRAE 90.1 in BC. However, ASHRAE 90.1-2016 had the highest savings based on energy costs.

Introduction

In December 2018, British Columbia updated Part 10 of its Building Code to reference the latest ANSI/ASHRAE/IESNA Standard 90.1 (ASHRAE 90.1) 2016 version and the 2015 version of the National Energy Code of Canada for Buildings (NECB). The City of Vancouver similarly followed suit at the beginning of January 2019 with its Energy Utilization Bylaw. Similar to how compliance previously applied, building projects may decide to follow either ASHRAE or the NECB (but not both) — unless the BC Energy Step Code applies.

BC Hydro, the Province's largest electricity provider, was interested in quantifying the legislated impacts of adopting the latest versions of ASHRAE 90.1 and the NECB as part of its efforts to help support and advance energy efficiency in British Columbia. In support of this effort, EnerSys Analytics Inc. assessed the relative energy efficiency of the applicable standards and codes (referred in this paper simply as "Standards"):

- ANSI/ASHRAE/IESNA Standard 90.1-2010: Energy Standard for Buildings Except Low-Rise Residential Buildings (ASHRAE 90.1-2010),
- ANSI/ASHRAE/IESNA Standard 90.1-2016: Energy Standard for Buildings Except Low-Rise Residential Buildings (ASHRAE 90.1-2016),
- National Energy Code of Canada for Buildings: 2011 (NECB 2011),
- National Energy Code of Canada for Buildings: 2015 (NECB 2015),
- National Energy Code of Canada for Buildings: 2017 (NECB 2017).

Note that the focus of this study was on commercial, institutional, and high-rise multiunit residential (Part 3) new construction in British Columbia, and included regional considerations.

Methodology

Comparing the energy performance impacts of the Standards first involved researching the key changes made to (1) ASHRAE 90.1 since the 2010 version and (2) the NECB 2015 and 2017 since the 2011 version, focusing on conditions that are prevalent in the British Columbia new construction market. It also inherently required comparing the NECB and ASHRAE to each other. Reading through the respective Standards and noting the differences was a primary task in the assessment. Further, reports on the comparative performance between ASHRAE 90.1-2010 and the 2013 and 2016 versions proved invaluable in evaluating if/what amendments may have provided for substantiated savings [Halverson, M., et al., 2017]. Similarly, reports concerning how the latter versions of the NECB compared to their respective preceding versions also proved useful in appreciating the applicable amendments [Cornick, S., et al., 2015; Knapp, D., 2017].

The assessment of the relative energy efficiency for the Standards involved comparing energy results from whole building energy simulations of archetype DOE2.1e building models. We configured the models so that key characteristics minimally complied with the prescriptive and mandatory requirements of the respective Standards. The modelling focused on those characteristics that captured the key changes between (1) ASHRAE 90.1-2010 and 90.1-2016, and (2) the NECB 2011 and the 2015 and 2017 versions. We also maintained consistency between ASHRAE and the NECB cases, as applicable. An exception to this was for environmental and certain market changes since our last comparative study in 2011 that involved a similar assessment of ASHRAE 90.1-2010 and the NECB 2011 [Hepting, C. and C. Jones, 2011].

We applied the prescriptive requirements instead of those representing the trade-off or performance path approaches for several reasons. First, from our experience and discussions with Vancouver code officials, the majority of new construction projects in British Columbia have applied this approach—although this is anticipated to decrease with continued adoption of the BC Energy Step Code. Second, the intent of the trade-off and performance paths is to provide equivalent performance to the prescriptive path. Even though this often is not the case in reality, the stringency of the performance and trade-off paths largely increase lockstep with the prescriptive requirements. Finally, the performance paths, and trade-off paths to a lesser degree, allow flexibility to apply almost limitless trade-offs among the prescriptive requirements. Hence, the number of combinations that may provide for compliance are such that it was not feasible to identify and model a significantly representative set of compliant cases (if even practically possible).

After completing the necessary simulations, we analyzed the annual energy use results for the five Standards from eight archetypes across three different BC regions, each with a representation of electric (including heat pump) and natural gas heating sources. For this study, we focused on regulated end-use energy—although we included common non-regulated end-uses (e.g., plug loads, vertical transportation, and to a lesser extent, commercial refrigeration and cooking) in the simulations. Representative average electricity and natural gas rates were applied to estimate the relative energy cost savings. Finally, we applied emission factors provided by BC Hydro to estimate the relative greenhouse gas savings.

Building Archetypes Models

We advanced archetype DOE2.1e models derived from whole building energy models originally provided by Natural Resources Canada for past comparative studies between various versions of ASHRAE 90.1 and the 1997 Model National Energy Code for Commercial Buildings (MNECB). These archetype models continued to be used and advanced for other similar studies sponsored by the BC Government and BC Hydro, including the most recent study that compared ASHRAE 90.1-2010 and the NECB 2011 to ASHRAE 90.1-2004 (and each other) [Hepting, C. and C. Jones, 2011]. The following lists the eight archetypal building types:

- Large offices
- Small offices
- Schools (K-12)
- Motels/hotels
- Extended care
- Strip malls
- Big-box retail
- Multi-unit residential (MURB)

The archetypes were developed to represent typical design practices for new buildings across different regions of British Columbia (and Canada, for that matter). The representation of building types, HVAC systems, envelope types, etc., represented common features found in the vast majority of the Part 3 new building stock. However, there are many less common, but significant building types that were not part of the analysis (e.g., hospitals, grocery stores, restaurants, recreation centres, warehouses). Further, while the HVAC systems are of limited types, they focus on providing for a representation of electric and natural gas heating—with heat pumps accounted for with most building types as well.

Before embarking upon any modelling, we first defined and listed summary descriptions and key characteristics for each of the archetypes. Further, this listing contained specific comments on analysis assumptions and market factors associated with particular Standard stipulations.

As a final note, market changes that have occurred since the British Columbia adoption of ASHRAE 90.1-2010 and the NECB 2011 may be ingrained in the comparative analysis in some cases. The primary example of this is how MURBs in British Columbia have transitioned away from design approaches that utilize corridor pressurization to provide ventilation to more effective direct-suite ventilation approaches. This affects the comparative analysis because of particulars associated with the conditions under which heat recovery may apply.

Climate Zones and Weather

In addition to representing a reasonable cross-section of commercial building types, we applied the analysis for the following representative regions, as required by the scope of work:

- Lower Mainland and Southern Vancouver Island, using Vancouver weather data (oftentimes referred to as the “South Coast”);
- Southern Interior, using Summerland weather data;
- Northern Interior, using Prince George weather data.

These weather regions provided for a relatively wide degree of weather variation across British Columbia. Moreover, the specific weather sites within the above regions represent major population centres in British Columbia.

For the previous study of ASHRAE 90.1-2010 and the NECB 2011, the South Coast region was classified as climate zone 5C for ASHRAE but zone 4 for the NECB. This difference was due to how ASHRAE 90.1-2010 referenced and classified Vancouver, Victoria (and Abbotsford) based on heating degree-days on a 65°F basis—possibly from inconsistent weather data. As it still does, the NECB classified the cities previously listed (and other similar locations) as climate zone 4 due to the heating degree-days based on an 18°C (64.4°F) basis being below 3000 °C-days . ASHRAE 90.1-2016 similarly now classifies Vancouver, Victoria, Abbotsford, etc. as climate zone 4C. (Note that Table A-5 still inconsistently classifies some locations in the Victoria area, such as the international airport, as 5C).

For the analysis, we maintained the original 5C climate zone requirements for ASHRAE 90.1-2010 as this referenced a representative snapshot in time for how the market applied ASHRAE (and continued to do so in The City of Vancouver, and elsewhere since many practitioners didn't realize the Province's clarification to reference climate zone 4). Given changes with ASHRAE and the Province's clarification after our 2011 study, we referenced climate zone 4C for the ASHRAE 90.1-2016 assessment. The City of Vancouver, which has it's own code separate from the rest of the Province, also changed to referencing climate zone 4C for ASHRAE 90.1-2016 from climate zone 5C for ASHRAE 90.1-2010 as of January, 2019 in its Energy Utilization Bylaw update.

The climate zone application for the Northern Interior similarly changed from our previous 2011 study. Based on Prince George heating degree-day indicators, it was previously assigned as climate zone 7. However, more recent weather data indicated Prince George has warmed so that it now falls within climate zone 6. Hence, while ASHRAE 90.1-2010 and the NECB 2011 applied climate zone 7 prescriptive requirements, the latter ASHRAE 90.1-2016 and NECB 2015 and 2017 modelling applied less stringent climate zone 6 requirements.

The net effect of applying different climate zone requirements to the South Coast and Northern Interior regions for the more recent Standards is that energy use slightly trends upward. This is due to assembly thermal conductivity and heat recovery requirements being less stringent for climate zones 4 vs. 5, and climate zones 6 vs. 7, respectively.

In addition to a warming shift in the climate zone assignments, the ASHRAE 90.1-2016 and NECB 2015 and 2017 models were simulated using updated typical (CWEC) weather files. The updated weather files are generally representative of weather trends from the late 1990s through roughly 2015, whereas the previous historical weather files were derived from roughly 1950s through 1980s data. As expected, the more recent weather files represent warmer weather, with markedly higher cooling degree-days and somewhat lower heating degree-days.

Application of the updated weather files applied to all locations, including Summerland. Combined with the climate zone reclassification for the South Coast and Northern Interior regions, this provided for some inherent savings associated with the more recent Standards. This is due to lessened heating requirements — which far surpass the absolute increase in cooling requirements (or the relaxed prescriptive requirements, for that matter).

Quantifying the overall impacts would require re-simulating the applicable models applying the same climate zone classifications and weather data. While this relatively large exercise was not feasible under the project scope, we tested the relative impact on ASHRAE 90.1-2010 for the small office archetype. For the British Columbia market, the warmer climate classification and weather data would have resulted in about a 1.5% energy use decrease, based on a 9.2% decrease in natural gas (for heating), partially offset by a 2.5% increase in electricity use (for cooling).

Weighting Factors

Using load research data supplied by BC Hydro, we applied three categories of weighting factors in calculating the Province-wide energy use, energy costs, and greenhouse gas emissions for each of the Standards. First, we applied regional market shares based on floor area. Within each region, the allocation of floor area by segment (building type) applied.

Table 1. Regional Market Share Factors by Segment

Building Type (Archetype)	Segment Market Share	Regional Allocation		
		South Coast	Southern Interior	Northern Interior
School	6.1%	0.73	0.13	0.14
Large Office	4.7%	0.97	0.02	0.01
Small Office	35.3%	0.87	0.07	0.06
Strip Mall	10.3%	0.82	0.10	0.08
Big Box Retail	10.3%	0.82	0.10	0.08
Extended Care	3.8%	0.81	0.12	0.07
Hotel/Motel	8.8%	0.68	0.20	0.11
MURB	20.7%	0.97	0.02	0.01
Across B.C.	100%	86%	8%	6%

Finally, applying research data from BC Hydro, we accounted for the estimated allocation of electric vs. natural gas heating, separately distinguished for space and service water heating. This applied by building type and region. Note that compared to the previous ASHRAE 90.1-2010 and NECB 2011 study, the relative share of electric heating appears to have increased in the BC new construction market.

Utility Rates and Emission Factors

Given the modelled energy use by source, applicable utility rates and greenhouse gas (GHG) emission factors were applied to estimate the respective utility costs and equivalent CO2 emissions. We applied these consistently across all the Standards.

For the energy costs, we started with blended (average) electricity and natural gas rates applied by building type for the previous ASHRAE 90.1-2010 and NECB 2011 study. Based on cumulative rate increases provided by BC Hydro, the electricity rates were updated to reflect current pricing — averaging about $0.12 per kWh (CDN) for the British Columbia market. We estimated the gas rates based on 2018 posted tariffs from the major gas utility in British Columbia, which came out at an equivalent average of $0.031 per ekWh.

GHG emission factors for electricity were taken from the Province's "*2016 B.C. Best Practices Methodology for Quantifying Greenhouse Gas Emissions*" at 0.01067 kg per kWh of eCO2 [British Columbia Ministry of Environment, 2016]. As it was problematic to derive a single equivalent CO2 factor from this source for natural gas, we referenced the Portfolio Manager's August 2017 listing for British Columbia of 53.19 kg per mmBtu (50.4 kg per GJ).

Code Compliance Considerations

As previously indicated, we applied the prescriptive requirements to each of the building archetype models. While this should approximate the relative energy impacts of the Standards, individual buildings and conditions will produce widely varying results—not only from a prescriptive standpoint, but when applying the trade-off and performance path approaches as well.

The NECB's envelope (Part 3) trade-off and performance path (Part 8) approaches are of particular note. As confirmed by Natural Resources Canada (NRCan) and the National Research Council (NRC), both dictate setting of the comparative reference building's glazing and doors "to the allowable fenestration and door areas prescribed in Section 3.2." (NECB 2011 §3.3.3.1, NECB 2015 and 2017 §3.3.1.1). In other words, fenestrations are set exactly at 20-40% of the gross wall area depending on the location's heating degree-days. Similarly, skylights are fixed at 5% the gross roof area for the NECB 2011 and 2015, and 2% for the NECB 2017. For instance, if a retail building in Vancouver has 8% fenestrations and no skylights, the comparative reference case would have its fenestrations increased by five times to 40% and skylights added to the roof.

This represents a significant departure that makes the NECB less efficient compared to ASHRAE's trade-off and performance paths (including Appendix G). We ran a sensitivity study with the wall and roof conductivities correspondingly decreased where applicable for each archetype. That is, we adjusted the overall gross wall and roof conductivities so that they would account for the maximum prescribed fenestration and skylight levels, without actually increasing the fenestrations. From this preliminary assessment, energy savings for the NECB 2011, 2015, and 2017 compared to ASHRAE 90.1-2010 dropped by 3.8%, 3.8%, and 2.0% points, respectively. The decrease in energy cost savings was only slightly less, but the drop in GHG savings was more pronounced at 4.3%, 4.6%, and 2.4% points, respectively.

While this nuance to the NECB is a notable deficiency in comparison to the prescriptive path, ASHRAE also has several significant inconsistencies that can provide for widely varying indicators compared to the prescriptive path. For instance, Appendix G is not a normative appendix to ASHRAE 90.1-2016, which means it provides for yet another path that projects may apply to demonstrate compliance. While there are many nuances that can make an Appendix G assessment diverge from the other compliance paths, arguably the most significant is how any building in British Columbia (or Canada for that matter) would be compared to a 100% gas heated baseline. This can be a significant disadvantage for some designs with electrical heat (including heat pumps) given that Appendix G (and energy cost budget) compliance is based on energy costs and electricity is nearly four times the equivalent price of natural gas in most of British Columbia.

Another consideration of note was how the NECB 2017 requires that losses associated with junctions between envelope elements are to be included. These previously unregulated losses include wall and window connections, parapets, roof-to-wall junctions, corner and edge discontinuities, shelf angles, etc. This required adjusting all of the archetype models, except the NECB 2017 ones, to account for these losses. We applied mid-range estimates based on experience from many actual new design projects, although such linear and point losses can vary widely between designs. Applying these unregulated losses to the overall wall conduction slightly increased the modelled energy use for all of the archetypes except for the NECB 2017 models.

Results

This section provides summary results for the comparative analysis between the Standards applied to the Part 3 market within British Columbia. Comparisons were made to ASHRAE 90.1-2010 mainly because it was most often referenced for BC Code compliance purposes. The alternative NECB 2011 seldom had been referenced in the market, but the 2015 version is increasingly being referenced with the present BC codes. Further, the summary results are for regulated end-uses and therefore exclude plug and process, vertical transportation, cooking, and commercial refrigeration (as requested by BC Hydro).

We produced detailed results for the individual building types and regions, including (1) ASHRAE 90.1-2016 compared to the 2010 version, and (2) the two most recent NECB versions compared to the NECB 2011. Results also included all energy use—both regulated and non-regulated.

Province-Wide Comparisons

The NECB 2017 worked out to be the most efficient in terms of energy use (i.e., lowest energy intensity), although ASHRAE 90.1-2016 provided for higher electricity savings. Because of the relative high cost of electricity, ASHRAE 90.1-2016 provided for the highest overall cost savings as well. As the NECB generally saves more on heating than ASHRAE (largely due to better combustion equipment efficiency requirements), it provided for lower natural gas use. Hence, all versions of the NECB saved more GHGs than ASHRAE 90.1 given that the equivalent CO2 content of natural gas was 17 times higher than that of electricity in British Columbia.

Figure 1 shows the energy use, energy cost and GHG savings for each of the Standards relative to ASHRAE 90.1-2010. Table 2 provides the same information but also breaks out electricity and natural gas use and costs.

Regional Comparisons

Given that the South Coast, covering most of the Lower Mainland, Fraser Valley and most of Vancouver Island, accounted for 86% of the Province's Part 3 market, the previous BC-wide results closely approximated those for the South Coast, as shown in Figure 2.

The Southern Interior's higher heating load requirements provided for generally higher savings than for that of the South Coast. Figure 3 shows the relative savings for each of the Standards relative to ASHRAE 90.1-2010. As shown in the figure, the Standards provide for 0.6–1.9% points higher energy savings than for the milder South Coast climate.

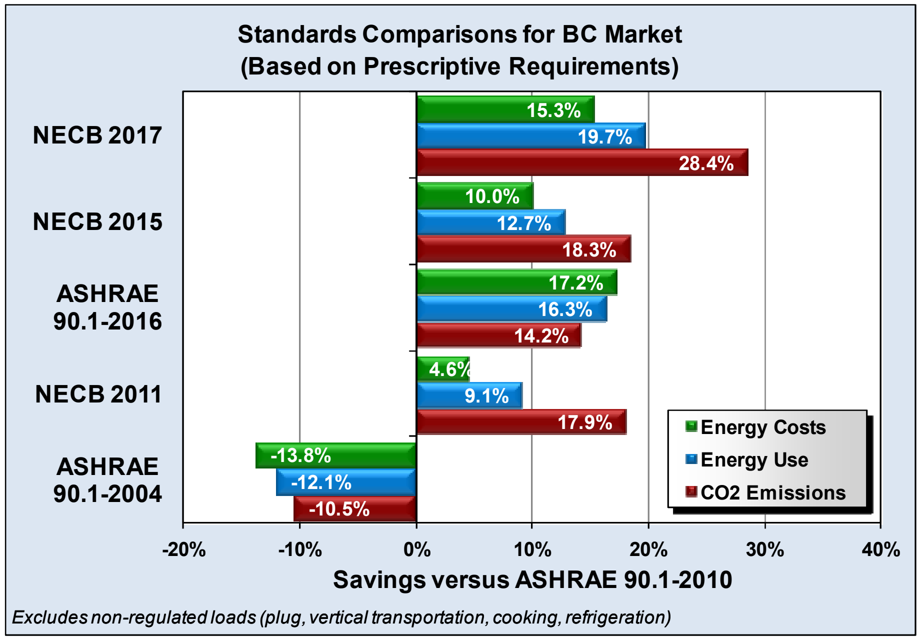

Figure 1. Comparative Savings vs. ASHRAE 90.1-2010 for BC

Table 2. Comparative Savings vs ASHRAE 90.1-2010

Building Code / Standard	Energy Use			Energy Costs		
	Electricity	Nat. Gas	Total	Electricity	Nat. Gas	Total
ASHRAE 90.1-2004	-14.6%	-10.2%	-12.1%	-14.5%	-10.2%	-13.8%
NECB 2011	1.7%	19.2%	9.1%	1.7%	19.2%	4.6%
ASHRAE 90.1-2016	18.0%	13.9%	16.3%	17.8%	13.9%	17.2%
NECB 2015	8.0%	19.1%	12.7%	8.2%	19.1%	10.0%
NECB 2017	12.3%	29.7%	19.7%	12.4%	29.7%	15.3%

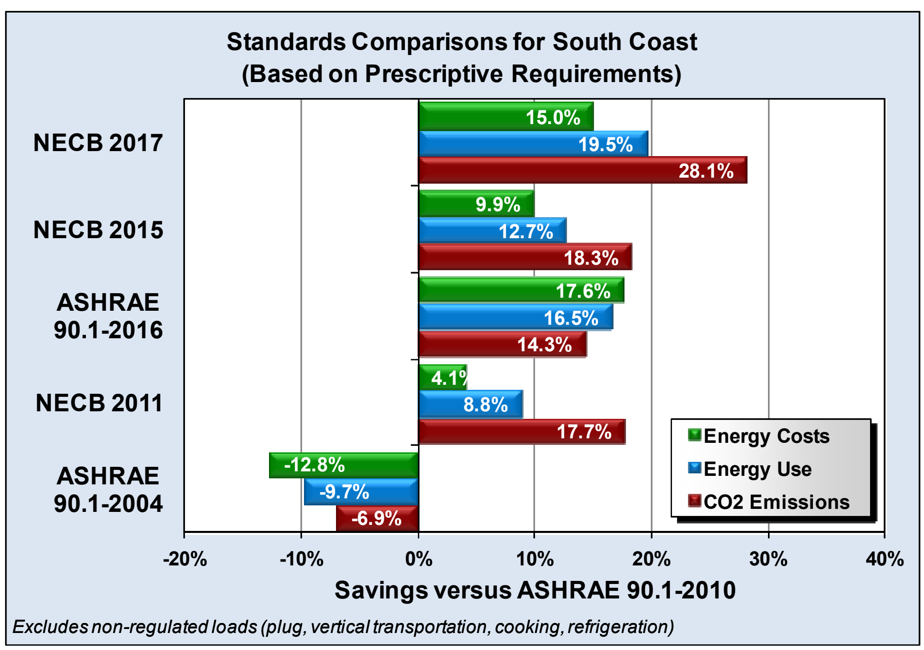

Figure 2. Comparative Savings vs. ASHRAE 90.1-2010 for Southern Interior

The Northern Interior's even higher heating load requirements provided for higher savings than for that of the South Coast or Southern Interior. Figure 4 shows the relative savings for each of the Standards relative to ASHRAE 90.1-2010. As shown in the figure, the Standards provide for significantly higher energy savings than for the South Coast or Southern Interior regions.

Conclusion

As discussed, we applied the prescriptive requirements for ASHRAE 90.1-2010, ASHRAE 90.1-2016, the NECB 2011, NECB 2015, and NECB 2017 to eight archetype models representing the large majority of the British Columbia Part 3 market. These archetypes were applied across three weather regions and included electric (including heat pump) and natural gas heating sources. The purpose of this assessment was to quantify the relative efficiency levels for the different Standards.

From this analysis, the NECB 2017 worked out to be the most energy efficient (i.e., provided for the lowest energy use) for all the BC regions and British Columbia as a whole. It also provided for the lowest GHGs; in fact, all versions of the NECB provided for lower GHGs than any version of ASHRAE 90.1 for the entire BC market. ASHRAE 90.1-2016, however, provided for lower energy costs based on current 2018 average utility rates (which happens to correspond to how compliance is determined for its envelope trade-off, Energy Cost Budget and Appendix G performance compliance approaches).

As discussed, this study took the perspective of applying the prescriptive aspects of ASHRAE and the NECB. This is an important distinction because the performance and trade-off approaches will result in different comparative indicators—sometimes significantly disparate in certain situations.

Further, while the NECB 2017 appeared to provide for the lowest energy use overall, that may not always be the case depending on the particulars for a given project. This potential variability was observed with some of the individual archetype results, in fact. For instance, all versions of the NECB resulted in higher energy use and GHGs for the school archetype compared to ASHRAE 90.1-2016 (largely due to demand controlled ventilation differences).

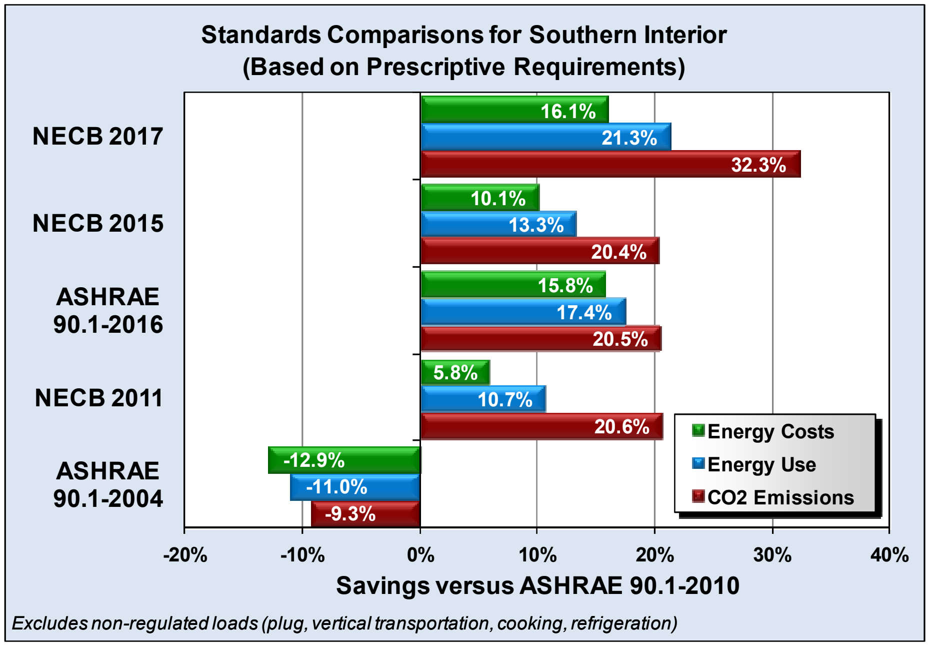

Figure 3. Comparative Savings vs. ASHRAE 90.1-2010 for Southern Interior

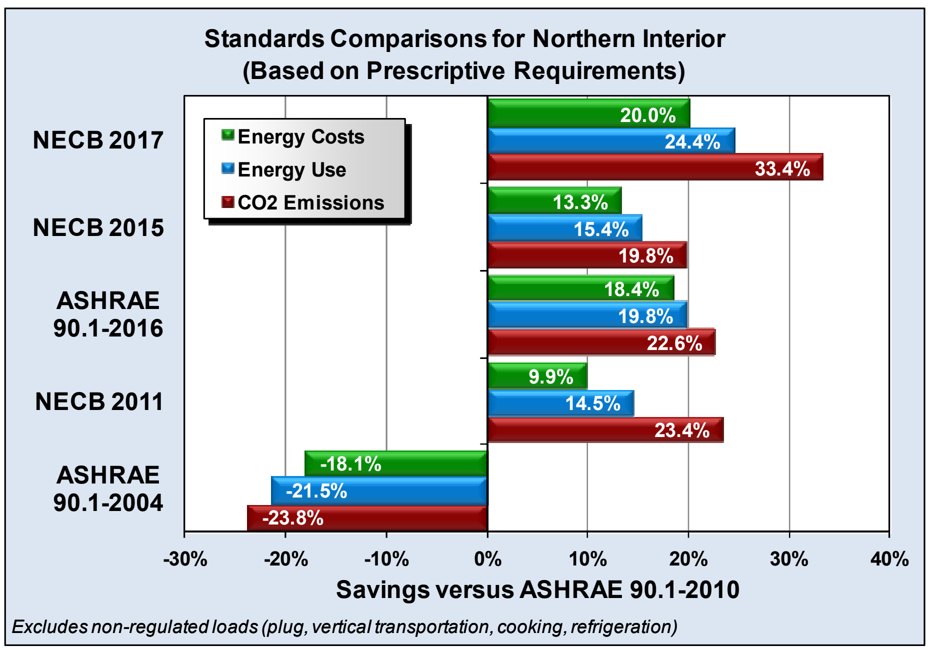

Figure 4. Comparative Savings vs. ASHRAE 90.1-2010 for Northern Interior

Application of the NECB trade-off provisions and its setting of fenestration areas at the prescribed maximum levels further dampened the NECB's relative efficiency—by about 2–4% overall.

Even with these variations, the latest energy Standards should provide for significant overall savings over those applied for BC Code compliance purposes prior to December 2018 (and for the City of Vancouver prior to January 2019). An exception might be for GHGs when compared to the NECB 2011—especially when applying older (colder) climate data. Should the NECB 2017 be adopted, it would further improve the savings.

Acknowledgement

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