NET-ZERO READY BUILDING CODES

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ABSTRACT

This paper provides an overview of current legislation and regulatory frameworks or proposals of three levels of government to achieve "net-zero energy ready" new construction over the next decade. The paper defines the performance standard, highlights policy drivers, and compares and contrasts the approach of three levels of government from the perspectives of technical performance of buildings, consistency, compliance and enforcement, and opportunities for transformative market change. While the scope of the paper is limited to current building code objectives, namely energy efficiency, it provides a foundation for future research on decarbonization and resiliency of buildings.

INTRODUCTION

This paper provides an overview of current legislation and regulatory frameworks or proposals of three levels of government to achieve "net-zero energy ready" new construction over the next decade. The three levels of government include the federal government publishing of the National Building Code of Canada (NBC), the Province of BC's Energy Step Code within the BC Building Code (BCBC) and the City of Vancouver's Building Bylaw and rezoning policy.

Codes Canada publishes the NBC and the National Energy Code for Buildings (NECB) approximately every five years, with the 2020 edition anticipated by the end of 2021. While the federal government publishes the NBC, it is the provinces, territories and charter cities such as Vancouver that adopt it in regulation, along with its various performance standards.

A key federal policy driver is the Pan Canadian Framework on Clean Growth and Climate Change. It states, "The Government of Canada will work with the provinces and territories to … develop a "net-zero energy ready" model building code, with the goal that provinces and territories adopt it by 2030" [ECCC 2016]. This precipitated amendments to the NBC and NECB that were posted for public review in early 2020.

The BCBC is adopted in regulation under the *Building Act*, applying to owners and developers of buildings. The *Local Government Act* and *Community Charter* enable local governments to implement the BCBC and enforce it through local government bylaws and building permits. Local governments are unable to enforce technical standards that are "matters" referenced in the BCBC unless the Building Act General Regulation [Queen Printer 2020-1] explicitly makes a matter "unrestricted" such as the form, exterior design, or finish of buildings relating to wildfire hazard (a topic of resiliency). In the case of the conservation of energy and the resultant reduction of greenhouse gas emissions, a local government can reference any step of the BC Energy Step Code in policy or bylaw.

A key policy driver is the 2018 CleanBC Plan that includes a commitment to "Improve the BC Building Code in phases leading up to 'net-zero energy ready' by 2032". This includes making homes and buildings 20 per cent more energy efficient by 2022, 40 per cent more energy efficient by 2027, and 80 per cent more energy efficient by 2032 – the net-zero energy ready standard" [BCECCS 2018].

The BCBC objectives include "Energy Efficiency and Water Use" to "limit the probability that, as a result of the design, construction or renovation of the building, the use of energy will be inefficient or the use of water will be excessive." [Queens Printer 2020-2]. Energy security, carbon intensity and resiliency are beyond the scope of this paper, but conclusions are drawn to inform future research on those topics.

The regulatory jurisdiction of the City of Vancouver is governed by the *Vancouver Charter*, and that includes authority to publish its own building bylaw with unique technical standards, including regulations for the reductions of greenhouse gas emissions [Queens Printer 2020-3]. In practice, the Vancouver Building Bylaw standards are harmonized with the BCBC, but in some areas adopt different standards. Vancouver's "rezoning policy" has very stringent energy efficiency and

emission management standards which is only triggered when changes in density, height or use is sought.

Definition of Net-Zero Energy Ready

There are several definitions on 'Net-Zero Energy' (NZE) vs. 'Net-Zero Energy Ready' (NZER) buildings/houses. The following established definitions are frequently referenced:

- The Canada Mortgage and Housing Corporation [CMHC 2018] defines a NZE house as:

A house that is designed and built to reduce household energy needs to a minimum and includes on-site renewable energy systems, so that the house may produce as much energy as it consumes on a yearly basis.

- Natural Resources Canada [NRCan 2020] defines:

A Net-Zero Energy (NZE) house is a house that produces as much energy from on-site renewable energy sources as it consumes each year, and

A Net-Zero Energy Ready (NZER) house is a variant of the NZE house in which the builders have not installed the renewable energy generation system.

- BC Energy Step Council [ESC 2020] defines:

Net-zero energy buildings produce as much clean energy as they consume. They are up to 80 percent more energy efficient than a typical new building, and use on-site (or near-site) renewable energy systems to produce the remaining energy they need, and

A net-zero energy ready building is one that has been designed and built to a level of performance such that it could, with the addition of solar panels or other renewable energy technologies, achieve net-zero energy performance.

DISCUSSION AND RESULT ANALYSIS

The current and proposed codes and standards to achieve net-zero energy ready construction are highlighted below.

BC Energy Step Code

The BC Energy Step Code (ESC) was included as an optional compliance path into the BC Building Code (BCBC) in April 2017. The fourth and most recent amendment was included in the BCBC 2018 mid-cycle revision that took effect on December 12, 2019 [MAH 2019]. The BC ESC provides a technical "roadmap" to net-zero energy ready construction. It includes between three and five tiers for the following building types in all climate zones within the province:

- Part 9 residential;
- Part 3 hotels and motels;
- Part 3 residential;
- Part 3 office; and,
- Part 3 business and personal services or mercantile.

The tiers have increasingly stringent energy efficiency requirements for whole-building or mechanical end-use intensity, building envelope thermal performance, and in some cases airtightness. The BC ESC does not include prescriptive solutions; rather is exclusively a performance-based code. All buildings are required to undertake energy modelling and conduct a whole building airtightness test.

Tier 1 is always equivalent to the performance of the BCBC Division B acceptable solutions set out in section 9.36 or section 10.2. The BCBC s9.36 is based substantially on the NBC 2015 and s10.2 references both ASHRAE 90.1 2016 and NECB 2015 as acceptable solutions. The BC ESC energy modelling is primarily based on the performance paths of BCBC/NBC s.9.36.5 or NECB 2015 Part 8. It also references the City of Vancouver Energy Modelling Guidelines.

The most recent amendment to the BC ESC included a first tier (with no performance requirements) for Part 3 public sector archetypes, including schools, libraries, colleges, recreation centres, hospitals and care centres, effectively requiring energy modelling and air tightness testing for those buildings [MAH 2019].

The BC ESC top tier is designed to be equivalent to "net-zero energy ready" construction. For houses, Step 5 requires a mechanical end-use intensity (MEUI) as low as 25 kWh/m^2/yr, excluding plug load and lighting, a thermal energy demand intensity (TEDI) of 15 kWh/m^2/yr, and an airtightness of 1 air change per hour at 50Pa pressure differential (ACH_{50}). Passive House certified houses are deemed compliant with Step 5. An alternative Step 5 compliance path for TEDI includes a 50% improvement compared to an EnerGuide Rating system reference house. Alternative compliance paths for both TEDI and MEUI apply to Steps 2 through 4 based on EnerGuide; up to 40% for MEUI and 20% for TEDI, aligned with the NBC 2020. MEUI for all steps depend on climate zone, size of house, and use of cooling energy. TEDI requirements can be adjusted to reflect the specific heating degree days in the community where the house is located.

For multi-family residential buildings, Step 4 is the highest tier, with total energy use intensity (TEUI) as low as 100 kWh/m^2/yr in Climate Zone 4, including plug load and lighting, and a TEDI of 15 kWh/m^2/yr. These figures increase to TEUI $\leq$ 140 and TEDI $\leq$ 60 in Climate Zone 8.

For hotels and motels Step 4 is the highest tier, with TEUI as low as 120 kWh/m^2/yr and TEDI $\leq$ 15 in Climate Zone 4.

For other Part 3 buildings, the top tier is Step 3, with TEUI as low as 100 kWh/m^2/yr and TEDI $\leq$ 20 in Climate Zone 4 for offices, and TEUI as low as 120 for

business and personal service and mercantile occupancies with TEDI ≤ 20.

National Building Code 2020

Codes Canada conducted the final public review of the next edition of the national codes from January to March 2020. Two proposed tiered performance requirements were introduced: one for the NBC Section 9.36. (Part 9 Residential Buildings) and one for the NECB (Part 3 Buildings). The tiers represent voluntary standards that have been codified. This provides increased flexibility to authorities having jurisdiction (AHJ). It is up to the AHJ to decide whether to adopt a tier or not, and at which level. The publication of these voluntary tiers in the code should help industry and the public prepare for potential upcoming code changes, essentially 'priming' the market for upcoming code cycles.

Tiered Performance (NBC Section 9.36.)

The Proposed Code Change Form (PCF) 1617 [Codes Canada 2020-1] introduces a new Subsection that establishes tiered performance requirements by defining five tiers in terms of overall energy performance improvement, improvement in building envelope performance, and airtightness level. The tiers are based on a reference case of the 2015 NBC and represent percentage improvements in energy performance of 10%, 20%, 40% and 70% for Tiers 2 through 5 respectively. For the envelope, the improvements are 5%, 10%, 20% and 50% compared to the reference case.

For airtightness, there are two target levels, albeit the PCF 1610 [Codes Canada 2020-2] includes 6 possible levels that span from 3 air changes per hour (at 50Pa) to 0.6 ACH_{50}. Two additional airtightness methodologies using the Normalized Leakage Area (NLA) or the Normalized Leakage Rate (NLR) approach are included – the NLA@10 and the NLR@50.

To supplement this tiered approach, it adds a new Subsection on prescriptive requirements for compliance with Tier 2 above (i.e., 10% improvement compared to reference case, 5% improvement in building envelope, level 1 airtightness) based on a points system that links to dozens of performance improvement technologies and designs. This is documented in PCF 1611 [Codes Canada 2020-3].

Tiered Performance Requirements (NECB)

Similar tiered performance requirements were introduced for the NECB through PCF 1527 [Codes Canada 2020-4].

As Tier 1 requirements are the same as the balance of the NECB there is no cost impact or energy savings attributed to this Tier.

Table 1. *NBC 2020 Tiered Performance.*

Tier	Performance vs. Target	% Improvement of Envelope	Airtightness Level [1]
1	≥0%	n/a	Test only
2	≥10%	≥5%	1
3	≥20%	≥10%	1
4	≥40%	≥20%	3
5	≥70%	≥50%	3

Note (1): Airtightness Levels are defined in Table 3.

Table 2. *NBC 2020 Airtightness.*

Airtightness Level	ACH_{50}	NLA_{10}		NLR_{50}	
		cm^2	$in^2/100\,ft^2$	$L/s/m^2$	cfm_{50}/ft^2
1	3.0	1.92	2.76	1.17	0.23
2	2.5	1.60	2.3	0.98	0.19
3	2.0	1.28	1.84	0.78	0.15
4	1.5	0.96	1.38	0.59	0.12
5	1.0	0.64	0.92	0.39	0.077
6	0.6	0.38	0.55	0.23	0.046

Table 3. *NECB 2020 Tiered Performance.*

Energy Performance Tier	Performance of Proposed Building Relative to Performance of Reference Building (% building energy target)
1	≤ 100%
2	≤ 75%
3	≤ 50%
4	≤ 40%

Progressive Tiers were selected to improve efficiency levels, leading to a fourth tier which is equivalent to net zero energy ready performance. Based on Codes Canada committee work Tier 4 was originally set at 25% of the reference building energy target, or a 75% reduction in energy use, the modelling rules, non-regulated loads, and fixed loads, made this target near impossible to achieve for several building typologies [Personal communications between author and committee]. As a result, the Tier was increased to 40%, for the proposed NECB-2020, to enable progressive designs to achieve Tier 4 irrespective of building type.

The four tiers for the NECB are shown in Table 3.

Vancouver Building Bylaw (VBBL)

In July 2016, Vancouver City Council approved the Zero Emissions Building Plan, aimed at reducing emissions from new buildings by 90% in 2025 [Vancouver 2016]. The Plan also adopted a target of reducing emissions from all newly permitted building to zero by 2030. To

achieve this, the City is setting limits on emissions and energy use in new buildings through several policy levers. As noted earlier, the Vancouver Building Bylaw closely matches the BC Building Code, with the exception of significantly more stringent standards for one- and two-family houses, not documented in this paper.

The Green Building Policy for Rezonings applies when a development falls outside of the "Community Plan" for the particular neighborhood with respect to height, density, occupancy and other factors. This represents a sizable proportion of construction activity in the city [Personal communication with City of Vancouver]. It includes two alternative compliance paths based on the carbon intensity of the fuels used for the building. Table 4 illustrates that energy efficiency requirements are less stringent for buildings with lower carbon fuels, resulting in an equivalent greenhouse gas intensity (GHGI) under both compliance paths.

Table 4. *VBBL Rezoning Requirements.*

Performance Limits Buildings Not Connected to a City-recognized Low Carbon Energy System			
Building Type	TEUI (kWh/m^2)	TEDI (kWh/m^2)	GHGI ($kgCO_2/m^2$)
Residential Low-Rise (< 7 storeys)	100	15	5
Residential High-Rise (7+ storeys)	120	30	6
Office	100	27	3
Retail	170	21	3
Hotel	170	25	8
All Other Buildings	EUI 35% better than Building By-law energy efficiency requirements, Section 10.2, in effect at the time of rezoning application		

Performance Limits Buildings Connected to a City-recognized Low Carbon Energy System			
Building Type	TEUI (kWh/m^2)	TEDI (kWh/m^2)	GHGI ($kgCO_2/m^2$)
Residential Low-Rise (< 7 storeys)	110	25	5
Residential High-Rise (7+ storeys)	130	40	6
Office	110	27	3
Retail	170	21	3
Hotel	170	25	8
All Other Buildings	EUI 35% better than Building By-law energy efficiency requirements, Section 10.2, in effect at the time of rezoning application		

TEUI: Total Energy Use Intensity
TEDI: Thermal Energy Demand Intensity
GHGI: Greenhouse Gas Intensity

Comparison and Analysis

The following highlight the differences between the four profiled "net-zero energy ready" codes – the BC Energy Step Code (BC ESC), the proposed National Building Code (NBC) 2020, National Energy Code for Buildings (NECB) 2020, and the City of Vancouver Green Buildings Policy for Re-zoning (COV).

All four codes include a performance path, leaving it to the developer/builder to ensure the building meets targeted performance outcomes. Up to four specific performance outcomes are required: (i) airtightness; (ii) energy use intensity (EUI), (iii) thermal energy demand intensity (TEDI), and (iv) greenhouse gas intensity (GHGI). Only the first requirement is measured, whereas the remaining three are modelled. The modelled values can be later verified through measured energy consumption and sub-metering; however, this falls outside of the timeframe that a building permit applies.

The primary driver for the BC ESC, NBC and NECB is energy efficiency. Up to three energy performance indicators are included – whole-building, building-envelope and airtightness. The NECB does not include TEDI. By having airtightness, TEDI, and/or a percentage envelope improvement to the reference building, the codes adopt an "building envelope first" framework, which prevents a designer from meeting the whole-building efficiency with mechanical solutions alone.

The COV drivers include both energy efficiency and greenhouse gas reductions, adding a limit to modelled emissions from the building, both direct from the combustion of fuels and indirect from the production of electricity. However, the approach allows for reduced energy efficiency for lower carbon fuels. This is misaligned with economic optimization given that low-carbon fuels are often higher cost to consumers and therefore there is rationale for increased levels of energy efficiency. This could compromise consumer affordability due to both lower energy efficiency and higher cost fuels. It would be appropriate to retain the TEDI between the two fuel choices for resiential, as Vancouver has done for office, retail and hotel (albeit not for residential), thereby reducing heat loss and protecting affordability.

Based on the author's experience the performance tiers of the BC ESC and COV are based on best practices of previously constructed buildings within generalized archetypes that represent a large proportion of construction. The reference case is based on a fixed EUI, TEDI and (for Part 9 Buildings only) airtightness level. In contrast the NBC and NECB are based on the building-specific reference case, a hypothetical building that aligns with the design and meets the prescriptive requirements of NBC and NECB. In all four codes, the design must have an energy performance that is better than the reference building.

In three of the codes (excluding COV), the lower tiers are aligned with financially optimized design solutions with a positive net-present value (NPV) of energy bill reductions versus incremental capital costs based on [BC Housing 2018]. The upper tiers are based on technical best practices and best-available technologies, which in some cases have a positive NPV and in other cases are

not strictly "cost-effective", depending on the architectural design of the building. However, the financial assessment overlooks the fact that current carbon pricing is unlikely to address the necessary costs to mitigate emissions, and henceforther market failures exist, a topic for future research.

With their fixed reference cases, the BC ESC and COV approaches allow for greater consistency, verifiability and enforcement. In contrast, the NBC and NECB with hypothetical reference cases can vary for each individual designer and energy modeller, thereby reducing consistency across the marketplace. The local autorities having jurisdiction will be unlikely able to verify the reference case due to the complexity of modelling. Several BC urban municipalities have concerns with the reference case for thermal performance in lieu of TEDI, suggesting this will undermine the "building envelope first" design approach. Absent a formal evaluation, measurement and verification system with calibrated energy modelling, it will be difficult to identify the differences between designers. Furthermore, the BC ESC and COV use energy modelling guidelines to enhance consistency, and the Engineers and Geoscientists of BC and Architectural Institute of BC have published professional practice guidelines for energy modelling services.

There are some differences in the number of tiers and their stringency, depending on the particular code. For Part 9 Buildings, both the BC ESC and NBC have the same number of steps and similar expectations of performance improvements of 10%, 20%, 40% and 50+% based on BC Housing [2018]. However, the airtightness requirements for the equivalent tier of the NBC are less stringent. For example, the Step/Tier 3 airtightness is 3ACH50 and 2.5ACH50 for NBC and BC ESC respectively. For Step/Tier 5, those compare at 2ACH50 and 1ACH50.

For Part 3 buildings, the BC ESC and NECB have the same number of steps, but slightly different expectations of performance improvements based on BC Housing [2018]. BC ESC steps 2, 3 and 4 are estimated to achieve improvements up to 40%, 50% and 60% [BC Housing 2018]. The percentage improvements in NECB-2020 are 25%, 50%, and 60% for tiers 2,3,4 respectively, as compared the prescriptive standards in NECB. To allow for comparison, separate research pegs NECB-2017 as about 5-9% improvement compared to NECB-2015 in British Columbia [EnerSys 2018], similar to the anticipated performance of NECB-2020. Thus, expected BC ESC Step 4 savings are 51-55% compared to NECB-2020, potenitally less stringent than the 60% improvement of Tier 4 in NECB-2020.

COV standards are comparable to BC ESC Step 3 for buildings over 7 storeys, and Step 4 for lower buildings. The Higher Building Policy is aligned with BC ESC Step 4, the equivalent to net-zero energy ready construction.

CONCLUSION

This paper has summarized four alternative "technical roadmaps" to net-zero energy ready construction, including the BC Energy Step Code, the proposed changes to the National Building Code and National Energy Code for Buildings and the Vancouver Rezoning Policy. The two significant differences were:

(1) The national codes are based on a hypothetical reference building of the same configuration being designed with prescriptive standards. Whereas, the BC ESC and COV have fixed energy performance references associated with a generic archetype building.
(2) The COV policy emphasizes greenhouse gas reduction, whereas the national codes and BC ESC emphasize energy efficiency.

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