Natural Resources Canada | Ressources naturelles Canada

Canada

HIGH-PERFORMANCE COMMERCIAL AND INSTITUTIONAL BUILDING DESIGN METRIC:

DISCUSSION PAPER

FEBUARY 20, 2016

Table of Contents

Acronyms and Abbreviations

AHRI	Air-Conditioning, Heating, and Refrigeration Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CaGBC	Canada Green Building Council
EUI	energy use intensity
EPA	Environmental Protection Agency
GDP	Gross Domestic Product
HVAC	Heating, Ventilation, and Air Conditioning
ICC	International Code Council
IECC	International Energy Conservation Code
IEA	International Energy Agency
LEED-NC	Leadership in Energy & Environmental Design - New Construction
MNECB	Model National Energy Code for Buildings (1997)
NECB	National Energy Code of Canada for Buildings (2011)
NRCan	Natural Resources Canada
OEE	Office of Energy Efficiency
PM	Portfolio Manager
SCIEU	Survey of Commercial and Institutional Energy Use
ZER	Zero Energy Rating

1 Consultation Overview

1.1 Purpose

Natural Resources Canada (NRCan) is holding this consultation on behalf of the federal/provincial/territorial Built Environment and Equipment Working Group (BEEWG) to gather views on a proposed metric to distinguish between commercial and institutional building designs that demonstrate significant progress along the path towards a net-zero energy ideal. The objective of the metric is to provide one standard, recognized, and accepted comparative measure of "ultra-high performance," which may be used by the industry to promote leadership in energy-conscious design. To help us achieve this objective, we invite you to engage in this process by sharing your insight as to how implementing such a rating system might impact your industry (or field of expertise).

This document provides an outline of the consultation context, technical background, and description of the metrics under investigation. NRCan staff reviewed several promising metrics in detail, and developed three new metric options. Experts' input is now being sought on the identification, development, and use of the metrics presented herein, within a context of how to best distinguish between building designs on the path towards net-zero energy.

We will use the results of this consultation to inform further development of metric options to promote ultra-efficient, high-performance buildings. Stakeholders expected to be interested in the development of this new metric include:

- architects/designers;
- building owners/managers/operation staff;
- energy suppliers (i.e., utilities);
- construction/supply/commissioning industries;
- energy services and other relevant consultants (beyond the above categories); and,
- government officials operating buildings programs or managing buildings.

1.2 Points for Consideration

We are seeking your views on benefits and consequences of introducing a high-performance building design metric and also on several specific metric options. Some specific points to consider in providing your feedback include:

- Potential advantages and disadvantages to the building market that would result from the creation and implementation of a single high-performance design metric;
- Identification of the primary characteristics required by a high-performance metric in order to be effective; and, whether any one characteristic should take precedence;
- Noting that a high investment in administrative resources is generally required to achieve a high degree of accuracy and/or verifiability in any rating system, your thoughts are sought on the challenges in achieving an appropriate trade-off/balance between these;
- Comparison of the advantages and disadvantages of the seven metrics (including impacts on the building market) presented in Section 3 of this discussion paper; and,
- The importance of linking a comparative "design-based" metric to eventual measure of actual (post-occupancy) energy consumption, and how that linkage can be best achieved.

Section 2 of this paper provides the context surrounding this issue and is provided to frame the above discussion points. Section 3 provides comprehensive descriptions of four (4) established metric options as well as the three (3) new metric options under consideration.

2 Introduction: Context for this Consultation

2.1 Building Sector's Contribution to National Energy Consumption

Canada's service sector represents nearly 70% of our nation's GDP. The vast majority of this economic activity takes place within Canada's estimated 482,000 commercial and institutional buildings[1]. In 2010, these facilities were responsible for 12% of our nation's energy consumption and 11% of our total carbon emissions[2]. Indeed, the sector spent $23 billion on energy in providing services to Canadians; consequently, any operational savings that may be achieved will impact the competitiveness of Canadian businesses. Since the early 2000's, a plethora of energy efficiency programs offered throughout Canada have increased energy efficiency throughout the sector, and we have observed a consequent decoupling between the growth in energy consumption and the growth in floor space. In 2010, this sector had reduced its energy use back to year 2000 levels, notwithstanding the 19% increase in total floor space.

Reducing building-related energy consumption has become a priority to many stakeholders. According to the International Energy Agency (IEA), the service sector offers more untapped potential for energy efficiency than any other sector.[3] Studies by the IEA and others on building energy use agree that "strong barriers hinder the market uptake of these cost-effective opportunities, and large potentials will remain untapped without adequate policies."[4] New buildings present a very real opportunity to substantially avoid energy consumption over the long term, especially when designers, buildings, and operators use an integrated systems approach to energy efficiency. Building to higher energy-efficiency standards requires an upfront commitment to a new way of thinking about design, construction, and investment. Designing holistically can help to ensure that all systems work together effectively, while facilitating the incorporation of major energy efficient features that would otherwise be difficult to implement. This in turn helps designers and operators to realize significant energy savings. Thus, designing buildings to higher standards of energy efficiency has both immediate and far-reaching benefits.

Maximizing the efficiency of existing buildings begins with an ongoing commitment to measure and benchmark energy use, combined with subsequent attention to operational practices, occupancy behavior, and retrofits (as required). Although the last touches on optimal design, the subject of existing buildings is otherwise outside the scope of this paper and consultation.

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[1] As estimated in 2009, by *The Survey of Commercial and Institutional Energy Use (SCIEU) 2009*, Her Majesty the Queen in Right of Canada, 2012

[2] *Energy Efficiency Trends in Canada, 1990 - 2010,* Natural Resources Canada, 2013

[3] *World Energy Outlook 2012,* International Energy Agency, 2012

[4] e.g., *IPCC, 2014: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 675). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.*

One of the main barriers continues to be insufficient awareness within the sector. Actions related to both new and existing buildings will thus be required to increase market awareness, but new building designs present a unique opportunity to demonstrate leadership. This leadership would best be shown by a combination of the adaptation of new technologies with a system-approach and integrated design principles. The promotion of leading-edge designs would therefore provide a suitable market "pull" to complement the "push" provided by increasingly stringent energy building codes. That recognition, in turn, will depend on an appropriate metric that helps the market to identify the highest current energy-performance designs.

2.2 History of Government Promotion of Energy-Efficient Design

Today's new buildings are expected to stand for 50 to 100 years, so their long term impact on the national energy footprint will be significant. Additionally, new building designs and practices can influence energy retrofit practices across the rest of the building stock.

Governments around the world recognize the potential to intervene in the new building sector. The IEA currently reports approximately 40 countries around the world that have implemented either voluntary or mandatory energy codes or standards. The United States has two active energy standards widely adopted by the individual states: the "American Society of Heating, Refrigerating, and Air-Conditioning Engineers' (ASHRAE) Standard 90.1: Energy Standard for Buildings Except Low-Rise Residential Buildings" and the "International Code Council's (ICC) International Energy Conservation Code (IECC)." Both are updated every 3 years.

In Canada, a consortium of stakeholders came together in 1997 to develop the *Model National Energy Code for Buildings* (MNECB 1997). Canada's first ever national standard for building energy performance influenced how Canadian buildings were designed. A number of financial incentive programs and the Canada Green Building Council's (CaGBC) Leadership in Energy and Environmental Design New Construction program (LEED-NC) referenced MNECB 1997 as a basis for specifying minimum energy performance. This successful use of MNECB 1997 eventually led to an updated version, the *National Energy Code of Canada for Buildings 2011* (NECB 2011), which increased upon the stringency of the standard by 25%. Provinces and territories are now in the process to adopt or adapt NECB 2011, or adopt an equivalent standard. As of 2015, five provinces (representing 70% of Canada's commercial/institutional new building space) have completed this adoption/adaptation and nearly all new Canadian buildings are expected to be covered by minimum energy standards or codes by 2017.

2.3 Next Step: Net-Zero Energy

Codes and standards are important because they define the <u>minimum</u> acceptable energy performance. However, these instruments do not inform innovative market leaders how well they are performing in reference to very high levels of efficiency. Comparisons to such early adopters are valuable because they encourage today's market towards advanced materials, technologies and practices. Those innovations, in turn, are bound to become the foundation of future codes and standards.

Many jurisdictions around the world recognize this natural progression and are already looking towards the next logical step: can buildings extend beyond improved efficiency, to become energy-neutral, or "net-zero". Several discrete definitions currently exist for net-zero, but essentially, it refers to buildings that produce as much renewable energy as they consume over a 12-month period. The incorporation of renewable energy generation is necessary for a building to reach net-zero. However, the method in which renewables are factored into each metric has not yet been fully explored and requires further consideration.

2.4 *Defining a Building Design on the Path towards Net-Zero Energy*

A number of approaches exist within the building market to identify high-performance building designs, but none currently distinguish between the very best designs that demonstrate significant progress on the path towards near- or net-zero energy. Certain emerging programs, such as the Living Building Challenge, verify buildings that have achieved net-zero, but almost no buildings in Canada are yet able to achieve that ideal. Indeed, there are very few anywhere in North America. Nonetheless, many designs do at least demonstrate progress along the path towards that ideal. Identifying this leadership effort toward achieving net-zero should motivate other stakeholders to build closer to net-zero performance. In order to do so, the metric will likely need to take into account several different technical perspectives on "high-performance," including: energy efficiency, absolute energy use, and how the implementation of renewables would be considered. The issue is how to differentiate between many designs and establish their relative performance on the path toward net-zero, in a transparent, clear, and cost effective way.

2.5 *Key Metric Characteristics*

We determined, in collaboration with this project's technical Steering Committee[5], that an appropriate metric should meet the following criteria:

- Clear and understandable by a range of building sector stakeholders;
- Transparent, credible, and defensible;
- Provide the basis for a subsequent communication tool(s); and,
- Cost effective for all parties using it.

3 Metrics Explored and Analyzed

The most simple and obvious metric would be a straightforward measure of *energy use intensity* (EUI), measured in $GJ/m^2 \cdot year$, because it aligns well with the standard industry practice of reporting EUI on a per-area basis (whether kWh/ft^2, GJ/m^2, or other variation). A building's EUI relates very directly to the ultimate goal of net-zero energy, and the lowest EUIs represent the most energy-efficient designs. While logical in theory, this simple measure does not capture the complex realities of building design, in which a given building may have genuinely credible reasons for operating at a higher EUI. We therefore analyzed a number of other approaches that could potentially serve the purpose of identifying building designs that are on the path toward net-zero energy. These included:

Existing Metrics:

i) Climate Adjusted Energy Use Intensity
ii) U.S. Environmental Protection Agency's Portfolio Manager/Target Finder System
iii) U.S. Dept. of Energy Commercial Building Energy Asset Score
iv) Percentage Performance relative to a Minimum Energy Code or Standard

New metrics developed by NRCan:

i) Percentage Performance relative to a High-Performance Reference
ii) Zero Energy Rating – the High-Performance Reference augmented by comparison to an archetype

5 See ANNEX 4 for details on the Steering Committee's composition and purpose.

iii) Zero Energy Rating (based on performance relative to code) – an alternate approach to measuring performance relative to a high-performance reference

For the purpose of this analysis and comparison of prospective metrics, we referenced new building designs previously submitted to NRCan's Design Validation program, from 2007 – 2011. We analyzed the energy models of the clients' proposed building designs and how their relative distribution with each different approach compared to EUI. A notable benefit of this approach is that it allowed us to work with *actual* (vs. purely hypothetical) building designs.

One early conclusion of the analysis is that different building types have different functional requirements that make comparison between building types ambiguous. For this reason, our analysis was performed on a sampling of different building types. To maintain clarity, however, the following discussion will focus on two we most concentrated on: medium-sized office buildings (representing the commercial sector) and primary schools (from the institutional sector).

As you review and consider these metric options, we wish to stress that neither NRCan, nor either of the consultation oversight committees (the Built Environment and Equipment Working Group and technical Steering Committee) are promoting or endorsing any particular one of the following. We are simply seeking your views on the technical aspects and considerations of all options, as per the questions posed in Section 1.2

3.1 Overview of the Analysis of Existing Metrics

3.1.1 Climate Adjusted Energy Use Intensity

Predicted EUI is a fundamental output of the EE4 building design modelling software. Our first assay at an appropriate metric was to apply a simple adjustment to the design's predicted EUI, in order to normalize for local climate. A simple formula was developed to make this adjustment, which included an assumption that 50% of a building's energy use is for heating, and, further, that heating energy is directly proportional to the number of heating degree days of the proposed building's climate. The resulting formula was:

$$\text{Climate Adjusted EUI} = \left(\frac{1}{2}\text{Predicted EUI}\right) + \left(\frac{1}{2}\text{Predicted EUI} \times \frac{\text{Heating Degree Days of Baseline (Montréal)}}{\text{Heating Degree Days of Proposed Building Climate}}\right)$$

This approach treats all designs equally, without consideration for factors such as hours of operations, or number of occupants. Such an approach may be considered unfair in the case of buildings which need to operate under more demanding conditions. Consider, for example, two otherwise similar office buildings, one which operates over a standard workweek (i.e., Monday-Friday; 7 AM – 6 PM) while the other is open through the weekend; the latter will inevitably use more energy and have a higher nominal EUI. This imbalance may even persist in cases where the latter contains energy-efficient features lacking in the former.

3.1.2 U.S. Environmental Protection Agency's Portfolio Manager / Target Finder

Portfolio Manager (PM) is the technical underpinning of the U.S. Environmental Protection Agency's (EPA) ENERGY STAR program. Used since 2000 in the United States, the PM tool was adapted for use in Canada in 2013. It is based on a comparative rating between an existing building's normalized EUI (for climate, occupancy, etc.) and a national building energy use database. In Canada, the reference database is the *2009 Survey of Commercial and Institutional Energy Use* (SCIEU)[6]. The normalization of a building's EUI is based on a regression analysis of the reference database, with a rating of 100 corresponding to the top percentile of existing buildings. While primarily positioned as an existing buildings program, new building designers may also use ENERGY STAR's associated *Target Finder* tool to rate the anticipated EUI of their design. We therefore examined this as a metric option for recognition of the optimal designs.

We found that new building designs that are on the path toward net-zero would necessarily exceed the performance of the best existing buildings. Our analysis of office building designs submitted to our Design Validation program confirmed that the higher performers are concentrated in a narrow range close to the 100 rating, see Figure 1, without any means for further discriminating between the "very good" and the "best".

This is perhaps not surprising, as the reference database is, by definition, limited to existing buildings, only very few of which would approach the "leading edge" sought by this high-performance metric. This approach therefore appears to have only limited value in identifying the highest-performers on the path toward net-zero energy.

Additionally, many of the values necessary to normalize a building's EUI were set to defaults (e.g., number of workers on the main shift, number of computers) because this data is not clearly represented in the building models. Also, details such as cooking and refrigeration equipment are not often explicitly designed in building models. Both of these are believed to be negatively affecting the scores for primary school designs seen in Figure 2.

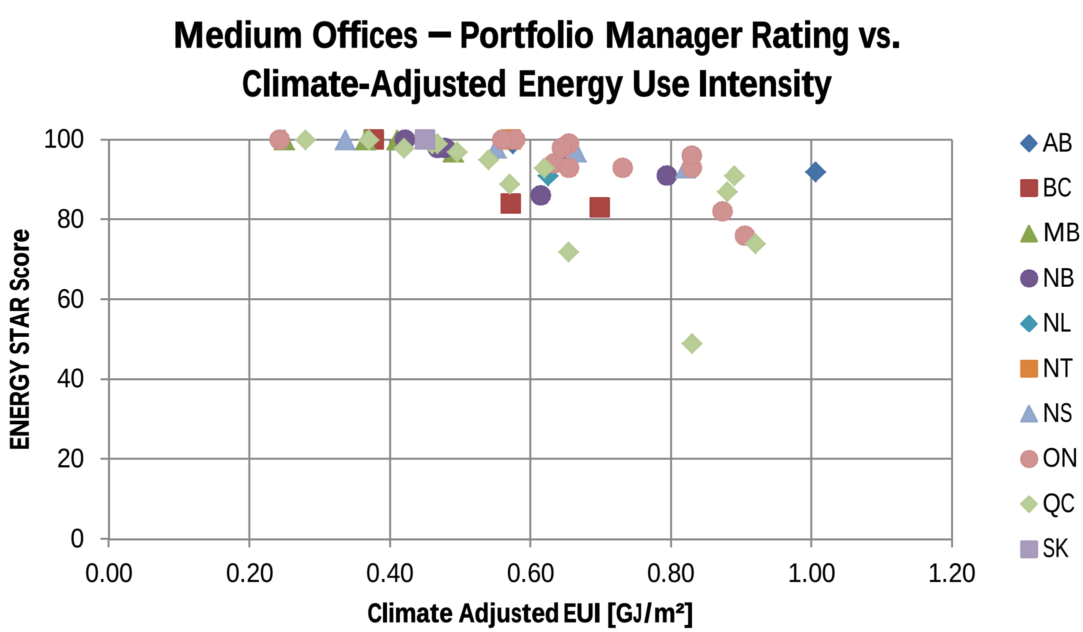

Figure 1: Portfolio Manager Rating vs. Climate Adjusted Energy Use Intensity – Medium Offices

[6] For the American version, EPA references the Commercial Buildings Energy Consumption Survey, which like SCIEU is updated periodically.

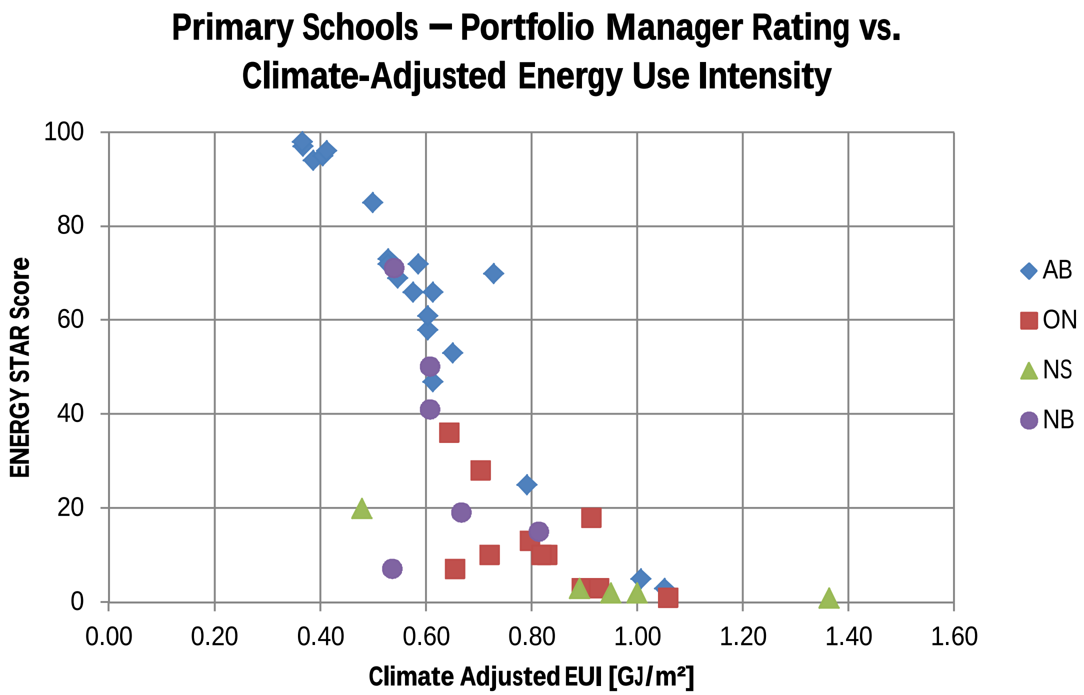

Figure 2: Portfolio Manager Rating vs. Climate Adjusted Energy Use Intensity – Primary Schools

3.1.3 U.S. Dept. of Energy Commercial Building Energy Asset Score

The DOE's new Asset Scoring Tool generates an *Asset Score* for a given building, based on an evaluation of its envelope and mechanical and electrical systems. This approach is quite distinct from the Portfolio Manager (PM) tool (3.1.2 above) which focuses primarily on how well a building is operating. The Asset Score provides an estimation of expected energy consumption based on the many factors (e.g., location, equipment specifications), then converts this into a source EUI, from which a 1-10 score is assigned; exact scoring results are rounded to half-point increments (e.g., "5.0", "5.5", "6.0"). A score of 10 is the highest achievable, but does not represent "net-zero energy." Instead, a "10" is awarded for achieving the lowest possible EUI that can be expected for a building of that particular type (e.g., office, school, etc.), using current technologies (and without accounting for on-site renewables). As with PM in the US, the scale references the U.S. Commercial Buildings Energy Consumption Survey, but only to determine an appropriate energy performance range for each building type (a score of 1.0 generically represents a "poor performing" building).

The Asset Rating approach may bring us closer to a design-based approach, but its building scores are based on simplified building models with many details being predicted based on statistical likelihood. This practice may be suitable for the evaluation of existing buildings, but fair comparison of leading new designs may require greater technical sophistication. We understand the rating's fundamental purpose is to increase general efficiency awareness and encourage upgrades within that existing stock. In principle, this approach can be applied to new designs, but it is uncertain how reliable it would be for identifying the foremost leaders in energy efficient technologies and practices.

3.1.4 Modeled Performance relative[7] to a Minimum Energy Code or Standard

This methodology involves the modelling of the proposed building in comparison to a similar "reference" building. The latter is essentially a version of the former designed to just meet the minimum requirements set by an energy code or standard. As with the simple climate-adjusted energy intensity approach (Section 3.1.1), this methodology makes use of a straightforward output of the EE4 modelling software. In this case, the purpose is to establish the design's energy performance level in terms of a percentage improvement of the proposed building "above Code". This methodology has been widely and successfully used in incentive programs across North America since the late 1990's.

Our analysis found only a weak correlation between the percentage performance above a code or standard and the climate adjusted EUI, even after adjusting for variables such as occupancy, scheduling, climate, etc.

Figure 3 and Figure 4 illustrate the relationship between performance achieved over MNECB 1997 versus the climate adjusted EUIs for offices and schools. There is virtually no correlation apparent for offices and low correlation for schools.

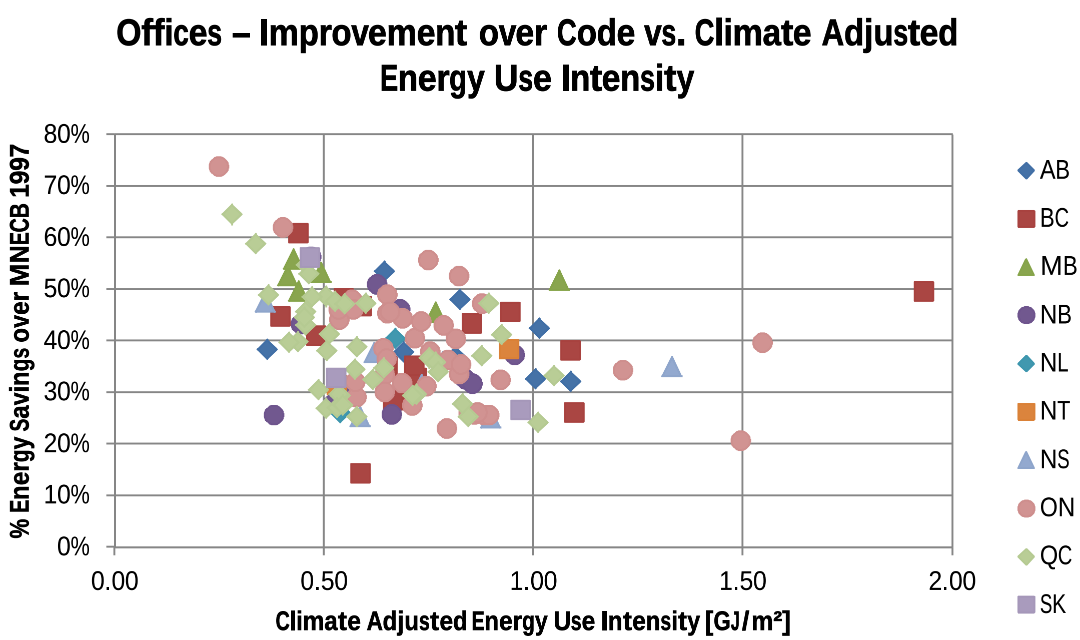

Figure 3: Percent Improvement over MNECB 1997 versus Climate Adjusted Energy Use Intensity – Offices

[7] This concept is sometime referred to in industry parlance, as "performance above Code", but the term "above" can be ambiguous – alternatively suggesting "better" performance...or more energy use.

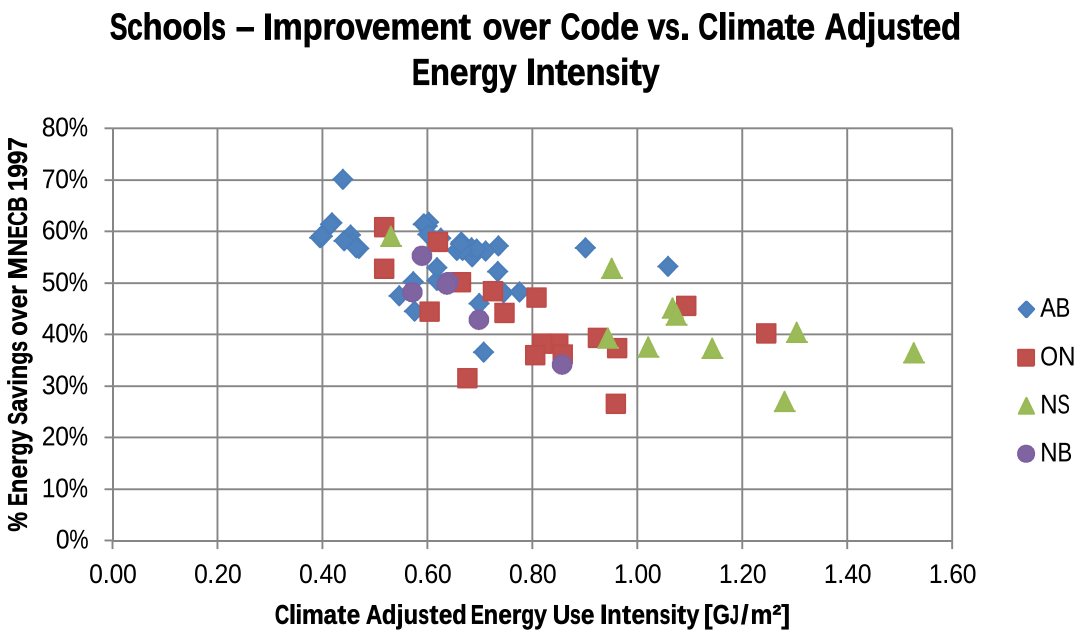

Figure 4: Percent Improvement over MNECB 1997 versus Climate Adjusted Energy Use Intensity – Schools

This weak correlation can be explained by a number of factors.

- The software generates the "reference" building based on the model of the proposed building. If there are multiple valid ways to model different parts of a building, the software will generate a different, and valid, reference building depending on how the modeller chooses to model the proposed building. Due to the complexity of building models (where there are many variables interacting with each other), this can lead to cases where the reference building's energy use changes based on modeling choices, and more importantly, the proposed building's energy use could change by a different amount; this would lead to a situation where modelling choices affect a building's energy performance relative to code.
    - For example, there may be flexibility for a modeller to choose to use different space types in their building model which would affect certain space characteristics such as lighting, occupancy, and equipment loads within the space in the reference building. Since a proposed building's lighting system would typically be fully modelled (and remain unchanged by the choice of space type), the choice of space type may affect the building's relative energy performance.
- The MNECB 1997 is a dated code; some building designs demonstrated greater than 70% energy reductions when compared to this baseline. When there is a large difference in the energy performance of a designed building and the baseline, small changes to the proposed building may end up being large changes in the reference building, consequently, the reference building may not be a steady baseline.

3.2 New Metrics Developed by NRCan

We also explored three new approaches that could potentially help rank the best energy performing designs that are on the path toward net-zero energy. These approaches were tested with a data set of 24 medium office buildings, and 24 primary schools.

3.2.1 Modelled Performance relative to a High-Performance Reference

This first alternative approach was inspired by the traditional "%-above-Code" approach described in Section 3.1.4 above. The key difference in this approach lies in its reference characteristics – instead of specifying performance above a minimum level, in relation to an energy code or standard, this new metric assesses how close the design approaches to a specified high-performance level. We posit that the comparison to a high-performance reference instead of a low performing reference will focus modelling choices towards best practices.

This comparison to the high-performance reference ("%-from high-performance Reference") maintains fairness by taking into account the special constraints of each building. It employs a similar method to the "%-above Code" approach, by creating a reference building which takes into account every unique design feature and functional requirement of the proposed building (e.g., geometry, occupancy patterns, etc.), whether these features help or hinder the energy efficiency of the building. The comparison is aimed towards determining how much the proposed building would benefit from incorporating high-performance characteristics.

To define the high-performance reference we examined the top 5% of characteristics, in terms of energy performance, reported in our Design Validation program, the Office of Energy Efficiency (OEE) equipment database, the ENERGY STAR database, and the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) database. These databases represent technologies that are currently in use and available. The performance level of the high-performance reference characteristics are listed in ANNEX 1.

To facilitate testing, each reference building was assigned the same fundamental type of heating, ventilation, and air-conditioning (HVAC) systems as the proposed building associated with it (e.g., a building with a ground source heat pump has a reference with a ground source heat pump), augmented with a set of "best current practice" features and settings. In order to compare heat pumps and boilers/furnaces as fairly as possible, reference buildings with heat pumps serving a majority of the heating load were assigned only mediocre coefficients of performance (equipment at the 50th percentile level instead of from the 95th percentile); this decision reflected an assumption that even mediocre heat pumps are a more energy efficient technology than conventional resistive electric or fuel-fired heating.

Results from our testing of this metric for medium offices and primary schools are illustrated below Figure 5 and Figure 6. In the case of schools (Figure 6), the correlation between "%-from high-performance Reference" with EUI appeared relatively good; better than the earlier result for "%-over Code" for this building type (Figure 4). One challenge with this analysis was that the new high-performance reference building was never considered in the original modeling, so the applicable "modelling decisions" could not be genuinely influenced by the high-performance reference. In addition, the graph's depiction of results may seem counter-intuitive, given its suggestion that approaching "0%" is "better"; doing so, however, represents a situation in which the design achieves an energy performance level similar to the high-performance reference.

The correlation was far less clear in the case of office buildings. To some extent, this can be expected, as the "office" category of building type includes a much higher variability in design, activity and occupancy parameters than is seen in schools. The latter are typically low-rise buildings mostly consisting of classrooms and other common elements, whereas buildings classified as "offices" come in all sorts of shapes and sizes, feature many different space uses and may operate on significantly diverse schedules. In addition, a closer examination of the outlying office cases often provides understandable reasons for their divergence from the correlation. For example, consider the two (yellow) highlighted outliers in Figure 5: the top left triangle represents a building with an atypically short operating schedule, while the bottom right diamond is for one with a 24/7 schedule; this additional insight explains how the latter could merit a "better" score despite its much higher EUI. In general, our analysis found the application of this metric resulted in fewer outliers than the more conventional "%-above Code" approach (Section 3.1.4); as with the above example, any remaining outliers were more easily explained.

If such a system was used, with known reference building criteria, it is possible that modelling decisions would still be influenced in much the same way that can happen in current design modeling (see the 3.1.2 discussion on factors affecting the correlation of % over code vs. EUI; page 5). Real world testing would be required to verify whether the impact on correlation with EUI would be as clear when referencing these new high-performance characteristics. Some of the predicted issues that may arise when comparing a proposed building to a reference building, specifically for our high-performance reference concept, are discussed in ANNEX 2.

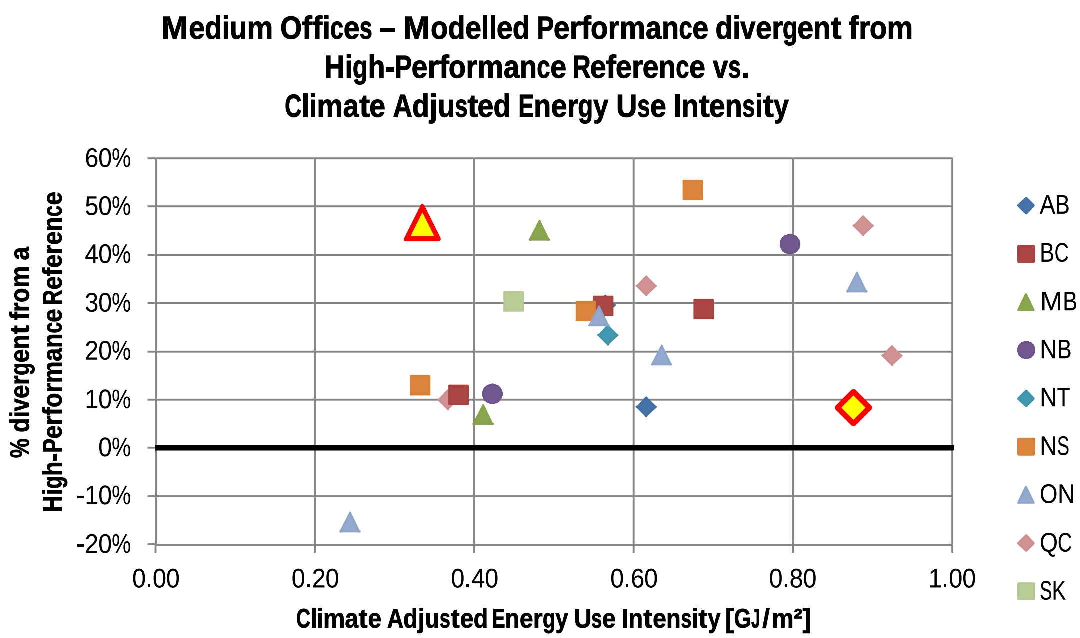

Figure 5: Performance related to a High-Performance Reference versus Climate Adjusted Energy Use Intensity – Medium Offices

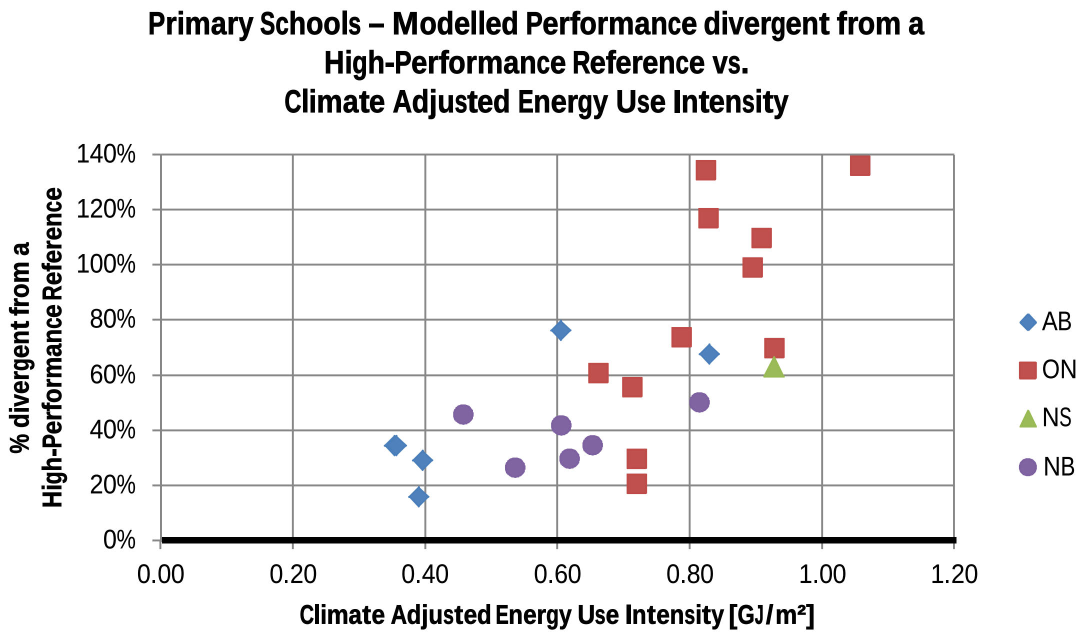

Figure 6: Performance related to a High-Performance Reference versus Climate Adjusted Energy Use Intensity – Primary Schools

3.2.2 Zero Energy Rating

The objective of the second new approach is to build on the above effort. The idea is to focus on the proposed buildings' EUIs , while facilitating the comparison between a number of proposed buildings across a variety of climate zones and at the same time treating fairly all buildings regardless of the specific constraints. We found it was impossible to meet all these objectives completely, but nonetheless developed an approach to approximate this goal, using the following formula:

$$\text{Zero Energy Rating} = \frac{\text{EUI}_{\text{proposed building}}}{\text{EUI}_{\text{high-performance archetype}}} \times \frac{\text{EUI}_{\text{proposed building}}}{\text{EUI}_{\text{high-performance reference}}}$$

The formula consists of two distinct factors, which each contribute to a fair assessment of the design. The first factor, "*EUI proposed building/EUI high-performance archetype*", compares the proposed building to a high-performance archetype building. This enables us to understand how the proposed building performs as compared to a "typical" or "average" building of the same type with high-performance characteristics. By enabling a comparison of buildings across many climate zones and operating characteristics (e.g., operating hours), this factor allows an understanding of whether the proposed building design uses more or less energy than "expected". A building that out-performs the high-performance archetype has a factor lower than one; if it underperforms the high-performance archetype, the factor is greater than one.

Archetype buildings had to be developed for the Zero Energy Rating (ZER). We began with archetypes developed by NRCan CanmetENERGY's Buildings and Renewables Group, based on the NECB 2011 prescriptive path, and archetype characteristic information obtained through the National Research Council's Standing Committee on Energy Efficiency in Buildings (also based on NECB 2011). These archetypes were then modified to operate at the same level of performance as the high-performance reference. The high-performance archetypes were then comprehensively analyzed by simulating them under systematically varying external conditions and functions (e.g., climate, hours of operation, occupancy density) and then a model was developed to determine how their EUIs varied with these conditions and functions. This enabled us to match the conditions and functions of a high-performance archetype to a proposed building so that, for example, we wouldn't be comparing the energy use of an office building open for 9 hours per day to the energy use of an archetype open for the NECB 2011 default of 11 hours per day.

The second factor "*EUI proposed building/EUI high-performance reference*" compares the proposed building to a high-performance version of itself. This is the same process governing the "Modelled performance relative to a high-performance reference" (see Section 3.2.1 above), and thus takes into account the specific design attributes of this building, and compares them more fairly.

The ZER is thus based on two considerations: i) whether the proposed building is using more or less energy than an appropriate archetype; and ii) how much the efficiency of the proposed building would increase with the inclusion of high-performance characteristics. When this exercise is performed for a number of proposed buildings of the same building type, it establishes a robust dataset which is used to compare relative building energy performance. You may refer to ANNEX 3 for a more in-depth, technical discourse on the underlying principles behind the ZER; taken from a report commissioned by NRCan to complete the development of the building archetype EUIs.

When the test buildings' ratings were plotted against their EUIs (Figure 7 and Figure 8), the resulting correlations (for both offices and schools) were far stronger than with the above metric options. As with the more simplified *Performance Relative to a High-Performance Reference* (Section 3.2.1), the "best" scores are those which approach zero.

Figure 7 and Figure 8 illustrate that "outliers" are even more obvious than before. And a deeper analysis confirms logical reasons: an office building which is open 24/7 (Figure 6) can be seen to use a fair amount of energy (greater than 0.90 GJ/m²), but is still able to achieve a modest ZER of 69; in Figure 8, schools with high designed occupancy are compensated for their expected higher energy use, and vice versa for low occupancy designs.

It is not intended for the lowest scores to be confused with "close to net-zero" since the ZER adjusts for a building's operating characteristics. For example, a building with long operating hours and high occupancy can achieve a good (low) score if it is energy efficient, but it would still use much more energy than a typical building. Noting that a score of zero can only be achieved when a building design reaches net-zero, two designs may earn the same ZER score through energy efficiency; however it would still be easier to reach net-zero for the design which uses less energy since it wouldn't need to incorporate as much renewable technology. This is one weakness of the ZER.

This ZER metric is the most complicated to determine and communicate, but also appears to have potential to return a relatively fair and accurate assessment of energy efficient design.

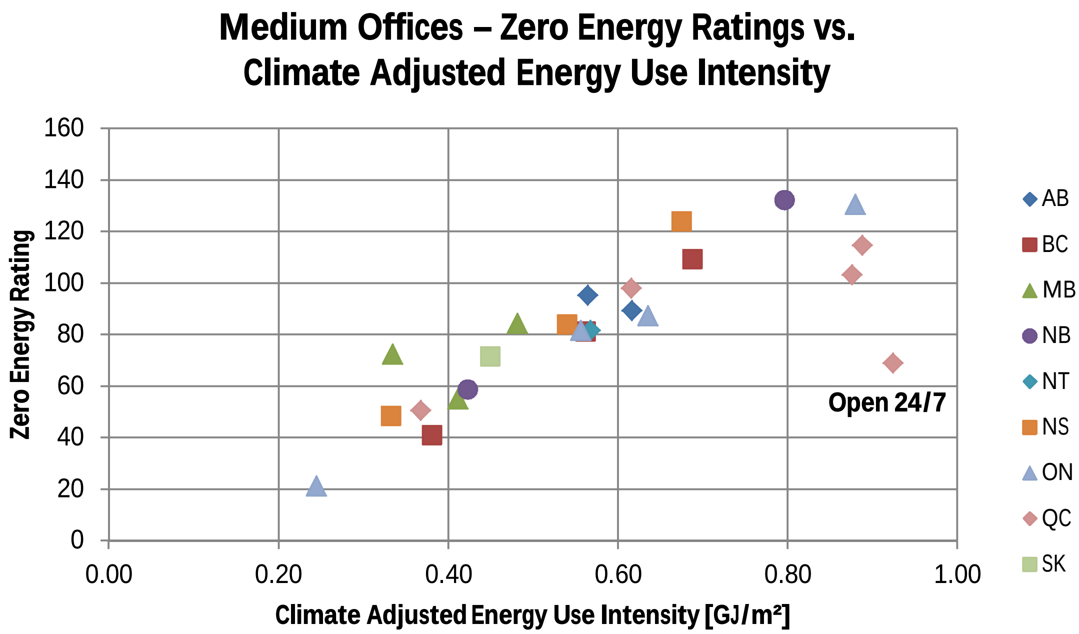

Figure 7: Zero Energy Rating versus Climate Adjusted Energy Use Intensity – Medium Offices

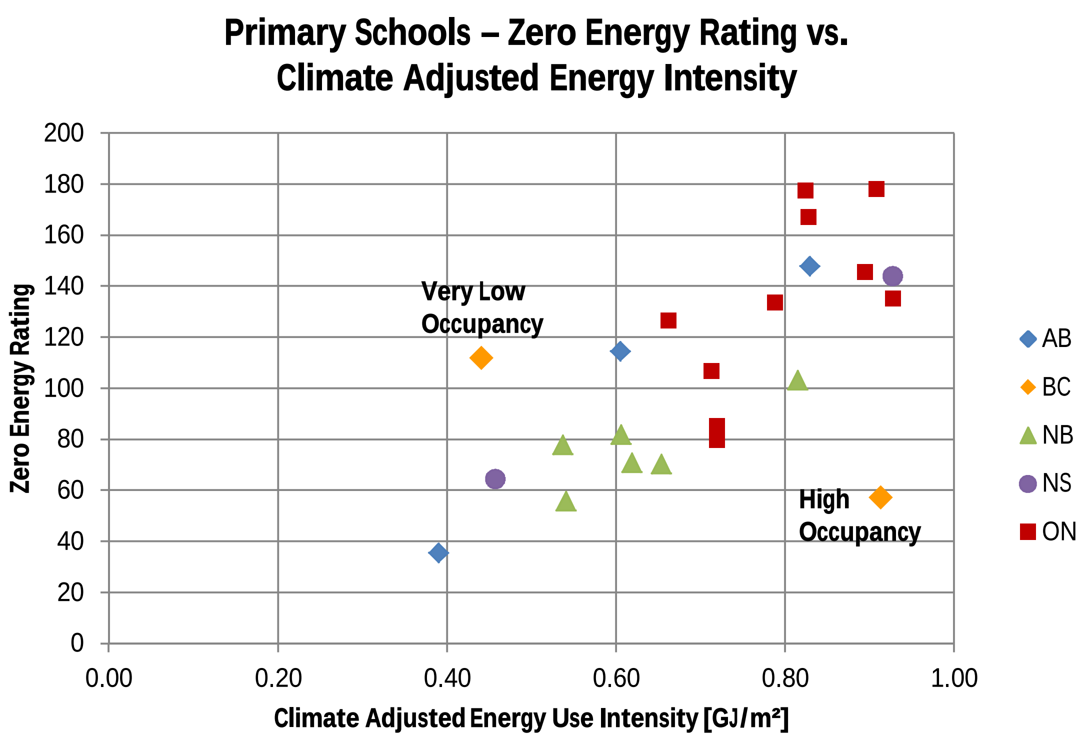

Figure 8: Zero Energy Rating versus Climate Adjusted Energy Use Intensity – Primary Schools

3.2.3 Zero Energy Rating (based on performance relative to code)

In a quality assurance study performed on the development of the ZER, some concerns arose about the additional work necessary to fully develop a consistent energy performance level for a high-performance reference building. It was suggested to use an existing code or standard instead. This would enable a consistent performance level to be set, and there would be an added advantage in aligning the modelling work with other energy modelling activities (e.g., code compliance modelling).

In consideration of this change to the ZER, we have recalculated the scores of the buildings from Figure 7 and Figure 8 by using a MNECB 1997 reference building instead of the high-performance reference (see the altered equation below). The results are shown in Figure 9 and Figure 10.

$$\text{Zero Energy Rating} = \frac{\text{EUI}_{\text{proposed building}}}{\text{EUI}_{\text{high-performance archetype}}} \times \frac{\text{EUI}_{\text{proposed building}}}{\text{EUI}_{\text{MNECB 1997 performance reference}}}$$

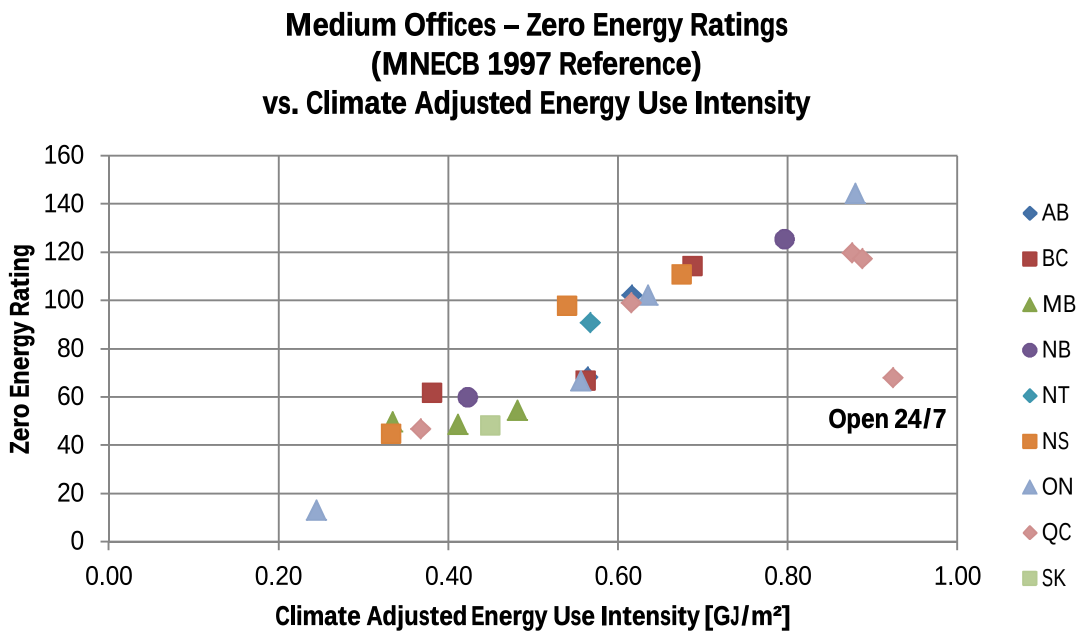

Figure 9: Zero Energy Rating (MNECB 1997 Reference) versus Climate Adjusted Energy Use Intensity – Medium Offices

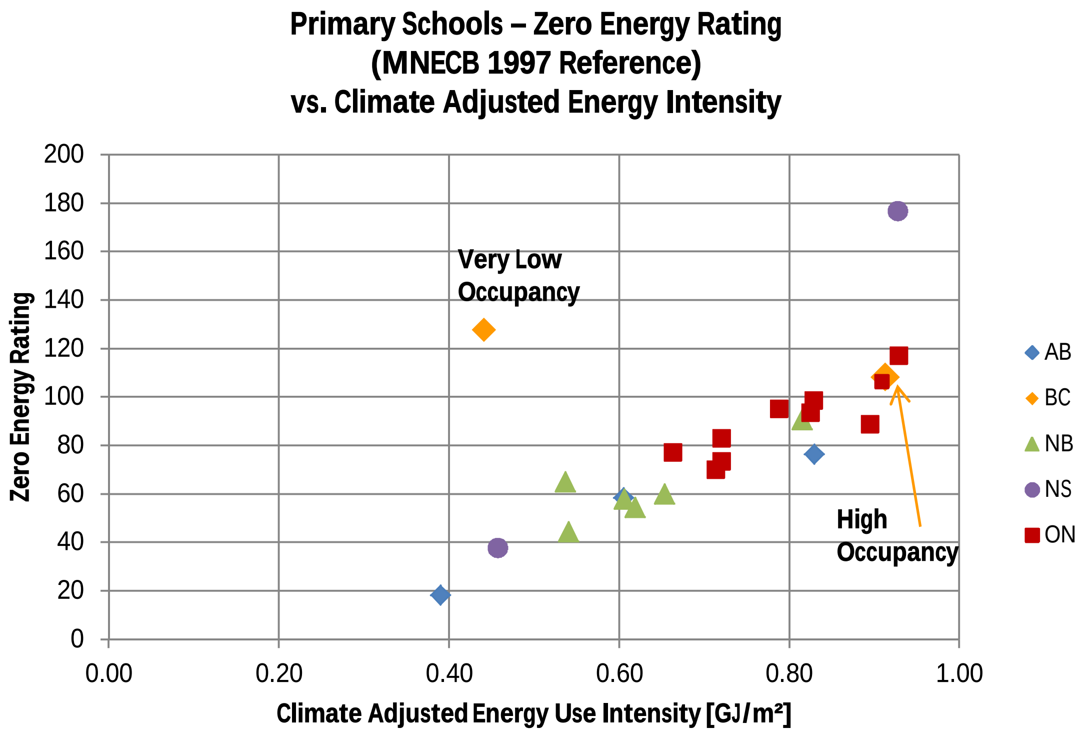

Figure 10: Zero Energy Rating (MNECB 1997 Reference) versus Climate Adjusted Energy Use Intensity – Primary Schools

We believe that the building design rankings obtained by using the high-performance reference (Figure 7 and Figure 8) are more accurate because of the weaknesses of the "performance relative to MNECB 1997" metric discussed in Section 3.1.4. Nevertheless, the ZER scores using the MNECB 1997 reference demonstrate the same general trends. The ZER scores still correlate strongly with climate adjusted EUI even though the energy performance level of the baseline has changed. Additionally, the metric is still able to recognize outliers (such as the 24/7 office building) and assign them scores according to their unique circumstances. This suggests that the ZER may be an effective metric if it references a standard or code, such as NECB 2011, instead of a very high-performance baseline.

4 Conclusion

Natural Resources Canada is interested in the development of a new metric to distinguish the highest-performing building designs that demonstrate significant progress along the path towards net-zero energy. We have undertaken the above analysis of several existing metric options. At the time we developed three new potential options that are intended to address shortcomings we perceived in the others. In keeping with our overall objective to provide one standard, recognized and accepted measure of "ultra-high performance", your insight and input will be extremely valuable. We have provided some key discussion points in Section 2, but invite you to propose other points for consideration and discussion which may occur to you.

ANNEX 1 **High-Performance Reference Building Characteristics**

Below is the current provisional list of high-performance characteristics that are used in the creation of the high-performance reference building. This list was developed from data obtained from real buildings submitted to NRCan's Design Validation program; from the Office of Energy Efficiency equipment database; from the ENERGY STAR database; and, from the Air-Conditioning, Heating, and Refrigeration Institute database. A technical committee would be formed to thoroughly research and discuss these characteristics if we were to move forward with the idea. The reader is invited to share thoughts on these and other potential reference characteristics.

	Building Type Independent High-Performance Characteristics	Medium Office Specific High-Performance Characteristics	Primary School Specific High-Performance Characteristics
Boiler Efficiency [%]	96.0%		
Furnace Efficiency [%]	96.7%		
Water Heater Efficiency [%]	98.0%		
Domestic Hot Water (DHW) Flow Rate [L/occ·day]		3.42	2.70
Ground Source Heat Pump [Heating COP] (Med. / High)	3.60 / 4.20		
Ground Source Heat Pump [Cooling COP] (Med. / High)	5.16 / 6.21		
Air Source Heat Pump [Heating COP] (Med. / High)	3.31 / 3.73		
Air Source Heat Pump [Cooling COP] (Med. / High)	3.28 / 3.66		
Water Loop Heat Pump [Heating COP]	5.70		
Water Loop Heat Pump [Cooling COP]	5.16		
Built-Up Cooling [COP]	5.39		
Packaged Cooling [EER]	13.0		
Packaged Cooling (> 50kW) [EER]	12.6		
Energy/Heat Recovery Ventilator Effectiveness (E/HRV) [%]	78.5%		
Demand Controlled Ventilation (DCV)	Yes		
Pump Efficiency [%]	76%		
Supply Fan Efficiency [%]	70%		
Return Fan Efficiency [%]	59%		
Wall RSI Value [m²·°C/W]	4.63		
Roof RSI Value [m²·°C /W]	7.59		
Window U-Factor [W/m²·°C]		1.54	2.06
Lighting Power Density (LPD) [W/m²]		6.01	5.65
Occupant Sensing Lighting (OSL)	Yes		
Daylight Sensors (DS)	Yes		

COP	Coefficient of Performance
EER	Energy Efficiency Ratio

Table 1: High-performance reference building characteristics

ANNEX 2 **Variable Effects on Modelled Performance Below a High-Performance Reference**

Below are the main concerns related to the high-performance (HP) reference building that need to be addressed in order to proceed forward. The reader is invited to comment on these and/or add further suggestions.

Variable	**Problem**	**Possible Actions**
HVAC System Type/Options	Not prescribed in HP Reference	Define these characteristics in the HP Reference
Passive Design Features	Designer may not receive credit for good design	Reward designer with evidence/ quantification of energy savings
Fenestration Ratio	Conflict between efficiency and functionality	Up for debate; market will determine fenestration lower limit
Surface-to-Volume Ratio	Uncertain effect on % score	Up for debate, difficult to adjust fairly; market will determine lower surface: volume ratio
Building Size	Affects actual building energy usage, but not the model	No suggestions, not in our interest to make further adjustments
Local Building Code and Regional Concerns	Consistent national HP Reference vs. Specialized local HP Reference	HP Reference seems less sensitive to change, National HP Reference may be sufficient
Process Load	Affects the % score	Subtract out the process load when calculating the % score; need to define clearly process load
Space Function Definitions	Different buildings of the same type may have different functional parts	Have the modeler provide specific information so that adjustments can be made
Lighting Power Density (LPD)	Oversimplified approach	Create custom HP Reference LPD for space types
Plug / Equipment Load	Affects the % score	Up for debate; could make adjustments based on space types; could leave as is, to encourage building owners to optimize building use; could remove from % score
Operating Hours, Occupancy Density, Service Water Heating Load	May affect the % score	Development of an adjustment (would need analysis)

Table 2: Variable effects on modelled performance relative to a high-performance reference

ANNEX 3 **Elaboration of the Zero Energy Rating Equation**

The following excerpt from a report commissioned by NRCan (Gravelle, A. "Impact of Neutral Variables on the Energy Use Intensity of a Medium-Size Office Building Archetype." (2013): 3-6.) provides a more comprehensive explanation of the development of the "Zero Energy Rating Equation"

The Zero Energy Rating Equation

The equation developed to define the ZER metric is as follows:

$$ZER = \underbrace{\left(\frac{EUI_{proposed}}{EUI_{high-performance\ archetype}}\right)}_{\textit{Absolute}\text{ factor}}\underbrace{\left(\frac{EUI_{proposed}}{EUI_{high-performance\ reference}}\right)}_{\textit{Relative}\text{ factor}}$$

Equation 1: Zero Energy Rating

Term definitions:

$EUI_{proposed}$ energy use intensity of the proposed building model to be rated

$EUI_{HP\ archetype}$ energy use intensity of the corresponding high-performance *archetype* building model

$EUI_{HP\ reference}$ energy use intensity of the corresponding high-performance *reference* building model

Understanding how this equation helps to identify optimal high-performance building designs begins with an appreciation of the role of each term and factor. Building attributes fall into two categories: those that are *separable* from a building model, such as the boiler efficiency and hours of operation; and those that are *inseparable* from the model, such as space use designations, shape, and layout of the building. Changing an 'inseparable' building attribute will fundamentally change the function of the building, and thus the modeling of its design. Both separable and inseparable attributes affect a building's projected energy use. In addition, some of these attributes are *design* features which affect the building's energy efficiency (e.g., boiler efficiency), and others are *functional requirements* (e.g., occupancy and hours of operation), which are considered neutral towards energy efficiency.

The ZER employs both "relative" and "absolute" factors. The "relative factor" rates a building design based on the energy use difference between a proposed building and its high-performance reference building. The high-performance reference building, in turn, uses the proposed building as a template and modifies separable design features, by raising them to a high-performance level. For purposes of the equation, we have more formally designated this factor as the *high-performance reference normalization factor.*

The "absolute factor", on the other hand, rates a building based on the energy use difference between the proposed building and its high-performance archetype. This archetype represents how a *typical* building of the proposed building's type (e.g., medium office) would be modelled. The separable design features of the archetype are then replaced with high-performance. For purposes of the equation, we have more formally designated this as the *archetype normalization factor.*

The key distinctions between the proposed, archetype, and reference building terms are summarized and highlighted in Table 3~~Table 3~~. This summary demonstrates that a rating just comparing the proposed building to the high-performance reference building (i.e., the relative factor) is not affected by the *inseparable design features*. Similarly, a rating just comparing the proposed building to the high-performance archetype (absolute factor) is affected by the *inseparable functional requirements*. Ideally, all functional requirements would be normalized, such as with the *separable functional requirements* (neutral variables), but due to their nature the task is currently beyond the scope of this study. This is why a *balanced* approach was proposed for the ZER; using both the absolute and relative perspectives.

	Inseparable or Difficult to Separate Attributes from the Model		*Separable Attributes from the Model*	
Building	**Design Features** (e.g., building shape)	**Functional Requirements** (e.g., space use)	**Design Features (Energy Efficiency Characteristics)** (e.g., boiler efficiency)	**Functional Requirements (Neutral Variables)** (e.g., hours of operation)
Proposed	Actual	Actual	Actual	Actual
Archetype	Typical for a Medium Office	Typical for a Medium Office	High-performance	Approximately the same as Actual
Reference	Same as Actual	Same as Actual	High-performance	Same as Actual

Table 3: Building model concepts in the ZER

Conceptually, the *reference* building is similar to the built-to-code version of a building used in conventional simulations, but its energy performance significantly exceeds basic code compliance. The reference building refers to a list of high-performance characteristics which reflect what is currently available within industry at the highest energy performance level. These characteristics replace whatever exists in the proposed building, even if they are actually lower performing than what exists in that proposed design. The archetype building also obtains its set of high-performance characteristics from a subset of that same list.

Summary and purpose of ZER factors:

The *archetype normalization factor*

$$\frac{EUI_{proposed}}{EUI_{archetype}}$$

- Compares the energy performance of the proposed building to that of a *typical* building of the same type, disregarding unique design features and functional requirements of the proposed building that are difficult to quantify
- Factor is useful for comparing the performance of many buildings in different climate zones, with different *hours of operation indexes*, etc. and establishes which building performs comparatively better in terms of *energy use*
- Answers the question, “Is the proposed building designed to use more or less energy than expected and by how much?”

The *high-performance reference normalization factor*

$\frac{EUI_{proposed}}{EUI_{reference}}$

- Compares the energy performance of the proposed building to a version of itself as if it had been designed with the highest performance characteristics currently available within industry, taking into account all unique design features and functional requirements whether they help or hinder *energy use* and energy efficiency
- Its purpose is to ensure that buildings that have specific design requirements are treated fairly, through an assessment of the amount of potential left to optimize energy performance
- Answers the question, "How much would the proposed building benefit from high-performance characteristics?"

These factors evaluate energy performance from different perspectives and bring independent information to the ZER. Table 4~~Table 4~~ outlines the four main ways in which buildings will score under the ZER metric, depending on the sub-score generated from each factor (note that a high-performer will score "lower"). If only one normalization factor was used, some tiers would be indistinguishable, such as tiers ① and ②**A** for the archetype normalization factor, or tiers ① and ②**B** for the high-performance reference normalization factor. The combination of the two factors allows a third rating tier to be distinguished, consisting of those who fall into ②**A** or ②**B**. This "tier" is made up of buildings that are difficult to assess because there are conflicting results from each ZER normalization term. This uncertainty is unavoidable given that the ZER is reducing the energy performance of unique and complex buildings down to a single number. However, this uncertainty is acceptable, since, as previously discussed, the primary goal of the ZER is to identify the *leaders* closest to reaching NZEB status, which will *all* score in tier ①.

		$\frac{EUI_{proposed}}{EUI_{reference}}$ *Considers energy efficiency characteristics*	
		Low Score (High relative performance)	**High Score** (Low relative performance)
$\frac{EUI_{proposed}}{EUI_{archetype}}$ *Considers inseparable attributes and energy efficiency characteristics*	**Low Score** (High absolute performance)	Tier ① *Low x Low*	Tier ②**A** *High x Low*
	High Score (Low absolute performance)	Tier ②**B** *Low x High*	Tier ③ *High x High*

Table 4: Description of ZER term-by-term scoring tiers

Also worth noting is the consequence that the ZER equation will generate a score of exactly zero when the proposed building EUI is exactly zero. When a proposed building's EUI is zero or lower (negative), it could be said to score in a separate tier ⓪**,** distinguishing them as NZEBs.

ANNEX 4 **Oversight Committees for this Consultation**

Built Environment and Equipment Working Group (BEEWG)

The Built Environment and Equipment Working Group, operating under the auspices of the Energy and Mines Ministers Conference (EMMC), has taken on this consultation as one of their federal/provincial/territorial projects to promote energy efficiency across Canada and its jurisdictions. The working group provides policy guidance to this project .

Co-Chairs

Candace Major..Ontario Ministry of Energy
Philip Jago..Natural Resources Canada

British Columbia Ministry of Energy and Mines........................Nathaniel Gosman
Alberta Ministry of Environment and Parks........................Brian Waddell
Saskatchewan Industry and Resources........................Howard Loseth
Government of Manitoba - Energy Division........................Rathan Bonam
Ontario Ministry of Energy........................Allan Kirschbaum, Senka Krsikapa
Ontario Independent Electricity System Operator........................Katherine Sparkes
Ministère des Ressources naturelles du Québec........................Mathieu Payeur
Énergie NB Power........................ Stephanie Wheaton, Tom MacDermott
PEI Department of Finance, Energy and Municipal Affairs........................Mike Proud
Nova Scotia Department of Energy........................Bob Green
Newfoundland and Labrador Office of Climate Change & Energy Efficiency...............Gerald Crane
Yukon Ministry of Community Services ....Doug Badry
Arctic Energy Alliance........................Craig Thomas
Nunavut Economic Development and Transportation........................Chris Down
National Energy Board........................Ken Newal
Canadian Electricity Association........................Ann Kelly
Canadian Gas Association........................Paul Cheliak
Canadian Renewable Energy Alliance........................Roger Peters
Canada Mortgage and Housing Corporation........................Duncan Hill
Natural Resources Canada, CANMET Energy ....Sophie Hosatte

Technical Steering Committee

The Committee on High Performance Building Design Metrics was formed at the outset of this project to provide technical advice and insight into NRCan's research into metric options. The committee met regularly to discuss the research undertaken and exchange ideas on metric options.

BC Hydro........................Toby Lau, Alexander Rosemann
Manitoba Hydro ....Devin Evenson
Ontario Independent Electricity System Operator........................ Daniel Carr, Donald Chu
Hydro Québec........................Philippe Thomas-Côté
Ministère des Ressources naturelles du Québec........................ Julien Dutel, Mathieu Payeur
City of Vancouver........................Gregory McCall, David Ramslie
CaGBC........................ Cloelle Vernon, Mark Hutchinson
BOMA Canada........................ John Smiciklas
Natural Resources Canada, Office of Energy Efficiency ....Marie Lyne Tremblay
Ian Meredith
Raymond Boulay
Adrien Gravelle
Warren Neill
Adam Hurd