# ZERO CARBON BUILDINGS FRAMEWORK

## For Commercial, Institutional and Multi-Family Buildings in Canada

November 2016

The CaGBC (www.cagbc.org) is the leading national organization dedicated to advancing green building and sustainable community development practices. As the voice of green building in Canada, we work closely with our national and chapter members in an effort to make every building greener. The CaGBC reduces environmental impacts from the built environment through project certification, advocacy and research, and has helped meet the demand for skilled workers by providing green building education to over 20,000 professionals across the country since 2002. CaGBC is the license holder of the LEED green building rating system in Canada, supports the WELL Building Standard and GRESB in Canada, and oversees the Canada Coalition for Green Schools. We are also a member of the World Green Building Council supporting international efforts to reduce environmental impacts from the built environment.

Contact:
Thomas Mueller, President & CEO
1456 West Hastings Street
Vancouver, BC V6E 0C3
Tel: +1 613-241-1184
Toll-Free: +1 866-941-1184
tmueller@cagbc.org

Mark Hutchinson, VP Green Building Programs
47 Clarence Street, Suite 202
Ottawa, ON K1N 9K1
Tel: +1 613-288-8063
Fax: +1 613-241-4782
mhutchinson@cagbc.org

## About the Researchers

Integral Group is a global network of Engineering, Architecture and Planning professionals, all collaborating under the single umbrella of deep green engineering and professional services practice that aspires to the be the best in the world. We are a mission-driven corporation that seeks out clients interested in pushing the boundaries of resilience, regenerative design, and deep carbon emissions reductions. Integral Group's Research and Planning Team specializes in the development of strategic plans and polices for cities, districts, neighbourhoods, and campuses to achieve net zero emissions and other energy and environmental goals. Through this work, we have acquired experience in all aspects of city-scale energy planning, from the development of high performance building codes and distributed energy systems, to existing building retrofit roadmaps, to building energy disclosure policies and green building standards. With a staff of over 330 located in 15 offices across the United States, Canada, and the UK, Integral Group is widely regarded as a pioneer in building design, sustainability and energy system transformation.

Contact:
Dave Ramslie, MSc, LEED AP, MCIP RPP
Principal, Head of Sustainability & Research
200 Granville Street, Suite 180
604-307-7184
dramslie@integralgroup.com

Lisa Westerhoff, PhD
Senior Sustainability Planner
200 Granville Street, Suite 180
604-687-1800 x 284
lwesterhoff@integralgroup.com

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# EXECUTIVE SUMMARY

At the first ever "Buildings Day" hosted at the COP21 event in Paris, the Canada Green Building Council (CaGBC) committed to developing a net zero verification program, and offered its support to the World Green Building Council's goals that all new buildings are constructed to be "net zero" by 2030, and that all buildings achieve net zero by 2050. This report presents the results of the first phase of the development of a verification program for commercial, institutional and high-rise residential buildings as part of a broader Zero Carbon Buildings initiative.

A zero carbon approach to new construction can play an important role in meeting Canada's GHG reduction target of 30% below 2005 levels by 2030, as established in 2016 through the Vancouver Declaration on Clean Growth and Climate Change. Indeed, if all new buildings in Canada over 25,000 square feet were built to achieve a net zero carbon level of performance between now and 2030, GHG emissions for this sector would be reduced to 17% lower than 2005 levels, saving 7.5 megatonnes of GHG emissions annually by 2030.[1]

In recent years, increased industry efforts to understand zero energy or zero emissions buildings has resulted in the emergence of various approaches that diverge in the definition and measurement of "net zero". In the spring of 2016, CaGBC embarked on a process to improve the understanding, clarity and consistency around the meaning of "net zero" across the Canadian building and construction industries, through the creation of a zero carbon buildings (ZCB) framework for Canada.

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[1] CaGBC, 2016. Building Solutions to Climate Change: How Green Buildings Can Help Meet Canada's 2030 Emissions Targets.

A set of broad principles were established to guide the development of the framework, including 1) efficacy in driving lower carbon design and construction; 2) flexibility to ensure broad applicability; 3) adaptability to provide longevity in the face of changing conditions and policies; and 4) transparency to ensure clear and effective communication of performance.

A Working Group composed of government bodies, industry members, and academia was created to inform the identification of needs and challenges associated with the development of a zero carbon buildings framework in Canada. To ensure the inclusion of additional sources of expertise and guidance, a series of workshops with the CaGBC's Energy and Engineering Technical Advisory Group and the LEED Canada Steering Committee were held between June and August, supplemented by additional interviews with industry representatives. This consultation process included approximately 50 individuals representing 40 organizations in the building sector. Research, facilitation and reporting were all provided by Integral Group.

This report presents the findings of this process, including a review of the key components of established "net zero" frameworks (e.g. the metrics used to calculate the energy-carbon balance; the factors used to determine primary energy and associated carbon; and acceptable forms of renewable energy procurement), as well as a review and assessment of nine prominent frameworks for net zero buildings.

The outcomes of this process of research and consultation with Canadian industry representatives were used by the CaGBC to formulate a Zero Carbon Buildings framework for Canada. The framework sets forth a definition and establishes five key components for evaluating the extent to which a building's design meets the objective of reducing the carbon footprint of buildings, as detailed below.

# Zero Carbon Buildings Framework

## Definition of a Zero Carbon Building:

***A highly energy efficient building that produces on-site, or procures, carbon-free renewable energy in an amount sufficient to offset the annual carbon emissions associated with building operations***

**Key Components**

1. A greenhouse gas intensity metric for assessing a building's emissions, calculated using regional emissions factors

   Rationale: To meet the primary goal of reducing building emissions, a greenhouse gas intensity (GHGI) metric should be used to calculate the zero emissions balance in order to effectively incentivize a shift toward low-carbon buildings. Although there is a strong case for the adoption of a national emissions factor, a regional emissions factor more accurately reflects actual building emissions, drives innovative and adaptive design decisions, and more readily integrates into provincial regulatory frameworks.

2. Energy intensity metrics to incentivize the design of highly efficient, reliable and resilient buildings

   Rationale: To incentivize good building design as well as reduce GHG emissions, the GHGI metric should be accompanied by additional measures to encourage high building performance. This will include both a total energy use intensity (TEUI) metric to obtain a measure of a building's total energy performance, as well as a thermal energy demand intensity (TEDI) metric to encourage the use of passive design strategies better able to ensure reliability and resilience.

3. A peak energy demand metric to encourage the use of "peak shaving" measures

   Rationale: While it is not commonly used in existing frameworks, the inclusion of a measure of peak energy demand can encourage the use of building systems that respond to grid supply and demand fluctuations, improving grid integration and alleviating stress on the grid during times of high demand. A peak energy demand metric will initially be used to track building energy performance.

4. An embodied carbon metric

   Rationale: While this work focuses on the GHG emissions associated with building operations, as these emissions decrease, a greater focus will be placed on carbon emissions associated with the materials used in building construction. As such, it is recommended that building designers should begin to track the carbon emissions embodied in the building structure and envelope to help foster the industry's ability to consistently and accurately measure embodied carbon.

5. A requirement that renewable energy included in the zero emissions calculation be either generated on-site or procured directly from a renewable energy generator

   Rationale: For a zero carbon buildings framework to drive down the GHG emissions of the local energy system, it is important to ensure that it actually incentivizes the added generation of carbon-free renewable energy connected to the local grid. As such, the energy-carbon balance should be calculated by considering only renewable energy that has been generated on-site or procured through a direct contractual arrangement from a renewable energy supplier.

The focus on carbon emissions (as opposed to energy) in this framework flows from the increasing urgency of addressing climate change by reducing GHG emissions from buildings. Although energy remains an important component, this work has prioritized the exploration of a suitable framework capable of influencing the building industry toward low- and no-carbon building designs.

While these five components represent the result of careful research and consultation, they are only a first step towards a program to support the adoption and verification of Zero Carbon Buildings in Canada. Next steps will include an investigation into:

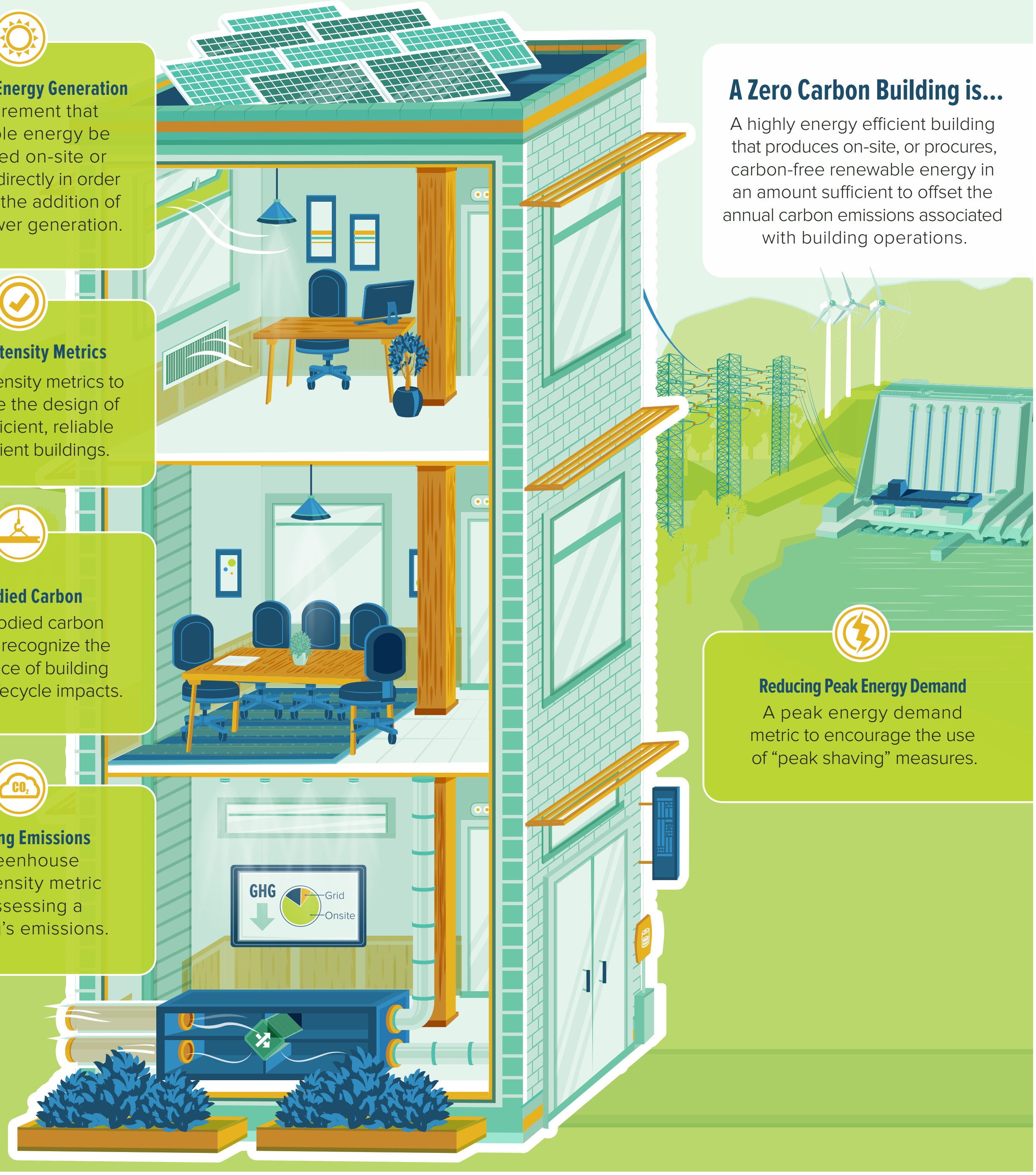
- Setting targets;
- Pathways to Zero Carbon Buildings;
- Verification requirements and processes;
- Methods of recognition and disclosure; and
- Broadening the applicability of the framework

The CaGBC expects to launch a Zero Carbon Buildings verification program by the end of the second quarter of 2017. The need for support tools, education, outreach and advocacy will be evaluated, and the CaGBC will seek input from stakeholders throughout.

Finally, though this framework has been developed with a focus on new construction, an important area for later expansion is the assessment of ongoing building performance, which is critical to optimizing and maintaining performance over time. Similarly, the framework will require refinement and adaptation in order to ensure its applicability at the campus, neighbourhood or community levels.

## Five Key Components of

# Zero Carbon Buildings




**Renewable Energy Generation**
A requirement that renewable energy be generated on-site or procured directly in order to ensure the addition of clean power generation.

**Energy Intensity Metrics**
Energy intensity metrics to incentivize the design of highly efficient, reliable and resilient buildings.

**Embodied Carbon**
An embodied carbon metric to recognize the importance of building material lifecycle impacts.

**Lowering Emissions**
A greenhouse gas intensity metric for assessing a building's emissions.

### A Zero Carbon Building is...

A highly energy efficient building that produces on-site, or procures, carbon-free renewable energy in an amount sufficient to offset the annual carbon emissions associated with building operations.

**Reducing Peak Energy Demand**
A peak energy demand metric to encourage the use of "peak shaving" measures.

# 1. INTRODUCTION

At the first ever "Buildings Day" hosted at the COP21 event in Paris, the Canada Green Building Council (CaGBC) committed to developing a net zero verification program, and offered its support to the World Green Building Council's goals that all new buildings are constructed to be "net zero" by 2030, and that all buildings achieve net zero by 2050. This report presents the results of the first phase of the development of a verification program for commercial, institutional and high-rise residential buildings as part of a broader Zero Carbon Buildings initiative.

A net zero approach to new construction can play an important role in meeting Canada's GHG reduction target of 30% below 2005 levels by 2030, as established in 2016 through the Vancouver Declaration on Clean Growth and Climate Change. Indeed, if all new buildings in Canada over 25,000 square feet were built to achieve a net zero carbon level of performance between now and 2030, GHG emissions for this sector would be cut to 17% lower than 2005 levels, saving 7.5 megatonnes of GHG emissions annually by 2030.[2]

Attempts to define and encourage "net zero" buildings have begun to emerge across the globe, with a growing number of terms used to describe burgeoning efforts to reduce the contribution of the built environment to climate change. "Net zero", "near net zero", "zero net carbon" and "zero emissions" are just a few of the ways these buildings have been described, each with a different approach to the creation of ultra-high performance buildings that use little if any energy to supply their operations. While there have been efforts to improve the consistency in the definition and measurement of net zero building performance, a process of building a common understanding of net zero for the Canadian building context has not yet been undertaken. This first phase of CaGBC's Zero Carbon Buildings initiative represents such a process.

In recognition of the significant impact of the built environment on Canada's total greenhouse gas emissions, the principal aim of this first phase has been to craft a framework that can effectively reduce greenhouse gas emissions associated with building operations. As such, this report focuses on the development of a framework and definition capable of shifting the Canadian industry towards the design and construction of zero carbon buildings (ZCBs).[3] In support of this effort, the CaGBC has fostered a process to generate broad buy-in across the Canadian design and construction industries in support of a singular definition to help reduce confusion among the industry and the public alike.

[2] CaGBC, 2016. Building Solutions to Climate Change: How Green Buildings Can Help Meet Canada's 2030 Emissions Targets.

[3] Given the range of approaches taken by existing frameworks the term "net zero buildings" is used to describe building frameworks in a general sense, while the term "zero carbon buildings" will be used in reference to the framework specifically proposed for adoption by the CaGBC.

This report is only the first stage towards a program to support the adoption and verification of ZCBs. Further, though this framework has been developed with a focus on new construction, an important area for later expansion will be the assessment of ongoing building performance, which is critical to optimizing and maintaining performance over time. Similarly, the framework will require refinement and adaptation in order to ensure its applicability at the campus, neighbourhood or community levels.

Future phases of the Zero Carbon Buildings initiative will include identifying pathways to zero carbon, a zero carbon building pilot program, and the development of a verification program to be launched by the end of the second quarter of 2017. The need for support tools, education, outreach and advocacy will be evaluated, and the CaGBC will seek input from stakeholders throughout.

## 1.1. Report Scope and Objectives

This report has been crafted to assist in identifying the most appropriate and effective components of a ZCB framework for Canada by:

- Providing a review of existing research and practice in net zero building metrics and assessment;
- Consulting with high performance building experts in both Canada and the United States, and;
- Undertaking peer review by both CaGBC staff and volunteers on technical committees.

Based on these inputs, a proposal for a standardized definition and framework for Zero Carbon Buildings for the Canadian industry was developed. While the achievement of significant emissions reductions is necessary across all building types, this study has focused on the development of a framework for commercial/institutional buildings.[4] This focus was based on market intelligence that identified the building types most in need of a standard, as well as the sectors most likely to lead a market transformation toward this high level of performance. To guide the development of the framework, a set of broad principles were established in conversation with key stakeholders, and are outlined in detail below.

[4] While the research conducted for this report focused on efforts to shift commercial and institutional buildings towards zero carbon emissions, further work will be conducted to explore the potential of applying a zero carbon building framework to other building typologies (e.g. industrial).

### Efficacy

For this framework to be effective, it must actually drive the building design and construction industry towards a new standard of high performance buildings with lower impact on the environment. Our increasingly urgent need to curb GHG emissions means that such a framework must significantly influence building design towards low carbon intensity outcomes. To date, many net zero building frameworks have focused on reducing building energy use with the assumption that reducing energy will translate into a reduction of GHG emissions. However, while a building's energy efficiency remains important to ensuring its lower impact on the environment, it cannot be the only driver. A framework that explicitly focuses on the reduction of GHG emissions (i.e. a Zero Carbon Buildings framework) will be necessary.

### Flexibility

Canada's building industry is as diverse as its landscape – buildings of various typologies connect to significantly different regional electricity grids under diverse climatic environments. For a zero carbon buildings framework to be widely applicable in Canada, it must be useful in driving improvements to building design across this broad range of contexts and in buildings with vastly different purposes, needs, and uses. A framework that sets a pathway for all building typologies to measure and increase their progress towards a zero carbon goal must be developed to allow buildings of all shapes and sizes to participate, broadening the uptake across the industry. Finally, the framework should be readily adaptable to assess ongoing building performance, and not only design and construction.

### Adaptability

A zero carbon buildings framework that is adaptable to changing conditions and policies is a framework that will be useful long into the future. Canada's energy mix is not fixed, but changes as political, technological, and social conditions evolve. Building performance standards are often revised every few years, creating a constantly shifting baseline from which building designers must constantly change their approach to building energy modelling and design. A stable framework that can account for or adapt to these changes will be necessary for it to remain relevant to the Canadian industry, independent of shifts in energy policy or building code.

### Transparency

To improve adoption and assist in broadening awareness and support of zero carbon buildings across Canada, it is important for the framework to be easily communicated and understood by both the building industry and the public. The various ways of defining "net zero" buildings can confound and discourage the building industry from driving the market towards the construction of ultra-high performance buildings. By creating a unifying framework and an associated metric that is both measurable and defensible, building industry representatives and the public can gain confidence and capacity in understanding what makes a zero carbon building.

## 1.2. Approach and Methodology

The contents of this report were developed using a process of stakeholder consultation to reflect the contributions of a range of thought leaders and members of the Canadian building sector. A Working Group made up of government bodies, industry members, and academics was formed to solicit Canadian expertise on the needs and challenges associated with the development of a zero carbon buildings framework in Canada. Working Group meetings were hosted by the CaGBC and led by Integral Group over the course of 2016 in order to establish broad consensus on the need and nature of a consistent definition of zero carbon buildings for the Canadian industry. The Working Group reviewed the key objectives and elements of a zero carbon buildings framework, contributed to the creation of a definition and criteria for zero carbon buildings, and assessed the merits of a certification program for high-performance, zero carbon buildings. A series of workshops were also held with several members of the CaGBC's Energy and Engineering Technical Advisory Group and the LEED Canada Steering Committee, as well as a number of interviews with industry representatives, to ensure the inclusion of additional sources of expertise and guidance (See Box 1).This period of consultation concluded in August 2016, having captured the perspectives approximately 50 individuals representing 40 organizations in the building sector.

In addition to these consultations, a review of existing approaches to "net zero", "near net zero", "zero emissions" and other similar building frameworks was conducted in order to identify relevant precedents, their strengths and weaknesses, and possible application in Canada. This review also drew on the prior research and efforts to define a suitable approach to "net zero" by both the City of Vancouver[5] and the City of Toronto[6]. This report references and builds on these efforts wherever possible to ensure their vast expertise has been captured, and as much consistency with other frameworks is maintained as possible, especially those in the United States (US).

## 1.3. Report Outline

The remainder of this report outlines the results of the research and consultation process, and presents the proposed approach to the development of a zero carbon buildings framework for Canada. In Section Two, the broad considerations necessary in the creation of a zero carbon buildings framework are reviewed, followed by an evaluation of existing definitions and frameworks for net zero buildings in Section Three. Section Four aggregates the results of this research and the process of consultation with Canadian industry representatives into a set of specific recommendations for the development of a Zero Carbon Buildings framework for Canada. Section Five then concludes the report with an outline of the key components of a Zero Carbon Buildings framework and a discussion of next steps.

[5] City of Vancouver. Zero Emissions Building Plan. Report to Council, July 5 2016. http://council.vancouver.ca/20160712/documents/rr2.pdf

[6] City of Toronto, 2015. Global Best Practices in Energy Efficiency Policy. https://www1.toronto.ca/City%20Of%20Toronto/City%20Planning/Developing%20Toronto/Files/pdf/TGS/Global%20Best%20Practices%20in%20Energy%20Efficiency%20Policy%20July%2016%202015.pdf

**Box 1:** A full list of consulted stakeholders

### Working Group Members

- Natural Resources Canada
- National Research Council
- Public Service and Procurement Canada – Real Property Branch
- Royal Architectural Institute of Canada
- Real Property Association of Canada
- Toronto and Region Conservation Authority
- Toronto Atmospheric Fund
- Pembina Institute
- Province of BC Building Safety Policy Branch
- ON Ministry of Municipal Affairs & Housing
- City of Toronto
- City of Vancouver
- University of British Columbia

### CaGBC Energy and Engineering Technical Advisory Group Members

- Jason Manikel (chair) – Energy Profiles
- Lindsay Austrom – Stantec Consulting Ltd.
- Eric Van Benscoten – Van-Fort Inc.
- Christian Cianfrone – Morrison Hershfield
- Kevin Henry – HDR Architecture Associates Inc.
- Curt Hepting – Enersys Analytics Ltd.
- Steve Kemp – RDH Building Science Inc.
- Wendy MacDonald – Advicas Group Consultants Inc.
- Craig McIntyre – Provident Energy Management Inc.
- Andrew Morrison – Caneta Research Inc.
- Jean-Francois Pelletier – SNC-Lavalin Inc.
- Martin Roy – Martin Roy et Associés Groupe Conseil Inc.
- Gordon Shymko – G.F. Shymko & Associates Inc.
- Anrej Simjanov – Mission Green Buildings

### Other Industry Organizations

- Canadian Solar Industries Association
- Canadian Wind Energy Association
- Independent Electricity System Operator
- International Living Future Institute (USA)
- New Buildings Institute (USA)
- Manitoba Hydro
- Province of BC Ministry of Energy and Mines

### LEED Canada Steering Committee Members

- Jennifer Sanguinetti (chair) – University of British Columbia
- Cindy Choy - Ministry of Infrastructure and Transportation, Government of Manitoba
- Marsha Gentile – Ledcor
- Arsheel Hirji - City of Calgary Engineering & Energy Services
- Edwin Lim – ECOlibrium
- Josée Lupien – Vertima
- Jamie MacKay – Morrison Hershfield
- Jason Manikel – Energy Profiles
- Grant Peters – Fluent Group
- Keith Robertson – Solterre Design
- Lyle Scott – Footprint
- Doug Webber – WSP Canada Inc.

## 2. DEFINING "ZERO"

"Net zero" buildings form a part of a broader classification of "ultra-low" energy buildings that are generally defined as those buildings that achieve such high levels of energy performance that a form of on- or off-site renewable energy can be used to power its operational needs. However, while the concept of "net zero" buildings may first appear to be straightforward, there are a number of considerations and parameters that must be taken into account when defining zero. Several issues that require attention when developing a definition for ZCB have been identified by scholars working in the field of net zero buildings, which are explained in detail below.[7]

[7] Marszal AJ, Heiselberg P, Bourrelle JS, Musall E, Voss K, Sartori I and Napolitano A. 2011. Zero Energy Building- A review of definitions and calculation methodologies. Energy and Building 43(4): 971-979.

## 2.1. Selecting a Source

Among the most important factors in selecting a definition of "net zero" buildings is the source metric used to calculate the balance. As noted in the introduction above, several approaches to calculating zero have used energy as the foundation for getting to zero. However, four primary ways of calculating the balance can be used, with different impacts on the extent to which they drive either energy efficiency or low-carbon outcomes. Each are discussed in turn below; a summary of the benefits and drawbacks of each of the four metrics is presented in Table 1.[8]

**Site Energy:**

Site, or delivered energy, refers to the energy that a building produces and consumes at the building site. A zero site energy building is therefore determined by verifying that the building produces as much energy as it uses, as measured by either on or off-site utility meters.

Using site energy as a metric is appealing in several respects. Site energy is relatively simple, making it easy for most building owners and managers to understand, and is an attractive method of calculating a building's energy balance. It furthermore offers a consistent means of verifying building performance, and encourages the incorporation of energy efficiency measures into building design. Finally, it restricts the calculation of a building's energy use to aspects that are within the direct control of building designers and owners, which can also be appealing for building owners. However, in ignoring the *source* of energy that a building uses, a site energy balance will not exert any influence on a building designer's choice of energy sources and thus can miss out on opportunities to reduce a building's overall impact on the climate and environment.

**Source Energy:**

A source energy metric begins to take the relative efficiency of different fuel types or energy sources in to account. Using a source energy metric, calculations of a building's energy use account for the energy consumed in the extraction, processing and transportation of each fuel type. Energy losses during the process of thermal combustion, transmission, and/or distribution of different fuels also create differences in the relative efficiency of energy sources, with implications for the way a building's energy balance is calculated. To make matters more complicated, many buildings draw on a mix of different energy sources, and can include a combination of electricity, fossil fuels, and on-site renewable energy.

To derive a more accurate zero energy balance that reflects these different sources of energy, a metric that uses the source, or primary energy as the basis for calculation is required. Calculating a building's source energy is more difficult than for site energy, as it requires the use of site-to-source conversion multipliers to calculate the total impact of both the energy imported and exported (or used and generated) by the building. Many energy performance calculators (e.g. Target Finder) and standards (e.g. Passive House) use national site-to-source ratios for each form of energy (e.g. electricity, natural gas), which average the efficiency of the full mix of energy sources within a country's border to ensure consistency across all regions or states. However, these national averages do not account for either regional differences that may affect the calculation of the balance, or daily variations in energy use.[9] As such, many have advocated for the use of regional conversion factors that more accurately reflect the relative efficiency of different local (i.e. provincial) energy sources and their associated energy infrastructure.[10]

[8] The four metrics for calculating the balance are derived from research conducted at the National Renewable Energy Laboratory in the U.S. by Torcellini P, Pless S, Deru M and Crawley D. 2006. "Zero Energy Buildings: A Critical Look at the Definition." ACEEE Summer Study on Energy Efficiency in Buildings, August 2006, Pacific Grove, CA. Golden, CO: National Renewable Energy Laboratory, 16 pp.

[9] Torcellini P, Pless S, Deru M and Crawley D. 2006. "Zero Energy Buildings: A Critical Look at the Definition." ACEEE Summer Study on Energy Efficiency in Buildings, August 2006, Pacific Grove, CA. Golden, CO: National Renewable Energy Laboratory, 16 pp.

[10] Sartori I, Napolitano A and Voss K. 2012. Net zero energy buildings: a consistent definition framework. *Energy and Buildings.*

Both regional and national conversion factors vary over time, requiring periodic revisions. The determination of conversion factors can also be a political as well as a scientific exercise, in that the desire to either promote or reduce the use of certain primary energy sources over others may result in the allocation of a lower conversion factor than might be otherwise used.[11]

**Energy cost:**

Instead of using the site or source energy that is produced and consumed by a building, a zero energy balance can also use the cost of energy as the metric of the balance. A building achieving a net zero balance using a cost metric must ensure that the amount of money a utility pays a building owner for the energy that the building exports to the grid is equal to, or greater than, the amount of money the owner pays the utility for the energy services and energy used, often over the course of a year. Such approaches to calculating the net zero balance are uncommon, as they are difficult to achieve. For example, the fixed costs associated with energy generation and distribution would require buildings to generate additional energy to offset them, over and above the actual energy that is consumed on-site. Energy charges can also vary from year to year, rendering the achievement of a net zero cost balance possible in one year and difficult in another. Finally, while a cost metric may be useful from an operator's standpoint, the impacts of energy use on the climate or environment are not taken into consideration.

**Energy Emissions:**

A final means of calculating a net zero balance uses the emissions associated with the energy a building consumes. Typically, those buildings that produce at least as much emissions-free renewable energy as they use from fossil fuel-based, emissions-producing energy sources, can be considered net zero emissions buildings. In cases where 100% of a building's energy needs are serviced via emission-free energy sources, the building may not be required to generate any on-site renewable energy. However, some frameworks expand the scope of emissions that are included into the calculation to the embodied carbon in the materials of the building itself, and/or the emissions associated with occupant travel to and from the building site.

Using a carbon metric ensures that the impact of a building's operations on the climate is accounted for, and as such is often the preferred approach for those interested in incentivizing low-carbon buildings and reducing GHG emissions from the built environment. However, like source energy, the calculation for a net zero emissions building requires conversion factors that take the varying GHG intensities of different energy sources into account. The question of using either a national or regional factor for the carbon intensity of electricity is similarly challenging and can be a contentious topic. This is because the carbon intensity of electricity in one region, province or state can be much higher or lower than in others, creating an uneven playing field for the achievement of a zero balance. As with source energy conversation factors, the selection of either a local or national emissions factor therefore requires careful consideration in the creation of a zero carbon buildings framework.

[11] Ibid

**Table 1:** Advantages and disadvantages associated with different energy source metrics

| Energy Source | PROS | CONS |
|---|---|---|
| **Site energy** | • Easily measured on site<br>• Easy to understand and implement<br>• Encourages aggressive efficiency measures<br>• Few external fluctuations (vs. e.g. cost) so is a consistent definition | • Does not account for impact of building on climate or environment<br>• Does not consider the relative efficiency or impacts of different energy sources |
| **Source energy** | • Provides a more accurate picture of the energy values of fuel types used on-site<br>• National conversion factors allow for broad comparisons across the country | • National source energy factors don't take regional variations into account and thus do not accurately reflect their true environmental impact<br>• Requires the use of conversion factors, which makes for an additional step in performing calculations |
| **Energy cost** | • Easy to implement and measure by building owner<br>• Can be verified by utility<br>• Allows demand-responsive control<br>• Encourages consideration of time of generation vs. time of use | • Changing energy rates make tracking balance over time difficult<br>• Does not account for impact of building on climate or environment<br>• Requires a net metering agreement to allow exported electricity to offset service charges |
| **Energy emissions** | • Encourage green energy generation<br>• Accounts for differences between fuel types | • Requires to use of appropriate emissions factors, which can be difficult to establish |

## 2.2. Calculating the Balance

A second aspect to consider when scoping a net zero balance is the type of metric used in the balance calculation, or what some refer to as the *balance boundary*. The means of calculating a building's balance depend on whether energy or emissions are the primary output of interest.

### 2.2.1. Energy metrics

Three options are commonly used to define and measure building *energy* use:

**Total Energy Use** refers to a building's full operational energy usage, including the energy required to power all heating, cooling, ventilation, lighting and other electrical needs, including both plug and process loads. Total Energy Use Intensity, or TEUI, gives a measure of total energy use normalized for building size. A TEUI metric gives a full picture of a building's energy needs, and can be used to incentivize more efficient choices in the selection of domestic hot water heating, space conditioning, building envelope strategies and appliances. A lower TEUI, expressed in kWh/m$^2$/year, indicates a more efficient building.

**Regulated Loads** refers to a building's operational energy usage, including the energy required to power all heating, cooling, ventilation, and lighting, *without* plug or process loads. While some standards also include select key services in this calculation, such as elevators or service water usage, “unregulated” plug loads are excluded. A regulated load EUI is attractive from a designer standpoint in that it addresses only those aspects of building design that can be more easily predicted or controlled. It is also useful for recognizing and/or influencing the efficiency of HVAC systems used in a building. However, it is rarely used in actual building energy calculations, as it gives an incomplete picture of total building energy use.

**Thermal Energy Demand** refers to a building's demand for heating and cooling only. Passive gains (e.g. via incoming solar radiation or lighting) and losses (e.g. via thermal bridging or ventilation) are included as a part of the thermal energy calculation, while process and plug loads are excluded. Using thermal energy demand as a metric for assessing building energy use is therefore a means of incentivizing high building energy efficiency via high quality building envelopes and the use of passive design strategies. The use of thermal energy demand intensity (TEDI) metric encourages a higher thermal performance of building envelopes, and the optimization of passive solar gains through windows. Envelopes with more insulation (i.e. higher R-values) and high-performance doors and windows lose less energy than those of poorer quality. A lower TEDI, expressed in kWh/m$^2$/year, indicates a higher level of energy efficiency.

In addition to operational energy metrics, some frameworks include **Embodied Energy** into the calculation of the zero balance, which refers to the total energy required to initially acquire, manufacture, transport and assemble all materials used in the construction of a building. The embodied energy of a building can also refer to the *recurring* energy that is required to maintain, repair or refurbish materials over the lifetime of the building. As the operational efficiency of buildings increases over time, the embodied energy of its materials and components takes on a proportionally higher significance when considering total building impact.[12] However, it has not yet become an established practice in building energy assessments.

[12] Measures of Sustainability. https://www.canadianarchitect.com/asf/perspectives_sustainibility/measures_of_sustainablity/measures_of_sustainablity_embodied.htm

### 2.2.1. Emissions metrics

The primary means of calculating the emissions intensity of a building is using a **Greenhouse Gas Intensity (GHGI)** metric. The GHGI of a building is a measure of the total amount of GHG emissions associated with a building's operational energy use. As outlined above, the use of a GHGI metric accounts for the relative carbon intensity of different energy sources and therefore encourages the use of low carbon energy, on-site renewable energy, and energy efficient building envelopes and components. A low GHGI, expressed in kg/m$^2$/year, indicates a building that emits fewer GHG emissions.

A building's emissions are often calculated to represent a building's operational energy demand; however, the actual scope of emissions included into the calculation can vary. The Greenhouse Gas Protocol, an accounting tool developed for the quantification of GHG emissions, breaks emissions into different categories by their source:

- *Scope 1* emissions refer to direct emissions derived from any on-site equipment, such as biomass or natural gas-fired boilers;
- *Scope 2* emissions refer to indirect emissions associated with the consumption of any energy that is purchased and delivered to the site (including electricity); and
- *Scope 3* emissions refer to indirect emissions associated with the extraction and production of materials, travel of building occupants to and from the building site, and any other on-site activities.[13]

As with embodied energy, the **Embodied Emissions** of a building can be calculated to account for the carbon costs associated with either a building's initial and/or its recurring energy use.[14] There are few frameworks that consider embodied emissions in their calculation of the net zero balance, and none yet that require it. However, as buildings' operational emissions fall over time, the proportional significance of embodied emissions in the built environment will increase.

[13] Greenhouse Gas Protocol. http://www.ghgprotocol.org/about-ghgp

[14] Initial embodied energy refers to the direct and indirect non-renewable energy associated with the acquisition of raw materials, their processing, manufacturing, transportation to site, and construction. Recurring embodied energy refers to the non-renewable energy consumed to maintain, restore, repair, refurbish, or replace building materials, components, or systems.

## 2.3. Balance Period and Calculation

While the period in which the zero balance of a building is calculated can range from hourly to the full life cycle of a building, the most common unit of measurement is an annual one. Using an annual balance period simplifies the calculation process and renders comparison across buildings much easier. However, this simplified balance also ignores the interaction of the building with the grid and the possible variations in the timing of electricity generation and use that may affect the net zero balance at smaller intervals (see next section).[15] For example, while a building might achieve a net zero energy balance over the course of a year, it may draw more energy from the grid in the winter when solar potential is lower, and less energy in the summer months when the potential to offset energy needs using on-site photovoltaics (PV) is highest. Some research has found that buildings that had achieved an overall annual net zero energy balance achieved a monthly balance only 70-80% of the time, and an hourly balance only 30% of the time.[16] This concern has led some to call for a smaller time interval to be used in the balance that would more accurately reflect the total energy use or emissions of a building.

The calculation of the balance can furthermore depend on the way that the boundary of the balance is defined. While it can be more common for smaller residential buildings to be designed as free-standing, off-grid buildings, commercial buildings are most often grid-connected. Two zero-sum balances in these grid-connected buildings are possible: 1) between a building's energy use and the renewable energy it generates on-site, or; 2) between the energy that is delivered to a building and the energy the building feeds back into the grid (i.e. renewable energy generated on-site and consumed on-site is not included in the calculation).[17] The actual output of these two different calculations are often the same; however, the differentiation can be helpful in their application at different stages. While the former is useful in the design stage of a building, the latter is more commonly used in the monitoring stage. Off-grid buildings can of course only use the energy use-to-generation calculation.

[15] Toward nearly zero-energy buildings. Definition of common principles under the EPBD. Final report. https://ec.europa.eu/energy/sites/ener/files/documents/nzeb_full_report.pdf

[16] Voss K and Musall E. 2011. Net zero energy buildings. International projects of carbon neutrality in buildings. Birkhäuser Verlag, Basel.

[17] Marszal AJ, Heiselberg P, Bourrelle JS, Musall E, Voss K, Sartori I and Napolitano A. 2011. Zero Energy Building- a review of definitions and calculation methodologies. *Energy and Building* 43(4): 971-979

## 2.4. Load Matching and Grid Interaction

Where buildings are grid-connected, they are able to purchase energy when it is required, and sell it when there is an abundance of on-site supply. However, the details of this interaction can be far more complicated than this simple interaction would perhaps indicate. Given the ease of using solar PV or hot water heating as a means of offsetting energy demand from the grid, the time of a building's generation is often highest in summer, while its actual demand is often highest in winter (depending on climate zone). The utility itself, which purchases excess energy from a building's on-site generation, is therefore considered an unlimited repository for excess energy generated by the building, allowing for the achievement of the net zero balance over the course of the year.

The time differential between a building's energy demand and its generation can therefore affect not only the achievement of the net zero balance, as noted above, but the functionality of the grid itself. The generation and export of electricity during times when there is already a sufficient supply of electricity can put additional stress on the grid. An increase in the total number of local generators will eventually require a significant upgrade in electricity distribution networks to handle the new prevalence of distributed energy generation.

To circumvent this issue, net zero building frameworks can require building designers to consider "load matching" the building's time of load and its time of energy demand in their calculations. Another approach is to ensure that the building's time of export to and import from the grid (or "grid interaction") is calculated in such a way as to minimize stress on the grid and ensure that building demand does not exacerbate already high periods of demand that could require the addition of new (and possibly more carbon intensive) sources of regional generation (e.g. natural gas back-up generators). Both approaches could require buildings to include a means of on-site storage that can act as a reservoir during times when on-site generation is inadequate to meet building demand.

## 2.5. Acceptable Sources of Renewable Energy

While improvements in energy efficiency can help reduce overall building energy demand, remaining energy needs must be supplied by some renewable low- or no-carbon source. This renewable energy supply can vary in both type and scale: while on-site renewable energy options typically include PV or solar hot water, buildings may also connect to electrical grids served by hydroelectricity, wind or solar, or to district energy systems powered by biomass or sewer heat recovery. Whether a building can use on- or off-site renewable energy depends in large part on the availability of local resources, the conditions of the building site, and the energy demand of the building itself. For example, while a low-rise residential building in a suburban environment may utilise local PV to supply building energy needs, a high-rise tower in a downtown core may require a connection to an outside source of energy.

One means of differentiating the various ways of achieving the net zero balance is to divide the classification of net zero buildings according to the location of their supply-side options.[18] Possible sources of renewable energy may include:

- Renewable energy generated within the building footprint or building site (e.g. PV, solar hot water, small-scale wind);
- Renewable energy sources imported to the site for on-site generation (e.g. biofuels, biomass);
- Renewable energy generated off-site:
    - Procured directly through standard utility service offerings (e.g. hydroelectricity, utility-scale wind or solar);
    - Procured directly through energy generated nearby and connected directly to the building (e.g. district energy systems, community solar, etc.);
    - Procured directly through Power Purchase Agreements that connect buildings to nearby renewable energy sources that would not have been generated otherwise;

[18] Pless S and Torcellini P. 2010. Net-zero energy buildings: a classification system based on renewable energy supply options. NREL Technical Report 550-44586

- Procured indirectly through energy generated nearby and provided to the building via a legal/ financial agreement rather than directly (e.g. virtual net metering);
- Procured indirectly through Virtual Power Purchase Agreements that allow buildings to purchase a source of renewable energy that is generated at a distance and provided to a nearby grid; and
- Procured indirectly through the purchase of Renewable Energy Credits (RECs).

The selection of one or more of these different options for renewable energy supply is central to the definition of a zero carbon framework, in that the accepted location or source of renewable energy generation can affect the zero energy balance. In general, the use of on-site or nearby energy sources ensures a higher level of confidence in the renewable energy supplied to a building. For example, using on-site or local sources of renewable energy reduces transmission and distribution losses that can be accrued by connecting to renewable energy generators at larger distances; however, on-site generation is not always possible or even desirable where other local alternatives are available. Connecting to a source of renewable energy, either directly or through a formal contractual agreement, also ensures that buildings are contributing to the addition of renewable generation capacity, thereby offsetting fossil fuel-based sources of energy.

In comparison, the use of RECs (also known as "green tags", or "green certificates") in net zero building frameworks have received some critique. RECs are tradable certificates that represent the purchase of one Megawatt-hour of renewably generated electricity, which are sold separately from the actual electricity that is generated. While some national REC markets are monitored more actively, many often go unregulated, rendering either the quality or quantity of renewable energy generated somewhat uncertain. There is additionally some concern that many RECs do not follow the principle of additionality, whereby a project or activity actually results in the generation of renewable energy over and above what would have taken place without it. This can occur as a result of the process of "double counting", in which the generation of on-site renewable energy by one building or facility is sold to another, while also using that generation to count toward their own zero energy or emissions balance. As such, confidence in the procurement of RECs as a means of offsetting fossil fuel-based energy can be low, particularly in unregulated REC markets.

## 2.6. Additional Goals

Finally, frameworks for net zero buildings can include additional requirements or goals that don't pertain specifically to the achievement of either low emissions or energy use. At a general level, most definitions and frameworks strongly advocate for the reduction of building energy demand as much as possible prior to the addition of renewable energy generation. Although a building may feasibly achieve a net zero energy or emissions balance through the extensive use of PV, the heavy reliance on low-emission forms of energy (e.g. hydroelectricity), or the purchase of large quantities of RECs, these strategies are generally regarded as inefficient and undesirable methods of achieving the balance. For example, while hydropower may be a relatively efficient and low-emission form of energy, the construction of additional dams to meet growing demand comes with its own social and environmental costs. Where peak loads outstrip the potential of low-emission forms of energy to meet demand, back-up generators are often in the form of carbon-based fuels, such as natural gas.

Beyond the prioritization of energy efficiency, some frameworks for net zero buildings include additional goals, such as ensuring thermal comfort, keeping building costs to an acceptable level, improving indoor air quality, or allowing flexibility in design. These stipulations ensure that net zero buildings are not constructed at the expense of the comfort or health of its occupants, or at a cost beyond what is feasibly replicable in the broader market. When prioritized and showcased appropriately, additional benefits of lowered cost and improved conditions for occupants can assist in increasing the market penetration of zero carbon buildings.

# 3. EXISTING FRAMEWORKS & DEFINITIONS

Several attempts at creating a consistent approach to the definition of “net zero” have been made to date, both in North America and elsewhere in the world. While there are similarities in the way that organizations and governments have approached the concept, there are also considerable differences. Some have sought to create consistent definitions applicable across an entire country or region; others have modified existing frameworks for the achievement of high performance buildings to include net zero targets. Others still have issued a net zero challenge, inviting members of the building design industry to pledge their commitment to an increasing set of targets. Each approach furthermore takes a different stance with regard to the six criteria described in Section Two, creating a diversity of understandings and associated metrics for the achievement of the net zero balance.

To explore these attempts and ensure that the proposed definition for a Canadian zero carbon buildings standard builds on these existing efforts, a review of nine approaches to net zero buildings was conducted to identify commonalities and differences between them. A total of nine frameworks were reviewed:

- U.S. Department of Energy's Zero Energy Buildings;
- ASHRAE's Vision 2020;
- The European Union's Energy Performance of Buildings Directive;
- United Kingdom's Department of Energy and Climate Change 's Zero Carbon Buildings;
- Architecture 2030's 2020 Challenge;
- New Building Institute's Zero Energy Performance Index (zEPI);
- Passive House Building Standard;
- Switzerland's Minergie, and
- International Living Future Institute's (ILFI) Net Zero Energy Buildings program.

Below, the key components, strengths and weaknesses of each framework are described.

## 3.1. U.S. DOE's Common Definition for Zero Energy Buildings

In September 2015, the National Institute of Building Sciences released a *Common Definition for Zero Energy Buildings* for the U.S. Department of Energy (U.S. DOE). The purpose of the report was to establish definitions, terminology and guidelines for the classification and measurement of net zero buildings for the U.S. building industry. During the consultation process, the Institute determined that the terminology of "net zero" was both redundant and lacked resonance with building owners, and as a result have shorted the terminology to simply "zero energy buildings".

The resultant definition for Zero Energy Buildings, or ZEB, refers to an energy-efficient building where, on a source energy basis, the actual annual delivered energy is less than or equal to the onsite renewable exported energy. The definition uses Total Energy Use Intensity (TEUI) to calculate the balance, and as such accounts for all building process and plug loads within the site boundary. To calculate the relative efficiencies of the different energy sources used in a building, the DOE draws on national average source energy conversion factors sourced from ASHRAE Standard 105.[19] The EPA's ENERY STAR Target Finder tool is suggested for use by owners and designers as a way of setting building energy performance targets, which also allows for a comparison of performance against either a target ENERGY STAR score or the median energy use of a particular building type.

| A Common Definition for Zero Energy Buildings | | | | |
|---|---|---|---|---|
| **U.S. Department of Energy** | | | | |
| **Metric:** Total EUI | **Energy use scope:** Source energy | **Conversion:** National average factors (ASHRAE 105) | **Renewable energy considerations:** Onsite RE only, with some exceptions | **Reference:** Absolute target of 0 carbon emissions |
| **Uptake:** Likely uptake across the US | **Balance period:** Annual | **Site:** Individual buildings + campuses, portfolios and communities | **Grid interaction:** Not considered | **Additional goals:** N/A |

[19] Standard 105-2014 – Standard Methods of Determining, Expressing, and Comparing Building Energy Performance and Greenhouse Gas Emissions: https://www.ashrae.org/standards-research--technology/standards--guidelines/titles-purposes-and-scopes#105

The DOE's approach to defining Zero Energy Buildings is notable in its requirement for the use of on-site renewable energy to meet the zero energy balance. However, the report creates a secondary classification to allow the use of renewable energy credits (RECs) by buildings that would have considerable difficulty accommodating a sufficient amount of renewable energy on-site. The "REC-ZEB" designation is intended to be used by multi-storey buildings in dense urban areas or buildings with high process loads (such as hospitals), which are required to consider the use of on-site renewable energy prior to adding RECs. However, there is no total cap or maximum allowance for the use of RECs under this designation. The resultant definition of a REC-ZEB is therefore an energy-efficient building where, on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy plus acquired RECs. The DOE also establishes the additional categories of Zero Energy Campuses, Portfolios and Communities to acknowledge the place of larger scales of renewable energy production and use.

## 3.2. ASHRAE's Vision 2020 and Net Zero Energy Buildings

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), is a member-based industry association that develops standards for the built environment, emphasizing efficiency in building and energy systems, as well as the design and maintenance of indoor spaces.  ASHRAE standards provide a benchmark for building energy codes in the United States and are a key foundation for codes and standards around the world. ASHRAE standards are frequently referenced within State and Provincial building codes (as well as in the LEED framework), which typically require buildings either to meet or exceed ASHRAE standards.

In the *Roadmap for the Future of Commercial Energy Codes* (2015), the ASHRAE Board of Directors adopted long-term targets for the evolution of its 90.1 standard to move towards 50% greater efficiency than 90.1-2010 by 2030. The Board also set a long-term target for ASHRAE 189.1 (Design of High Performance Green Buildings) to achieve net zero by 2030, with the exception of Low-rise Residential Buildings.[20, 21]

Based on U.S. Department of Energy (DOE) and National Renewable Energy Lab (NREL) research, this new standard would reduce a building's energy use by up to 34% relative to the previous 90.1-2007 standard, and would incorporate a broad range of sustainability aspects that extend beyond energy efficiency, including recycling, water use efficiency, and other aspects of site sustainability. Compliance with the standard is either met through the completion of a set of prescriptive requirements or achieving the modelled performance requirements. The mandatory design requirements set out in the 189.1 standard also allow it to be easily implemented as a building code – however, the standard does not include any specific energy or water consumption targets that could be applied to monitor the building's performance post-completion.

[20] Pacific Northwest National Laboratory. 2015. Roadmap for the future of commercial energy codes. http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-24009.pdf

[21] Frappé-Sénéclauze T-P and Kniewasser M. 2015. The path for "net-zero energy" buildings in BC. The case for action and the role of public policy. Pacific Institute for Climate Solutions. https://www.pembina.org/reports/pembina-path-to-net-zero-energy-buildings-in-bc.pdf

In 2008, ASHRAE released a *Vision 2020* report, which outlines its intent to drive the market towards Net Zero Energy Buildings (NZEB) by 2030 through a series of strategies.[22] A NZEB is defined as a building that produces as much renewable energy as it consumes when measured at the site on an annual basis, while maintaining reasonable levels of service and functionality. A specific metric for calculating the zero energy balance has not yet been developed; however, the report advocates for the use of site energy use intensity (EUI) to avoid the complications of using source EUI and the conversions it requires. The Vision 2020 document notes the need to explore both base and peak loads, and permits up to 50% of a building's energy balance to be made up using RECs. Actions identified in the Vision 2020 document include 1) the development of new tools; 2) facilitating the use of new technologies through publications and education; 3) using public relations and marketing to increase awareness, and 4) revising ASHRAE-related energy resources to harmonize new and old products. Among the options explored in its visioning document, building certification, professional accreditation, and labels and/or dashboards that indicate building energy consumption are noted as high priorities. Indoor air quality is also noted as an important consideration in the design of low energy buildings.

The widespread use of ASHRAE as a foundation for building codes across North America indicates a high potential for the ASHRAE NZEB standard to elicit considerable impact on the building sector. However, the pace at which the 90.1 standard moves towards a net zero target has been critiqued as insufficient to meet important climate and energy reduction goals. The exclusive focus on site energy, including the lack of any consideration of the relative efficiency or GHG emissions intensity of different fuel sources, is additionally critiqued for its insufficiency at meeting climate and energy goals. The ASHRAE Vision statement acknowledges this constraint in noting the importance of developing a means of quantifying GHG emissions as well. The ASHRAE 105 Standard furthermore includes procedures for moving beyond site energy calculations to include the impact of building energy use on primary (source) energy and GHG emissions.

Also notable is ASHRAE's Building Energy Quotient (bEQ), which offers a labelling program for the energy efficiency of buildings, either as designed or in operation. For the latter, bEQ uses the same methodology as Standard 100 Energy Efficiency in Existing Building Types, which uses normalized median EUIs for building types covered by the U.S. Energy Information Administration's (U.S. EIA) Commercial Buildings Energy Consumption Survey (CBECS). Net Zero buildings assessed under the bEQ receive a score of A+. The bEQ has been noted for its ability to easily compare modelled and actual energy performance, an important factor in improving overall building design.

| Vision 2020 | | | | |
|---|---|---|---|---|
| ASHRAE | | | | |
| **Metric:** Balance of energy use and onsite generation | **Energy use scope:** Site energy | **Conversion:** N/A | **Renewable energy considerations:** Up to 50% RECs permitted | **Reference:** % better than ASHRAE 90.1/189.1 |
| **Uptake:** Widespread use as basis for North American codes | **Balance period:** Annual | **Site:** Individual building | **Grid interaction:** Exchange with grid supported; storage options to be explored | **Additional goals:** Indoor air quality |

[22] ASHRAE Vision 2020. 2008. https://www.ashrae.org/file%20library/doclib/public/20080226_ashraevision2020.pdf

## 3.3. The European Union's Energy Performance of Buildings Directive

The Energy Performance of Building Directive (EPBD) is the EU's main legal instrument used to set standard requirements for building energy performance.[23] The EPBD aims to reconcile the considerable difference in building energy efficiency guidelines across EU Member States, while also recognizing the important differences in building regulations and climates within the EU. Under this directive, each Member State must create a national plan to increase the number of net zero energy buildings in their country and ensure that all new buildings are "nearly zero-energy" by 2020, with all new public buildings nearly zero-energy by 2018.

Nearly zero-energy buildings (nZEB) have a very high energy performance and thus a low energy demand, with the demand met primarily by renewable energy, including generated on-site or nearby.[24]

Each Member State is responsible for implementing the EPBD in a way that both acknowledges local conditions and achieves baseline prescribed targets.[25] These plans are required to include minimum requirements for energy performance and must be re-evaluated every 5 years to ensure that targets are being met. The specific requirements for building construction are decided by each EU Member State based on the conditions of their respective built environment and regulatory framework to account for technical and feasibility issues in determining a reasonable primary energy use requirement and the percent of primary energy that must be renewable. Given this level of national autonomy with respect to building performance rating and certification systems, each Member State is required to report their methodologies and approaches to the EU Commission, as a way of coordinating and monitoring efforts towards NZEBs. These building performance ratings are generally in the form of Energy Use Intensity (EUI) calculations, as well as minimum energy performance requirements for heating and cooling.

| EPDB Nearly Zero-Energy Buildings (nZEB) | | | | |
|---|---|---|---|---|
| **EU – Energy Performance of Buildings Directive** | | | | |
| **Metric:** Energy use intensity and heating and cooling performance | **Energy use scope:** Source energy | **Conversion:** Not included, but recommended to use a load match index | **Renewable energy considerations:** Loosely defined to include all RE, but recommended to be made more specific before 2021 | **Reference:** Energy consumption requirement |
| **Uptake:** Foundation for zero-energy building performance in EU Member States | **Balance period:** Annual | **Site:** Individual building | **Grid interaction:** Not considered, but recommended to be addressed, including with regard to national political and climate considerations | **Additional goals:** Indoor temperature control (to avoid overheating) |

[23] Directive 2010/31/EU of the European Parliament and of the Council, May 2010. http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010L0031&from=EN

[24] Toward nearly zero-energy buildings. Definition of common principles under the EPBD. Final report. https://ec.europa.eu/energy/sites/ener/files/documents/nzeb_full_report.pdf

[25] BPIE. Principles for nearly zero-energy buildings Executive Summary. 2011. http://bpie.eu/wp-content/uploads/2015/10/HR_executive-summary_nZEB.pdf

In a separate document, the EPBD also developed a set of Common Principles to help guide Member States towards their targets, including a number of recommendations:[26]

- Combine both prescriptive and performance based approaches;
- Use a source energy metric supplemented by a total GHG emissions indicator to reflect the GHG reduction focus of EU energy policy;
- Take the time of generation and use into account via a load matching requirement; and
- Add thermal comfort requirements.

If adopted, these additional recommendations would strengthen the EU framework's breadth relative to others, particularly in the addition of a GHG indictor. Load matching requirements are also rare among frameworks, as only the Swiss Minergie standard has begun to explore it.

## 3.4. UK DECC's Zero Carbon Buildings Program

In response to the Energy Performance of Buildings Directive, the United Kingdom's Department of Energy & Climate's (UK DECC) released the Zero Carbon Buildings program as part of the broader Carbon Plan published in 2011. Under the program, all new homes constructed from 2016 onward would be required to meet a zero carbon standard.[27] Although it was terminated in July 2015 (along with the program's Zero Carbon Hub), the proposed framework nonetheless provides an instructive example of a zero energy building regulatory definition.

UK DECC's proposed Zero Carbon Buildings focused on carbon dioxide-equivalent ($CO_2e$) emissions from regulated energy. *Regulated* energy includes heating, cooling, lighting, and hot water, but not energy use from appliances, which is considered *unregulated*. The Zero Carbon Buildings definition included three core requirements:

1. Reduce regulated energy demand (measured in kWh/m$^2$/year) through fabric energy efficiency, where the fabric performance of the property must, at a minimum, comply with the Fabric Energy Efficiency Standard (FEES).

2. Carbon dioxide-equivalent ($CO_2e$) emissions remaining after consideration of fabric performance, heating, cooling, fixed lighting and ventilation, must be less than or equal to a Carbon Compliance limit. Although not formally adopted, carbon compliance limits (measured in kg$CO_2$e/m$^2$/year) were proposed for detached houses (10), attached houses (11) and low rise apartment blocks (14).[28]

3. $CO_2$ emissions remaining from the use of regulated energy uses must be reduced to zero either by over-performing on requirements 1 and/or 2 or through investing in carbon reduction projects via local (preferable) or remote measures termed "Allowable Solutions".

[26] Toward nearly zero-energy buildings. Definition of common principles under the EPBD. Final report. https://ec.europa.eu/energy/sites/ener/files/documents/nzeb_full_report.pdf

[27] Zero Carbon Hub. Zero carbon homes and nearly zero energy buildings. UK Building Regualtions and EU Directives. http://www.zerocarbonhub.org/sites/default/files/resources/reports/ZCHomes_Nearly_Zero_Energy_Buildings.pdf

[28] Zero Carbon Hub. Allowable Solutions for Tomorrow's New Homes. An Introduction. http://www.zerocarbonhub.org/sites/default/files/resources/reports/Allowable_Solutions_for_Tomorrows_New_Homes%20_An_Introduction.pdf

The inclusion of "Allowable Solutions" is particularly notable in its intention to give developers an economical way of compensating for the GHG emissions reductions that would be difficult to achieve using conventional building design and construction methods. While they were never fully defined, Allowable Solutions were expected to include both a prescribed list (i.e. menu) and a set of criteria (i.e. rules).[29] Two types of Allowable Solutions were proposed prior to the program's completion: Type 1, which allowed developers to pay into a carbon fund to invest in carbon-saving projects, and Type 2, which required developers to invest in carbon-saving projects in their own developments.[30]

The Zero Carbon Buildings program is also interesting for other two reasons. First, it took a GHG emissions-based approach, driven first and foremost through energy performance requirements. Second, it considered how building performance programs could be linked to carbon pricing to fund off-site renewable energy, energy efficiency, and other types of GHG reduction projects. While it could be seen as a more cumbersome framework administratively, the DECC's approach could help transform the local building and energy markets.

| Zero Carbon Buildings | | | | |
|---|---|---|---|---|
| UK – Zero Carbon Buildings Program | | | | |
| **Metric:**<br>GHG emissions intensity per square foot, plus EUI | **Energy use scope:**<br>Site; regulated energy use | **Conversion:**<br>Unclear | **Renewable energy considerations:**<br>Allowable Solutions included both renewable energy projects and a carbon fund | **Reference:**<br>UK carbon reduction strategy; Fabric Energy Efficiency Standard |
| **Uptake:**<br>Program scrapped | **Balance period:**<br>Annual | **Site:**<br>Individual building | **Grid interaction:**<br>Not considered | **Additional goals:**<br>Noted as indirectly supporting energy security and fuel poverty issues<br>Noted as indirectly supporting energy security and fuel poverty issues |

[29] Zero Carbon Hub. Allowable Solutions. http://www.zerocarbonhub.org/zero-carbon-policy/allowable-solutions

[30] Zero Carbon Hub. Zero Carbon Strategies for Tomorrow's New Homes. http://www.zerocarbonhub.org/sites/default/files/resources/reports/Zero_Carbon_Strategies_for_Tomorrows_New_Homes.pdf

## 3.5. The 2030 Challenge

Architecture 2030's Challenge provides a second net zero carbon framework, designed for individuals, designers, and governments to achieve carbon neutral buildings, developments, and major renovations by 2030. "Carbon neutral" is defined as a state in which no fossil fuel-based, GHG-emitting energy is used to operate a building (including both Scope 1 and Scope 2 emissions). The Architecture 2030 Challenge does not explicitly include either embodied or travel energy sources in the calculation of the balance, but designers are encouraged to consider them. Designers are also permitted to meet their targets by purchasing RECs to a maximum of 20% of the total renewable energy use.

The Challenge offers a set of interim targets to reach carbon neutral buildings by 2030, which began at 50% of the regional or national average for that building type in 2005 and now increases 10% every 5 years. The current reduction standard for new buildings, developments, and major renovations is 70% below the baseline. This will be increased to 80% below the baseline in 2020 and 90% in 2025.[31] The baseline for a building's target goals are based on the regional (or national) average energy consumption of that building type reported in the 2003 Commercial Buildings Energy Consumption Survey (CBECS) database. As in ASHRAE's Vision 2020, a national site EUI is used in place of source EUI in order to avoid the complications of conversions necessitated by the use of source EUI. Architecture 2030 recommends the use of the EPA's Target Finder Tool as a way of exploring energy consumption and determining appropriate energy reduction targets.

The 2030 Challenge creates a set of interim targets to which designers and others can aspire to, thereby fostering the potential for broader market participation. The framework is clear and easy to implement, given the flexibility with which designers can achieve their targets, as well as the ability to use RECs to fulfill the Challenge's requirements. The framework suffers from a lack of clarity, however, in that it targets total building energy use and uses site energy as its basic metric, but frames the program through a carbon neutrality lens. However, Architecture 2030 recently released a white paper in conjunction with New Buildings Institute and Rocky Mountain Institute that proposes a zero net carbon (ZNC) definition and outlines the requirements for such a standard.[32] The white paper highlights the need to focus on efficiency first, and defines a ZNC building as "a highly energy efficient building that produces on-site, or procures [from off-site], enough carbon-free renewable energy to meet building operations energy consumption annually."

| The 2030 Challenge | | | | |
|---|---|---|---|---|
| **Architecture 2030** | | | | |
| **Metric:**<br>Total building energy use (modelled and actual) | **Energy use scope:**<br>Site energy (embodied encouraged) | **Conversion:**<br>Not included | **Renewable energy considerations:**<br>Max 20% RECs can be purchased; RE generation encouraged | **Reference:**<br>Absolute target of 0 carbon emissions |
| **Uptake:**<br>Industry associations, governments, building professionals in North America[33] | **Balance period:**<br>Annual | **Site:**<br>Individual building | **Grid interaction:**<br>Not considered | **Additional goals:**<br>N/A |

[31] The 2030 Challenge. http://architecture2030.org/2030_challenges/2030-challenge/

[32] Zero Net Carbon (ZNC) Building. http://www.architecture2030.org/downloads/znc_building_definition.pdf

[33] Including 80% of the top 10 and 70% of the top 20 architecture/engineering/planning firms in the U.S., the American Institute of Architects, ASHRAE, the U.S. Conference of Mayors, the U.S. federal government, state and local governments, Canada's Royal Architectural Institute of Canada, the Ontario Association of Architects, and Canadian cities such as Vancouver

## 3.6. Zero Energy Performance Index (zEPI)

In contrast to other frameworks is the New Buildings Institute's Zero Energy Performance Index (zEPI), a tool developed in response to the identified need to move beyond the "% better than code" approach to commercial building energy efficiency. In using zero energy as the fixed goal, the zEPI framework creates an unchanging scale that allows designers to identify either the modelled or actual energy use of a building relative to zero energy. The zEPI framework sets targets for actual total building energy consumption as a function of their distance from zero energy, using energy use intensity targets for different building types that are adjusted for climate.

The scale itself extends from 0 to 100, where a zEPI score of 0 indicates a net zero building, and a zEPI score of 100 indicates a building with an energy consumption equivalent to the average energy consumption of a similar building in the year 2000 (based on 2003 CBECS data). The scale can accommodate for Net Positive buildings by simply extending the scale (e.g. a zEPI score of -10). There is currently no certification of labelling scheme associated with the framework.

The zEPI framework can be applied to either new construction or existing buildings. To calculate an *existing building's* zEPI score, the building's energy use is divided by the energy use of the appropriate reference building in the 2003 CBECS data and multiplied by 100. To calculate a *new building's* score, a zEPI score can be generated for the code clone to which the building is being modelled. The building's zEPI score can then be determined by multiplying the code baseline zEPI by the building's EUI and divided by the code clone EUI. Overall, the zEPI framework creates an easy means of measuring building performance as a function of the distance to zero energy, allowing full market participation. By focusing on total site energy use, the zEPI framework is easily implemented and helps to encourage energy efficiency measures across both new and existing commercial and institutional buildings. The framework can be used easily alongside existing codes and standards, and is easy to implement and understand. However, it focuses exclusively on energy efficiency and does not consider the emission values associated with different fuel sources.

| zEPI | | | | |
|---|---|---|---|---|
| New Buildings Institute | | | | |
| **Metric:** Total building energy use (modelled or actual) | **Energy use scope:** Site energy | **Conversion:** N/A | **Renewable energy considerations:** N/A | **Reference:** Absolute target of 0 energy |
| **Uptake:** Included into IgCC 2015 | **Balance period:** Annual | **Site:** Individual building only | **Grid interaction:** Not considered | **Additional goals:** N/A |

## 3.7. Passivhaus Building Performance Standard

The Passivhaus building performance standard is a voluntary, third party environmental rating system that sets standards for sustainable practice in building design, construction, and operation. In wide use around the world, Passivhaus encourages energy efficiency by imposing rigorous standards for heating, cooling, airtightness and energy use. Achieving Passivhaus Classic certification requires buildings to satisfy four key requirements by performing at or below the following:[34]

- Airtightness of 0.6 ACH @ 50 Pascals
- Heating energy consumption of 15 kWh/m$^2$/year, or peak heating load of 10 W/m$^2$
- Cooling energy consumption of 15 kWh/m$^2$/year
- Primary energy demand of 120 kWh/m$^2$/year

Passivhaus recently introduced two additional certifications: Passivhaus Plus and Passivhaus Premium, which replace the former primary energy demand requirement with a requirement on overall primary energy demand and renewable energy generation. These requirements are based on energy consumed and generated per year, and are quantified as follows:

- *Classic:* maximum demand of 60 kWh/m$^2$/year; no minimum generation requirement
- *Plus:* maximum demand of 45 kWh/m$^2$/year; minimum generation of 60 kWh/m$^2$/year
- *Premium:* maximum demand of 30 kWh/m$^2$/year; minimum generation of 120 kWh/m$^2$/year

In addition to these requirements, designers are required to incorporate several prescriptive requirements into building design, including compact form and orientation, high R-value insulation, high U-value windows, thermal bridging-free construction, and high efficiency heat recovery ventilation systems.[35]

One of the primary benefits of the Passivhaus standard is the relatively few mandatory requirements, which make for superior design flexibility in the execution of building design. As with other source energy-based approaches, the use of primary energy as the metric of choice requires users to convert different energy sources using specified conversion ratios, which can require additional time and effort but helps to capture the relative efficiencies of different energy sources. To help support users, the Passivhaus Institute provides the Passivhaus Planning Package (PHPP) to assist designers in modelling the building's thermal energy balance, or the Annual Heat Demand.

| Passivhaus | | | | |
|---|---|---|---|---|
| Passivhaus Institute (Germany) | | | | |
| **Metric:** EUI and renewable energy generation | **Energy use scope:** Source energy | **Conversion:** National weighting factors | **Renewable energy considerations:** Onsite RE generation required in higher classes | **Reference:** Target of near/full zero energy |
| **Uptake:** Used worldwide | **Balance period:** Annual | **Site:** Individual building | **Grid interaction:** Not considered | **Additional goals:** Thermal comfort |

[34] Passive House Institute. 2016. Criteria for the Passive House, EnerPHit and PHI Low Energy Building Standard. http://passiv.de/downloads/03_building_criteria_en.pdf

[35] Passive House Canada. Design Fundamentals. http://www.passivehousecanada.com/

## 3.8. MINERGIE® Sustainable Building Standard

Developed in Switzerland, MINERGIE is a voluntary energy rating standard for new buildings and major renovations that has certified over 18,000 buildings to date. It requires buildings to achieve a select number of simple, performance-based requirements. This approach allows for measureable energy and carbon performance that is impossible to achieve without addressing critical factors like energy efficiency, while leaving room for creative and context-specific design solutions.

MINERGIE prescribes an annual net zero energy balance for a range of building types, and offers three certification classes to achieve: MINERGIE, MINERGIE-P, and MINERGIE-A. Higher classes build on the baseline of MINERGIE certification with additional and more stringent requirements. Each class includes both performance-based and prescriptive targets focusing on actual energy use and various passive design strategies. In general, the basic MINERGIE standard requires a building to use at least 25% less energy than an average code-compliant building, and requires that fossil fuels supply a maximum of 50% of energy use. The basic MINERGIE standard requires the following:[36]

- Total heat demand is at least 10% lower than the Swiss standard SIA 380/1
- Year-round controlled air exchange
- Weighted energy index under 38 kWh/m$^2$
- Proof of thermal comfort in summer

MINERGIE's "weighted energy index" includes energy for space heating, domestic hot water and electricity used for heat pumps and mechanical ventilation.[37] Weighting factors are set to account for gross (source) energy consumption based on the energy source, and are designed to promote the use of renewable energy sources.

MINERGIE-P has more stringent performance and prescriptive requirements, including that total heat demand is at least 40% lower than the Swiss standard SIA 380/1 and a weighted energy index below 30 kWh/m2, among other requirements such as energy-efficient household appliances.[38] MINERGIE-A seeks near-zero energy performance. It has the same total heat demand requirement as the basic MINERGIE standard, but requires that at least half of the heat demand be met by solar panels and requires a weighted energy index less than 0 kWh/m$^2$.[39]

| MINERGIE | | | | |
|---|---|---|---|---|
| **MINERGIE (Switzerland)** | | | | |
| **Metric:** Regulated loads only for base level | **Energy use scope:** Source energy and embodied | **Conversion:** National weighting factors | **Renewable energy considerations:** Onsite RE generation required; RE cannot be sold to 3rd party | **Reference:** Target of 0 energy and % better than code |
| **Uptake:** Switzerland and Europe | **Balance period:** Annual | **Site:** Building clusters accepted | **Grid interaction:** Contemplating load matching requirements | **Additional goals:** Thermal comfort Limited additional costs |

[36] Ecolabel index. Minergie. http://www.ecolabelindex.com/ecolabel/minergie

[37] Zgraggen J-M et al. 2006. Case study of a low-energy (Minergie®) multifamily complex in Switzerland. First appraisal after two years of exploitation. PLEA2006 23rd Conference on Passive and Low Energy Architecture, Geneva Switzerland. http://immobilierdurable.eu/images/2128_uploads/retourdexperienceminergie.pdf

[38] Ecolabel index. Minergie-P. http://www.ecolabelindex.com/ecolabel/minergie-p

[39] Ecolabel index. Minergie-A. http://www.ecolabelindex.com/ecolabel/

For each standard, certain building types must also meet requirements related to lighting and commercial electronic equipment. Other primary focuses of MINERGIE include user comfort, indoor environmental quality and health, and transparency through labelling and plaques.

MINERGIE also offers MINERGIE-ECO, a certification focused on ecological and social requirements that can be added to any of the other three certification classes. These include aspects of occupant comfort, such as indoor air quality and acoustics, daylighting instead of electricity use, as well as the use of low impact building materials from a lifecycle perspective.[40]

The MINERGIE standard also takes steps to maintain feasibility and increase use. MINERGIE stipulates that additional building costs must not be more than 10% more than the building costs of a comparable code-compliant building. MINERGIE also certifies products and services to meet their standards. This helps to unify the design and construction of MINERGIE buildings, while lowering product and service costs through increased diversity and competition in the market.

MINERGIE's use of primary energy as the base metric for the energy balance creates both additional challenges in implementation as well as a more accurate picture of building energy impacts. The specific focus on renewable energy sources in addition to energy efficient design simultaneously drives building energy performance up while pushing climate impacts down. The MINERGIE standard has been noted for its flexibility in design and has been applied in several countries around the world.

[40] Ecolabel index. Minergie-Eco. http://www.ecolabelindex.com/ecolabel/minergie-eco

## 3.9. ILFI's Net Zero Energy Building Certification™ (NZEB)

The International Living Future Institute's (ILFI) Net Zero Energy Building Certification (NZEB) is a certification scheme offered to buildings that can generate 100% of the building's energy needs using on-site renewable energy, without the use of on-site combustion. In addition to 100% on-site renewable energy generation, projects are required to achieve a selection of the Living Building Challenge Imperatives, including the first half of Imperative 1: *Limits to Growth* (appropriate siting of buildings); Imperative 19: Beauty and Spirit; and Imperative 20: *Inspiration and Education*.[41] While NZEB certification can be achieved on its own, project registrants are encouraged to pursue Petal recognition in other areas, as well as full Living Building status.[42]

To be certified, the following energy-related documentation is required of project applicants:[43]

- An energy narrative that summarizes the energy system
- A schematic drawing of the energy system
- Photographs of the energy system components
- Energy bills for a 12-month period (or a letter stamped and signed by an engineer and the owner if sub-metered or not connected to a utility)
- Completed Energy Production and Demand Table with monthly energy use data from meters or other onsite tracking systems
- Calculations that demonstrate the required amount of energy storage (optional)

Though challenging to achieve, the NZEB framework may drive more positive overall outcomes than other, less stringent standards. Like zEPI, the NZEB framework focuses on total site energy use, but requires 100% renewable energy generation, resulting in net zero emissions as well. Neither onsite combustion nor RECs are permitted under the NZEB framework, rendering its achievement fairly challenging.

| NZEB | | | | |
|---|---|---|---|---|
| **International Living Future Institute (United States)** | | | | |
| **Metric:** Total building energy use and renewable energy generation | **Energy use scope:** Site energy | **Conversion:** N/A, must use on-site renewable energy sources | **Renewable energy considerations:** On-site RE generation required | **Reference:** Target of net zero energy, or preferably net positive energy |
| **Uptake:** 30+ buildings across North America | **Balance period:** Annual | **Site:** Building; Multiple cooperating projects | **Grid interaction:** Not defined beyond optional storage | **Additional goals:** Land use, ecological habitat, community engagement |

[41] ILFI. Net Zero Energy Building Certification requirements. https://living-future.org/net-zero/requirements

[42] For a full overview of Living Building Challenge Requirements, see https://living-future.org/sites/default/files/reports/FINAL%20LBC%203_0_WebOptimized_low.pdf

[43] ILFI. Net Zero Energy Building Certification Documentation Requirements. https://living-future.org/sites/default/files/photos/15-0105%20NZEB%20DocReq-FINAL.pdf

## 3.10. Summary

The full results of the evaluation of existing net zero building frameworks are presented in Table 2, including the extent to which each one meets the broad goals of the CaGBC. As can be seen from the table, few frameworks meet the full range of goals outlined for the development of a zero emissions building framework for Canada. However, the evaluation of existing frameworks reveals a number of insights into the points of convergence and divergence among the variety of approaches to defining and measuring net zero buildings.

**Energy vs. Emissions**

Among the most important issues of note is that the majority of net zero building frameworks continue to focus on reducing building energy use, to the relative neglect of GHG emissions. Many frameworks, such as Architecture 2030 and the Energy Performance of Buildings Directive, are framed in such a way that the desired outcome of energy reduction efforts are correlative reductions in GHG emissions. However, they nevertheless use energy use as a proxy for emissions reductions. Of these, total Energy Use Intensity (TEUI) is the most common metric used to calculate the balance, though a few frameworks have combined TEUI with additional metrics or requirements.

An exception is the United Kingdom's Zero Carbon Buildings program, which requires all new residential buildings to be zero carbon by 2016, and all new commercial construction to achieve carbon neutrality by 2019.[44] Both the Zero Carbon Buildings program and the ILFI's Net Zero Energy Building certification also indirectly target emissions by requiring on-site renewable energy generation as the primary source of building energy, and in the case of the ILFI, explicitly disallowing any on-site combustion of fossil fuels. In the former, building performance is assessed using both TEUI and GHG intensity (GHGI) metrics, while in the latter utility bills are used to ensure the building generates as much renewable energy as it consumes. A recent white paper by Architecture 2030 has added to the number of emissions-focused frameworks. The white paper defines a *Zero Net Carbon* building as "a highly energy efficient building that produces on-site, or procures, enough carbon-free renewable energy to meet building operations energy consumption annually". However, an associated metric for calculating the zero carbon balance has not yet been released.

[44] The DECC program has since been terminated, along with its supporting body the Zero Carbon Hub.

### Flexibility in achieving compliance

A second general finding is the considerable difference in the way each framework approaches compliance. All frameworks clearly emphasize the need to prioritize energy efficiency and improved building envelope performance as a way of ensuring that building energy needs are reduced as much as possible prior to the addition of renewable energy sources. However, the ways in which different sources of renewable energy are permitted to make up this difference varies across frameworks. For example, the ILFI's Net Zero Energy Building program takes a stringent approach to requiring all renewable energy to be supplied via on-site generation, limiting the number of options for compliance with the program.[45] Higher tiers of the voluntary Passivhaus and Minergie standards similarly require some on-site generation, setting a minimum percentage of building energy demand.

In contrast, other frameworks allow a certain proportion of the energy balance to be met using RECs in order to allow for a more flexible means of achieving compliance. For example, in recognition of the difficulty select building typologies may have in achieving a zero energy balance, the U.S. Department of Energy issued a definition of "REC-Zero Energy Buildings", which they extend to larger, energy-intensive buildings (e.g. hospitals) located in dense urban centres. Other frameworks, such as Architecture 2030 and ASHRAE's 2020 Vision statement, also allow the use of RECs but are more specific in limiting the proportion of RECs that can be used in achieving a zero balance (20% and 50%, respectively).

### Considering the grid

A commonality among all frameworks reviewed for this study is their use of an annual balance period in the calculation of the zero balance, whether modelled for expected performance (e.g. zEPI) or assessed using actual utility bills (e.g. ILFI). As noted in Section Two, this use of an annual balance period risks ignoring the actual interaction between the building and the grid, particularly where there is a mismatch between the seasonal or daily time of generation. Of the frameworks reviewed, only ASHRAE's Vision 2020 and the Minergie standard have begun to consider and/or encourage the integration of load matching considerations. All others assume unlimited and unfettered access to the grid.

### Other considerations

Finally, different frameworks have made varying attempts to cover aspects of building performance over and above building operations. Once again, the various incarnations of the Swiss Minergie standard have gone furthest in including additional considerations into building assessment, including the embodied energy in building materials, indoor environmental quality, occupant thermal comfort, and a cap on building construction costs. Architecture 2030 also encourages building designers to explore embodied carbon, but has not yet included its explicit measurement into either its 2030 Challenge or Zero Net Carbon frameworks. The EU's EPBD and ASHRAE's Vision 2020 also recommend the consideration of thermal comfort and indoor air quality, respectively, while the ILFI has included a number of broader Living Building Challenge requirements into its Net Zero Energy Building program. All others have elected to focus exclusively on energy and/or emissions.

[45] However, the ILFI also allows "scale jumping", in which buildings can achieve net zero status through collaborations with other nearby buildings

**Table 2:** An evaluation of existing net zero frameworks

| KEY CHARACTERISTICS | DOE ZEB | DOE REC-ZEB | ASHRAE VISION 2020 | EU EPBD nZEB | UK DECC | ARCH 2030 | ARCH 2030 ZNC | zEPI | PASSIVHAUS | MINERGIE | ILFI NZEB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Primary metric considered?** | TEUI | TEUI | TEUI + Onsite RE generation | TEUI + Heating & Cooling | EUI + GHG intensity | TEUI | GHG | TEUI | TEUI + TEDI | TEUI + Regulated load | TEUI + RE generation |
| **Type of energy use considered?** | Source | Source | Site | Source | Site | Site | Site | Site | Source | Source | Site |
| **Source energy conversion factors** | National | National | - | National | - | - | - | - | National | National | - |
| **Emissions factor** | - | - | - | - | National | - | TBD | - | - | Set weighting factors | - |
| **Embodied energy/ emissions considered?** | No | No | No | No | No | Encouraged | TBD | No | No | Yes | No |
| **Balance period?** | Annual | Annual | Annual | Annual | Annual | Annual | Annual | Annual | Annual | Annual | Annual |
| **Other scales (e.g. community, campus) considered?** | Yes | Yes | No | No | No | Yes | TBD | No | No | Yes | Yes |
| **Load matching considered?** | No | No | No | Yes | No | No | TBD | No | No | Under consideration | No |
| **Grid interaction considered?** | No | No | Encourage & under exploration | No | No | No | TBD | No | No | Under consideration | No |
| **Sources of acceptable RE?** | Onsite | RECs OK | Up to 50% RECs OK | Onsite or nearby | Onsite + Allowable Solutions | Up to 20% RECs OK | On or offsite* | N/A | On or offsite | On or offsite | Onsite |
| **Associated certification or label?** | No | No | No | No | No | No | No | No | Yes | Yes | Yes |
| **Additional criteria considered?** | No | No | IAQ | Thermal comfort | No | No | No | No | No | Cost, comfort IAQ | LBC criteria |
| **CaGBC OBJECTIVES** | | | | | | | | | | | |
| **Encourages building energy efficiency?** | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔✔ | ✔✔ | ✔✔ |
| **Encourages GHG emissions reductions?** | | | ✔ | | ✔ | | ✔ | | | | ✔ |
| **Flexibility in meeting balance?** | ✔ | ✔ | ✔ | ✔ | ✔✔ | ✔ | ✔✔ | ✔✔ | ✔✔ | ✔✔ | ✔ |
| **Clear and transparent metric?** | ✔ | ✔ | ✔ | | ✔ | ✔ | ✔ | ✔✔ | ✔✔ | ✔✔ | ✔ |
| **Broad market participation possible?** | ✔ | ✔✔ | ✔ | ✔ | | ✔✔ | ✔✔ | ✔✔ | ✔ | ✔ | |

# 4. A DEFINITION AND FRAMEWORK FOR CANADA

The review above provides a solid foundation for the development of a zero carbon buildings framework for Canada in identifying their commonalities and differences, as well as the extent to which each one meets the goals of the CaGBC. While it is important to draw on this body of existing work, it is also necessary to assess the applicability and relevance of each one to the Canadian context. In reviewing each framework, it becomes clear that several frameworks immediately fail to meet the single most important criterion of the CaGBC: to explicitly focus on the reduction of building emissions. Though a measure of consistency with one or more existing frameworks is desirable, their limited focus on emissions limits the ability to easily adopt an existing framework.

However, the recent and joint release of the *Zero Net Carbon* definition by Architecture 2030, NBI, and the Rocky Mountain Institute has begun to shift their focus from energy to emissions, and can provide a sound basis from which to develop a relevant and appropriate definition for Canada. Following a process of consultation with key stakeholders, the following definition of a *zero carbon building* is therefore recommended:

*A highly energy efficient building that produces on-site, or procures, carbon-free renewable energy in an amount sufficient to offset the annual carbon emissions associated with building operations.*

The remainder of this section builds on this definition by presenting a discussion and recommendation for the each of the key dimensions of a framework. In contrast to the terminology of "net zero" used to describe the broad suite of frameworks, "Zero Carbon Buildings" will be used to refer to the specific framework put forward by the CaGBC. Each dimension of this proposal was presented to key stakeholders for their review and feedback, and received broad support. While this final proposal certainly does not represent full industry consensus, it nevertheless represents a framework that has been generally accepted and supported by the majority of key stakeholders in the Canadian building design and construction industry consulted to date.

## 4.1. Prioritizing Carbon Emissions Reduction

*Adopt greenhouse gas intensity (GHGI) as the primary metric for evaluating performance to directly reduce GHG emissions resulting from building operations.*

As noted several times above, the primary focus of this effort has been to develop a framework that directly targets a reduction in the emissions associated with building operations.[46] While energy use and carbon emissions are certainly related, an exclusive focus on energy risks ignoring the varying carbon intensities of different energy sources used to make up any remaining energy balance. To effectively incentivize a shift toward the use of low-carbon energy sources, the explicit use of a greenhouse gas intensity (GHGI) metric is the primary foundation for the development of a zero carbon buildings framework. This focus on carbon emissions reductions is consistent with the CaGBC's goal and vision of leading the transformation of the built environment toward a sustainable state, and was supported by all stakeholders consulted as a part of this process. By setting a decreasing set of GHGI targets, the Canadian industry would be required to focus its efforts on designing buildings that depend on fossil fuel-free energy sources.

[46] Scope 1 and 2 emissions are included. Scope 3 emissions related to sources such as transportation and water/wastewater were thought to render evaluation unduly complicated. However, design/construction as well as operations teams should consider measures to address scope 3 emissions. The LEED rating system provides many measures that help to lower scope 3 emissions

## 4.2. Selecting an Emissions Factor

*Calculate GHGI using regional emission factors to accurately reflect the carbon intensity of buildings.*

With the creation of a carbon-based framework comes the need to select conversion factors to use in the calculation of the carbon emissions intensity of different sources of energy. While this choice may at first appear straightforward, it is one that has several political and regulatory implications, and that was heavily debated among stakeholder groups consulted for this project. The source of this debate lies in the wide variation in emissions intensity of electricity across the country: while some provincial grids (e.g. British Columbia, Manitoba and Quebec) rely principally on low-carbon hydroelectric dams for the supply of electricity, others (e.g. Alberta, Saskatchewan, Nova Scotia) depend on grids supplied by fossil fuels (See Table 3).

**Table 3:** Provincial electricity grid emission factor[47]

| Province | Electricity consumption intensity* g $CO_2$ eq / kWh (2014) |
|---|---|
| **Newfoundland and Labrador** | 31 |
| **Prince Edward Island** | ** |
| **Nova Scotia** | 720 |
| **New Brunswick** | 280 |
| **Quebec** | 2.3 |
| **Ontario** | 50 |
| **Manitoba** | 3.9 |
| **Saskatchewan** | 820 |
| **Alberta** | 820 |
| **British Columbia** | 14.7 |
| **Yukon** | 44 |
| **NWT and Nunavut** | 430 |

** Consumption intensity values include unallocated energy and sulfur hexafluoride emissions from transmission lines*

*** Because of high imports of energy, the intensity for the province of New Brunswick is considered accurate for PEI*

Selecting an emissions conversion factor that captures this diversity and yet allows for a standardized means of comparison across the country therefore presents a considerable challenge. Two primary options were considered for inclusion into the CaGBC's Zero Carbon Buildings framework – the use of a national emissions factor as an average across all provincial grids, or regional factors that represent the diversity of each province's fuel mix. It should be noted that as both approaches have some degree of inaccuracy imbedded within them, neither is perfect. As such, the decision to select one methodology over the other required a careful weighing of trade-offs, including the extent to which each approach aligns with the goals and objectives of the proposed framework. A summary of arguments for both approaches is provided below.

**National**

The rationale for a national emissions factor is founded primarily in concerns over the difficulty with which buildings located on higher carbon intensity grids would be able to achieve low or zero carbon targets. However, the use of regional factors was not found to truly make it more challenging to achieve low or zero carbon targets. While buildings in regions with more carbon intensive electrical grids naturally begin with a higher carbon intensity, it is as easy or easier to offset this carbon with renewable energy. Since electricity from the grid and renewable electricity generated on-site (for simplicity) are deemed to have the same carbon intensity, it is equally easy to offset grid electricity in all regions. Furthermore, as renewable electricity generated on-site is deemed less carbon-intensive in regions with clean electrical grids, buildings in these regions have a significantly greater challenge in offsetting any fossil fuels used on-site.

Therefore, it can be fairly stated that reaching zero carbon is actually easier in regions with more carbon intensive electrical grids, as buildings can decrease the amount of renewable energy required by using fossil fuel. That said, it remains true that *without the use of renewable energy*, regional emissions factors make it more difficult for buildings in regions with carbon-intensive electrical grids to achieve low carbon targets. As building designers are largely unable to influence the emissions intensities of the grids on which their buildings are located, the use of a national emission factor was seen as a potential means of "leveling the playing field".

[47] 2016NIR – PT3

A second argument for the use of a national emissions factor is more abstract. While different provinces may generate, distribute, and regulate electricity differently, the national (or indeed, continental) grid can nevertheless be considered as a single "pool" of electrons, one electron indistinct from another. The boundaries between provincial grids are similarly fuzzy, in that electricity is often exported from areas of high supply to those in need. However, the difference in the emissions intensity between any locally-generated electricity and electricity that is imported is not tracked with equal levels of rigor in all provinces and territories. Further, the amount of electricity being imported and exported is always dynamic. As such, it can be argued that the actual emissions intensity of one grid over another cannot be accurately captured in actual building GHGI calculations.

A third argument in support of a national emissions factor is its potential for comparison and integration into other building standards and metrics. A number of organizations have elected to use national GHG and/or source efficiency factors for electricity, including NREL, NBI, Green Globes, Target Finder, ASHRAE, and others. One of the strengths of a national factor lies in its comparability across buildings – with a single emission factor, the emissions performance of buildings across an entire country can be easily compared. As the average across all grids, national emissions factors are also more stable, in that changes to the fuel mix of individual grids are absorbed into the larger "pool".

**Regional**

While arguments for a national emissions factor are compelling, the primary consideration in the selection of an emission factor must be its impact – in other words, the effectiveness with which it drives building design toward low carbon outcomes. The selection of a national emissions intensity factor would ignore the actual emissions produced in the operation of a building, reducing both the accuracy and credibility of any zero carbon building framework. While regional factors reported by individual provinces may themselves be somewhat inaccurate, they nevertheless represent the accepted standard for assessing the carbon intensity of different grids. This differentiation may render the achievement of a zero carbon building more difficult in some provinces over others, but ultimately creates a realistic portrayal of actual building emissions.

Using regional intensity factors also helps drive smarter design decisions. For example, the use of fossil fuels in regions with clean electrical grids is strongly penalized, as several units of renewable energy must be used to offset each unit of fossil fuel energy. Similarly, the use of fossil fuels in regions with carbon intensive electrical grids is recognized as a way to very quickly decrease the carbon intensity of the buildings. However, project teams in these regions should carefully consider the fact that these electrical grids are expected to de-carbonize over time and that buildings will not be able to maintain their zero carbon status unless they move away from on-site fossil fuels or significantly increase the renewable energy they generate.

**Table 4:** The pros and cons of regional or national emissions factors

| | National Grid Intensity Factor | Regional Grid Intensity Factor |
|---|---|---|
| **Advantages** | ✔ Provides consistent comparison across Canada<br>✔ More stable over time<br>✔ Acknowledges import/export between regions | ✔ Improved accuracy of carbon intensities<br>✔ Easier integration into regulatory frameworks |
| **Challenges** | ✖ Sends signal that carbon intensity doesn't matter<br>✖ Limited applicability to regulatory frameworks | ✖ Uneven 'playing field' between provinces<br>✖ Reported carbon intensities are more time-sensitive + inaccurate |

A third and powerful argument for the selection of a regional factor lies in its potential uptake by individual provinces. In Canada, electric emissions intensities are reported by different provinces to the federal government in their annual greenhouse gas emissions inventories. The selection of a regional emissions factor would therefore align with existing regulatory frameworks, easing its adoption by individual jurisdictions. The use of a regional emissions factor is furthermore being adopted by an increasing number of organizations and programs, including the *arc* performance platform (which calculates building emissions as a factor of carbon emissions per capita and can be used towards LEED certification) and the LEED for Building Design and Construction rating system (which calculates cost savings based on regional utility prices). The selection of a regional factor would therefore help to align with these and other regionally-based tools and standards (e.g. Target Finder). In sum, while the use of regional emissions factors may create more varied energy efficiency solutions in different locations across the country, it will improve accuracy and compatibility with provincial and federal programs and legislation. For these reasons, a regional emissions factor has been selected for inclusion in the Zero Carbon Buildings framework.

Of course, the carbon intensity of different grids is not fixed, but can change over time as political priorities change and/or infrastructure ages and is replaced. To reflect this changing context, it is important for the framework to either be revised periodically (perhaps every 3-5 years), or to reference a source of emissions factors that is itself maintained and regularly updated by the federal government.

## 4.3. Incentivizing Good Building Design

*Ensure buildings are designed for energy efficiency by supplementing the GHGI metric with additional energy use intensity metrics.*

The design of buildings that reduce carbon emissions economically depends in large part on the prioritization of energy efficiency of the building. The use of high efficiency mechanical systems and appliances, passive design principles, and high-performance building envelopes with improved airtightness all help to reduce building energy loads, thereby lowering energy costs and reducing the total amount of renewable energy needed to meet building energy demand.

In contrast, a sole focus on building carbon emissions to the neglect of other aspects of building performance risks allowing poorly constructed buildings. This is particularly the case where buildings are located on “clean”, or low carbon-intensity grids and as such have an advantage in achieving lower GHG emission intensity performance. Thus, while the reduction of carbon emissions from building operations is the primary goal of this framework, it should be accompanied by additional measures that encourage high building performance. Two primary metrics are proposed to achieve this goal:

**Total Site Energy Use Intensity (TEUI):**

Measured in kWh/m$^2$/year, TEUI provides a measure of full building energy use, including plug and process loads. By setting a TEUI target, building designers are compelled to consider measures to reduce the full energy use of a building. Setting the TEUI target at the building site scale renders this an easier metric to calculate, as it does not require a conversion factor (as in the use of a source energy metric).

**Thermal Energy Demand Intensity (TEDI):**

TEDI is another energy use intensity metric calculated in kWh/m$^2$/year, providing an indication of the total amount of energy need to heat and cool a building, once all passive gains and losses are accounted for. The use of a TEDI metric is important to incentivize building designers to use passive design strategies to minimize building thermal demand, including appropriate building orientation, the use of compact, rational building form, high performance building envelopes, and strategies for passive heating, cooling, ventilation, and lighting.

Using these energy use intensity metrics in combination with the GHGI metric outlined above will ensure the design of economical, high-performance buildings and allow for a comparison in energy efficiency across building types and in different locations. As with the GHGI metric, specific and decreasing TEUI and TEDI targets could be set either by the CaGBC, or by individual jurisdictions.

## 4.4. Improving Grid Integration

*Reduce peak energy demand in buildings by optimizing building systems to operate in response to grid supply and demand fluctuations.*

As noted above, few net zero frameworks as yet give full consideration to the interaction between zero energy or zero carbon emissions buildings and the broader grid to which they are connected. However, there are significant benefits in more explicitly connecting building energy generation and use with larger networks of distribution.

To begin, many Canadian grids are already experiencing significant stresses as populations grow and the frequency of extreme weather events (e.g. heat waves) increase. As the number of net zero buildings grows, so too will the number of buildings designed to use electricity as the primary source of building thermal energy (e.g. through the use of heat pumps), increasing peak demand in winter. This increase in demand can result in the need for additional sources of generation, which might depend on natural gas as a source of energy, pushing up the marginal emissions of electricity use. This is particularly the case in Southern Ontario, where the marginal emissions of electricity use are far higher than the average (through the use of natural gas-fired back-up generators).

Furthermore, the increasing prevalence of building-scale generation of renewable energy will also increase the incidences of two-way transfer between buildings and the grid. As peak renewable energy generation can often coincide with low periods of usage, an increase in these distributed energy resources risks reducing the efficiency of electricity grids. For example, the generation of renewable energy (e.g. through solar PV) peaks during the day while peak energy demand for winter heating occurs in the evenings.

The recommended means of addressing these concerns is the inclusion of a peak energy demand metric. Peak energy demand metrics are already commonly used in building codes to appropriately size mechanical equipment and building components. The explicit addition of the metric into a zero emissions building framework will help to drive building design toward lower overall peaks, as well as provide a measure of resilience to climatic and other shocks and stressors.

As with embodied carbon, it is recommended that a peak energy demand metric should be initially used only to track performance, and not in the calculation of zero carbon building performance. However, it will be valuable in incentivizing building designers to begin to consider grid integration and the use of demand management measures, such as on-site storage, interactive metering, and others. Select jurisdictions may wish to set specific peak demand limits.

## 4.5. Exploring Embodied Carbon

*Recognize the growing importance of materials and prime the industry to track embodied carbon.*

While operations currently account for the majority of building emissions, the carbon emissions associated with the materials used in building construction will make up an increasing proportion of the total carbon budget as operational emissions are reduced. The question of how to account for this embodied carbon was discussed at length by several stakeholders and was raised as an important dimension to include into a zero carbon building framework. However, it was also noted that to achieve broad buy-in and minimize the complexity of the framework, a zero carbon framework should remain as focused as possible on operational emissions. Furthermore, the current version of LEED (v.4) has already begun to address the need to consider the impact of building materials by incentivizing the life cycle assessment of basic building envelope and structural materials (e.g. wood, steel and concrete) during early design. It also incentivizes the selection of buildings products (e.g. furniture and finishes) with lower life cycle impacts.

Given this burgeoning interest in embodied energy/carbon, the zero carbon building framework should require or encourage building designers to note the embodied carbon in building envelope and structural materials. Requiring such information will help the industry to begin to shift design decisions toward lower-carbon materials, grow in their capacity to measure embodied carbon, and identify an appropriate standard for its measurement. However, embodied carbon should not be used in calculating a building's progress toward a zero carbon balance. As building emissions are reduced and capacity to measure embodied carbon grows, this metric could be gradually incorporated into the evaluation of zero carbon buildings in the future evolution of the framework.

## 4.6. Connecting to Renewable Energy

*Prioritize on-site generation and direct procurement to increase the overall production and connectivity of renewable energy sources.*

For a zero carbon buildings framework to drive down the GHG emissions of the local energy system, it is important to ensure that it actually incentivizes the added generation of carbon-free renewable energy connected to the local grid. As such, the zero carbon-energy balance should be calculated by considering only that renewable energy that has been generated on-site or procured through a direct contractual arrangement from a renewable energy supplier (e.g. via standard utility offers, power purchase agreements, virtual energy metering, or district energy systems). In doing so, the framework will help to foster a measurable increase in the actual amount of local renewable energy generated as a result of a new building's construction, and avoid potential issues associated with the purchase of RECs noted above.

As the contribution of renewable energy to the zero carbon-energy balance relies on a continuous decision to procure it by building owners and/or managers, some assurance of a direct and long-term contractual arrangement should also be required. To promote local renewable energy generation, only sources of renewable energy within a set local boundary should be considered a means of meeting the zero carbon-energy balance. Where building owners do elect to connect to sources of renewable energy outside the local boundary (e.g. RECs, virtual PPAs), they should not be considered a means of meeting the balance.

It should also be noted that while direct generation or procurement should be prioritized, RECs were noted by several stakeholders as a potential means of providing additional flexibility. During the process of consultation, some stressed the importance of allowing individual buildings to find zero carbon solutions that make the most economic sense for their particular use, site, and grid. While there was broad consensus that RECs should not be allowed as a means of "buying" a way out of compliance, there was also some agreement that they could provide an interim means of achieving compliance while the market shifted. In some jurisdictions, the possibility of using alternative energy procurement methods (such as power purchase agreements) may further be limited by utility regulations. As such, while the framework should prioritize on-site generation and/or direct procurement, it should be recognized that some building owners may nevertheless have limited options. Thus, a REC-based compliance option may be considered within the zero carbon buildings framework on an interim or case-by-case basis. In the event that RECs are allowed, measures to ensure their locality (i.e. generated in Canada) and high quality (e.g. those that have received EcoLogo certification) should also be considered.[48]

## 4.7. Keeping it Simple

*Limit the framework to building emissions*

While the addition of other dimensions such as thermal comfort, indoor air quality, and cost were considered for inclusion into the zero carbon buildings framework, many stakeholders agreed that a simple framework was necessary to improve its impact. While other aspects of building performance are important, the addition of other factors risks transforming the framework into a larger building performance standard. As the LEED rating system is already a highly valuable and well-accepted means of driving overall building design,[49] it is recommended that the framework limit its current focus to building carbon emissions.

[48] The EcoLogo program is a widely used program that provides environmental standards for RECs and other products and services in Canada.

[49] The LEED rating system includes numerous elements of good overall building design that target occupant comfort and health. It also includes many strategies that reduce GHGs, such as energy efficiency; renewable energy; demand response; life cycle assessment of materials; material re-use and recycling; measures to reduce emissions from transportation and refrigerants; the provision of daylighting; and reduction of heat island effect.

# 5. CONCLUSION AND NEXT STEPS

Together, the considerations discussed in the previous section can be merged into a single proposal for a Zero Carbon Buildings Framework that includes the following five components:

1. A GHGI metric for assessing a building's emissions, calculated using regional emissions factors;
2. TEUI and TEDI metrics to incentivize the design of highly efficient, reliable and resilient buildings;
3. A peak energy demand metric to encourage the use of "peak shaving" measures;
4. An embodied carbon metric to recognize the importance of buildings material lifecycle impacts and to build momentum and capacity for assessing these impacts; and
5. A requirement that all renewable energy included in the zero emissions calculation be either generated on-site or procured directly from a renewable energy generator in order to ensure the addition of clean power generation.

As the entry of new certification programs at building and district scales has created a risk of market fatigue, future developments will ensure that the Zero Carbon Buildings standard and verification program aligns as much as possible with existing tools and approaches. This will include the selection of metrics, the approach to their calculation, and verification process requirements.

## 5.1. Setting Targets

The framework presented above has not detailed any specific GHGI, TEUI, or other targets. Future developments of the framework will consider the benefits of a single "all or nothing" target; thresholds for different levels of performance; and targets that evolve over time to encourage building design towards lower emissions outcomes. The notion of a minimum threshold for each metric was considered by several stakeholders to be an important and desirable outcome of an emerging framework, so long as they would not result in inappropriate solutions and the market was given sufficient time to adapt. Targets could also be set by provinces and/or municipalities to reflect the baseline performance of key building types, with a set minimum rate of improvement in the form of a stretch (or "step") code. The CaGBC may be able to provide energy benchmarking support to jurisdictions without existing baseline datasets to help set appropriate tiers and timelines for improved performance.

## 5.2. Pathways to Zero Carbon Buildings detailed in Section Four

In order to inform design, strategies for zero carbon buildings of different types and sizes will be evaluated across different climates and electrical grids. For instance, in a region with carbon intensive electricity, a strategy of building electrification may not be optimal.

## 5.3. Verification Requirements and Processes

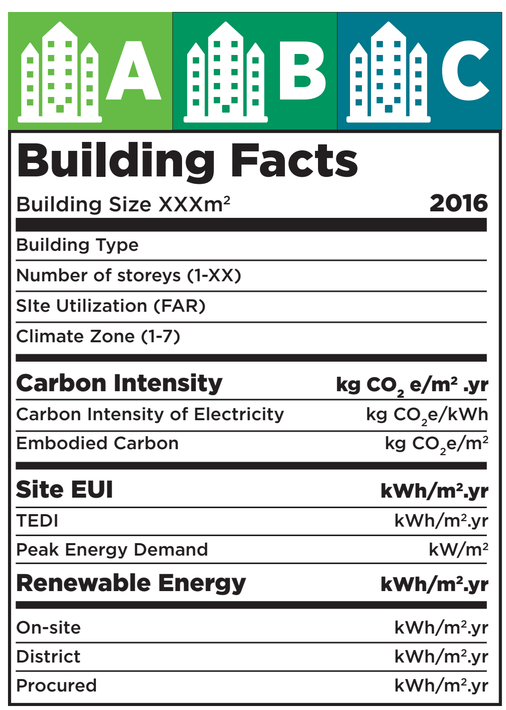
The requirements and processes of a verification program remain to be developed. In order to support broad adoption, requirements and processes should be streamlined and simplified to the extent possible. They may take different forms when providing different types of recognition.

## 5.4. Recognition and Disclosure

Recognition of efforts to achieve low-carbon building performance is a key incentive for the uptake of a given framework or certification system. One means of providing this recognition is through the development of a building labelling program, akin to Europe's building energy performance certificates. The information provided in a label would also help building designers and owners to better understand and improve building performance. Were it made accessible to the public, a label would improve the ability of everyday citizens to make informed choices about the kinds of buildings in which they live and work.

Figure 1 presents a rough conceptualisation of the kinds of information such a label could present. Metrics for carbon intensity, energy use intensity and renewable energy are indicated in bold to highlight their importance and contribution to the zero emissions balance, while details and ancillary metrics (e.g. TEDI, embodied, carbon, etc.) provide additional information. To ensure some measure of context is provided, information on site utilization (Floor Area Ratio, or FAR), climate zone, and the carbon intensity of electricity are also provided.

**Figure 1:** Building Performance Label Mock-Up



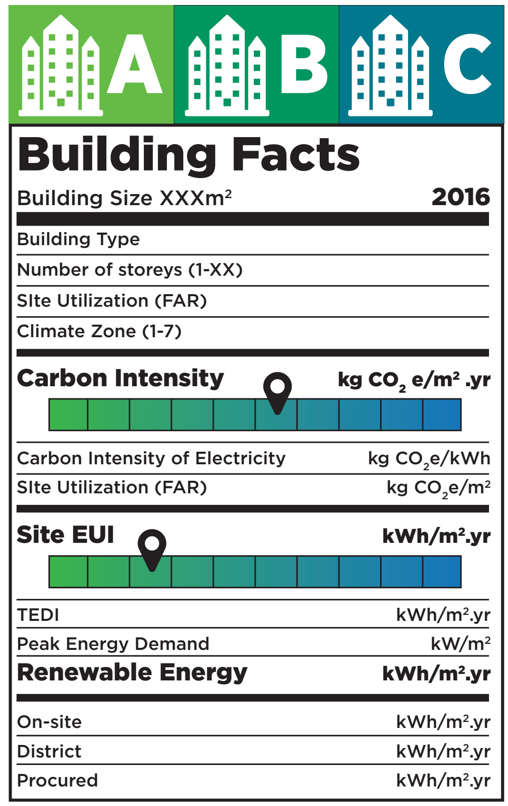
To provide a clear indication of performance level and assist in the fast and easy interpretation of overall building performance, a visual display of performance has also been included. Depicted here as letter grades with corresponding colours to indicate high, moderate, or low building performance, this may be adjusted to fit existing LEED levels of certification (i.e. Silver, Gold, and Platinum). The appropriate approach to branding should be determined in a process of public consultation to ensure its impact and clarity for the general public, while ensuring adequate information is captured to convey the details of building performance.

While the CaGBC could issue such a label to indicate high levels of achievement, individual jurisdictions may elect to require the use of such a label in all new construction to incentivize higher building performance. A relative measure of performance could also be included in a building label (Figure 2). The use of a scale adds an additional layer of information to allow for the easy comparison of a building's performance to others of similar types or location. Any scheme would have to consider how ongoing performance would be recognized in a way that was clear and transparent.

## 5.5. Broadening the Applicability of the Framework

Future work will outline how the framework can be applied to ongoing performance as well as to campus, neighbourhood or community scales. Assessment of ongoing performance is critical to optimizing and maintaining performance over time, and the framework should serve to guide how performance is measured. A label could be updated over time (e.g. annually) to reflect ongoing performance, including the effect of major retrofits, changes to occupancy, or changes in grid intensity. Such information would be valuable to building owners and designers, helping to "close the gap" in building performance. Continued updates could readily be assimilated with existing LEED programming, such as the LEED program's *arc* performance platform.

**Figure 2:** Building Label with Performance



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**Canada Green Building Council**
202-47 Clarence Street
Ottawa, ON  K1N 9K1
**Tel.:** +1 (613) 241-1184
**Fax:** +1 (613) 241-4782
**Toll-free:** +1 (866) 941-1184
www.cagbc.org

*Direct Contact:*
**Mark Hutchinson**
+1 (613) 288-8063
mhutchinson@cagbc.org