ZERO CARBON BUILDING

DESIGN STANDARD
VERSION 4

CAGBC Canada Green Building Council

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Zero Carbon Building – Design Standard Version 4

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The Zero Carbon Building – Design Standard™ Version 4 (ZCB-Design v4) responds to changes in the Canadian design and construction market since the previous version was launched in 2022.

Updates to ZCB-Design were developed using the following guiding principles, established by the Canada Green Building Council's Zero Carbon Steering Committee:

ZERO CARBON BUILDING – DESIGN STANDARD GUIDING PRINCIPLES				
Prioritize carbon emissions reductions	Ensure energy efficient design	Encourage good grid citizenship	Incentivize reductions in embodied carbon	Keep it simple and accessible

Revisions to the Standard were informed by two years of market feedback, as well as changing market expectations on operational and embodied carbon emissions. The Zero Carbon Steering Committee oversaw the changes to ZCB-Design, with the support of the Canada Green Building Council's Embodied Carbon Technical Advisory Group and the Energy & Engineering Technical Advisory Group.

Canada Green Building Council® extends its deepest gratitude to our committee and working group members.

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01 INTRODUCTION

To avoid the worst impacts of climate change, all nations must focus their efforts on carbon reduction.

In Canada, building construction and operations must effectively eliminate greenhouse gas (GHG) emissions to meet the national target of carbon neutrality by 2050. To achieve this goal, each new building design must target zero carbon emissions to avoid costly retrofits down the line. There is no time to wait.

The Intergovernmental Panel on Climate Change (IPCC) has fixed the world's remaining carbon budget – the maximum amount of carbon dioxide (CO_2) that can be released into the atmosphere – at 500 gigatonnes (Gt) of CO_2.[1] This budget has been set to keep global warming to 1.5 C with a 50 percent likelihood. However, based on data from 2019 emissions, at the world's rate of 40 Gt of total GHG emissions per year, our remaining carbon budget will be depleted in less than eight years, risking a global temperature increase that will significantly alter our climate.

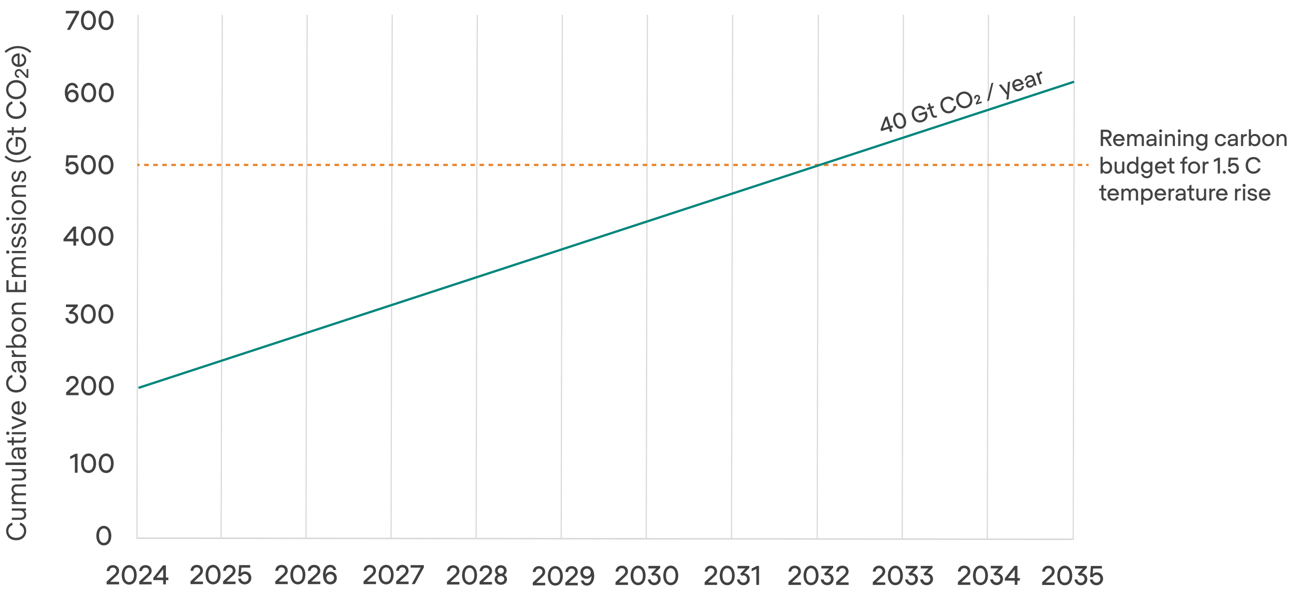

Figure 1 – Estimated cumulative net global anthropogenic CO_2 emissions to limit global warming to 1.5 C.

[1] IPCC. (2021). *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*.

Staying within the remaining carbon budget and mitigating the effects of climate change requires collective action from across the building sector. Every year that passes without significantly reducing GHG emissions erodes the global carbon budget, shortening what little time we have left to reach zero carbon and remain within our planetary boundaries.[2]

Fortunately, the building sector is well-positioned to support Canada's decarbonization efforts. Building operations are responsible for 17 percent of Canada's carbon emissions,[3] with construction and materials representing an estimated 10 percent more.[4] The transition to zero-carbon buildings will generate new and innovative design strategies, expanding opportunities for industry growth and job creation.

The Canada Green Building Council® (CAGBC) launched the Zero Carbon Building Standards™ (ZCB Standards) in 2017 to assist the industry's transition to zero carbon. Every day, projects pursuing certification under the ZCB Standards are pushing the boundaries and demonstrating that there is a zero-carbon future for all buildings. Certifying under the ZCB Standards mean taking responsibility for all carbon emissions over a building's life cycle. It is an ambitious but nonetheless critical objective, because within the context of a global carbon budget, every kilogram of carbon counts.

Published in 2019, CAGBC's *Making the Case for Building to Zero Carbon* report confirmed that zero-carbon buildings are both technically feasible and financially viable.[5] On average, zero-carbon buildings can provide a positive financial return over a 25-year life cycle when considering national carbon pollution pricing. They also require only a modest capital cost premium. The financial returns for zero carbon buildings will only increase as the cost of carbon rises, while they also help mitigate future costs from utilities, regulations, retrofits and extreme weather.

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[2] Rockström et al. (2009). *Planetary Boundaries: Exploring the Safe Operating Space for Humanity*.

[3] Environment and Climate Change Canada. (2016). *Pan-Canadian Framework on Clean Growth and Climate Change. Canada's Plan to Address Climate Change and Grow the Economy*.

[4] Global Alliance for Buildings and Construction. (2024). *Global Status Report for Buildings and Construction*.

[5] Canada Green Building Council. (2019). *Making the Case for Building to Zero Carbon*.

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INCREMENTAL LIFE CYCLE RETURNS ACROSS CANADA

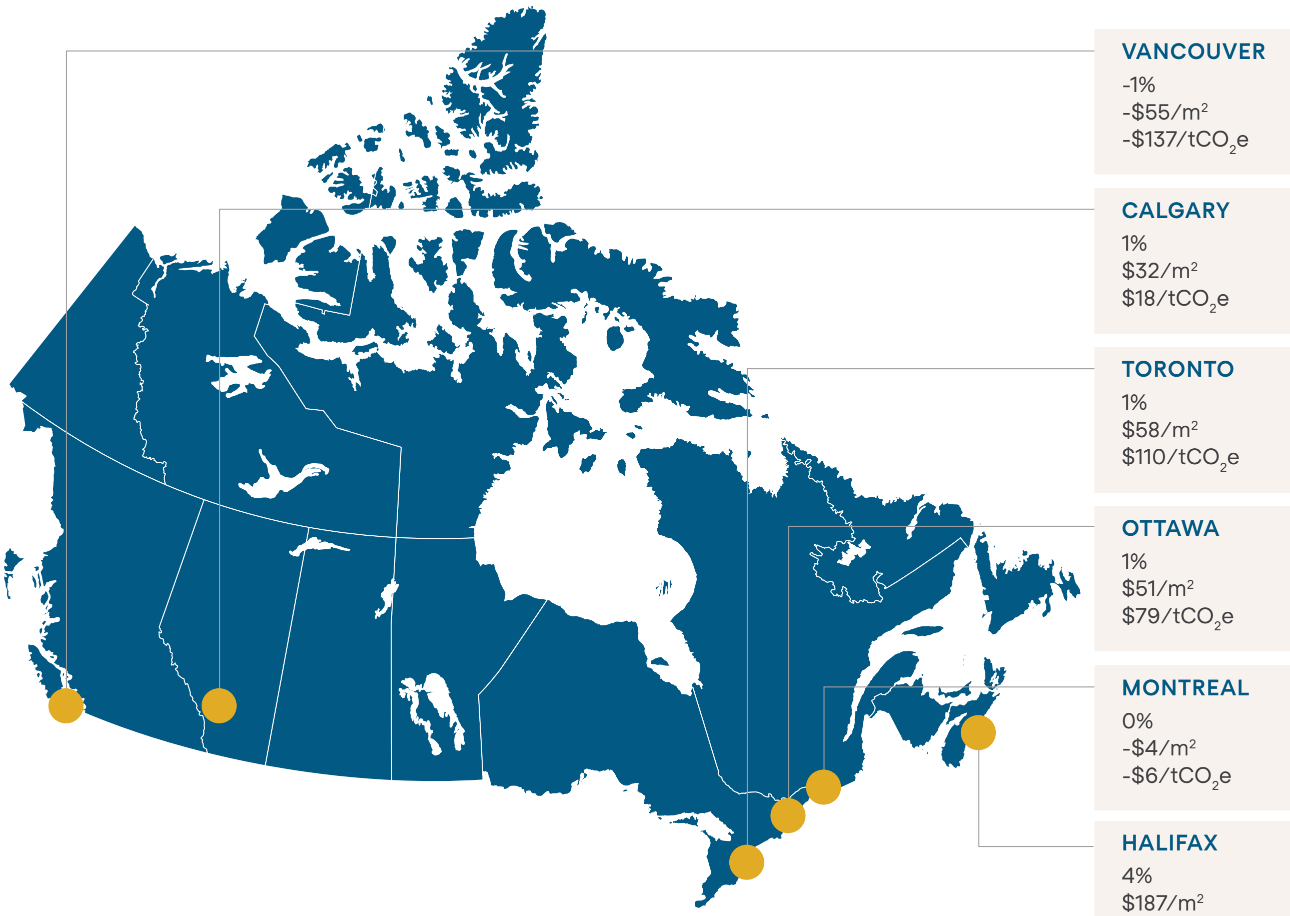

Figure 2 – Incremental life cycle returns across Canada.[6]

In 2021, CAGBC released the *Decarbonizing Canada's Large Buildings* report, which studied the costs of deep carbon retrofits for 1970s and 1990s vintage buildings, identifying key market barriers and solutions. The archetypes within the study can reduce fossil fuel consumption by at least 93 percent, while slashing energy usage by more than 70 percent. Many of the archetypes also yielded a positive financial return on a deep carbon retrofit using a 40-year life cycle, with the remainder becoming cost viable as carbon and energy prices increase.

[6] Ibid.

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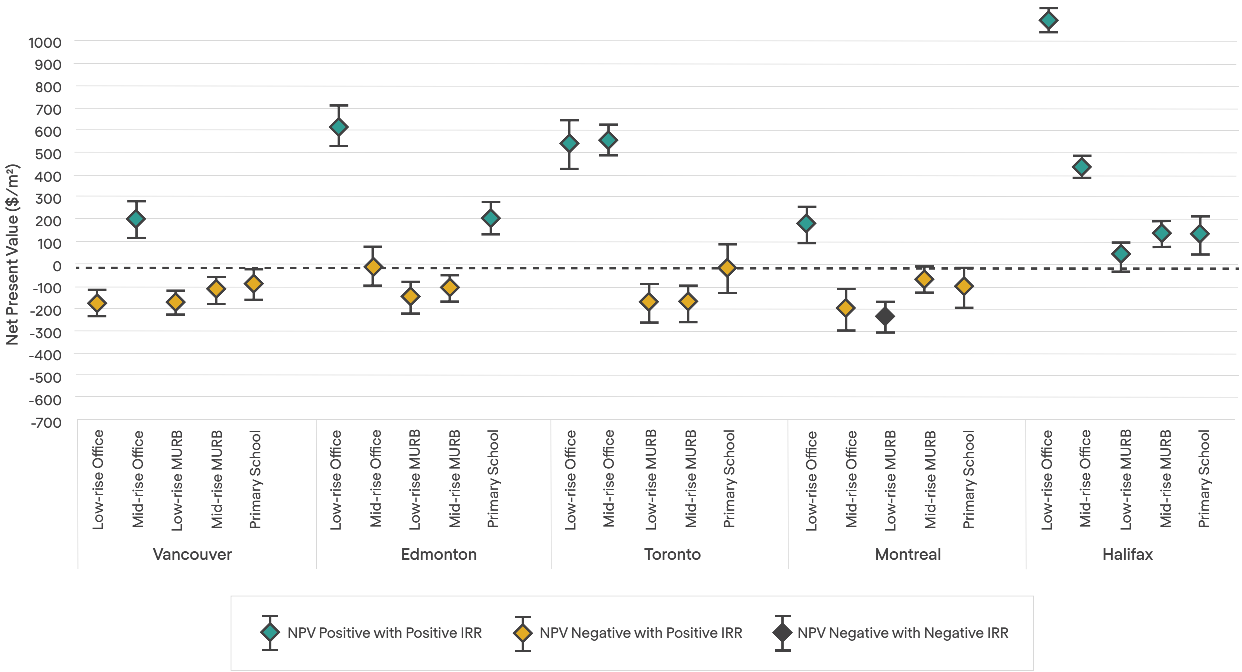

Figure 3 – Net present value of deep carbon retrofits for 1970s vintage buildings.[7]

In 2019, the World Green Building Council called for a 40 percent reduction in **embodied carbon**[8] by 2030.[9] While Canada's building sector has made strides in designing buildings that operate without operational carbon emissions, addressing embodied carbon remains a significant challenge. In 2021, CABGC released a white paper titled *Embodied Carbon: A Primer for Buildings in Canada* to equip the building sector with essential information to understand and tackle embodied carbon in both new and existing buildings. The paper posits that between 2022 and 2050, embodied carbon could account for over 90 percent of emissions from new buildings. This is a significant source of emissions that demands attention during the design stage of any project.

Lastly, provinces and territories are embarking on a large-scale energy transition to accommodate Canada's national strategy for a low-carbon future. Buildings can and must do their part to support the transition. CAGBC envisions buildings as "good grid citizens" that ensure energy efficiency, generate renewable energy onsite, and take steps to reduce and manage peak electrical demand, which may include energy storage and active participation in demand response programs.

[7] Canada Green Building Council (2021). *Decarbonizing Canada's Large Buildings*.

[8] To assist readers, key terms are bolded and defined in the Glossary.

[9] World Green Building Council. (2019). *Bringing Embodied Carbon Upfront: Coordinated action for the building and construction sector to tackle embodied carbon*.

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THE PROCESS OF DESIGNING FOR ZERO CARBON

INTEGRATED DESIGN

The application of an integrated design process is the first step towards ensuring the success of any project targeting zero carbon. Bring a broad, interdisciplinary team together as early as possible and collaborate throughout the course of the new building or deep retrofit project to find the best, lowest-cost approach to zero carbon.

LIMITING COMBUSTION

Eliminating onsite combustion is the top priority when designing for zero carbon. A well-designed electric building will have lower carbon emissions in almost all regions of Canada today, and ongoing efforts to reduce the carbon intensity of electrical grids will ensure that the emissions of combustion-free buildings continue to decline.

MINIMIZING THERMAL ENERGY DEMAND AND EMBODIED CARBON

Project teams must balance the dual goals of minimizing embodied carbon and reducing energy demand – particularly the heating and cooling loads. Improvements to the building's envelope are critical to lower thermal energy demand, enable heating solutions that avoid combustion, and minimize peak demand on the electricity grid. However, envelope improvements can increase embodied carbon, and in many regions of Canada, the embodied carbon of efficient, all-electric buildings already outweighs the cumulative operating emissions over the life of the building. Teams must also consider costs, comfort, passive survivability, and other criteria.

ENERGY EFFICIENCY

Meeting a building's energy needs efficiently is a critical next step to reduce energy use and save on energy costs. From ventilation, heating and cooling to hot water and lighting, efficiency focuses on meeting energy needs with the least energy and carbon emissions.

GREEN POWER AND ENERGY STORAGE

Next, consider how a building might generate onsite renewable energy, accounting for grid interactions to ensure real carbon reductions. Energy storage, whether electrical or thermal, is a recognized strategy to help minimize grid impacts, reduce or eliminate the need for fossil fuels to meet peak heating demand, and increase building resilience. Procuring green power generated offsite can also contribute to mitigating emissions.

CARBON OFFSETS

The residual emissions from embodied carbon, energy use and refrigerant leaks can be mitigated through the purchase of carbon offsets as a final measure towards attaining zero carbon.

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02
OVERVIEW

The Zero Carbon Building – Design (ZCB-Design) Standard™ is a made-in-Canada framework that guides the design of low-carbon, highly efficient buildings and sets a strong foundation for achieving zero-carbon operations once the building commences occupancy. It applies to new construction and major renovations.

The Standard recognizes that many strategies exist for reducing **whole-life carbon** emissions at the design and operating stages and provides enough flexibility for eligible buildings of all types and sizes to achieve certification.

ZCB-Design evaluates energy efficiency and carbon emissions across the building life cycle based on the project's final design. Even the best building design cannot ensure zero carbon operations, thus the Canada Green Building Council® (CAGBC) Zero Carbon Building – Performance (ZCB-Performance) Standard™ can be used to verify the building's impact on the climate annually. ZCB-Performance relies on operating data over the course of one year of operation, including purchases of energy and **carbon offsets**.

Thunder Bay Art Gallery Waterfront, Thunder Bay, Ontario, ZCB-Design v2.

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The ZCB-Design and ZCB-Performance Standards work in tandem as illustrated below.

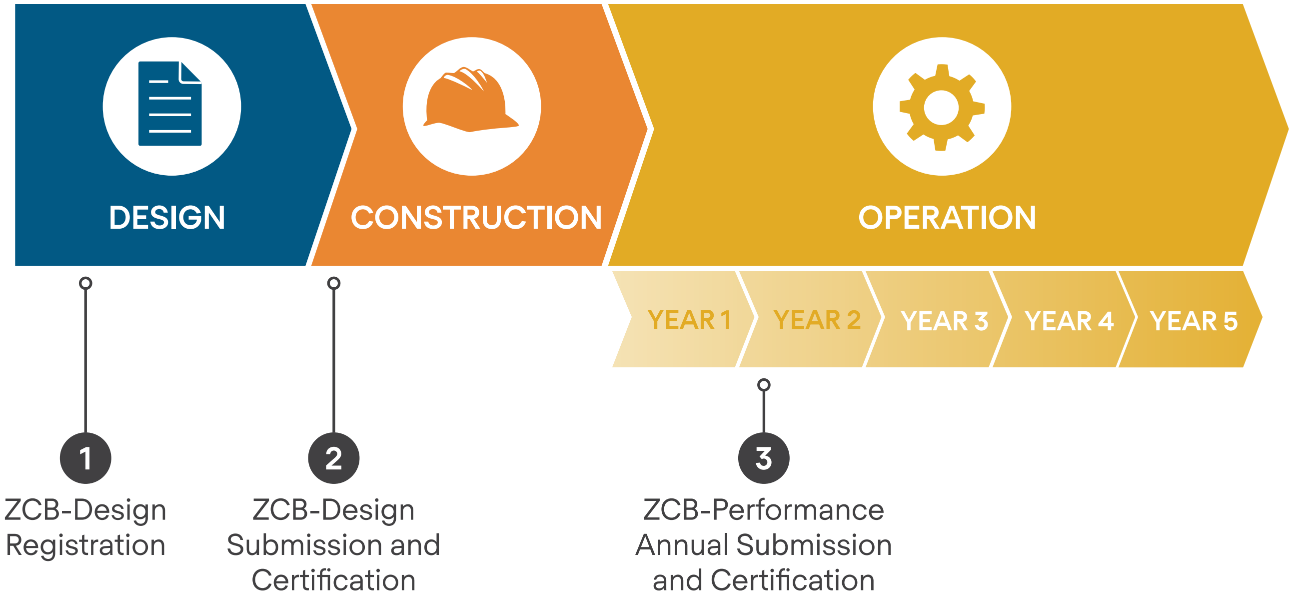

Figure 4 – Milestones in the sequence of ZCB-Design and ZCB-Performance.

1. Registration indicates the intent to pursue certification to ZCB-Design and confirms the version of the Standard to be used.

2. Teams can submit for certification once the construction documents are completed. CAGBC reviews the materials provided, clarifies outstanding issues, and awards certifications if the requirements have been met. Certification is awarded based on the project's final design.

3. Projects are eligible to submit for ZCB-Performance certification after 12 months of operations if they have achieved ZCB-Design. The first ZCB-Performance certification includes verification of airtightness. The embodied carbon of the structural and envelope materials must also be offset, either in the first ZCB-Performance certification or in equal amounts annually over as many as five years. Projects that have not achieved ZCB-Design are eligible to submit for ZCB-Performance after three years of operations.

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2.1 PROJECT CLAIMS AND MARKETING

ZCB-Design certified projects are not permitted to display a certification mark (logo and year) on the building or make a claim of zero carbon operations. Communications about the achievement of ZCB-Design certification should instead reflect the expectation that operations will be verified through certification under the ZCB-Performance Standard following building occupancy. More information on how to market ZCB-Design certified projects can be found on cagbc.org.

ZCB-Design certification may not be used to make a carbon-neutral claim about a product or service originating from a ZCB-Design certified building; however, it may form part of a strategy to achieve a carbon neutral claim.

2.2 ELIGIBILITY

The ZCB-Design Standard applies to new buildings and major renovations to existing buildings, provided they include HVAC, envelope, and/or interior renovations that require a new certificate of occupancy and/or prevent normal building operations from occurring while they are in process. Proposed changes of use to the building are also considered major renovations. ZCB-Design applies to all buildings except single and multi-family residential buildings that fall under Part 9 of the National Building Code. That is, the Standard applies to all buildings except residential buildings that are three storeys or less, and smaller than 600 m^2.

ZCB-Design was created to evaluate entire individual buildings but may also be applied to attached buildings and additions, per Sections *2.2.1* and *2.2.2*. Multiple buildings that share a common site cannot be certified under a single project unless attached by programmable space. Buildings that have no physical connection or are connected only by corridors, parking, mechanical rooms, or storage rooms are considered separate buildings.

2.2.1 ATTACHED BUILDINGS

A building that is attached to another building may independently pursue ZCB-Design certification. The following rules apply:

1. An attached building must be physically distinct to be considered separately for certification.
2. The attached building must have a distinct identity. This ensures that the certification is communicated appropriately to the building users and the public.
3. Attached buildings generally share a common site and will need to consider appropriate separation of that site to determine the emission sources to include in the project.
4. An attached building must have a separate ventilation system and energy meters capable of measuring energy use for electricity, heating, and cooling. This is necessary to demonstrate compliance with the energy and carbon requirements of the Standard.
5. Applicants must seek clarification with CAGBC by emailing zerocarbon@cagbc.org if they are uncertain about attached building compliance.

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2.2.2 ADDITIONS

New building additions may pursue ZCB-Design certification. The following rules apply:

1. Additions must be physically distinct, representing a newly constructed, unique area of a building. The distinct space must also be reflected in the project name when registering.
2. Additions must have separate ventilation systems as well as energy meters capable of measuring energy use for electricity, heating, and cooling. This is necessary to demonstrate compliance with the energy and carbon requirements of the Standard.

2.3 EMISSIONS COVERED

The ZCB-Design Standard applies to the entirety of the building site and includes all emissions outlined below. For the purpose of classifying emissions, all building energy use is assumed to be under the control of the building owner.

Table 1 – Emissions covered by ZCB-Design.

EMISSIONS CATEGORY	CLASSIFICATION
Emissions from the combustion of fuels onsite, including tenant equipment	Direct, Scope 1
Fugitive emissions from the leakage of refrigerants from base building HVAC systems, service hot water systems, and commercial refrigeration equipment, including tenant equipment	Direct, Scope 1
Emissions from purchased electricity, heating, and cooling, including tenant equipment	Indirect, Scope 2
Embodied carbon emissions that are associated with new structural and building envelope materials	Indirect, Scope 3

2.4 REQUIRED DOCUMENTATION

Applicants must complete the *ZCB-Design v4 Workbook*™ to demonstrate compliance with ZCB-Design requirements. The workbook contains a full list of required supporting documentation. Applicants should use the most recent version of the *ZCB-Design v4 Workbook*™; however, they may opt to use the version available at the time of project registration, provided that the **emission factors** from the most recent version are applied.

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Please refer to the *ZCB Certification Guide* for instructions on submitting the required documentation, as well as information regarding the certification process.

The *ZCB-Design v4 Energy Modelling Guidelines*™ is also an important resource that must be followed. The guidelines contain requirements specific to the development of the energy model required for ZCB-Design certification, as well as additional guidance that projects must follow.

2.5 REQUIREMENTS AT A GLANCE

Revisions to the ZCB-Design Standard were informed by two years of market feedback, as well as changing market expectations and capabilities related to operational and **embodied carbon** emissions. The requirements for the ZCB-Design v4 Standard were developed using the following guiding principles established by the Zero Carbon Steering Committee:

ZERO CARBON BUILDING – DESIGN STANDARD GUIDING PRINCIPLES				
Prioritize carbon emissions reductions	Ensure energy efficient design	Encourage good grid citizenship	Incentivize reductions in embodied carbon	Keep it simple and accessible

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A high-level summary of the ZCB-Design v4 Standard's requirements is presented below. A summary of changes from the previous version can be found in *Appendix III*.

ZERO CARBON BALANCE

Model a carbon balance of zero or better based on the net sources and sinks of embodied, operational, and avoided emissions. **Green power products** (e.g. **renewable energy certificates**) and **carbon offsets** are permitted as part of the carbon balance but do not need to be purchased at the time of ZCB-Design certification.

LIMITS TO EMISSIONS

- Demonstrate that the embodied carbon intensity is at or below the established target or meets the percentage reduction target compared to a baseline building.
- Demonstrate that all space heating is designed to be provided using non-combustion-based technologies down to an outdoor air temperature of -15 C or the design temperature, whichever is higher.
- Demonstrate that all **service hot water** is designed to be provided without using onsite combustion-based technologies. Multi-unit residential buildings, long-term care facilities, and other occupancy types with significant hot water demand may adopt a hybrid water heating approach where service hot water is heated to at least 45 C without combustion; further heating to reach the set-point may use combustion. Alternatively, at least 70 percent of the total annual load must be provided without combustion.
- Demonstrate that refrigerants used in all HVAC equipment, service hot water systems, and commercial refrigeration equipment comply with **global warming potential (GWP)** limits.
- Combustion-based fireplaces, as well as gas stoves and ranges in residential suites, are not permitted.

ALTERNATIVE DESIGN AND TRANSITION PLAN

Projects that use any combustion for space heating or service hot water must evaluate an alternative design that does not use these forms of combustion and prepare a **Zero Carbon Transition Plan**.

ENERGY EFFICIENCY

- Report the modelled thermal energy demand intensity (TEDI) and energy use intensity (EUI).
- Meet the energy performance requirements of the selected approach to energy efficiency.

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RESILIENCY TO FUTURE WEATHER

Applicants are encouraged to submit the results of any design condition or energy model sensitivity analysis performed using future weather data.

AIRTIGHTNESS

Justify the use of a lower modelled air leakage rate, if applicable.

GRID CITIZENSHIP

- Report the summer and winter peak electrical demand.
- Projects with any **onsite renewable energy**, energy storage, or demand response capabilities that reduce peak electrical load should report the reduction as a percentage.

IMPACT AND INNOVATION

Demonstrate the inclusion of two Impact and Innovation strategies. At least one of these strategies must come from the pre-approved list.

When pursuing ZCB-Performance certification, projects certified under ZCB-Design v2 and later versions must meet the additional requirements below; compliance will be reviewed during the first annual ZCB-Performance review.

1. Offset the embodied carbon reported for ZCB-Design certification.
2. Perform airtightness testing prior to occupancy.

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A summary and comparison of ZCB-Design and ZCB-Performance requirements is provided in *Table 2*.

Table 2 – ZCB-Design and ZCB-Performance requirements compared.

	ZCB-DESIGN v4 One-time certification for new buildings and major renovations	**ZCB-PERFORMANCE v2** Annual certification for existing buildings
ZERO CARBON BALANCE	Model a zero carbon balance; purchase of green power products or offsets not required	Achieve zero carbon balance with purchase of green power products or offsets if needed
LIMITS TO EMISSIONS	Meet limits for embodied carbon, space heating, service hot water, refrigerants, fireplaces, stoves, and ranges	Offset emissions
ALTERNATIVE DESIGN AND TRANSITION PLAN	If required, evaluate alternative design and develop Transition Plan	Update Transition Plan every 5 years
ENERGY EFFICIENCY	Meet one of three approaches	Report EUI
RESILIENCY	Report findings from an optional future-weather sensitivity analysis	No requirement
AIRTIGHTNESS	Justify if an air leakage rate lower than the default is used	Conduct testing if ZCB-Design v2, v3, or v4 certified
GRID CITIZENSHIP	Report seasonal peaks and any electrical load reductions	Report seasonal peaks
IMPACT AND INNOVATION	Apply two strategies	No requirement

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03 ZERO CARBON BALANCE

A carbon balance of zero or better is the ultimate goal of decarbonization efforts. The carbon balance reaches zero when the sources and sinks of carbon emissions in a building are balanced over a 60-year lifespan.

This section of the Standard explains the carbon accounting used to demonstrate a carbon balance of zero or better.

A carbon balance of zero or better must be demonstrated for Zero Carbon Building – Design (ZCB-Design) Standard™ certification. ZCB-Design recognizes that the holistic assessment of carbon emissions is the best measure of progress toward minimizing climate change impacts from buildings. Applicants must quantify, reduce, and optimize emissions across the building's life cycle, recognizing the impact of construction materials and building operations, as illustrated in *Figure 5*.

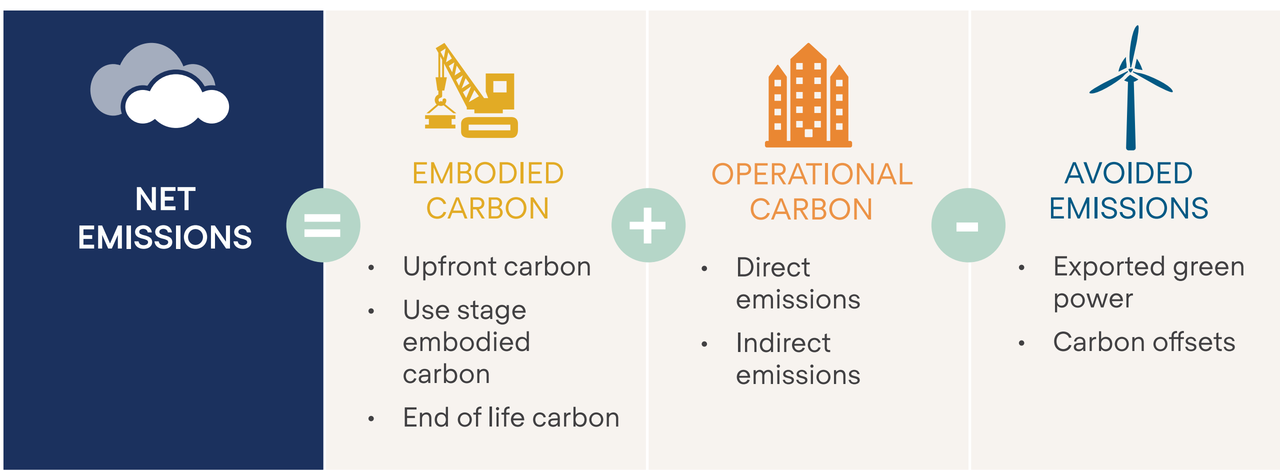

Figure 5 – Calculating the carbon balance.

Embodied carbon, **operational carbon**, and avoided carbon emissions are separately addressed in Sections *3.1*, *3.2*, and *3.3*. Together, embodied carbon and operational carbon over the life of the building are known as **whole-life carbon**.

The *ZCB-Design v4 Workbook*™ has been designed to simplify the calculation of the carbon balance, and applicants must use this tool to demonstrate the zero carbon balance has been achieved.

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3.1 EMBODIED CARBON

Embodied carbon emissions are derived from the manufacturing, transport, installation, use, and end-of-life of building materials.

> Embodied carbon can significantly outweigh operational carbon, and most of it is emitted before a building is even operational.

In many regions of Canada, an efficient, all-electric building's embodied carbon will outweigh its cumulative operating emissions over its entire lifespan.[10] Globally, embodied carbon emissions represent approximately 10 percent of all energy-related carbon emissions.[11] Furthermore, emissions occurring during the production and construction phases of a building, a subset of embodied carbon referred to as upfront carbon, are released into the atmosphere before the building is even operational; given that the timeframe for meaningful climate action is shrinking, there is a growing awareness of the critical importance of addressing this upfront carbon.

The ZCB-Design Standard focuses on carbon emissions across the entire life cycle of the building. As such, reductions in embodied carbon should be pursued as part of an approach that includes consideration of carbon from building operations ('operational carbon'). Decisions about embodied carbon may impact operational carbon and vice versa.

To assess embodied carbon's contribution to the carbon balance of the project, **a whole-building life cycle assessment (wbLCA)** must be done in conformity with Section *3.1.1 Whole-Building Life Cycle Assessment*.

Projects must also report their embodied carbon intensity or the total embodied carbon divided by the built floor area. It should be noted that **built floor area** includes the floor area of underground spaces including parking but excludes balconies and terraces.[12]

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[10] Derived from: Canada Green Building Council. (2021). *Embodied Carbon: A Primer for Buildings in Canada*.

[11] Global Alliance for Buildings and Construction. (2024). *Global Status Report for Buildings and Construction*, p. 29. This figure may be conservative as it only includes concrete, steel, aluminum, brick, and glass. It also only accounts for manufacturing and does not include other life cycle stages (construction, use, and end of life).

[12] For guidance on calculation of embodied carbon intensity see the National Research Council's 2024 *National Whole-building Life Cycle Assessment Practitioner's Guide: Guidance for Compliance Reporting of Embodied Carbon in Canadian Building Construction*.

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After minimizing embodied carbon emissions during design and construction, projects that have achieved ZCB-Design must offset their embodied carbon to achieve Zero Carbon Building – Performance (ZCB-Performance) Standard™ certification. Projects that intend to seek ZCB-Performance certification may wish to offset their embodied carbon using the capital budget for design and construction. While this approach is encouraged, ZCB-Performance provides the flexibility to mitigate embodied carbon by offsetting equal amounts annually over as many as five years. **Beyond the life cycle carbon** (life cycle stage D) is not included in embodied carbon and does not need to be offset when seeking ZCB-Performance certification.

Projects that have certified under ZCB-Design will be required to offset their embodied carbon to achieve ZCB-Performance certification.

3.1.1 WHOLE-BUILDING LIFE CYCLE ASSESSMENT

Projects must conduct a **whole-building life cycle assessment (wbLCA)** of the building materials that includes the following life cycle stages, as illustrated in *Figure 6*:

- **Upfront carbon** (life cycle stages A1-5)
- **Use stage embodied carbon** (life cycle stages B1-5)
- **End of life carbon** (life cycle stages C1-4)

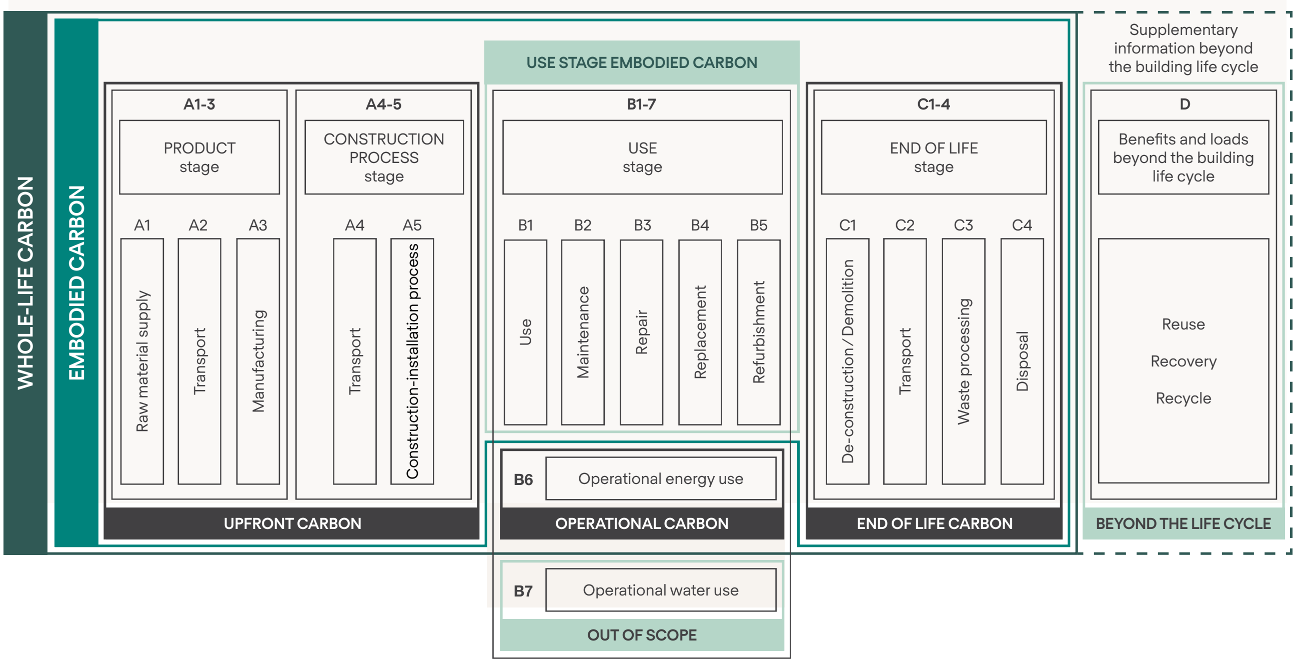

Figure 6 – Embodied carbon life cycle stages.

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The **wbLCA** must be conducted using the methodology from the *National Research Council (NRC) – National Whole-Building Life Cycle Assessment Practitioner's Guide: Guidance for Compliance Reporting of Embodied Carbon in Canadian Building Construction* (hereafter referred to as the *National wbLCA Practitioner's Guide*). This document provides practical guidance on how to assess and demonstrate reductions in the estimated **embodied carbon** of new construction and renovation designs. It is meant to complement and be used in conjunction with the *National Guidelines for Whole-Building Life Cycle Assessment*. The *National wbLCA Practitioner's Guide* was created to enable greater consistency in the methodologies, boundaries, and assumptions used in wbLCAs for Part 3 buildings that intend to demonstrate compliance with certification programs and jurisdictional requirements. Using a common Canadian methodology, it streamlines the work for practitioners and begins to allow for program comparisons.

Projects must adhere to the following direction when applying the *National wbLCA Practitioner's Guide*. Where there are differences between the guide and the ZCB-Design Standard, the latter takes precedence. Projects must:

1. Follow the Cradle-to-Grave Embodied Carbon Assessments approach outlined in the guide, addressing life cycle stages A1-A5, B1-5, and C1-C4. The guide provides direction on handling stages for which information is not available. As noted in the guide, life cycle stage D shall not be included in the embodied carbon calculations used for compliance but may be calculated and reported separately.

2. Follow the required scope elements for structure and enclosure, specifically substructure (foundations, subgrade enclosures, slab-on-grades) and shell (superstructure, exterior vertical enclosures, exterior horizontal enclosures). Currently, ZCB-Design v4 does not include those elements identified as 'optional scope' (e.g., interiors, sitework, and mechanical, electrical, and plumbing systems) in assessing embodied carbon's contribution to the project's carbon balance.

3. Conduct a wbLCA for each building. Where buildings attach through an underground parking garage, each building must pursue certification independently, as noted in Section *2.2 Eligibility*. Project teams must separate the embodied carbon assessment for the underground space and appropriately attribute it to the buildings aboveground based on their floor areas or another suitable methodology. While the *National wbLCA Practitioner's Guide* allows for wbLCA assessments to be completed on multiple buildings joined only by underground parking, ZCB-Design v4 does not.

The embodied carbon assessment must reflect the Construction Documents Stage, as noted in the *National wbLCA Practitioner's Guide*; an Early Design Stage assessment cannot be used for certification. Note, it is recommended that discussions on embodied carbon begin during pre-design, and that analysis begin no later than schematic design to influence project outcomes.

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3.2 OPERATIONAL CARBON

Operational carbon emissions are associated with energy use and potential releases of refrigerants during regular building operations.

When targeting ZCB-Design certification, reducing fossil fuel consumption and the resulting **operational carbon**, is the priority.

The ZCB-Design Standard leverages the GHG Protocol's Corporate Accounting and Reporting Standard methodology for quantifying emissions from building operations.

Once occupied, operational carbon becomes the critical measure of annual carbon emissions. To achieve ZCB-Performance certification, operational carbon must be compensated for with avoided emissions (**carbon offsets** and exported **green power**) to demonstrate that a building has minimized its climatic impact during the performance period.

Operational carbon must be assessed and reported in the *ZCB-Design v4 Workbook*™, following the details below. While this section details how projects account for operational carbon in the carbon balance, Section *4.0 Limits to Emissions* specifies the maximum limits for several sources of operational carbon.

3.2.1 DIRECT EMISSIONS

Direct emissions refer to emissions that occur at the project site because of the combustion of fuels or the release of refrigerants.

3.2.1.1 FUGITIVE EMISSIONS FROM REFRIGERANTS

Low-carbon designs often take advantage of efficient heat pump technology. Refrigerants used in heat pump equipment can contribute to climate change if they leak into the atmosphere or are improperly disposed of. Project teams should consider the **global warming potential (GWP)** of refrigerant options when making design decisions, as the heat-trapping potential of some can be hundreds or even thousands of times greater than other choices.

ZCB-Design certification requires projects to report the total quantity, type, and GWP of each refrigerant contained in all base building HVAC systems, **service hot water** systems, and commercial refrigeration equipment. The total global warming impact of the refrigerants will be assessed in the *ZCB-Design v4 Workbook*™, enabling project teams to understand how refrigerants impact the carbon balance. The Workbook includes GWP values for common refrigerants, referencing the IPCC 5th Assessment Report as shown in *Table 5* of Section *4.2 Refrigerant Limit*. In calculating the carbon balance, the *ZCB-Design v4 Workbook*™ also incorporates assumptions for annual average refrigerant leakage.

The ZCB-Performance Standard requires that any fugitive refrigerant emissions be offset.

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Careful selection of mechanical systems and establishing commissioning and preventative-maintenance plans can reduce the amount of **carbon offsets** needed in the future.

Consistent with the approach taken by Canada's *National Inventory Report*, emissions in the ZCB-Design Standard are presented in carbon dioxide equivalents (CO_2e), or the volume of CO_2 emissions that would have an equivalent GWP over 100 years.

However, projects are encouraged to also consider emissions using 20-year GWP values. Some types of refrigerants act as **near-term climate forcers**, which means they have a short life but a high heat-trapping potential. For example, HFC-32 has 2,330 times the heat-trapping potential of CO_2 when measured over 20 years, but only 677 times the heat-trapping potential of CO_2 over 100 years, as shown in *Figure 7*.[13] Using 100-year GWP values misrepresents the large heat-trapping impact of these emissions over the next few decades – the period of time that we have left to take meaningful action on climate change.[14]

REFRIGERANT GLOBAL WARMING POTENTIAL

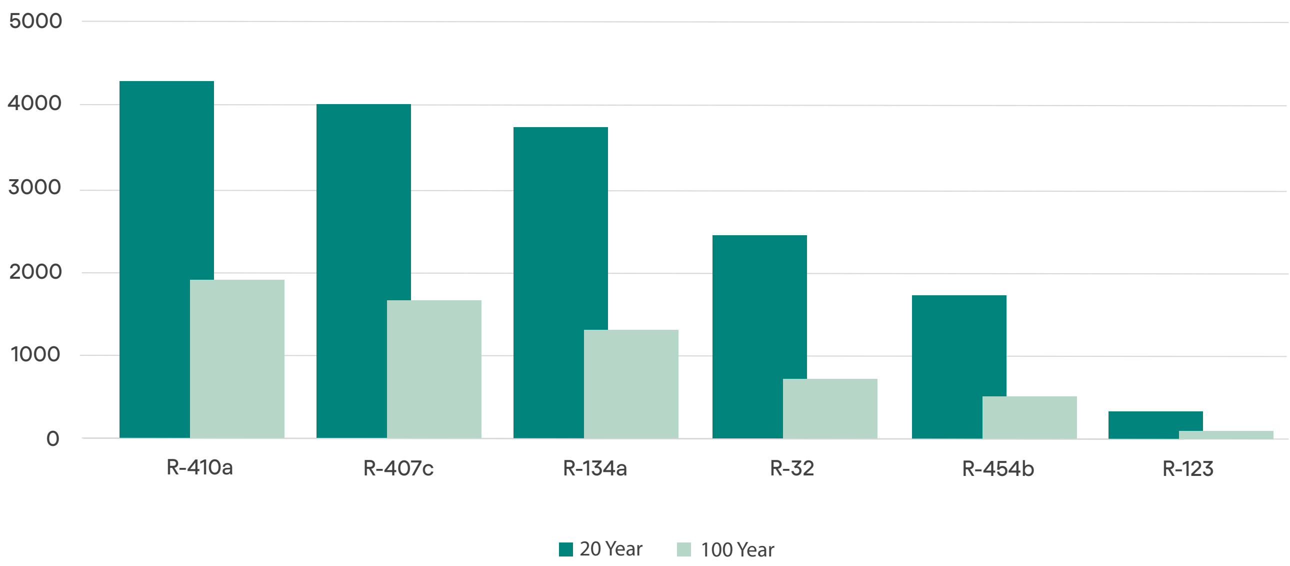

Figure 7 – Global warming potential (GWP) values of common refrigerants.

3.2.1.2 COMBUSTION

The *ZCB-Design v4 Workbook*™ applies **emissions factors** to calculate annual building emissions associated with onsite combustion. Provincial GHG factors are used for natural gas, while national factors are used for other fossil fuels (e.g., propane, fuel oil, and diesel). Emission factors are sourced from the most recent release of Canada's *National Inventory Report* and may be updated periodically. Projects must use the emissions factors in the most recent *ZCB-Design v4 Workbook*™ available at the time of submission for certification.

[13] IPCC. (2013). *Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Values are derived from Table 8.A.1.

[14] Chartered Professional Accountants Canada, *The Time Value of Carbon – Smart Strategies to Accelerate Emissions Reductions*, p.11.

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Fuel used in emergency **backup generators** does not need to be estimated for ZCB-Design certification; however, it must be included in the carbon balance for ZCB-Performance certification.

3.2.1.2.1 BIOGAS

The ZCB-Design Standard recognizes the benefits of certain forms of renewable natural gas (biogas). Eligible biogas resources that can be used onsite include gaseous products produced by the anaerobic decomposition of organic wastes from one of the following sources:

1. Sewage treatment plants;
2. Manure and other farm and food/feed-based anaerobic digestion processing facilities; or
3. Landfill gas.

Applicants must either produce their own biogas onsite, or purchase biogas from their natural gas provider for it to be eligible. Eligible biogas is treated as a zero emissions biofuel and assigned an emissions factor of zero; it does not contribute to **direct emissions**.

ZCB-Design certification does not require a contract for the purchase of biogas; purchases are verified as part of ZCB-Performance certification. However, projects must show proof that an eligible supply is available, as noted in the *ZCB-Design v4 Workbook*™.

3.2.1.2.2 BIOMASS

The ZCB-Design Standard does not treat all biomass as carbon neutral but does recognize the benefits of certain forms of renewable biomass. As such, applicants who use an onsite form of biomass may propose more specific emissions factors where they can be verified by a registered professional.

Biomass resources used onsite that are eligible to be treated as **zero emissions biofuels**[15] include:

1. Solid biomass removed from fields and forests that are managed by following sound environmental management practices.[16] Solid biomass can either be whole plants, parts of plants, or harvesting and industrial by-product residues arising from the harvesting and processing of agricultural crops or forestry products that would otherwise be landfilled or incinerated;
2. Dedicated energy crops with a rotation of less than 10 years; and
3. Liquid fuels derived from biomass as defined in items (1) and (2) above, including, among other things, ethanol, biodiesel, and methanol.

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[15] 'Zero emissions' is meant to characterize certain biofuels from a net-carbon emissions perspective; it is understood that other combustion products are released during combustion.

[16] Refer to *UL 2854 Standard for Sustainability for Renewable Low-Impact Electricity Products* for a definition of 'sound environmental management practices'.

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Biomass resources that are ineligible to be treated as zero emissions biofuels include:

1. Municipal solid waste; and
2. Those manufacturing process by-products that have been treated in the manners listed below:
   i. Wood coated with paint, plastics or Formica;
   ii. Wood treated with preservatives containing halogens, chlorine or halide like chromated copper arsenate or arsenic;
   iii. Wood that has been treated with adhesives; and
   iv. Railroad ties.

If the treated biomass types (per (2) above) comprise one percent or less by weight of the total biomass used, and the remainder is from eligible sources of biomass, all biomass may be treated as a zero emissions biofuel.

Zero emissions biofuels are assigned an emissions factor of zero and do not contribute to **direct emissions**.

ZCB-Design certification does not require a contract for the purchase of biomass; purchases are verified as part of ZCB-Performance certification. However, projects must show proof that an eligible supply is available, as noted in the *ZCB-Design v4 Workbook*™.

3.2.2 INDIRECT EMISSIONS

Indirect emissions refer to emissions that do not occur directly within the project site, such as those emissions associated with purchased energy, water use, waste, and transportation from commuting. As detailed below, indirect emissions within the scope of ZCB-Design certification include only the emissions associated with purchased energy, such as electricity or thermal energy.

3.2.2.1 ELECTRICITY

Provincial **location-based electricity grid emissions** factors are used to represent the average emissions of all grid-connected electricity generation in a province. Provincial location-based electricity grid **emissions factors** are included in the *ZCB-Design v4 Workbook*™, which is periodically updated to reflect the latest emission factors from Environment and Climate Change Canada's *National Inventory Report*.[17] Projects may substitute a market-based **residual mix emissions factor** if their local utility has published one. Residual mix emissions factors are an emerging way to account for the retirement of **green power products** within a specific geographic boundary; however, they are not widely available in North America. Projects wishing to use this option may enter a custom emissions factor in the *ZCB-Design v4 Workbook*™ and provide the source of the residual mix emissions factor.

[17] For the latest version of the report, go to Environment and Climate Change Canada's National Inventory Report webpage and find the most recent Inventory Report. In past years, electricity emission factors have been in Part 3, Annex 13. Alternatively, see "C-Tables-Electricity-Canada-Provinces-Territories" on *Canada's Official Greenhouse Gas Inventory* page.

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The ZCB-Design Standard recognizes that electricity may be sourced from a **district energy system** or an **islanded grid** (a small grid not connected to the provincial grid). The **emission factors** for these specific sources may be used where they are available and can be verified by a registered professional. Projects wishing to use this option may enter a custom emissions factor in the *ZCB-Design v4 Workbook*™.

Electricity used by electric vehicle charging stations that service vehicles used outside the project site, regardless of whether the vehicles are fleet vehicles or otherwise, should be separately metered and excluded from the calculation of indirect emissions from grid electricity.

3.2.2.2 OWNED RENEWABLE ENERGY SYSTEMS

Owned **renewable energy** systems, whether onsite or offsite, reduce the need for grid electricity, fuel, heating and/or cooling, lowering the emissions associated with these energy sources. **Renewable energy** systems typically take the form of solar or wind power generation and solar thermal heating.

If more **green power** is generated than energy used on an hourly basis, it contributes to the avoided emissions from exported green power (see Section *3.3.1 Exported Green Power*).

All **environmental attributes** (in the form of **renewable energy certificates**) associated with the onsite or offsite generation and/or export of green power must be retained by the applicant and cannot be sold if the power generation is to count toward achieving a zero carbon balance. Exceptions may be made where retaining environmental attributes is outside the control of the project team. Examples include where a non-negotiable **net-metering** contract or local energy legislation requires that the attributes be surrendered to the local utility or government.

3.2.2.2.1 ONSITE

Onsite renewable energy helps to improve building resilience in the face of power outages, reduces total energy use and overall demand from the electrical grid, minimizes environmental impacts from power generation facilities, and helps build the knowledge and marketplace for a distributed energy future.

Applicants to the ZCB-Design program must report their total modelled onsite renewable energy. Note that the usable energy produced by the renewable energy system is the output energy from the system less any transmission and conversion losses, such as standby heat loss or losses when converting electricity from DC to AC.

Onsite power generation systems may or may not be net metered. **Net-metering** allows a project to connect renewable power generation equipment to the local grid and receive a credit on their bill for any electricity that is exported to the grid.

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3.2.2.2.2 OFFSITE

Offsite **renewable energy** systems must be new and virtually net-metered to the building seeking certification. **Virtual net-metering** is an arrangement with the utility whereby **green power** generation equipment is installed in another location and net-metered against (deducted from) the building's electricity bill. Alternatively, offsite systems may take the form of green power systems installed on adjacent buildings within a campus.

3.2.2.3 GREEN POWER PRODUCTS

Green power products involve the purchase of **bundled green power** or green power **environmental attributes**. Each kilowatt-hour of procured **green power** products can replace an equivalent amount of grid electricity in the calculation of the carbon balance. Procured green power products cannot be used to reduce other sources of emissions.

To qualify under the ZCB-Design Standard, green power products can be generated anywhere in Canada. However, project teams are encouraged to consider local options first. Green power products must be generated from:

- Solar energy;
- Wind;
- Water (including low-impact hydro, wave, tidal, and in-stream sources);
- Qualifying biogas (see *3.2.1.2.1 Biogas*);
- Qualifying biomass (see *3.2.1.2.2 Biomass*); or,
- Geothermal energy.

Green power products purchased to meet regulatory programs may also contribute to the carbon balance provided they meet the ZCB-Design program's requirements. For example, where a building is in a municipality or province that requires buildings to offset their operational energy consumption with the purchase of **green power**, these purchases can also be used to meet the requirements of the ZCB-Design Standard.

Not all forms of green power products provide the same level of additionality. Additionality refers to the likelihood that the procurement of green power products will result in new renewable electricity generation equipment that would not otherwise have been installed. The following hierarchy has been established to ensure that project teams are aware of the different options available and can explore the highest quality options first.

1. **Power Purchase Agreements (PPAs):** A **power purchase agreement** is a contract for green power and the associated environmental attributes that typically includes the purchase of a significant volume of electricity under a contract that lasts for at least fifteen years. **PPAs** are among the highest-quality forms of green power product procurement. They are most often used at the company-wide scale and are not suitable for use by a single building. PPAs are also not available in all regions of Canada. All PPAs must be certified by either ECOLOGO or Green-e® Energy, or meet the requirements outlined in *Appendix I – Requirements for Bundled Green Power Products that are not ECOLOGO or Green-e® Certified*. All power must be from green power facilities in Canada.

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2. **Utility Green Power:** **Utility green power** is a product offered by some Canadian utilities where the electricity and the associated environmental attributes (in the form of **renewable energy certificates**) are sold together. Unlike a PPA, utility green power purchases often do not require a volume purchase or fixed term. All utility green power must be certified by either ECOLOGO or Green-e® Energy, or meet the requirements outlined in *Appendix I – Requirements for Bundled Green Power Products that are not ECOLOGO or Green-e® Certified*. All power must be from green power facilities in Canada.
3. **Renewable Energy Certificates (RECs):** **Renewable energy certificates** are market instruments that represent the environmental benefits associated with one megawatt hour of electricity generated from renewable resources such as solar and wind. They can be purchased from a third party. All **REC**s must be certified by ECOLOGO or Green-e® Energy and generated from green power facilities located in Canada.

ZCB-Design certification allows project teams to indicate the volume (kWh) of green power products anticipated to be purchased annually. Applicants are not required to purchase the green power products at the time of ZCB-Design submission; purchases are verified as part of ZCB-Performance certification.

3.2.2.4 DISTRICT HEATING AND COOLING

The *ZCB-Design v4 Workbook*™ requires the **emissions factors** for district heating and cooling systems to be entered manually. The emission factors must be verified by a registered professional.

3.2.2.4.1 GREEN HEAT FROM DISTRICT ENERGY SYSTEMS

Green heat is district heating that is generated using clean energy technologies or **zero emissions biofuels**. When the associated **environmental attributes** are bundled in the purchase of green heat, each unit of procured green heat energy can replace an equivalent amount of district heating in the calculation of the carbon balance. Procured green heat cannot be used to reduce other sources of emissions.

To claim green heat, a signed commitment letter from the building owner to procure green heat for the project must be provided, along with confirmation from the district energy provider that sufficient green heat from non-combustion-based sources is available. The green heat must be generated from sources on the **district energy system** to which the building is connected.

The accounting for the district energy provider's green heat program must meet the quality criteria established by the GHG Protocol Scope 2 Guidance.[18] The district energy provider must obtain an annual third-party audit of the generation and sale of green heat as well as compliance with the quality criteria.

[18] World Resources Institute. 2015. *GHG Protocol Scope 2 Guidance*. Table 7.1 page 60.

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3.3 AVOIDED EMISSIONS

Avoided emissions are emissions reductions that occur outside of the value chain or life cycle of a building.

Avoided emissions are critical to achieving a zero carbon balance. For example, they enable **embodied carbon** and refrigerant leaks to be mitigated.

Avoided emissions must be assessed and reported in the *ZCB-Design v4 Workbook*™ following the direction provided below.

The ZCB-Design Standard recognizes avoided emissions from investments in carbon offset projects, as well as avoided emissions based on grid-level impacts from exporting green power.

3.3.1 EXPORTED GREEN POWER

If the **renewable energy** generated exceeds the energy used (as evaluated on an hourly basis) and is then exported to the electricity grid, it is recognized as contributing to avoided emissions, provided that the associated **renewable energy certificates** are retained. Avoided emissions from exported **green power** can only be used to reduce **indirect emissions** from electricity.

A project's avoided emissions are calculated using **marginal electricity grid emissions factors** for each province. These factors are based on the emissions intensity of the non-baseload electricity generation, which better captures the grid-level emissions reductions that are achieved (given that baseload electricity generation is unaffected by additions of intermittent renewable energy). The GHG Protocol's Guidelines for *Quantifying GHG Reductions from Grid-Connected Electricity Projects* champions a marginal approach to quantify emissions reductions based on the grid-level carbon impacts. This approach is further supported by a recent working paper from the GHG Protocol titled *Estimating and Reporting the Comparative Emissions Impacts of Products*. This working paper advocates for avoided emissions to consider the system-level impacts when bringing products (such as buildings) to market.

Project teams that would rather use provincial **location-based electricity grid emissions factors** to measure avoided emissions may opt to do so at their discretion. These factors are based on the average emissions intensity of all types of electricity generation within a province. In high-carbon grids where the average emissions intensity is higher than the marginal emissions intensity (for example, where baseload is substantially met with coal-fired electricity generation and marginal electricity is provided from other sources), using the average emissions intensity allows for more appropriate sizing of renewable energy systems and recognizes that efforts are underway to decarbonize Canada's electricity grids.

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3.3.2 CARBON OFFSETS

Carbon offsets are a credit for reductions in greenhouse gas emissions that occur somewhere else, which can be purchased to compensate for **direct emissions** or **indirect emissions** on a per tonne basis. Carbon offsets are the only means of mitigating the impacts of **embodied carbon** and refrigerant leaks.

Applicants are only required to provide a quote for the purchase of carbon offsets.

The *ZCB-Design v4 Workbook*™ provides an estimate of the volume of carbon offsets that will be required to cover the embodied carbon of the final design and one year of operations. Applicants are required to provide a quote for the purchase of the defined volume of carbon offsets. Purchase of the carbon offsets is not required for ZCB-Design certification; rather, carbon offset purchases are required for ZCB-Performance certification, where the quantity purchased is determined based on actual building performance.

High-quality carbon offsets ensure that offset projects include safeguards related to:

- Additionality: The likelihood that the emissions reductions would not have happened anyway.
- Permanence: The likelihood that the emissions removed will not be returned to the atmosphere later (for example, a commitment to maintain a forest could be repealed).
- Leakage: The risk that emissions reductions will result in increased emissions elsewhere (for example, designating a forest as protected without precautions to prevent increased deforestation in unprotected areas).

To qualify under the Zero Carbon Building – Design (ZCB-Design) Standard™, carbon offsets must meet one of the following criteria:

- Certified by Green-e® or equivalent; and/or
- Derived from carbon offset projects certified under one of the following high-quality international programs:[19]
  - Gold Standard
  - Verified Carbon Standard (VCS)
  - The Climate Action Reserve
  - American Carbon Registry
- Sourced from Canadian provincial or federal carbon offset programs, including the following:
  - BC Carbon Registry
  - Alberta Emission Offset System
  - Canada's Greenhouse Gas Offset Credit System

[19] While Green-e® Climate certified carbon offsets provide the highest level of consumer confidence, additional programs are listed to ensure a diverse selection of offset project types and geographical locations are available.

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Carbon offsets may come from projects anywhere in the world and from any project type that meets the requirements of the programs listed above. Project teams may choose to apply their own criteria when deciding on the selection of carbon offsets.

Carbon offsets purchased to meet regulatory programs may also contribute to ZCB-Design certification provided they meet the above requirements. For example, where a building is in a municipality or province that requires buildings to offset their carbon emissions with the purchase of carbon offsets, these purchases can also be used to meet the requirements of the ZCB-Design Standard.

UBC Gateway, Vancouver, British Columbia, ZCB-Design v2.

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04 LIMITS TO EMISSIONS

Zero Carbon Building – Design (ZCB-Design) Standard™ v4 projects should strive to eliminate greenhouse gas (GHG) emissions in all forms, and must meet limits to emissions from space heating, service hot water, refrigerants, and embodied carbon.

The limits to carbon emissions are the most critical and direct measures to reduce the building's carbon footprint.

4.1 EMBODIED CARBON LIMIT

ZCB-Design projects must meet a minimum achievement threshold for **embodied carbon**. Two compliance paths are offered, in alignment with the *National wbLCA Practitioner's Guide*. Refer to Section *3.1.1 Whole-Building Life Cycle Assessment* for information on how to determine embodied carbon emissions.

PATH 1: EMBODIED CARBON INTENSITY

The embodied carbon intensity of the project must not exceed the applicable target in *Table 3*. No baseline needs to be created. Targets are only available for certain building types due to the limited availability of benchmark data.

Table 3 – Embodied carbon intensity targets.

BUILDING TYPE	MAXIMUM EMBODIED CARBON INTENSITY (kg CO_2e/m^2 of built floor area)
All buildings except warehouses and distribution centres	425
Warehouses and distribution centres, including similar structures with untenanted spaces	350

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PATH 2: IMPROVEMENT OVER BASELINE

The project's **embodied carbon** must be at least 10 percent less than that of a functionally equivalent baseline building. This path is available for all project types.

Projects that have special structural or envelope requirements, or location challenges that make these targets unrealistic, are encouraged to contact the Canada Green Building Council® (CAGBC) at zerocarbon@cagbc.org to discuss options early in the project.

Note that **biogenic carbon**[20] is not included in the embodied carbon values reported for demonstration of compliance and therefore does not contribute to meeting the minimum performance threshold. However, project teams are encouraged to report impacts associated with biogenic carbon separately.

Note that an incentive is provided for projects to exceed the minimum level of performance. See Section *10.0 Impact & Innovation* for additional information.

[20] Biogenic carbon is the carbon stored in biomaterials through natural processes but not fossilized or derived from fossil resources. Sequestering (storing) biogenic carbon in building materials is one way to reduce upfront carbon. Materials can lock carbon away over many decades and, in some instances, in perpetuity. It is sometimes even possible to store more carbon in materials than results from their manufacturing and other upfront life cycle stages. As such, upfront carbon emissions can be a negative value. However, there is currently no consensus on the accounting of biogenetic carbon, and as such, it is not included in the wbLCA for compliance.

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4.2 REFRIGERANT LIMIT

Refrigerants used in all heating, ventilation, and air conditioning (HVAC) equipment, service hot water systems, and commercial refrigeration equipment are subject to the global warming potential (GWP) limits specified in *Table 4*. Equipment is not subject to GWP limits if it is not listed in *Table 4* or the equipment is already in place, as in the case of a retrofit project. Refer to *Appendix IV* for a description of the equipment types.

Table 4 – GWP limits by refrigeration system type.

REFRIGERATION EQUIPMENT TYPE	GWP LIMIT (100-YEAR)
Stand-alone medium-temperature refrigeration system	1400
Stand-alone low-temperature refrigeration system	1500
Condensing unit	2200
Chiller (other than absorption or adsorption)	750
Centralized refrigeration system	2200
Heat pump	2000
Commercial air conditioning	2000
Absorption or Adsorption heat pump or chiller	1

The refrigerant GWP limits in ZCB-Design v4 align with the limits from the Government of Canada's offset protocol for refrigerant emissions.[21] The *ZCB-Design v4 Workbook*™ includes the GWP of common refrigerants, listed for convenience in *Table 5*.

Table 5 – 100-year GWP of common refrigerants.[22]

REFRIGERANTS	GWP (100-YEAR)
R-410a	1924
R-407c	1624
R-134a	1300
R-32	677
R-454b	467
R-123	79
R-744 (CO_2)	1
R-717 (NH_3)	0

[21] Environment and Climate Change Canada (2023). *Federal Offset Protocol: Reducing Greenhouse Gas Emissions from Refrigeration Systems*. Values are from Table 2 GWP Limits for Eligible Refrigerants.

[22] IPCC. (2013). *Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Values are derived from Table 8.A.1.

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4.3 ONSITE COMBUSTION LIMIT FOR SPACE HEATING

Where onsite combustion is used, zero emissions biofuels should be considered.

Space heating systems should be designed to operate without onsite combustion whenever possible. However, to provide greater design flexibility and recognize current technological and financial barriers, some onsite combustion for space heating is permitted.

Where onsite combustion is used, zero emissions biofuels should be considered. However, projects should recognize that the potential supply of **zero emissions biofuels** is limited and use of these fuels should be reserved for industries where eliminating combustion is impractical.

Projects must be designed to provide all space heating with installed non-combustion-based technologies at an outdoor air temperature of -15 C or the design temperature, whichever is higher. Space heating technologies whose performance is not directly affected by outdoor air temperature (e.g., ground source heat pumps, electric resistance) must meet the same fraction of the annual heating demand as a non-combustion system that is supported by onsite combustion at outdoor air temperatures below -15 C (or the design temperature, whichever is higher).

CAGBC will consider requests for exemptions to the onsite combustion limit for space heating for those projects located in remote regions of Canada on **islanded grids**, or for locations with electricity supply issues.

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4.4 ONSITE COMBUSTION LIMIT FOR SERVICE HOT WATER

Projects designs must provide all **service hot water** heating without onsite combustion-based technologies. A special allowance is provided for multi-unit residential buildings, long-term care facilities, and other building types with significant service hot water needs. These projects can choose to use a hybrid water heating approach where combustion provides some of the service hot water heating. In this approach, projects must demonstrate one of the following:

1. Service hot water is heated to at least 45 C without combustion;[23] or,
2. At least 70% of the service hot water annual heating load is provided without combustion.

Projects with significant service hot water needs, other than multi-unit residential buildings or long-term care facilities, should refer to the ZCB Interpretation Database for guidance on whether a hybrid approach is permissible or contact CAGBC at zerocarbon@cagbc.org if needed.

CAGBC will consider requests for exemptions to the onsite combustion limit for service hot water for projects located in remote regions of Canada that are on **islanded grids**, or in locations with electricity supply issues.

[23] Combustion may be used for the additional heating required to reach the set-point for compliance with safety standards.

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4.5 LIMITS TO OTHER SOURCES OF COMBUSTION

The following appliances may not be used in buildings seeking ZCB-Design certification:

- Gas stoves and ranges in residential suites. Commercial kitchens are excluded from this requirement.
- Combustion-based fireplaces, including decorative fireplaces and those used for heating. In recognition and respect for the importance of fire in Indigenous cultures, wood fireplaces, hearths, and fire pits that are intended to support or reflect Indigenous culture, such as ceremonial practices, are permitted. The expected carbon emissions must be reported based on estimated future use. If the wood selected is sourced sustainably (which is not a requirement), the impact on the carbon balance will be reduced. For more details, refer to Section *3.2.1.2.2 Biomass*. Additionally, the fireplace must be accounted for in the energy model, even if it is not intended for heating.

Backup generators or **district energy systems** that rely on combustion-based technology may not be used to mitigate peak electrical events.

Centennial College Block A Expansion, Toronto, Ontario, ZCB-Design v1.

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05 ALTERNATIVE DESIGN EVALUATION AND TRANSITION PLAN

Zero Carbon Building – Design (ZCB-Design) Standard™ projects that use onsite combustion to meet a portion of their space heating or service hot water demand must evaluate an Alternative Design with no onsite combustion and develop a Zero Carbon Transition Plan, regardless of whether zero emissions biofuels are used.

ZCB-Design requires that options for eliminating onsite combustion in the short and long term be considered.

There are also requirements for buildings connecting to a **district energy system** that uses combustion, as specified in Section *5.4 Application to District Energy Systems*.

5.1 EVALUATION OF ALTERNATIVE DESIGN WITHOUT ONSITE COMBUSTION

An alternative design, which does not use onsite combustion for space heating or **service hot water**, must be developed and evaluated against the chosen design.
The alternative design evaluation must include:

1. A summary of the basic mechanical approach for both the chosen design (which incorporates combustion for a portion of the space heating and/or service hot water) and the alternative design.
2. A table or list providing details of the space heating and/or service hot water equipment (as applicable) of the chosen design and the alternative design, including:
   - Name/description of equipment;
   - Anticipated service life;
   - Area or loads served;
   - Input capacity;
   - Output capacity; and/or
   - Nameplate efficiency (%).

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3. A description of the measures considered and those implemented in the chosen design to minimize space heating and service hot water loads and respective peak demand loads, such as:
   - How the building envelope performance was addressed, recognizing that the building envelope can significantly impact the sizing and operation of space heating equipment;
   - Thermal energy recovery strategies;
   - Thermal storage; and/or
   - Low-flow water fixtures.
4. A description of the measures considered and those implemented in the chosen design to facilitate the future conversion to non-combustion-based technologies, such as:
   - Designing the heating, ventilation and air conditioning (HVAC) distribution system for low-grade heat;
   - Allocating space for electric-based heating technologies (e.g., heat pumps);
   - Ensuring electrical capacity for full electrification in the future; and/or
   - Making provisions for onsite **renewable energy** systems (e.g., photovoltaic (PV) ready design) and electric or thermal energy storage.
5. A detailed description of the reasons why the non-combustion-based systems weren't chosen.

Project teams are encouraged to consider a holistic approach to emissions by including other sources of onsite combustion in the evaluation, such as humidification and process loads.

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5.2 ZERO CARBON TRANSITION PLAN

A **Zero Carbon Transition Plan** is a costed plan that outlines how a building will adapt over time to remove combustion from building operations, decreasing the need for carbon offsets to mitigate annual emissions.

The **Transition Plan** must include:

1. A narrative describing the future energy and carbon reduction measures that would be implemented to eliminate onsite combustion for space heating and **service hot water** by the earlier of either:
   - The expected end of life of the combustion-based equipment, or;
   - A date no later than December 31st, 2049.
2. A table or list providing the following for each measure:
   - Impact on annual carbon emissions;
   - Impact on energy consumption;
   - Impact on capital costs; and
   - Impact on operating costs.
3. A timeline identifying when measures would be implemented, leveraging natural intervention points such as the mechanical system's anticipated end of life. The timeline must include:
   - Annual carbon emissions; and
   - Building milestones, such as the expected end-of-service life of relevant equipment (e.g., mechanical systems, windows, enclosure, and/or roof).
4. A five-year capital plan outlining the measures that the project intends to pursue over the first five years following initial occupancy or renovation. The capital plan must include:
   - A narrative summarizing the proposed measures;
   - Estimated costs;
   - Estimated savings,
   - Carbon emission reductions;
   - Energy savings, including any improvements to **energy use intensity (EUI)** and **thermal energy demand intensity (TEDI)**; and
   - A narrative summarizing the business case.
5. An evaluation of the electrical capacity available and any upgrades needed to implement the energy and carbon reduction measures including a description of the feasibility and challenges of any upgrades.

Project teams are encouraged to consider how building performance regulations, equipment regulations and increasing market and investor expectations might drive equipment replacement before its end of life.

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If not already integrated into the project design, teams are also encouraged to consider:

- Solutions to minimize or eliminate other sources of emissions, such as humidification, refrigerants, fire suppressants, and process loads.
- Solutions to reduce grid impacts and, potentially, utility costs, such as **onsite renewable energy**, and/or thermal and electrical energy storage.
- Future EV charging infrastructure needs, which might impact the electricity available to electrify space heating and **service hot water** fully. The potential for bi-directional charging could also be considered.

To ensure the Zero Carbon **Transition Plan** is implemented and evolves to reflect the latest technologies and costs:

- Building owners and operators are encouraged to integrate the Transition Plan within the building's capital planning process to ensure alignment of budgets and timing.
- Project teams are encouraged to pursue Zero Carbon Building – Performance (ZCB-Performance) Standard™ certification once in operation to verify the outcomes of implementing the Transition Plan and ensure that the plan is updated every five years.

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5.3 FINANCIAL ANALYSIS

A financial analysis must be conducted to compare the net present value of two scenarios:

1. The chosen design including **Zero Carbon Transition Plan** measures.
2. The alternative design.

The net present value must be evaluated over a period of at least 20 years, which represents the lower end of the expected service life for most key building systems (mechanical and otherwise).

The chosen design must include the Zero Carbon Transition Plan measures identified for implementation within the 20-year period of the financial analysis, to reflect the likelihood that regulation and market drivers will require implementation of the Transition Plan. For example, if the Transition Plan requires replacement of **auxiliary heating system** gas-fired boilers with air source heat pumps after 15 years of operation, the financial analysis must include the capital cost of replacement in year 15.

The net present value calculation must include projected fuel cost escalation, and a three percent discount rate must be used.

Project teams are encouraged to use the *Zero Carbon Building Life Cycle Cost Calculator*™ for the financial analysis. This tool facilitates a comprehensive and mindful financial evaluation of proposed projects. It uses Environment and Climate Change Canada's projection of future electrical grid emission factors to capture the ongoing evolution of power generation in Canada.[24]

[24] Environment and Climate Change Canada's projection is available at Canada's Greenhouse Gas Emissions Projections, under "Electric Grid Intensity by Province (without Biomass and RNG CO_2 emissions)".

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5.4 APPLICATION TO DISTRICT ENERGY SYSTEMS

ZCB-Design projects that are connected to **district energy systems (DES)** using combustion to generate heating or cooling must provide one of the following:

PATH 1: GREEN HEAT

A commitment to procure eligible **green heat**, in conformance with the requirements of Section *3.2.2.4.1 Green Heat from District Energy Systems*.

PATH 2: BUILDING TRANSITION PLAN

A **Transition Plan** for the building that shows how the building can disconnect from the **district energy system** and provide onsite heating, cooling, and service hot water without the use of combustion.

PATH 3: DISTRICT ENERGY SYSTEM TRANSITION PLAN

A **Transition Plan** for the **district energy system** that shows how the system will adapt over time to remove combustion from its operations. The Transition Plan must include:

1. A general description of the current district energy system operations.
2. A description of each thermal energy generation system, including:
   a. Capacity and output;
   b. Fuel mix and respective consumption; and
   c. GHG intensity of each output (chilled water, hot water, steam, and electricity), as applicable.
3. Details of any established district energy system decarbonization goals, including GHG reduction targets and timelines.
4. A conceptual district energy system decarbonization study, including technologies and pathways considered, an analysis of options against clear evaluation criteria, and a recommended path to decarbonization. The study must also include a high-level analysis of capital and operating cost implications (including relative $/ tonne CO_2e reduced) for the options considered.

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06 ENERGY EFFICIENCY

Projects pursuing Zero Carbon Building – Design (ZCB-Design) Standard™ certification must demonstrate superior energy efficiency using one of three approaches.

Energy efficiency is critical to ensuring the financial viability of zero-carbon designs.

Energy efficiency is critical to ensuring the financial viability of zero-carbon designs. It reduces environmental impacts and facilitates the electrification of Canada's economy by reducing the burden of additional power generation, transmission, and distribution. Thermal efficiency, particularly envelope design, is also critical to resiliency and passive survivability during power outages.

Three different approaches are available to demonstrate energy efficiency. Project teams may choose the approach most suited to their project.

Table 6 – The three energy efficiency approaches.

1 FLEXIBLE APPROACH	2 PASSIVE DESIGN APPROACH	3 RENEWABLE ENERGY APPROACH
• Thermal energy demand intensity (TEDI) target • Energy use intensity (EUI) target	• Aggressive thermal energy demand intensity (TEDI) target	• Thermal energy demand intensity (TEDI) target • Zero carbon balance for operational carbon achieved without green power products or carbon offsets

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The first approach provides projects with the greatest flexibility, with multiple paths available for meeting both thermal energy demand and total energy use requirements.

The second approach recognizes projects that pursue more aggressive thermal energy demand reductions, putting additional emphasis on the building envelope and ventilation strategies.

The third approach provides a path for projects that wish to achieve zero carbon in their annual operations without relying on purchased measures like **carbon offsets** or **green power products** (e.g., **renewable energy certificates**). These projects will generally be smaller, achieving success by focusing on energy-use reductions and **renewable energy** from owned assets.

Energy models created for demonstrating compliance with the energy efficiency requirements must be prepared in accordance with the *ZCB-Design v4 Energy Modelling Guidelines*™.

Ka Ni Kanichihk Daycare Expansion, Winnipeg, Manitoba, ZCB-Design v2.

CORE ENERGY EFFICIENCY PRINCIPLES

The energy efficiency requirements of the Zero Carbon Building – Design (ZCB-Design) Standard™ are underpinned by two key metrics, **energy use intensity (EUI)** and **thermal energy demand intensity (TEDI)**. A brief introduction to the metrics is provided below.

ENERGY USE INTENSITY

Energy use intensity (EUI) refers to the annual sum of all site (not source) energy consumed on the project site (e.g., electricity, natural gas, district heat), including all process energy, divided by the building **modelled floor area**. The addition of onsite renewable energy does not reduce EUI.

Evaluating EUI ensures that the energy efficiency of all building systems is considered holistically. All energy efficiency strategies, both passive and active, contribute to reducing EUI. EUI is also important as it relates both to design and operations, enabling project teams to verify performance and evaluate design and construction practices.

THERMAL ENERGY DEMAND INTENSITY

Thermal energy demand intensity (TEDI) refers to the annual heat loss from a building's envelope and ventilation, after accounting for all passive heat gains and losses. When measured with modelling software, this is the amount of heating energy delivered to the project from all types of space heating equipment, per unit of **modelled floor area**. The inclusion of a TEDI metric helps contribute to greater occupant comfort and ensures that building designers focus on minimizing a building's demand for energy prior to producing or procuring **renewable energy**. The metric also helps to ensure long-term energy performance, as building envelopes have long life spans and yield very reliable efficiency gains. Furthermore, building envelope retrofits can be costly and are typically challenging to implement without disturbing occupants.

Finally, improved thermal performance correlates with improved resilience during power outages, as buildings are better able to maintain comfortable interior temperatures when the power supply is disrupted.

Ventilation strategies such as heat recovery and dedicated outdoor air systems can significantly impact TEDI. Strategies to improve building envelopes, such as increasing thermal insulation levels, can be effective in reducing TEDI. These strategies may increase the amount of **embodied carbon**, however, and project teams are encouraged to weigh the embodied carbon and **operational carbon** implications of their choice of building envelope strategies. Teams may also wish to consider the grid-level impacts, such as when the grid peaks and the marginal power generation source at that time, ensuring that the building's life cycle carbon is minimized.

The TEDI of a building increases as the climate gets colder. For this reason, climate zones are used to determine the TEDI targets for achieving ZCB-Design (see *Figure 8*).

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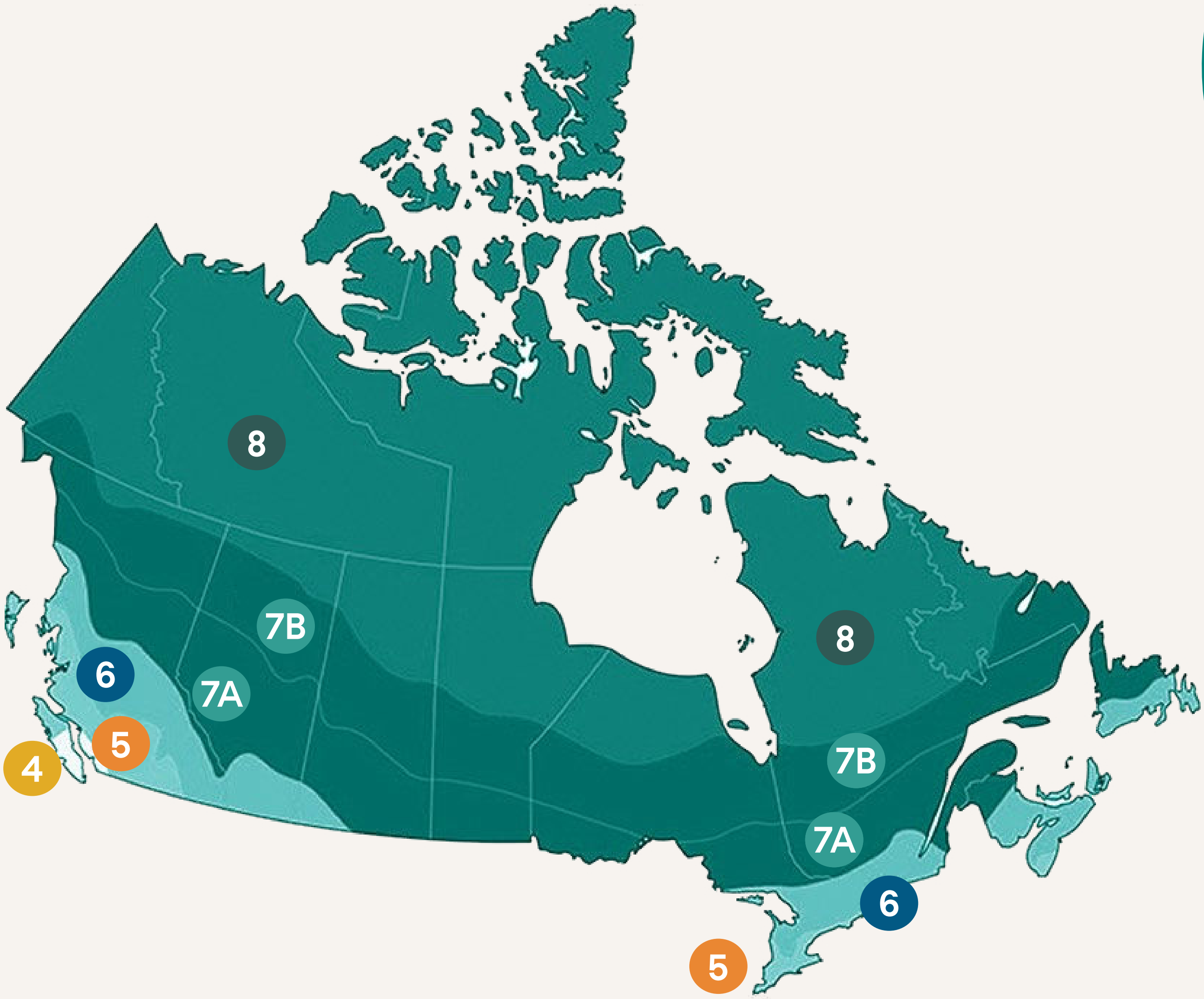

Figure 8 – Climate zones used to determine TEDI targets.

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6.1 FLEXIBLE APPROACH

The Flexible Approach provides a customizable path to satisfying the energy efficiency requirements of ZCB-Design. Projects are required to satisfy both TEDI and EUI requirements but may choose the best available pathway for each.

6.1.1 TEDI REQUIREMENTS

Projects pursuing the Flexible Approach can choose from four paths to meet **TEDI** requirements. These options provide flexibility to select the most appropriate pathway based on criteria such as whether onsite combustion is used, the project's location, and if the project has unique heating or ventilation loads.

Table 7 – TEDI pathways for Flexible Approach.

PATH	DESCRIPTION	ELIGIBILITY
1	No Combustion	All projects except those connecting to a district energy system (DES) with combustion-based technologies
2	ZCB-Design TEDI Target	All projects
3	Adjusted TEDI Target	Projects with unique heating and ventilation requirements or that are located in climate zones 7 or 8
4	Detailed TEDI Analysis	Projects with unique heating and ventilation requirements or that are located in climate zones 7 or 8

PATH 1: NO COMBUSTION

Projects that use non-combustion-based technologies (onsite or as part of a district energy system) for all space heating are not required to meet a **TEDI** target. Projects located in climate zones 4, 5, or 6 must demonstrate a space heating **seasonal coefficient of performance (SCOP)** of at least two to minimize energy consumption and **peak demand**. TEDI must still be reported.

Emergency **backup generators**, including those powered by fossil fuels, are permitted, provided they are used exclusively to prevent loss of heating or essential operations during power failures.

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PATH 2: ZCB-DESIGN TEDI TARGET

Projects pursuing this pathway must meet the **TEDI** targets outlined below, as a function of the project's climate zone.

Table 8 – TEDI targets for Path 2 of Flexible Approach.

CLIMATE ZONE	TEDI TARGET (kWh/m²/yr)
4	30
5	32
6	34
7	36
8	40

PATH 3: ADJUSTED TEDI TARGET

Projects with unique heating and ventilation requirements or that are in climate zones 7 or 8 can use an adjusted **TEDI** target. Projects that are unsure if their heating or ventilation loads qualify as unique should contact the Canada Green Building Council® (CAGBC) for guidance at zerocarbon@cagbc.org.

Projects pursuing this path must use the *National Energy Code of Canada for Buildings (NECB) 2020* prescriptive requirements (i.e., *NECB 2020* reference building) to determine the target for the portions of the building that have unique heating and ventilation loads and the ZCB-Design TEDI Targets (see *Table 8*) to determine the target for the remaining space. An adjusted TEDI target for the building is calculated by weighting the two targets based on floor area.

Projects must meet the following requirements:

- The building as a whole must meet the adjusted TEDI target;
- The portions of the building that do not have unique heating/ventilation loads must meet the ZCB-Design TEDI Target (see *Table 8*); and
- The entire building shall not exceed the maximum overall thermal transmittance values (U-values) of the NECB 2020, using either the prescriptive or trade-off methodology. *NECB 2020* U-values account for thermal bridging. Refer to the *ZCB-Design v4 Energy Modelling Guidelines*™ for more detail on *NECB 2020* U-value tables.

PATH 4: DETAILED TEDI ANALYSIS

Projects with unique heating and ventilation requirements, or that are in climate zones 7 or 8, have the option of completing a detailed TEDI analysis. Projects that are unsure if their heating or ventilation loads qualify as unique should contact CAGBC for guidance at zerocarbon@cagbc.org.

Under this path, the project must conduct modelling analysis and prepare a report that includes:

- A thermal breakdown showing TEDI values for each source of heating demand (ventilation, infiltration, envelope, reheat etc.);

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- A summary of the actions taken to reduce the TEDI for each source of heating demand;
- A rationale for why further action could not be taken for each source of heating demand, such as a financial comparison of different options or an explanation of technological or programmatic limitations;
- A summary of heat gains, including their impact on TEDI; and
- The entire building shall not exceed the maximum overall thermal transmittance values (U-values) of the *NECB 2020*, using either the prescriptive or trade-off methodology. *NECB 2020* U-values account for thermal bridging. Refer to the *ZCB-Design v4 Energy Modelling Guidelines*™ for more detail on *NECB 2020* U-value tables.

6.1.2 EUI REQUIREMENTS

Projects pursuing the Flexible Approach must demonstrate a minimum level of **energy use intensity (EUI)** performance. This may be demonstrated using a minimum improvement compared to an *NECB 2020* reference building or by achieving a minimum level of EUI performance, as per the eligibility requirements below.

Table 9 – EUI pathways for Flexible Approach.

PATH	DESCRIPTION	ELIGIBILITY
1	Improvement against reference building	All projects
2	Energy use intensity (EUI) target	Office, multi-unit residential, hotel/motel, retail

PATH 1: IMPROVEMENT AGAINST REFERENCE BUILDING

Site energy use intensity must be at least 25 percent better than Tier 1 of *NECB 2020*, without accounting for **renewable energy**.

PATH 2: ENERGY USE INTENSITY TARGET

Projects must meet the **EUI** targets from *Table 10*, as measured in kWh/m^2/yr, without accounting for **renewable energy**. Targets for projects in climate zones 7 and 8 are determined using a formula that accounts for the heating degree days used in the energy model weather file. Projects located in climate zone 8 may contact CAGBC if the calculated EUI target poses challenges.

Projects that have a mix of space types with their own respective EUI targets in *Table 10* (e.g., Retail and Office) shall use average weighted EUI targets, as outlined in the *ZCB-Design v4 Energy Modelling Guidelines*™. If one space type accounts for at least 75 percent of the building's total modelled floor area, the EUI target for the space type can be used for the entire building.

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Table 10 – EUI targets for Path 2: Energy Use Intensity.

CLIMATE ZONE	OFFICE	RETAIL	MULTI-UNIT RESIDENTIAL	HOTEL / MOTEL
4	95	90	95	120
5	95	90	100	130
6	95	95	110	130
7 and 8	0.0074 × HDD18 + 74	0.0068 × HDD18 + 67	0.011 × HDD18 + 63	0.0091 × HDD18 + 92

6.1.3 ADDITIONAL REPORTING REQUIREMENTS

The Flexible Approach also requires project teams to report the following energy metrics:

- The anticipated **EUI** of the building in kWh/m^2/year. EUI does not take into account onsite **renewable energy**.
- The anticipated summer and winter seasonal **peak demand** (or 'peak power'). Peak demand must represent the highest winter and summer electrical demand requirements on the grid, reflecting any peak-shaving impacts from demand management strategies, including onsite power generation or energy storage. Peak demand must be reported in kilowatts (kW).
- Projects with any onsite renewable energy, energy storage, or **demand response** capabilities that reduce peak electrical load should report the reduction as a percentage.

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6.2 PASSIVE DESIGN APPROACH

The Passive Design Approach recognizes those projects that pursue more aggressive thermal energy demand reductions by putting additional emphasis on the building envelope and ventilation strategies.

6.2.1 TEDI REQUIREMENTS

Projects must meet a more aggressive set of **TEDI** targets, as specified in *Table 11*.

Table 11 – TEDI targets for Passive Design Approach.

CLIMATE ZONE	TEDI TARGET (kWh/m²/yr)
4	20
5	22
6	24
7	26
8	30

6.2.2 ADDITIONAL REPORTING REQUIREMENTS

The Passive Design Approach also requires project teams to report the following energy metrics:

- The anticipated EUI of the building in kWh/m²/year. EUI does not take into account **onsite renewable energy**.
- The anticipated summer and winter seasonal peak demand (or 'peak power'). Peak demand must represent the highest winter and summer electrical demand requirements on the grid, reflecting any peak-shaving impacts from demand management strategies, including onsite power generation or energy storage. Peak demand must be reported in kilowatts (kW).
- Projects with any onsite renewable energy, energy storage, or **demand response** capabilities that reduce peak electrical load should report the reduction as a percentage.

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6.3 RENEWABLE ENERGY APPROACH

The Renewable Energy Approach provides a path for projects that wish to achieve zero carbon in their annual operations without relying on purchased measures such as **carbon offsets** or **green power products** (e.g., **renewable energy certificates**). Such projects are generally smaller and achieve success by focusing on energy use reductions and renewable energy from owned assets (see Section *3.2.2.2 Owned Renewable Energy Systems*).

6.3.1 TEDI REQUIREMENTS

Projects must meet the **TEDI** targets specified in *Table 12*.

Table 12 – TEDI targets for Renewable Energy Approach.

CLIMATE ZONE	TEDI TARGET (kWh/m²/yr)
4	30
5	32
6	34
7	36
8	40

6.3.2 ZERO CARBON BALANCE REQUIREMENTS

Projects must achieve a zero carbon balance for **operational carbon** without **green power products** or **carbon offsets**. Refer to Section *3.2 Operational Carbon* for more information on carbon accounting.

6.3.3 ADDITIONAL REPORTING REQUIREMENTS

The Renewable Energy Approach also requires project teams to report the following energy metrics:

- The anticipated **EUI** of the building in kWh/m²/year. EUI does not account for **onsite renewable energy**.
- The anticipated summer and winter seasonal **peak demand** (or 'peak power'). Peak demand must represent the highest winter and summer electrical demand requirements on the grid, reflecting any peak-shaving impacts from demand management strategies, including onsite power generation or energy storage. Peak demand must be reported in kilowatts (kW).
- Projects with any **onsite renewable energy**, energy storage, or **demand response** capabilities that reduce peak electrical load should report the reduction as a percentage.

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07 RESILIENCY TO EXTREME WEATHER

Project teams are encouraged to evaluate their design's sensitivity to future extreme weather conditions.

Assessing climate resilience helps manage physical and financial risk, occupant safety, and can impact the energy and emissions performance of the building.

As average global temperatures increase, the changing climate will result in more frequent and severe weather events such as high winds, ice storms, flooding, and periods of extreme heat and cold. Changing weather will also increase the risk from wildfire. This will pose increased risks to buildings and the infrastructure they rely on, such as electricity grids, thermal networks, and transportation systems. Project teams should understand that meeting current design conditions does not ensure the building will deliver satisfactory performance over its lifetime.

Building design can be adapted to future weather conditions, such as adjusting structural elements to support heavier snow loads, situating mechanical and electrical systems to avoid damage from flooding, and designing ventilation systems to cope with poor air quality from wildfires. Project teams are encouraged to evaluate resiliency and adaptation strategies broadly. Particular attention should be paid to the impact of heat, humidity, and wildfire smoke on the HVAC and envelope systems that are core to the achievement of ZCB-Design certification.

ANALYSIS OF FUTURE DESIGN CONDITIONS

Project teams are encouraged to use the future design conditions for heat and humidity to inform their design. Teams may consider making improvements to the building envelope, such as better U-values, greater airtightness, and solar shading. Adjustments to massing and orientation may be contemplated. Ventilation strategies, including dedicated outdoor air systems (DOAS) and higher-performing heat recovery, may reduce the impact of hotter and longer duration summer extremes. HVAC and controls provisions for responding to smoke from wildfires are encouraged to be evaluated.[25]

Project teams may also consider making provisions to facilitate future upgrades that will allow the building to adapt to more extreme weather conditions, such as right-sizing HVAC terminal and distribution systems, provision of additional electrical capacity, allotment of space for additional cooling equipment, and/or measures to accommodate shade elements.

[25] ASHRAE is working on a guideline, see *Planning Framework for Protecting Commercial Building Occupants from Smoke During Wildfire Events*.

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Projections of future design conditions for temperature and humidity are available from the Pacific Climate Impacts Consortium's (PCIC) Design Value Explorer. The Global Warming Level (GWL) "1.5 C above 1986-2016" scenario can provide guidance on the conditions the building is likely to face in the near term, while the "3.0 C above 1986-2016" scenario can provide guidance on the conditions the building might face late in the likely life expectancy of a typical building envelope.[26]

The TJul97.5 and/or TwJul97.5 values represent the projected increase in design temperature and humidity.[27]

ANALYSIS OF FUTURE BUILDING PERFORMANCE

Project teams may also evaluate how well the proposed design is expected to maintain thermal comfort in a representative future year. Performing an hourly simulation using a future weather file with the same Global Warming Level (GWL) as above (1.5 C and 3.0 C) can, for example, determine the unmet hours for different zones of the building.

Future weather files are available from PCIC and National Research Council Canada (NRC).[28] PCIC's future weather files for "RCP 8.5 2050s scenario",[29] or NRC's "GW 2.0 scenario"[30] weather files, can be used for evaluating overheating risk and resilience to future extreme climate conditions and temperature events.[31]

Project teams may also find value in modelling the impact extreme heat events have on the energy and emissions performance of the building.

REPORTING

Project teams that evaluate the implications of future extreme weather are encouraged to provide their findings in the appropriate section of the *ZCB-Design v4 Workbook*™ and in the project narrative.

[26] The Representative Concentration Pathway (RCP) 8.5 emissions scenario corresponds to an estimated 3.0 C global temperature increase by the year 2080.

[27] Values can be found by selecting the project location from the Design Value Explorer map, then finding the intersection of the 1.5 or 3.0 C column and the TJul97.5 (and/or TwJul97.5) row.

[28] Selection of future climate files for modelling should account for design service life of building and/or building components, and the selected Global Warming Level.

[29] From the link provided, click "Access the future-shifted weather files", choose city, click "Show", and download the file for the 2050s time period.

[30] From the link provided, click "View downloads" and then download the user guide for assistance.

[31] NRC GW 2.0 scenario corresponds to 2034-2064 and is roughly equivalent to PCIC RCP 8.5 2050s scenario.

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Go to 8.0 AIRTIGHTNESS >

08
AIRTIGHTNESS

Airtightness is a critical factor for energy consumption, occupant comfort, and resilience in high-performance buildings.

Zero Carbon Building – Design (ZCB-Design) Standard™ projects are eligible to submit for certification once construction documents are ready. Therefore, ZCB-Design does not require projects to perform airtightness testing for certification.

Careful attention to detailing at the design phase, and diligent implementation and inspection at construction, are required to achieve high levels of airtightness.

The *ZCB-Design v4 Workbook*™ specify a default air leakage rate. Airtightness testing must be conducted prior to Zero Carbon Building – Performance (ZCB-Performance) Standard™ certification, providing an opportunity to verify results against expectations. Therefore, energy models can assume an air leakage rate lower than the default value.

Project teams that wish to use an air leakage value that is lower than the default must explain what strategies are being taken to ensure the lower value is met as well as provide a sensitivity analysis, as described in the *ZCB-Design v4 Energy Modelling Guidelines*™.

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09
GRID CITIZENSHIP

Provincial and municipal electrical grids are experiencing pressure as populations grow, urban areas densify, the economy electrifies, the IT sector grows, and extreme weather events challenge the reliability of utility service delivery. Designers should consider how buildings can be good grid citizens.

Good grid citizenship is the responsibility of all stakeholders. Regulators, utilities and electrical system operators play a critical role in incenting responsible conservation measures at the building level.

Good grid citizenship means taking measures to diminish the need for additional electrical grid power generation, transmission, and distribution capacity, while helping improve the resilience and reliability of the electrical grid. An important element of good grid citizenship is contributing to meeting increasing needs for power through onsite or offsite owned **renewable energy** systems.

Even more critical is reducing the building's peak electrical demand. An individual building's **peak demand** is likely to coincide with peak demand on the grid, contributing to the sizing of electrical infrastructure. As peak power generation often relies on dispatchable energy sources (such as natural gas) that are more carbon-intensive than baseload energy sources, managing peak demand can also reduce the carbon intensity of electricity in many regions.

Finally, buildings can also be designed to attenuate electrical demand in response to signals from the electrical grid.

It is incumbent on all stakeholders to consider how to ensure the decarbonization of Canada's economy can proceed cost-effectively and in a manner that maintains the reliability of our electricity. Regulators, utilities, and electricity system operators can encourage buildings to be good grid citizens. In many cases, there are already conservation programs, rate structures targeting peak demand, and other market signals.

To understand the impacts of designs on electrical grids, both summer and winter seasonal peak demand need to be considered. Projects must report their winter and summer peak demand, as *per the Additional Reporting Requirements of the Energy Efficiency Approaches*, Sections *6.1.3*, *6.2.2*, and *6.3.3*.

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Project teams should consider additional measures to reduce peak demand and improve grid citizenship, including:

- **Onsite renewable energy**, such as solar and wind power,
- Electrical and/or thermal energy storage,
- Demand-response capabilities.

Where any of the above measures are implemented, projects should report the percent reduction in summer and winter peak demand, as per Sections *6.1.3*, *6.2.2*, and *6.3.3*. To encourage consideration of these measures, Section *10.0 Impact & Innovation* includes strategies that recognize efforts towards good grid citizenship.

Okanagan College Health Sciences Center, Kelowna, British Columbia, ZCB-Design v1.

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10
IMPACT & INNOVATION

The Impact and Innovation requirements ensure that project teams pursuing Zero Carbon Building – Design (ZCB-Design) Standard™ certification incorporate strategies that take advantage of new technologies and design approaches for new buildings and major renovations.

Incorporating these strategies can not only improve the carbon and energy performance of projects, but also help build skills and develop markets across Canada for low-carbon products and services.

Design strategies for achieving zero carbon buildings are constantly evolving and improving. New technologies are continually introduced to the marketplace, and ongoing scientific research in this space influences building design strategies.

ZCB-Design certification requires projects to demonstrate the inclusion of at least two Impact and Innovation strategies into design. At least one of these strategies must come from the numbered list of pre-approved strategies below.

GOOD GRID CITIZENSHIP STRATEGIES

1. Reduce annual peak electrical demand by 10% using **onsite renewable energy** and/or energy storage.
2. Reduce annual peak electrical demand intensity to no more than 18 W/m^2 of **gross floor area** for warehouses and distribution centres (except cold storage), or 30 W/m^2 for all other buildings.
3. Incorporate intelligent building systems that can receive and automatically respond to demand response requests from a utility, electrical system operator, or third-party **demand response** program provider, ensuring the building is able to respond by shedding at least 10% of its electricity demand. Projects must also:
   - Provide the details of the demand response program; and,
   - Demonstrate how the building design and operation strategies will allow it to meet the demand response program's eligibility requirements; and,
   - Confirm the building operator will participate in the demand response program.

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4. Incorporate **onsite renewable energy** systems capable of generating 5% of total energy needs onsite, or solar photovoltaic systems covering 40% of the **gross roof area**. Refer to Section *3.2.2.2 Owned Renewable Energy Systems* for details of the requirements for **onsite renewable energy** systems.
5. Incorporate **building integrated photovoltaics (BIPV)** capable of meeting 2% of total energy needs or covering 15% of the total façade area and/or total roof area. Systems must be seamlessly integrated into building components such as the windows, roofs, or building façades to be eligible.

OPERATIONAL CARBON STRATEGIES

6. Provide 100% of space heating using non-combustion-based technologies.
7. Design **service hot water** systems to operate without combustion in multi-unit residential buildings or long-term care facilities. Other building types with significant service hot water needs will be considered on a case-by-case basis.
8. Use refrigerants with a 100-year **global warming potential (GWP)** lower than 750 in all heat pump equipment that serves as the **primary heating system**.

EMBODIED CARBON STRATEGIES

9. Limit **upfront carbon** emissions (life cycle phase A) to zero or less after accounting for **biogenic carbon** sequestration.
10. Demonstrate an improvement beyond the required minimum level of performance needed for **embodied carbon** by meeting one of the following:
    - Embodied carbon at least 20% less than a functionally equivalent baseline building.
    - Embodied carbon intensity of no more than 350 kg CO_2e /m^2 of built floor area for all buildings except warehouses and distribution centres, or 275 kg CO_2e /m^2 of built floor area for warehouses and distribution centres, including similar structures with untenanted spaces.
11. Demonstrate deeper reductions in embodied carbon by meeting one of the following:[32]
    - Embodied carbon at least 40% less than a functionally equivalent baseline building.
    - Embodied carbon intensity of no more than 260 kg CO_2e /m^2 of built floor area for all buildings except warehouses and distribution centres, or 230 kg CO_2e /m^2 of built floor area for warehouses and distribution centres, including similar structures with untenanted spaces.

Additional Impact and Innovation strategies may be proposed to the Canada Green Building Council® (CAGBC) for approval. Project teams must be prepared to demonstrate the environmental benefits associated with their strategy using the carbon and energy metrics of the ZCB-Design Standard and provide information to support the strategy as appropriate for the project. Only one of the two required innovation strategies may be an alternative strategy.

Projects are encouraged to submit a ZCB Interpretation or contact CAGBC at zerocarbon@cagbc.org early in design to review potential alternate innovation strategies.

[32] Strategies 11 and 12 are independent; a project earning strategy 11 by necessity earns strategy 10.

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APPENDIX I – REQUIREMENTS FOR BUNDLED GREEN POWER PRODUCTS THAT ARE NOT ECOLOGO OR GREEN-E® CERTIFIED

Bundled green power products that are not ECOLOGO or Green-e® Energy certified may be used if the applicant can demonstrate that the **green power** facility meets the following criteria:

- Electricity is generated within the calendar year in which the product is sold, the first three months of the following calendar year, or the last six months of the prior calendar year.
- Electricity generating equipment was placed in operation no more than 15 years ago or repowered no more than 15 years ago such that 80% of the fair market value of the project is derived from new generation equipment installed as part of the repowering.
- Local land use polices and building codes are conformed to. The green power project must achieve planning permission and all applicable local permits as defined by the Authority Having Jurisdiction.
- The requirements of the acceptable sources of offsite green power are met (see Section *3.2.2.3 Green Power Products*).
- For combustion-based systems, the requirements for biogas and biomass are met (see Sections *3.2.1.2.1 Biogas* and *3.2.1.2.2 Biomass*).
- For combustion-based systems, all local and regional air quality by-laws and requirements are met, and all necessary air quality permits are received from the Authority Having Jurisdiction.
- For all water-powered systems, the facility's installation and operations must achieve all regulatory licenses, requirements, and all other authorizations pertaining to fisheries, without regard to waivers or variances authorized. These include authorizations issued by the relevant provincial authorities, and under Section 35(2) of the *Fisheries Act*, by the Minister of Fisheries and Oceans or regulations made by the Governor in Council under the *Fisheries Act*.
- For all water-powered systems, the facility's installation and operations may not achieve authorization with terms that allow for the harmful operation and or disruption or destruction of fish habitat, as verified by a registered professional biologist.
- For wind-powered systems, the facility must not be in known migratory routes for avian or bat species, and the impacts on avian and bat species must be minimized as verified by a registered professional biologist.

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In addition, applicants must provide the following documentation:

- A report that notes the methodology and calculations that were used to ensure that the design and operation of the facility will be sufficient to meet the contractual commitment made to the applicant. It will also note and detail the resources used to generate the energy and outline any limiting factors that may impact the ability of the facility to deliver energy. In such cases where resources are prone to fluctuations, a range will be provided to represent the best and worst-case scenarios, noting the methodology used to develop these scenarios (e.g., if the wind blows as anticipated; if the wind blows at the lowest annual recorded levels, etc.).
- Proof of the commitment to retire the **environmental attributes** (i.e., **renewable energy certificates (RECs)**) that have been procured by the applicant. For example, the project team could provide proof that RECs have been registered within a third-party tracking system that will ensure the RECs are retired (not made available to others).

The Co-operators, Guelph, Ontario, ZCB-Design v1.

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APPENDIX II – REQUIREMENTS FOR DISTRICT ENERGY SYSTEMS

For convenience, all information in Zero Carbon Building – Design (ZCB-Design) Standard™ v4 pertaining to buildings connecting to **district energy systems (DES)** is summarized below.

Ineligibility for **thermal energy demand intensity (TEDI)** exemption if **DES** uses combustion (Section *6.1 Flexible Approach, Path 1: No Combustion*):

- Projects connecting to district energy systems with combustion-based technologies are not eligible for the No Combustion pathway for TEDI compliance in the Flexible Approach for demonstrating energy efficiency.

Accounting for Indirect Emissions from electricity provided by a DES (Section *3.2.2.1 Electricity*):

- The ZCB-Design Standard recognizes that in some instances electricity may be sourced from a district energy system or an **islanded grid** (a small grid not connected to the provincial grid). The **emission factors** for these specific sources may be used where they are available and can be verified by a registered professional. Projects wishing to use this option may enter a custom emissions factor in the *ZCB-Design v4 Workbook*™.

Accounting for green heat from a DES (Section *3.2.2.4.1 Green Heat from District Energy Systems*):

- **Green heat** is district heating that is generated using clean energy technologies or **zero emissions biofuels**. When the associated **environmental attributes** are bundled in the purchase of green heat, each unit of procured green heat energy can replace an equivalent amount of district heating in the calculation of the carbon balance. Procured green heat cannot be used to reduce other sources of emissions.
- To claim green heat, a signed commitment letter from the building owner to procure green heat for the project must be provided, along with confirmation from the district energy provider that sufficient green heat from non-combustion-based sources is available. The green heat must be generated from sources on the district energy system to which the building is connected.
- The accounting for the district energy provider's green heat program must meet the quality criteria established by the GHG Protocol Scope 2 Guidance.[33] The district energy provider must obtain an annual third-party audit of the generation and sale of green heat as well as compliance with the quality criteria.

[33] World Resources Institute. (2015). *GHG Protocol Scope 2 Guidance*. Table 7.1 page 60.

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Requirements of a **Transition Plan** for a district energy system with combustion-based technologies (Section *5.4, Path 3: Transition Plan*):

- A Transition Plan for the district energy system that shows how the system will adapt over time to remove combustion from its operations. The Transition Plan must include:
  - A general description of the current district energy system operations.
  - A description of each thermal energy generation system, including:
    - Capacity and output;
    - Fuel mix and respective consumption; and
    - Greenhouse gas (GHG) intensity of each output (chilled water, hot water, steam, and electricity), as applicable.
  - Details of any established district energy system decarbonization goals, including GHG reduction targets and timelines.
  - A conceptual **district energy system** decarbonization study, including technologies and pathways considered, an analysis of options against clear evaluation criteria, and a recommended path to decarbonization. The study must also include a high-level analysis of capital and operating cost implications (relative including $/ tonne CO_2e reduced) for the options considered.

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APPENDIX III – SUMMARY OF V4 CHANGES

Building standards must evolve with the market and take advantage of new ideas, new technologies and new processes. The fourth iteration of the Zero Carbon Building – Design (ZCB-Design) Standard™ continues the trend of introducing greater rigour while maintaining flexibility to support the goal of achieving zero carbon across all buildings and geographies. To further the effectiveness and market uptake of ZCB-Design, the following key enhancements were made.

1. **Embodied carbon:** As market knowledge of low-**embodied carbon** design continues to improve, the availability of low-carbon materials expands, and more project data become available, ZCB-Design v4 has been able to refine embodied carbon requirements. More stringent objectives have been set, and warehouses and distribution centres have been differentiated. Targets can still be met using an improvement against a baseline or an embodied carbon intensity threshold.

2. **Onsite combustion:** Over 78 percent of Canadian building emissions emanate from fossil fuel combustion for space heating and **service hot water**.[34] This represents significant **direct emissions** from building operations. ZCB-Design v4 imposes a new limit to onsite combustion for service hot water production to minimize or eliminate fossil fuel consumption, depending on building type and hot water demand. The Impact and Innovation strategy will remain for multi-unit residential buildings, long-term care facilities, and other building types with high hot water demand that provide 100 percent of service hot water without onsite combustion. The onsite combustion limit for space heating has also been lowered from -10 C to -15 C, representing further emissions reductions from operations.

3. **Zero Carbon Transition Plans:** While over 70 percent of buildings certified to ZCB-Design are fully electric, not all buildings can readily eliminate combustion for space heating and service hot water. For those buildings that still rely on onsite combustion for some space heating or service hot water, additional guidance and new requirements are provided to assist projects in further decarbonizing operations. An alternative design that does not use onsite combustion must be evaluated, including a detailed financial analysis. Buildings connecting to **district energy systems** with combustion will benefit from additional guidance for detailing **Zero Carbon Transition Plan** requirements for the district energy system.

4. **Refrigerants:** Refrigerants are an increasingly important issue as buildings decarbonize their operations with heat pump technology, which can be a significant source of greenhouse gases through **fugitive emissions**. ZCB-Design v4 expands the range of mechanical equipment that must be reported to include all heating, ventilation, and air

[34] https://natural-resources.canada.ca/energy-efficiency/green-buildings/green-building-principles/25301

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conditioning (HVAC) equipment, service hot water systems, and commercial refrigeration equipment.

Additionally, assumed annual refrigerant leakage is now factored into the carbon balance, which aligns with the scope of emissions reporting in the Zero Carbon Building – Performance (ZCB-Performance) Standard™. Maximum **global warming potential (GWP)** limits have also been introduced for refrigerants in different types of equipment. The Impact and Innovation strategy for projects that use low-GWP refrigerants (GWP below 750) is maintained.

5. **Good grid citizenship:** As different sectors of the economy electrify, it is incumbent on all stakeholders to ensure this transition can proceed cost-effectively and in a manner that maintains reliability. Regulators, utilities, and electricity system operators can encourage buildings to be good grid citizens. In many cases, there are already conservation programs, rate structures, and other pricing signals to support good grid citizenship. To further encourage building owners and designers to consider measures that reduce the impact of buildings on electrical grids, ZCB-Design v4 introduces three good grid citizenship strategies to Section *10.0 Impact & Innovation*. These include peak electrical demand reduction thresholds, peak electrical demand intensity targets, and dynamic **demand response**. The existing Impact and Innovation strategy for **onsite renewable energy** generation remains.

6. **Resiliency:** Guidance is provided to assist project teams in evaluating the possible impact of future design conditions for heat, humidity and wildfire smoke, and to help them evaluate the proposed design's ability to maintain thermal comfort in a representative future year.

7. **Updating to NECB 2020:** *The National Energy Code of Canada for Buildings (NECB)* has been updated since the previous 2017 version, allowing ZCB-Design v4 to now leverage *NECB 2020*.

8. **EUI Targets:** Office and multi-unit residential building **energy use intensity (EUI)** targets have been lowered for climate zones 4, 5, and 6. New guidance has been added for mixed-use buildings to determine an EUI target based on the proportion of floor area of each occupancy type.

9. **Layout and wayfinding:** Improvements have been made to the structure and layout of the Standard to make it more user-friendly and easier to navigate.

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APPENDIX IV – EQUIPMENT DESCRIPTIONS

REFRIGERATION SYSTEM TYPE	DESCRIPTION
Stand-alone medium temperature refrigeration system	Self-contained refrigeration system with components that are integrated within its structure and that is designed to maintain an internal temperature ≥ 0°C.
Stand-alone low temperature refrigeration system	Self-contained refrigeration system with components that are integrated within its structure and that is designed to maintain an internal temperature < 0°C but not < -50°C.
Centralized refrigeration system	Refrigeration system with a cooling evaporator in the refrigerated space connected to a compressor rack located in a machinery room and to a condenser located outdoors, and that is designed to maintain an internal temperature at ≥ -50°C.
Condensing unit	Refrigeration system with a cooling evaporator in the refrigerated space connected to a compressor and condenser unit that are located in a different location, and that is designed to maintain an internal temperature at ≥ -50°C.
Chiller	Refrigeration or air-conditioning system that has a compressor, an evaporator and a secondary coolant, other than an absorption chiller or adsorption chiller.
Commercial air conditioning (AC) system	Air conditioning system, other than a chiller, including large single split or multi-split air-conditioning, variable refrigerant flow (VRF) systems and ducted or packaged rooftop systems.
Heat Pump	Reversible air-conditioning / heat pump units that can operate as an air-conditioning unit in hot weather or can provide heating in cold weather, other than an absorption heat pump or an adsorption heat pump. In heating mode, the indoor unit functions as condenser and the outdoor unit as evaporator.

Reproduced from Environment and Climate Change Canada (2023). *Federal Offset Protocol: Reducing Greenhouse Gas Emissions from Refrigeration Systems*. Values are from Table 1 Baseline Scenario Refrigeration Systems.

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GLOSSARY

Auxiliary heating system: An alternate or secondary heating system designed to support the **primary heating system**, enabling the building to meet indoor temperature setpoints.

Backup generators: A power system intended only for emergency use to prevent loss of heating or essential operations during a power failure.

Beyond the life cycle carbon: Emissions or emissions savings from the reuse or recycling of building materials at the end of life, or emissions avoided through energy capture by using end of life materials as fuel (life cycle stage D). **Beyond the life cycle carbon** is part of **life cycle assessment** but is not included in the definition of **embodied carbon**.

Biogenic carbon: The carbon stored in **biomaterials** through natural processes, but not fossilized or derived from fossil resources.

Biomaterial: A material derived from, or produced by, biological organisms like plants, animals, bacteria, fungi and other life forms.

Building integrated photovoltaic (BIPV): Solar power generating building products or systems that are seamlessly integrated into the building envelope, replacing conventional building material.

Built Floor Area (BFA): The BFA is the **gross floor area** with the addition of the floor area of any underground spaces including parking garages or attached garages that form part of the building. Note that the floor area attributed to balconies and terraces is excluded from this definition.

Bundled green power product: A product that includes both **green power** and the associated **environmental attributes (RECs)**, such as **power purchase agreements (PPAs)** or **utility green power**.

Carbon offset: A credit for reductions in greenhouse gas emissions that occur somewhere else, which can be purchased to compensate for the emissions of a company or project. High quality **carbon offsets** include third party verification of emissions reductions as well as additionality, permanence, and leakage criteria.

Demand response: The ability of a building to reduce electricity demand in response to a signal from the electrical grid.

Direct emissions: Emissions that occur directly at the project site, for example, natural gas that may leak or be combusted to heat the building.

District energy system: An energy system that supplies heating, cooling and/or power to multiple buildings from a centralized plant or from several interconnected but distributed plants.

Embodied carbon: Carbon emissions associated with materials and construction processes throughout the whole-life cycle of a building.

Emissions factor: A conversion factor that is used to estimate the emissions associated with a measurable activity, such as energy use for heating or cooling a building.

End of life carbon: The **embodied carbon** emissions associated with deconstruction or demolition of a building, including transport from site, waste processing, and disposal stages (stages C1-4) of a building's life cycle.

Energy use intensity (EUI): The sum of all **site energy** (not **source energy**) consumed onsite (e.g., electricity, natural gas, district heat), including all process loads, divided by the building **modelled floor area**.

Environmental attributes: The representation of the environmental costs and benefits associated with a fixed amount of energy generation.

Fugitive emissions: Emissions that occur accidentally because of gas leaks. Natural gas and refrigerants are common sources of **fugitive emissions**.

Geo-exchange: A system that exchanges heat with the earth or a body of water, usually with the goal of providing efficient heating and cooling using heat pumps.

Global warming potential (GWP): A measure of how much heat is trapped by a greenhouse gas over a specified timeframe, relative to carbon dioxide.

Green heat: District heating that is generated using clean energy technologies or **zero emissions biofuels**. **Green heat** may not be generated from the direct combustion of fossil fuels. Examples of **green heat** include thermal energy generated from heat pump technology, qualifying biomass, or qualifying biogas (renewable natural gas).

Green power: Electricity generated from renewable resources such as solar, wind, geothermal, low-impact biomass, and low-impact hydro resources. **Green power** is a subset of **renewable energy**, but does not include **renewable energy systems** that do not produce electricity, such as solar thermal systems.

Green power product: A contractual purchase of offsite green power. Green power may be in the form of **bundled green power products** or **renewable energy certificates (RECs)**.

Gross floor area (GFA): Consistent with ASHRAE & LEED, the gross floor area is the sum of the floor areas of all enclosed spaces inside the building. Measurements must include walls and therefore must be taken from the exterior faces of exterior walls. Enclosed parking and access roads are excluded, as are air shafts, pipe trenches, chimneys, and penthouse spaces with headroom height of less than 2.2 meters (7.5 feet).

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Gross roof area: The total surface area of a building's roof, including all covered sections, projections, and overhangs. It is measured from the exterior faces of the roof's structure.

Indirect emissions: Emissions that do not occur directly within the project site, such as emissions associated with purchased energy, water use, waste, and transportation from commuting.

Islanded grid: A small electricity grid that is not connected to the provincial grid.

Life cycle assessment (LCA): As defined by ISO 14040, LCA is a systematic set of procedures for compiling and examining the inputs and outputs of materials and energy, and the associated environmental impacts directly attributable to a building, infrastructure, product, or material throughout its life cycle. When the process is applied to a building, rather than the building products and elements, it is referred to as **whole-building LCA (wbLCA)**.

Location-based electricity grid emissions factor: An emissions factor for an electricity grid that is based on the average emissions intensity of all types of generation within a defined locational boundary.

Marginal electricity grid emissions factor: An **emissions factor** for an electricity grid that is based on the emissions intensity of the peaking (non-baseload) generation within a defined locational boundary.

Modelled floor area (MFA): The total enclosed floor area of the building, as reported by the energy simulation software, excluding exterior areas and indoor (including underground) parking areas. All other spaces, including partially conditioned and unconditioned spaces, are included in the MFA.

Near-term climate forcer: A greenhouse gas that has a short atmospheric life and a high global warming potential, which results in a near-term warming effect.

Net-metering: An arrangement with the electric utility that allows the export of excess green power to the local grid in exchange for a credit on the building's electricity bill.

Onsite renewable energy: **Renewable energy** that is generated onsite. Where a site is not connected to the electricity grid, only the energy that can be consumed (or stored and then consumed) onsite is considered onsite renewable energy.

Operational carbon: The emissions associated with refrigerant leaks, or the energy used to operate the building.

Peak demand: The building's highest electrical load requirement on the grid, measured and reported in kW, reflecting any peak shaving impacts from demand management strategies including onsite renewable energy and energy storage.

Power purchase agreement (PPA): A power purchase agreement is a contract for green power and the associated **environmental attributes** that typically includes the purchase of a significant volume of electricity under a contract that lasts for at least fifteen years.

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Primary heating system: The main system responsible for providing the base heating requirements of a building or space under standard operating conditions.

Renewable energy: A source of energy that is replenished through natural processes or using sustainable management policies such that it is not depleted at current levels of consumption. Examples include solar and wind energy used for power generation and solar energy used for heating. Air-source and ground-source (**geo-exchange**) heat pump systems do not constitute renewable energy systems.

Renewable energy certificate (REC): An authorized electronic or paper representation of the **environmental attributes** associated with the generation of one megawatt hour of **renewable energy**.

Residual mix emissions factor: An **emissions factor** that has been adjusted to account for the retiring of contractual arrangements (such as RECs) within a defined geographic boundary.

Seasonal coefficient of performance (SCOP): A measure of system efficiency calculated by dividing the annual heating load of the building by the annual energy use for space heating. Refer to the *ZCB-Design v4 Energy Modelling Guidelines*™.

Service hot water: Heating water for domestic or commercial purposes other than space heating and process application requirements.

Site energy: The amount of energy used on the building site.

Source energy: The amount of raw fuel that is required to operate the building, incorporating all transmission, delivery, and production losses (such as in the generation and transmission of electricity).

Thermal energy demand intensity (TEDI): The annual heat loss from a building's envelope and ventilation after accounting for all passive heat gains and losses, per unit of **modelled floor area**.

Transition Plan: Refers to a **Zero Carbon Transition Plan**.

Upfront carbon: The **embodied carbon** emissions caused in the materials production and construction stages (stages A1-5) of the life cycle before the building is operational.

Use stage embodied carbon: The **embodied carbon** emissions associated with materials and processes needed to maintain the building during use such as for refurbishments (stages B1-5). These are additional to **operational carbon** emissions.

Utility green power: Utility green power is a product offered by some utilities in Canada where the electricity and the associated **environmental attributes** (in the form of **RECs**) are sold together.

Virtual net-metering: An arrangement with the electric utility whereby **green power** generation equipment is installed offsite and the electricity produced is credited (deducted from) the building's electricity bill.

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Whole-building life cycle assessment (wbLCA): The application of **life cycle assessment** to a building.

Whole-life carbon: Emissions from all life cycle stages, encompassing both **embodied carbon** and **operational carbon** together (stages A1 to C4).

Zero carbon building (ZCB): A highly energy-efficient building that produces onsite, or procures, carbon-free **renewable energy** or high-quality **carbon offsets** in an amount sufficient to offset the annual carbon emissions associated with building materials and operations.

Zero Carbon Transition Plan: A costed plan that outlines how a building will adapt over time to remove combustion from building operations, and as a result, remove operational **carbon offsets**.

Zero emissions biofuel: Biogas or biomass fuels considered to be carbon neutral as the amount of carbon released by combustion approximately equates to the carbon that would have been released by natural decomposition processes.

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ACRONYMS

BIPV: Building integrated photovoltaic

BFA: Built floor area

CO_2e: Carbon dioxide equivalents

COP: Coefficient of performance

EUI: Energy use intensity

GFA: Gross floor area

GWP: Global warming potential

HVAC: Heating, ventilation, and air conditioning

kWh: Kilowatt hour

LCA: Life cycle assessment

MFA: Modelled floor area

NECB: National Energy Code of Canada for Buildings

PPA: Power purchase agreement

REC: Renewable energy certificate

SCOP: Seasonal coefficient of performance

TEDI: Thermal energy demand intensity

VRF: Variable refrigerant flow

wbLCA: Whole-building life cycle assessment

ZCB: Zero carbon building

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RESOURCES

17.1 EMBODIED CARBON RESOURCES

National Research Council – National Whole-building Life Cycle Assessment Practitioner's Guide: Guidance for Compliance Reporting of Embodied Carbon in Canadian Building Construction
https://nrc-publications.canada.ca/eng/view/object/?id=533906ca-65eb-4118-865d-855030d91ef2

This document provides practical guidance on how to assess and demonstrate reductions in the estimated embodied carbon of designs for new construction or building renovation in Canada. It is meant to complement and be used in conjunction with the National Guidelines for *Whole-Building Life Cycle Assessment*.

National Research Council – National Guidelines for Whole-Building Life Cycle Assessment
https://nrc-publications.canada.ca/eng/view/object/?id=f7bd265d-cc3d-4848-a666-8eeb1fbde910

This document provides comprehensive instruction for the practice of **life cycle assessment** applied to buildings, based on relevant standards and keyed to various intentions. The goal is to harmonize the practice of **whole-building life cycle assessment (wbLCA)** across different studies and assist in interpretation of and compliance with relevant standards.

Strategies for Low Carbon Concrete: Primer for Federal Government Procurement
https://nrc-publications.canada.ca/eng/view/object/?id=d15ccce0-277b-4eed-80ac-d0462b17de57

Produced by the National Research Council through the Low-Carbon Assets Through Life Cycle Assessment initiative[2], this primer introduces the concept of **embodied carbon** of concrete, presents current industry best practices to reduce CO_2 emissions associated with concrete production, identifies approaches in mix design and specification, and provides a high-level overview of the federal procurement process with potential insertion points where new low-carbon concrete policies and procedures could be introduced into the federal procurement process.

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Carbon Leadership Forum Resource Library
https://carbonleadershipforum.org/resource-library/

The Carbon Leadership Forum is an organization at the University of Washington that works to accelerate the reduction of **embodied carbon** within the building sector. They produce numerous research papers and resources that are useful for practitioners, including:

- Carbon Leadership Forum Material Baselines for North America, August 2023
- Embodied Carbon Benchmark Study (work is underway on version 2)
- Tools for Measuring Embodied Carbon

Additionally, they include regional hubs throughout North America and an online community where practitioners can discuss and pose questions.

The Carbon Smart Materials Palette
https://materialspalette.org/

The Carbon Smart Materials Palette, produced by Architecture 2030, provides attribute-based design and material specification guidance for immediately impactful, globally applicable and scalable **embodied carbon** reductions in the built environment.

Bringing Embodied Carbon Upfront
https://www.worldgbc.org/news-media/bringing-embodied-carbon-upfront

Bringing Embodied Carbon Upfront is a 'call to action' report focusing on **embodied carbon** emissions as part of a whole life cycle approach and the systemic changes needed to achieve full decarbonization across the global buildings sector. It was produced by the World Green Building Council.

17.2 OPERATIONAL CARBON RESOURCES

The GHG Protocol – A Corporate Accounting and Reporting Standard
https://ghgprotocol.org/corporate-standard

The GHG Protocol Corporate Accounting and Reporting Standard provides requirements and guidance for organizations preparing a corporate-level greenhouse gas (GHG) emissions inventory and forms the basis for the GHG quantification methodology used in the ZCB-Design Standard.

The GHG Protocol – Scope 2 Guidance
https://ghgprotocol.org/scope_2_guidance

The GHG Protocol Scope 2 Guidance standardizes how corporations measure emissions from purchased or acquired electricity, steam, heat and cooling (called **indirect emissions** in the ZCB-Design Standard).

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National Inventory Report: GHG Sources and Sinks in Canada
https://www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gas-emissions/inventory.html

Each year, Canada submits a national GHG inventory to the United National Framework Convention on Climate Change (UNFCCC). The report from Environment and Climate Change Canada covers human caused emissions and removals. The current **emissions factors** for fuels and electricity in Canada are also published in the report.

The Time Value of Carbon: Smart Strategies to Accelerate Emission Reductions
https://www.cpacanada.ca/en/business-and-accounting-resources/financial-and-non-financial-reporting/sustainability-environmental-and-social-reporting/publications/time-value-of-carbon-smart-strategies

Produced by CPA Canada, The Time Value of Carbon examines how to accelerate GHG reductions by addressing **near-term climate forcers (NTCFs)**, the short-lived GHGs that significantly contribute to global warming.

Refrigerants & Environmental Impacts: A Best Practice Guide
https://www.integralgroup.com/news/refrigerants-environmental-impacts/

This best practice guide by Integral Group is intended to help those responsible for the design, installation, commissioning, operation, and maintenance of building services to make well-informed decisions about the design of refrigerant-based systems. This guide is particularly useful during initial design stages, when these systems are being considered.

Research & Development Roadmap: Next-Generation Low Global Warming Potential Refrigerants
https://www.energy.gov/eere/buildings/downloads/research-development-roadmap-next-generation-low-global-warming-potential

This research and development (R&D) roadmap for next-generation low-**GWP** refrigerants was prepared by the U.S. Department of Energy and provides recommendations that will help accelerate the transition to low-**GWP** refrigerants across the entire HVAC&R industry.

17.3 AVOIDED EMISSIONS RESOURCES

Carbon Offset Guide
http://www.offsetguide.org/

The *Carbon Offset Guide* is an initiative of the GHG Management Institute and the Stockholm Environmental Institute, designed to help companies and organizations seeking to understand **carbon offsets** and how to use them in voluntary GHG reduction strategies. It may also be useful for individuals interested in using **carbon offsets** to compensate for their personal emissions.

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Guidelines for Quantifying GHG Reductions from Grid-Connected Electricity Projects
https://www.wri.org/publication/guidelines-quantifying-ghg-reductions-grid-connected-electricity-projects

This report explains how to quantify reductions in GHG emissions resulting from projects that either generate or reduce the consumption of electricity transmitted over power grids. It is a supplement to the *Greenhouse Gas Protocol for Project Accounting* and was produced by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD).

17.4 ALTERNATIVE DESIGN EVALUATION AND TRANSITION PLAN RESOURCES

New Buildings Institute – Building Electrification Technology Roadmap
https://newbuildings.org/resource/building-electrification-technology-roadmap/

The *Building Electrification Technology Roadmap* is a guide for utilities and other organizations developing, implementing and supporting electrification projects to advance high-efficiency technologies, reduce GHG emissions, and improve public health.

Green Building Council Australia – A Practical Guide to Electrification
https://new.gbca.org.au/news/gbca-media-releases/electrifying-future/

A *Practical Guide to Electrification* outlines the steps involved in delivering an all-electric new building and the types of technologies used today to replace natural gas systems with electric solutions. The guide was written for building owners, developers, facility managers, consultants, and building professionals.

17.5 ENERGY EFFICIENCY RESOURCES

Low Thermal Energy Demand for Large Buildings
https://research-library.bchousing.org/Home/ResearchItemDetails/8685

Developed by BC Housing, this guide aims to broaden the common understanding of how large buildings can meet higher levels of performance as required by the ZCB-Design Standard, and has a focus on current Canadian code requirements, construction practice, and tested systems.

Building Envelope Thermal Bridging Guide
https://research-library.bchousing.org/Home/ResearchItemDetails/722

Developed by BC Housing, this guide aims to help the construction sector realize more energy-efficient buildings by looking at current obstacles and showing opportunities to improve building envelope thermal performance.

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Advanced Energy Design Guide – Achieving Zero Energy
https://www.ashrae.org/technical-resources/aedgs/zero-energy-aedg-free-download

The *Advanced Energy Design Guide – Achieving Zero Energy* series provides a cost-effective approach to achieving advanced levels of energy savings. Guides offer contractors and designers the tools needed for achieving a zero-energy building including recommendations for practical products and off-the-shelf technology. These guides have been developed through the collaboration of ASHRAE, the American Institute of Architects (AIA), the Illuminating Engineering Society (IES), and the U.S. Green Building Council (USGBC), with support from the U.S. Department of Energy (DOE).

The National Energy Code of Canada for Buildings
https://nrc.canada.ca/en/certifications-evaluations-standards/codes-canada/codes-canada-publications/national-energy-code-canada-buildings-2020

Published by NRC and developed by the Canadian Commission on Building and Fire Codes in collaboration with Natural Resources Canada (NRCan), the *National Energy Code of Canada for Buildings 2020 (NECB)* sets out technical requirements for the energy-efficient design and construction of new buildings. The 2020 edition is an important step toward Canada's goal of achieving 'Net Zero Energy Ready (NZER)' buildings by 2030, as presented in the *Pan-Canadian Framework*.

Illustrated Guide - Achieving Airtight Buildings
https://research-library.bchousing.org/Home/ResearchItemDetails/1765

This guide from BC Housing is an industry resource to design, build, and test airtight buildings. It also consolidates information on achieving airtightness in buildings, with a focus on larger or more complex building types, while ensuring building enclosure performance, including moisture management, thermal performance, and durability.

Climate Data for a Resilient Canada
https://climatedata.ca

ClimateData.ca is a climate data portal produced collaboratively by the country's leading climate organizations and supported, in part, by the Government of Canada. The goal of this portal is to support decision makers across a broad spectrum of sectors and locations by providing the most up to date climate data in easy-to-use formats and visualizations.

17.6 IMPACT AND INNOVATION RESOURCES

Building-Integrated Photovoltaics
https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/pdf/solar-photovoltaic/NRCan_BIPV_Factsheet_EN.pdf

This factsheet by Natural Resources Canada provides details on **BIPV** in Canada including definitions, examples, and research activities.

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