ACCELERATING TO ZERO

Upskilling for Engineers, Architects, and Renewable Energy Specialists

ACKNOWLEDGMENTS

The Canada Green Building Council (CaGBC) received support from Environment and Climate Change Canada, Government of Canada, to conduct a study on the zero carbon building skills gaps and training needs of Canadian engineers, architects and renewable energy specialists.

This paper puts forward solutions to address the existing gaps in the skills required to deliver zero carbon buildings in Canada. It also identifies training requirements and recommends delivery models to drive zero carbon building skills training.

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

In this critical decade of climate action, it has become abundantly clear that all nations must reduce carbon emissions to avoid the worst impacts of climate change.

Under the Paris agreement, Canada has committed to reaching a 30 per cent reduction below 2005 levels of greenhouse gas (GHG) emissions, and with the goal of achieving net-zero emissions by 2050.

Carbon-intensive industries must act if Canada is to reach these goals. Among the highest emitters, the building and construction industry has an opportunity to play a crucial role. Building operations represent 17 per cent of Canada's carbon emissions,[1] but closer to 30 per cent when materials and construction are considered.[2] Changing how buildings are designed, built and operated could significantly reduce emissions.

Zero carbon buildings represent the best opportunity for cost-effective emissions reductions. These buildings are technically achievable and financially viable according to research by Canada Green Building Council (CaGBC).[3] Building to a zero carbon standard does require building industry project teams to work much more collaboratively, from design through to completion and operation.

Despite the potential of zero carbon buildings and the low-carbon, future-proof jobs they could bring to the workforce, barriers to acquiring zero carbon skills still exist. The building industry must have access to zero carbon education and training if Canada hopes to reach its carbon reduction goals and achieve market resilience. Zero carbon building skills are essential for engineers, architects, and renewable energy specialists as their decisions early in the building process have a direct role in achieving a zero carbon performance.

To better understand what these key professions require in zero carbon education and training, this study was designed to:

- Establish Canada's first professional industry baseline of zero carbon building skills and knowledge among engineers, architects, and renewable energy specialists;
- Identify knowledge and skills gaps, as well as a preferred learning approach for engineers, architects, and renewable energy specialists for the design, construction and operation of zero carbon buildings; and,
- Recommend ways that education and training providers, accreditation and professional bodies, and policy decision-makers can support zero carbon building education and training for engineers, architects, and renewable energy specialists.

This study focused on continuing education and continuing professional development. It references CaGBC's Zero Carbon Building Standard to define the core competencies and sub-competencies needed to effectively evaluate the skills and knowledge required to deliver zero carbon building (see Figure 1). The requirements established under this Standard are consistent with those in zero carbon standards guiding construction in other countries.

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[1] Canada. 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*, p. 14.

[2] United Nations Environment Programme (2019). *2019 Global Status Report for Buildings and Construction: Towards a Zero-Emission, Efficient and Resilient Buildings and Construction Sector*, p. 9.

[3] Canada Green Building Council (2020). *Making the Case for Building to Zero Carbon*, p. 6–7.

To document the gaps in zero carbon building skills and knowledge among engineers, architects, and renewable energy specialists,[4] a comprehensive survey was administered to the building industry with 318 completed responses.[5]

Respondents were asked to self-report on their perceived knowledge and practical experience for the competencies related to zero carbon buildings, while also rating the importance of each competency to their job.

Figure 1: Summary of the importance of and gaps related to zero carbon building competencies

CORE COMPETENCIES	**Zero Carbon Balance**	**Energy Efficiency**	**Renewable Energy**	**Low Carbon Materials**	**Future Weather**
SUB-COMPETENCIES	Zero Carbon Building Principles in General Greenhouse Gas (GHG) Accounting Calculating a Zero Carbon Balance Transition Plans Impact of Buildings on Climate Change Reducing Energy Demand Through Passive Design	Thermal Energy Demand Intensity (TEDI) and Cooling Demand Intensity Energy Use Intensity (EUI) Strategies for Reducing Heating and Cooling Energy Demand Strategies for Improving Energy Efficiency and Reducing Peak Demand	Onsite Renewable Energy Generation Offsite Renewable Energy Generation	Embodied Carbon in Construction Performing Life-Cycle Assessment (LCA) and Calculating Embodied Carbon	Resilient Building Design Adaptable Building Design Designing for Future Weather Conditions
INSIGHTS	**Engineers, Architects and Renewable Energy Specialists** Identified GHG Accounting and Transition Plans as a high priority **Architects** Identified as having low experience with achieving a Zero Carbon Balance	**Engineers** Identified as important to their job and having the highest practical experience with this competency **Architects** Identified as a high priority gap with regards to knowledge and job importance	**Renewable Energy Specialists** Identified high knowledge of Onsite Renewable Energy; moderate practical experience with Offsite Renewable Energy	**Engineers** Identified a low-level of expertise and understanding **Architects** Identified as high importance to job	**Engineers** Identified as low expertise and low job importance. Resilient Building Design a high priority **Architects** Identified as high practical experience and job importance

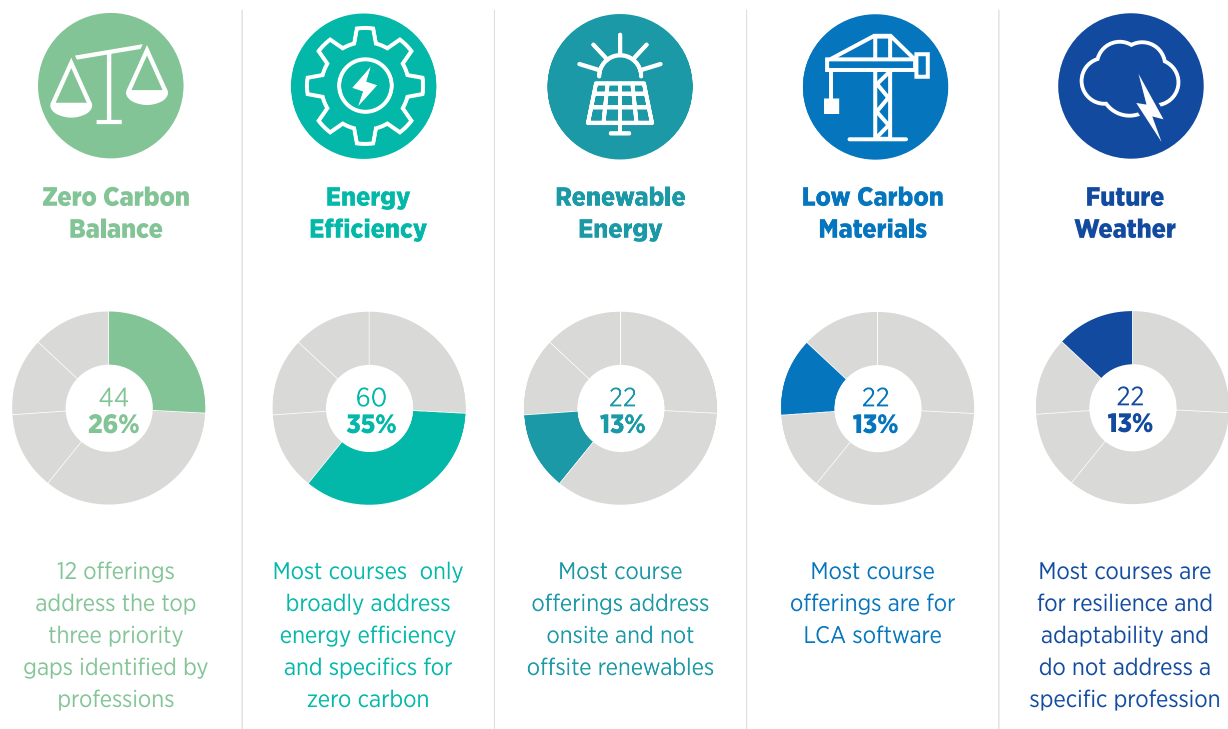
[4] For the purpose of this research we defined renewable energy specialists to as those working with solar systems, wind technology, ground source heat pumps, and other onsite building renewable energy technologies.

[5] Some respondents to the survey fell outside of primary professions evaluated for this study, and included builders, sustainability specialists, and LEED practitioners, among others and were not included with the results.

The survey results show that the current depth of knowledge and familiarity with zero carbon building competencies and sub-competencies, as well as the level of job importance, varies by building profession. Overall, building professions have embraced the importance of applying a carbon metric for the design and retrofit of buildings. However, building professionals will need to continue to develop specific knowledge to better assess and calculate current and future carbon emissions. As well, an increased focus will be required by education and training providers, accreditation and professional bodies, and policy decision-makers to support building professions, and to address gaps in understanding, and to highlight the role of embodied carbon in achieving a zero carbon building.

The survey results were complemented by an online scan of continuing education course offerings, including in-person courses available in Canada, as well as online offerings (see Figure 2). The study identified 170 education and training offerings that fit within the context of the zero carbon building competencies.

Figure 2: Number of course offerings for zero carbon building competencies



With these insights, available education solutions were evaluated to determine their ability to increase industry capacity. Although education and training resources were identified for the primary competencies, most of the sub-competencies lacked targeted resources and, in some cases, did not specifically address the individual upskilling needs of engineers, architects, and renewable energy specialists.

This study highlights some immediate opportunities to address zero carbon skills and knowledge gaps for engineers, architects, and renewable energy specialists. Recommendations are divided between two key priorities: ensuring that education and training are relevant and accessible and, investing in zero carbon capacity building. Many of the actions the study identified will require collaboration among education and training providers, accreditation and professional bodies, and policy decision-makers.

Ensure Education and Training is Relevant and Accessible

To address the need for zero carbon workforce upskilling, education and training providers, as well as accreditation and professional bodies, are encouraged to act on the following recommendations:

1. **Ensure education and training curricula address zero carbon building competencies.**
   Post-secondary institutions, accredited training organizations, continuous learning providers, and industry need to ensure that curriculum supports the application of zero carbon building competencies and sub-competencies to address high-priority knowledge gaps for engineers, architects, and renewable energy specialists – with a specific focus on: Zero Carbon Balance, GHG Accounting, Thermal Energy and Cooling Demand Intensity, and Embodied Carbon in Construction, among others. The use of industry partnerships can accelerate curriculum updates by ensuring content is relevant and keeps pace with a rapidly changing building industry.

2. **Support upskilling by establishing common terminology for courses and by investing in self-assessment tools.**
   Industry groups and associations need to work with accredited education and training providers to establish common terminology to make it easier to identify courses related to zero carbon building competencies. If courses make use of common terminology and clearly state the target audiences, finding and accessing zero carbon education and training opportunities will be less challenging for professionals. Determining which courses are most needed by specific professions can be improved with the use of self-assessment tools which suggest training and education options based on the gaps in an individual's knowledge.

3. **Drive enhanced professional credentialing requirements.**
   Accreditation bodies or certified education and training providers need to support the development of zero carbon building skills by incentivizing their members to upgrade their knowledge and training to reflect the required competencies. This would lead to increasing market demand particularly if training providers update existing offerings and develop new education options to meet the continuing professional development requirements related to zero carbon.

4. **Invest in, develop and support multiple delivery methods and formats.**
   In order to accommodate the preferred learning style of building-industry professionals, zero carbon education and training providers need to offer a variety of delivery methods and formats. The use of blended delivery formats (e.g., online and in-person) is especially desirable, as it can enable education providers to deliver more choice, increase knowledge transfer, and more effectively address zero carbon building knowledge and skills gaps for building-industry professionals.

Support and Invest in Education and Training for Zero Carbon

Policy decision-makers are encouraged to act on the following recommendations to maximize zero carbon training uptake:

5. **Demonstrate leadership through government-wide learning.**
   By making zero carbon building competencies part of the core public sector training curriculum, governments can equip public servants with a common understanding of the importance of embodied and operational carbon in building construction and operation. This knowledge will strengthen Canada's capacity for innovation as well as drive the market transformation towards a zero carbon future.

6. **Address gap for in-person learning with targeted incentives.**
   While in-person training is a preferred option for most building-industry professionals, access to these types of zero carbon training opportunities remain limited across Canada. Governments can support market uptake of zero carbon upskilling by directing capacity-building incentives to address this preferred delivery format gap, especially for small and mid-sized enterprises and self-employed professionals.

7. **Support the adoption of zero carbon building codes and related training and education.** With Canada committed to achieving net-zero emissions by 2050, governments will need to accelerate the adoption of building codes that support zero carbon buildings. Aside from provincial approvals, governments can minimize delays and encourage the uptake and application of new codes by ensuring there are capacity-building programs in place that support the needs of professionals for zero carbon competencies and sub-competencies training and education.

Working together, Canada's education and training providers, accreditation and professional bodies, and policy decision-makers can provide the leadership needed to create a highly educated and empowered professional workforce – one able to support Canada's transition to a zero-carbon future.

1 INTRODUCTION

It is abundantly clear that all nations must focus their efforts on carbon reduction if we are to avoid the worst effects of climate change.

Action must be taken, with carbon-intensive industries such as transportation and buildings expected to play a crucial role in this low-carbon transformation.

In Canada, building operations represent 17 per cent of carbon emissions,[6] with construction and materials representing a further 11 per cent.[7] The building construction and operations industry has a crucial role in helping eliminate Canada's greenhouse gas (GHG) emissions by 2050. To achieve this target, new construction projects must incorporate design elements that will achieve zero carbon emissions, while existing buildings will require deep emission reduction targets in their retrofit plans.

Among other measures, the Canada Green Building Council (CaGBC) has identified that meeting this objective will require all new buildings over 25,000 sq. ft. be built to zero carbon standards. This is roughly the equivalent of 47,500 new residential units and 4,800 new commercial or institutional zero carbon buildings annually.[8] By adopting zero carbon buildings Canada could reduce carbon emissions, decrease demand for carbon-intensive energy, and create future-proof jobs able to propel the country towards a new low-carbon future.

Achieving this zero carbon transition requires the industry to develop a shared understanding of the importance of carbon in the construction and operation of buildings. It also requires that the entire building supply chain possess zero carbon skills, especially among engineers, architects, and renewable energy specialists. These professionals are directly involved in the initial design stages for new buildings and retrofits. As such, their decisions impact the likelihood of achieving a zero carbon building – decisions such as specifying materials used and the associated embodied carbon footprint,[9] as well as the selection of construction practices, mechanical systems, energy supply, and energy sources used.

Canada's need for zero-carbon skills is immediate. However, a transition of this magnitude requires new and innovative thinking. To help support the nation's goal of deeper emissions reductions,[10] the building industry must first address issues with finding and accessing zero carbon education and training.

Currently, the complete knowledge and skillsets required for zero carbon building have yet to be fully developed. Further, access to the zero carbon educational resources needed to enhance competencies and expand practical expertise in zero carbon buildings is limited.

To address gaps in knowledge and the limited access to educational resources, CaGBC conducted a study. The goal was to determine self-perceived zero-carbon knowledge among engineers, architects, and renewable energy specialists in relation to job importance.

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[6] Canada. 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*, p. 14.

[7] United Nations Environment Programme (2019). *2019 Global Status Report for Buildings and Construction: Towards a Zero-Emission, Efficient and Resilient Buildings and Construction Sector*, p. 9.

[8] Canada Green Building Council (2016). *Building Solutions to Climate Change: How Green Buildings Can Help Meet Canada's 2030 Emissions Targets*.; Canada Green Building Council (2019). *Making the Case for Building to Zero Carbon*.

[9] World Green Building Council (2019). *Bringing Embodied Carbon Upfront, Coordinated Action for the Building and Construction Sector to Tackle Embodied Carbon* p. 5-6.

[10] Canada Green Building Council (2020). *Zero Carbon Building – Performance Standard Version 2*.

The study further evaluated education solutions available to increase industry capacity and highlight the actions education and training providers, accreditation and professional bodies, and policy decision-makers could take to meet the upskilling needs of engineers, architects, renewable energy specialists.

There are two primary pathways for these professions to acquire the knowledge and skills needed. The first pathway is through post-secondary institutions such as universities, colleges, technical institutes and other accredited organizations. The second pathway focuses on continuing education and continuing professional development. This study focuses on the second pathway to support the immediate need of practicing engineers, architects, and renewable energy specialists looking for zero carbon training and education.

To summarize, this study undertook to:

1
ESTABLISH
Establish Canada's first professional industry baseline of zero carbon building skills and knowledge among engineers, architects, and renewable energy specialists.

2
IDENTIFY
Identify knowledge and skills gaps, as well as a preferred learning approach for engineers, architects, and renewable energy specialists for the design, construction and operation of zero carbon buildings.

3
RECOMMEND
Recommend ways that educational and training providers, accreditation and professional bodies, and policy decision makers can support zero carbon building education and training for engineers, architects, and renewable energy specialists.

A comprehensive overview of the skills required by trades and other sectors involved in the construction and operation for zero carbon building was documented in CaGBC's seminal report *Trading Up: Equipping Ontario Trades with the Skills of the Future*[11] and in *Trading Up Alberta: How Alberta's Trades Can Build a Zero-Carbon Future*.[12]

Defining a Zero Carbon Building
A zero carbon building is a highly energy-efficient building that produces onsite, or procures carbon-free renewable energy, or procures high-quality carbon offsets in an amount sufficient to counterbalance the annual carbon emissions associated with building materials and operations.[13] A building has achieved a carbon balance of zero in operation when the net emissions resulting from sources and sinks of carbon emissions are zero.[14] To accomplish this requires an integrated approach to minimize embodied carbon and energy demand, to meet the building's energy needs efficiently, to integrate onsite and – when needed – offsite renewable energy systems, and to encourage innovation in design features and energy generation.

CaGBC research confirms that zero carbon buildings are technically feasible and financially viable. On average, zero carbon buildings achieve a positive financial return on investment over a 25-year lifecycle (inclusive of carbon pollution pricing) and require only a modest capital cost premium.

[11] Canada Green Building Council (2019). *Trading Up: Equipping Ontario Trades with the Skills of the Future, 2019*. The report highlights that beyond new technical skills and in-depth knowledge required, soft skills such as communication and cooperation between key stakeholders are important factors in making zero carbon building projects successful and that these skills are essential for the entire construction workforce to rigorously respond and act on the challenge for a zero carbon economy.

[12] Canada Green Building Council (2020). *Trading Up: How Alberta's Trades Can Build a Zero-Carbon Future*.

[13] Canada Green Building Council (2020). *Zero Carbon Building - Design Standard Version 2*, p 7.

[14] Net emissions are defined as embodied carbon (upfront carbon, use stage embodied carbon, end-of-life carbon) plus operational carbon (direct emissions, indirect emissions) less avoided emissions (exported green power, carbon offsets), Ibis.

This financial return grows as the cost of carbon rises, while zero carbon buildings also mitigate future costs for utilities and retrofits.[15]

Applying zero carbon building principles delivers more than just financial benefits. Zero carbon buildings can reduce energy consumption and overall operational costs. Also, zero carbon buildings can improve the indoor and outdoor environment, enhance occupant health and wellbeing, and boost productivity – which makes a compelling case for building owners, tenants and developers.

A Note on Methodology

To document the gaps in zero carbon building skills and knowledge among engineers, architects, and renewable energy specialists,[16] a comprehensive online survey was administered with 318 completed responses from across Canada.[17] The survey results were complemented by an online environmental scan of continuing education course offerings, including in-person courses available in Canada, as well as online offerings. The full study methodology is provided in Appendix 1.

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[15] Canada Green Building Council (2020). *Making the Case for Building to Zero Carbon*, p 6–7.

[16] For the purpose of this research we defined renewable energy specialists to as those working with solar systems, wind technology, ground source heat pumps, and other onsite building renewable energy technologies.

[17] Some respondents to the survey fell outside of primary professions evaluated for this study, and included builders, sustainability specialists, and LEED practitioners, among others and were not included with the results.

2 LEARNING FOUNDATION FOR ZERO CARBON BUILDING

The building industry is continuously evolving with innovations in design approaches, materials, and ever more demanding sustainability requirements.

The shift towards more zero carbon buildings requires an upskilled workforce with access to current, high-quality education and training. Engineers, architects, and renewable energy specialists, among other building professionals, will require a new set of zero carbon building skills supported by established and new pathways for learning.

Pathways and Known Barriers to Learning

There are two pathways for engineers, architects, and renewable energy specialists in Canada to acquire the knowledge and skills needed for zero carbon buildings. However, the pathways, requirements, and related credentials vary for each profession and by region.

The first pathway is typically foundational or first principle-based. It is usually delivered through post-secondary institutions, including universities, colleges, technical institutes, and other accredited organizations, such as professional associations. Post-secondary institutions and other accredited training organizations continuously evolve their programs to reflect current trends and building advancements as part of the requirements to earn a degree, diploma or certificate.

The second pathway involves continuing education and training. It can result in additional professional credentials by accessing courses and programs that enhance an individual's understanding of relevant topics. In some instances, this path can also require maintaining professional credentials through continuing professional development (CPD). There are organizations that license and certify green building professionals, some of which are specific to a profession (e.g., architectural and engineering associations), while others are credential-based and part of an industry standard (e.g., Green Business Certification Inc. or Passive House Canada).

Building professionals seek continuing education for many reasons, including career advancement, credential maintenance, and employer requirements for upskilling. Recent studies confirm that promoting and supporting continuous learning is on the rise in organizations. At the same time, more individuals are indicating a desire to access to self-directed learning. Yet, while interest in continuous learning increases, there are acknowledged barriers inhibiting access, such as: [18]

- Cost for maintaining training and education (including the cost of set-up and maintenance of learning management systems and tools);
- Lack of a supportive organizational culture that encourages self- or continuous learning;
- Expectations or requirement for employees to complete learning during personal time or through unpaid time-off;
- Difficulty with identifying, accessing, and utilizing the right education and training resources and supporting learning technology; and,
- Perceived lack of understanding the value of learning when it is not directly related to an individual's professional skills or accreditation.

[18] Towards Maturity CIC Ltd (2017). In L&D: Where Are We Now? 2017-18 Learning Benchmark Report and Canada Green Building Council (2019). Trading Up: Equipping Ontario Trades with the Skills of the Future, and Canada Green Building Council (2020). Trading Up Alberta: How Alberta's trades can build a zero-carbon future, and strategic HR inc (2013). Barriers to Effective Training and Development, https://strategichrinc.com/barriers-to-effective-training-and-development/.

Addressing these barriers will require active engagement and support from education and training providers, accreditation and professional bodies, and policy decision-makers. The support of these key stakeholders is needed to ensure the uptake of zero carbon building competencies and the application of practical approaches to the design, building, and operation of zero carbon buildings.

Core Competencies for Zero Carbon

To support industry efforts to better understand, assess, and implement zero carbon building strategies, CaGBC has engaged with many stakeholders. CaGBC's goal was to identify the key components that define a zero carbon building, and collect critical insights into what should be considered, calculated, and reported in order to certify a building for zero (or negative) emissions. This process involved speaking with engineers, architects, contractors, manufacturers, public and private owners and operators of large buildings, design firms, policymakers, among others.[19]

These insights helped to develop the first Zero Carbon Building Standard (ZCB Standard) in North America.[20] The ZCB Standard for Design and Performance is continuously improved upon based on active engagement with building professionals involved with real-world zero carbon building design, development, and operation.

This involvement ensures the latest approaches, techniques, materials, insights, and experience are incorporated into the ZCB Standard.[21] Key elements for zero carbon building are referenced in the ZCB Standard. They include embodied carbon of construction materials, the fundamentals of energy-efficient design, the carbon footprint of the energy grid, the consideration for onsite and offsite renewable energy sources, and adaptation and resilience to future weather.

This study references the ZCB Standard to define the core competencies and sub-competencies needed to effectively evaluate the skills and knowledge that engineers, architects, and renewable energy specialists require to support zero carbon building. A summary of the competencies included in the study are provided in Figure 3, and a comprehensive overview of how the competencies are foundational to zero carbon building is provided in Appendix 2.

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19 Canada Green Building Council (2016). Zero Carbon Buildings Framework - For commercial, Institutional and Multi-Family Buildings in Canada. This was the first framework in Canada to define a zero carbon building and the foundational principles for zero carbon building.

20 Canada Green Building Council (2017). Zero Carbon Building Standard. This standard was part of a two-year Zero Carbon Buildings Pilot Program, featuring 15 of Canada's most innovative projects. The primary purpose of the pilot was to use the experience gained from real-world zero carbon buildings to enhance the Standard as well as tools, resources and education to accelerate market transformation for zero carbon building.

21 Canada Green Building Council (2020). Zero Carbon Building - Design Standard Version 2. and Zero Carbon Building – Performance Standard Version 2. The Zero Carbon Building – Design Standard is a made-in-Canada framework for designing and retrofitting buildings to achieve zero carbon. It ensures the best potential to achieve zero carbon once in operation. The Standard recognizes that there are many strategies for reducing carbon emissions at the design and operating stages, providing flexibility for buildings across Canada of all sizes and uses to achieve certification. The Zero Carbon Building – Performance Standard is an annual verification of the performance of zero carbon buildings. Certification is awarded based on twelve months of operations, and projects achieving certification may use the certification mark. The Zero Carbon Building Standard is the only standard in Canada that uses carbon as the key performance metric. The Standard includes the importance of embodied carbon which accounts for the life-cycle of carbon and goes beyond the carbon associated with the operation of a building.

Figure 3: Zero Carbon Building Standard core competencies and related sub-competencies

Zero Carbon Balance	Energy Efficiency	Renewable Energy	Low Carbon Materials	Future Weather
Zero Carbon Building Principles in General	Thermal Energy Demand Intensity (TEDI) and Cooling Demand Intensity	Onsite Renewable Energy Generation	Embodied Carbon in Construction	Resilient Building Design
Greenhouse Gas (GHG) Accounting	Energy Use Intensity (EUI)	Offsite Renewable Energy Generation	Performing Life-Cycle Assessment (LCA) and Calculating Embodied Carbon	Adaptable Building Design
Calculating a Zero Carbon Balance	Strategies for Reducing Heating and Cooling Energy Demand			Designing for Future Weather Conditions
Transition Plans	Strategies for Improving Energy Efficiency and Reducing Peak Demand			
Impact of Buildings on Climate Change				
Reducing Energy Demand Through Passive Design				

3 ZERO CARBON BUILDING SKILLS AND KNOWLEDGE

The assessment of zero carbon expertise and the identification of building professionals' related skills gaps are critically important to understand the steps required to drive zero carbon building adoption.

An online survey was designed to gain these insights and administered across Canada using CaGBC's network. Through self-identification, the respondent breakdown included: 34 per cent engineers, 19 per cent architects, and 8 per cent renewable energy specialists. The remaining 39 per cent of respondents fell outside of these targeted professions and thus, were excluded from the study.

Respondents were asked to self-report on their perceived knowledge and practical experience for the competencies related to zero carbon buildings, while also rating the importance of each competency to their job. Each competency included a set of sub-competencies to solicit a more refined assessment of the skills and knowledge needed for zero carbon buildings.

For each competency, the highest-ranked priority gap is identified by profession, along with an overview of the results by competency. A high priority gap is identified by the difference between the knowledge to job importance ratings. Respondents were also asked to identify their preferred format of learning. The full survey is provided in Appendix 3.

Zero Carbon Balance

The carbon balance is the net emissions that result from sources and sinks of carbon emissions, and it is calculated based on the embodied (i.e., emissions from the manufacturing, transport, installation, use, and end-of-life of building materials) and operational carbon (i.e., the emissions associated with energy use and the release of refrigerants during regular building operations) as well as avoided emissions. A zero carbon building achieves a balance of zero or less emissions, measured annually in terms of embodied and operational emissions. To achieve that balance, GHG emissions associated with building operations must be reduced through building design or offset through low carbon renewable energy or other verified carbon reduction measures.

Zero Carbon Balance sub-competencies:

Zero Carbon Building Principles in General	Greenhouse Gas (GHG) Accounting	Calculating a Zero Carbon Balance	Transition Plans	Impact of Buildings on Climate Change	Reducing Energy Demand Through Passive Design

Highest-priority gap rankings:

Engineers	Architects	Renewable Energy Specialists
Greenhouse Gas (GHG) Accounting	Greenhouse Gas (GHG) Accounting	Greenhouse Gas (GHG) Accounting
Transition Plans	Transition Plans	Transition Plans
	Calculating a Zero Carbon Balance	Calculating a Zero Carbon Balance

Highlights for Zero Carbon Balance Competency

- All professions acknowledged the importance of the Zero Carbon Balance competency for their job. They also identified a good level of understanding of Zero Carbon Building Principles, the Impact of Buildings on Climate Change, and Reduction of Energy Demand through Passive Design.
- Transition Plans for buildings to move towards future decarbonization, as well as GHG Accounting, were identified as high priority topics by all professions.
- Architects and renewable energy specialists identified Calculating A Zero Carbon Balance as a high priority for future learning.
- Of the three professions, architects rated their experience with achieving a Zero Carbon Balance, relative to all other competencies, the lowest.

Energy Efficiency

Energy Efficiency is the first step to reduce energy demand and associated energy costs, cut emissions, improve the operating performance of a building, and reduce the environmental impacts of energy production. Energy efficiency is usually associated with heating, cooling, hot water, and lighting. It focuses on meeting energy needs with the least amount of energy use and carbon emissions while also reducing the peak demand on the electricity grid.

Energy Efficiency sub-competencies:

Thermal Energy Demand Intensity (TEDI) and Cooling Demand Intensity	**Energy Use Intensity (EUI)**	**Strategies for Reducing Heating and Cooling Energy Demand**	**Strategies for Improving Energy Efficiency and Reducing Peak Demand**

Highest-priority gap rankings:

Engineers	Architects	Renewable Energy Specialists
Strategies for Improving Energy Efficiency and Reducing Peak Demand	Strategies for Improving Energy Efficiency and Reducing Peak Demand	The majority self-reported moderate to high levels of knowledge and practical experience, with corresponding ratings for job importance
Thermal Energy Demand Intensity (TEDI) and Cooling Demand Intensity	Thermal Energy Demand Intensity (TEDI) and Cooling Demand Intensity	

Highlights for Energy Efficiency Competency

- Engineers and architects identified this competency as the most important for their job and rated their practical experience the highest out of all five core competencies. This is likely a result of the current emphasis given to energy efficiency to reduce energy use in comparison to the evolving importance of taking a zero carbon design approach.
- Architects identified more significant gaps between their level of knowledge and job importance for all sub-competences under Energy Efficiency, while engineers had relatively smaller gaps. Both professions indicated knowledge gaps related to Thermal Energy Demand Intensity (TEDI), or the use of a similar metric for cooling, as well as for Improving Energy Efficiency and Reducing Peak Demand.
- Renewable energy specialists did not demonstrate any significant gaps in this competency, primarily due to being rated as of lower importance to their job.

Renewable Energy

Building emissions can be reduced using either onsite or offsite sources of renewable energy. Renewable energy is referred to as a source of energy that is replenished through natural processes or uses sustainable management policies, such that it is not depleted at current levels of consumption.[22] Examples can include solar and wind energy used for power generation and solar energy used for space and water heating. For projects where onsite renewable energy is not feasible, off-site renewable energy presents an additional option for emissions reductions.

Renewable Energy sub-competencies:

Onsite Renewable Energy Generation	Offsite Renewable Energy Generation

Highest-priority gap rankings:

Engineers	Architects	Renewable Energy Specialists
A high-priority gap was not identified	A high-priority gap was not identified	A high-priority gap was not identified

Highlights for Renewable Energy Competency

- For all professions, there were no high-priority gaps identified based on a comparison of knowledge to job importance.
- Both engineers and architects identified moderate levels of knowledge and job importance for Onsite Renewable Energy, with slightly lower levels of knowledge and job importance for Offsite Renewable Energy.
- Renewable energy specialists indicated a high importance to their job as well as a high knowledge level for all sub-competencies under Renewable Energy. Practical experience related to Onsite Renewable Energy was also identified as high, while practical experience related to Offsite Renewable Energy was given a more moderate rating. This is likely a result of renewable energy specialists not having to be engaged with offsite renewable energy systems, which are connected directly to the grid and operated by a local utility.

[22] Canada Green Building Council (2020). *Zero Carbon Building - Design Standard Version 2*, p 42.

Low Carbon Materials

Low carbon materials refer to the reduced carbon emissions associated with manufacturing, transportation, construction and end of life phases of all built assets.[23] This is accomplished by tracking the embodied carbon (emissions) associated with materials throughout the whole life-cycle of a building.

Low Carbon Materials sub-competencies:

Embodied Carbon in Construction	**Performing Life-Cycle Assessment (LCA) and Calculating Embodied Carbon**

Highest-priority gap rankings:

Engineers	Architects	Renewable Energy Specialists
Respondents reported low levels of knowledge and expertise but also identified a low level of importance to their job. As this is a newer concept, some engineers may be unaware of the importance of their involvement relating to the reduction of embodied carbon on a project. As such, this could reflect an unperceived educational need	Embodied Carbon in Construction	Respondents reported moderate to lower levels of knowledge for both sub-competencies, as well as low levels of practical expertise
	Performing Life-Cycle Assessment (LCA) and Calculating Embodied Carbon	

Highlights for Low Carbon Materials Competency

- Engineers and renewable energy specialists indicated a similar level of moderate to low knowledge for this competency. Both professions also identified low to moderate levels of job importance, which corresponds to the lack of high-priority gaps for these professions.
- Architects indicated moderate to low levels of knowledge related to the two sub-competencies while rating this competency of more importance for their job. This reveals a knowledge gap for both sub-competencies, with a higher emphasis on Performing Life-Cycle Assessment (LCA) and Calculating Embodied Carbon.
- All three professions rated their experience with this competency as the lowest when compared to the other competencies. Architects rated a high level of importance to their job, as they are intrinsically linked to the building design and specification of materials. Engineers and renewable energy specialists rated lower levels of importance to their job.

[23] World Green Building Council (2019). *Bringing Embodied Carbon Upfront: Coordinated Action for the Building and Construction Sector to Tackle Embodied Carbon*, p 7.

Future Weather

Over 80 per cent of today's current buildings will still be in operation by 2050 and the majority will not be designed to adapt to changing climates and the impacts of extreme weather events including intense forest fires, heavy flooding, damaging winds, and prolonged power outages. Building professionals will need to be well-equipped with the skills required to design, construct, and operate adaptable and resilient buildings that are also zero carbon.

Future Weather sub-competencies:

Resilient Building Design	**Adaptable Building Design**	**Designing for Future Weather Conditions**

Highest-priority gap rankings:

Engineers	Architects	Renewable Energy Specialists
Resilient Building Design	Adaptable Building Design	Resilient Building Design
	Designing for Future Weather Conditions	

Highlights for Future Weather Competency

- Architects rated their practical expertise with this competency as high, as well as the importance to their jobs, while engineers and especially renewable energy specialists indicated lower levels of expertise and lower ranking in terms of the level of importance. This could be an expected outcome as the sub-competencies of this category focus on design for resilience and adaptation and could be assumed to be related mostly to the building design. At the same time, there is a need for engineers and renewable energy specialists to give increased consideration for how future climate factors will directly impact their decision-making processes.
- Notable sub-competency knowledge gaps for architects included Adaptable Building Design and Designing for Future Weather Conditions. A gap also existed for both engineers and renewable energy specialists regarding the Resilient Building Design sub-competency.

Preferred Learning Approach

With the continued evolution of technology to support education and training, there are many dynamic delivery formats that can support upskilling – including online and in-person options. Respondents were asked to indicate their preferred method(s) of learning based on how education and training offerings are currently delivered, with the option to choose multiple preferred formats based on the following:[24]

- Online courses
- In-person courses
- Education and training on the jobsite
- Physical job aids or instructional guides (e.g., paper-based checklists, etc.)
- Electronic resources (e.g., online educational resources, electronic versions of buildings codes, etc.)
- Online community of interest (e.g. individuals ask questions and/or provide guidance to others)

In-person courses, online courses, and electronic resources were identified as the most popular methods of delivery, with a range of 20 to 24 per cent of respondents favouring each of these methods. Respondents indicated a lower level of preference for job-site training opportunities (14%) and job aides (11%). The least popular method of learning was online communities (8-10%).

In order of preference, the following are the top three preferred methods of delivery by profession:

Engineers	Architects	Renewable Energy Specialists
1. In-person courses	1. Online courses	1. In-person courses
2. Online courses	2. In-person courses	2. Online courses
3. Electronic resources	3. Electronic resources	3. Electronic resources

Highlights for Preferred Learning Approach

All target professions identified the same top three preferred methods of education and training delivery. While the top two preferences varied, the level of ranking between the formats was minimal. The third favourite learning approach for each group was access to electronic resources.

[24] Additional delivery methods that were not specifically evaluated included, one-to-one learning, small group activities, mobile learning, virtual instructor learning, or blended learning. Several of these delivery formats were captured by the broader formats listed in this report (e.g. virtual learning under online courses).

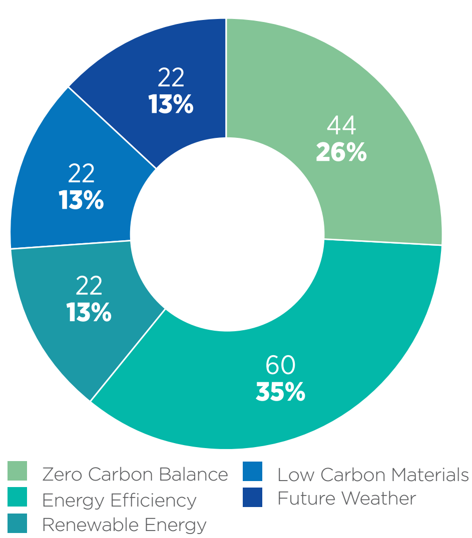
4 UPSKILLING OPPORTUNITIES FOR ZERO CARBON BUILDING

A scan of in-person and online education and training opportunities for engineers, architects, and renewable energy specialists in Canada was conducted to map the availability of continuing professional learning opportunities for zero carbon building competencies.

Existing Continuing Professional Learning Options

A total of 170 education and training offerings were identified.[25] Figure 4 summarizes the offerings by core competency for zero carbon buildings.

Figure 4: Number of identified courses for each core competency.



When considering the highest-priority gaps in terms of competencies and sub-competencies by profession, several insights emerged regarding the education and training needs as outlined in Figure 1.

Although education and training resources were identified for the primary competencies, most of the sub-competencies lacked targeted resources and, in some cases, did not specifically address the individual upskilling needs of engineers, architects, and renewable energy.

The insights identified include:

- Some education and training offerings applied to multiple sub-competencies due to the close relationship of the topics. For example, offerings relating to Strategies for Improving Energy Efficiency and Reducing Peak Demand also related to Thermal Energy and Cooling Demand Intensity. While course similarities can provide broader appeal, it can also indicate a lack of dedicated education and training content which can result in insufficient information to enable individuals to fully master a competency or sub-competency.
- Embodied carbon was not identified as a high-priority gap by engineers and renewable energy specialists. The majority of online courses related to embodied carbon were directed to life-cycle assessment (LCA) and the use of LCA software especially. As a core competency, Calculating Embodied Carbon is fundamental to zero carbon building. Overall, there is a gap in targeted embodied carbon education and training opportunities for professionals. This will require future investment to keep pace with a rapidly growing area of focus for zero building development.

[25] The environmental scan was conducted between February and March 2019. It can be expected that additional zero-carbon building educational and training programs will be made available as increased emphasis is placed projects aiming to achieve zero emission buildings.

- Several courses addressed the technical aspects of reducing carbon emissions, such as better mechanical design and building envelopes. However, the offerings did not address the fundamental role of the integrated design process (IDP) in supporting zero carbon building. IDP is a well-established approach for the design and development of high-performance buildings, which typically require more collaboration between different professions and trades. A well-informed integrated team can better identify technologies and ensure that commissioning and hand-offs are implemented appropriately. To date, a strong link has not been made between current educational and training options for IDP and zero carbon buildings.
- An under-serviced sub-competency for all professions was Designing for Future Weather Conditions. The ability for buildings to withstand, respond to, and recover from extreme weather events and long-term changes in climate is paramount to resiliency for occupants and the building's physical infrastructure. Existing and future education and training will need to place greater emphasis on the impact of weather and changing climates in terms of the design, as well as the operation of buildings.

Figure 5: High priority sub-competencies and related education

Competency	Engineers	Architects[26]	Renewable Energy Specialists	
	Sub-Competency Highest Priority Gap			**Course Availability Per High-Priority Gaps**
Zero Carbon Balance	Greenhouse Gas (GHG) Accounting	Greenhouse Gas (GHG) Accounting	Greenhouse Gas (GHG) Accounting	**7 offerings:** 3 (30 minutes to 2.5 hours) 3 (8-20 hours) 1 downloadable course (no duration specified) No in-person offerings
	Transition Plans	Transition Plans	Transition Plans	No available online or in-person offerings.
	-	Calculating a Zero Carbon Balance	Calculating a Zero Carbon Balance	**5 offerings:** 3 (30 minutes - 1 hour) 1 (15-20 hours) 1 downloadable course with no duration specified No in-person offerings

[26] Architects identified more knowledge and skills gaps across all core competencies relative to engineers and renewable energy specialists. This might be a result of architects self-reporting higher levels of job importance in combination to the relatively new concept of carbon metric that requires increased emphasis to a detailed and integrated design, as well as technical calculations associated with every design choice. For engineers and renewable energy specialists, energy systems have been traditionally associated with the building operations and performance, having now the additional element of carbon emissions.

Competency	Engineers	Architects	Renewable Energy Specialists	
	Sub-Competency Highest Priority Gap			Course Availability Per High-Priority Gaps
Energy Efficiency	Strategies for Improving Energy Efficiency and Reducing Peak Demand	Strategies for Improving Energy Efficiency and Reducing Peak Demand	A high-priority gap was not identified*	**48 offerings:** Majority online (1-2 hours) 5 in-person (8-37.5 hours); 3 of the in-person courses related to reducing energy demand through passive design Only 3 offerings relating directly to the topic of peak demand Search terms applied include improving energy efficiency for buildings, reducing energy demand, reduce energy demand through passive design and, building envelopes. *Note: Offerings overlapped with 'Thermal Energy and Cooling Demand Intensity' sub-competency.*
	Thermal Energy Demand Intensity (TEDI) and Cooling Demand Intensity	Thermal Energy Demand Intensity (TEDI) and Cooling Demand Intensity		**44 offerings:** Majority online (30 min- 2 hours) 5 in-person (8-37.5 hours): 4 of the in-person courses related to reducing energy demand through passive design *Note: Offerings overlapped with 'Strategies for Improving Energy Efficiency and Reducing Peak Demand' sub-competency.*

* The majority of renewable energy specialists self-reported moderate to high levels of knowledge and practical experience in the energy efficiency sub-competencies, with corresponding ratings for job importance. Hence, there were no high priority gaps identified.

Competency	Engineers	Architects	Renewable Energy Specialists	
	Sub-Competency Highest Priority Gap			Course Availability Per High-Priority Gaps
Renewable Energy**	A high-priority gap was not identified	A high-priority gap was not identified	A high-priority gap was not identified	A high-priority gap was not identified

** For all professions, there were no high priority gaps identified for the renewable energy sub-competencies (onsite and offsite renewable energy). Both engineers and architects identified moderate levels of knowledge and job importance for onsite renewable energy, with slightly lower levels of knowledge and job importance for offsite renewable energy. Renewable energy specialists indicated a high importance to their job as well as a high knowledge level for all sub-competencies under renewable energy.

Competency	Engineers	Architects	Renewable Energy Specialists	Course Availability Per High-Priority Gaps
	Sub-Competency Highest Priority Gap			
Low Carbon Materials	Embodied Carbon in Construction	Embodied Carbon in Construction	Embodied Carbon in Construction	**22 offerings:** Majority online (1-1.5 hour) 2 downloadable courses with no duration specified 1 full-day in-person course 11 online courses were offered by a single provider dealing with their specific LCA software (6-19 minutes) *Note: Most courses were tagged under LCA, Performing LCA, and LCA Reporting. All offerings overlapped within these two sub-competencies.*
	-	Performing Life-cycle Assessment (LCA) and Calculating Embodied Carbon	-	

Competency	Engineers	Architects	Renewable Energy Specialists	Course Availability Per High-Priority Gaps
	Sub-Competency Highest Priority Gap			
Future Weather	Resilient Building Design	-	Resilient Building Design	**17 offerings:** 11 online (1-1.25 hours) 6 online (1.75-2.5 hours) No in-person offerings *Note: 9 offerings overlap with 'Adaptable Building Design' sub-competency.*
	-	Adaptable Building Design	-	**13 offerings (1-2.5 hours):** No in-person offering *Note: 9 offerings overlapped with 'Resilient Building Design' sub-competency.*
	-	Designing for Future Weather Conditions	-	Search terms using the title did not identify available training. A search using "buildings + climate change" resulted in 2 offerings.

Ability to Access Necessary Skills and Knowledge

Delivery of education and training is dependent on several considerations. These include available budget, size and type of workforce needing training, location of requested training, timeframe for delivery, and training goals. Adding to this complexity are the varied training delivery formats that are preferred by individuals who wish to access training (e.g., in-person training vs. accessing online education resources). What is paramount is the need to make education and training for zero carbon building easy to locate, while also providing access to training and delivery in a multitude of delivery formats. Insights identified in the process of the environmental scan include:

- Most of the education and training options available for zero carbon building were accessible online, with only 13 per cent delivered in-person. Of the in-person offerings, the scan did not identify if a course was offered for a limited period (e.g., if the course was no longer available), and it did not reflect a broad delivery model inclusive of multiple deliveries in communities across Canada. Based on respondents' preference for both in-person and online learning, it's clear there is a gap in these types of training opportunities.
- Industry professionals showed a preference for in-person courses, online courses, and electronic resources. This suggests the potential for blended-learning options that provide the individual with in-person experience combined with online self-directed learning options. This can help minimize the time an individual needs to be away from work to attend a course, while also allowing greater flexibility.
- With regards to the depth and breadth of the available courses, only a small portion were longer (e.g. ranging from 4-37.5 hours). The majority of courses were approximately one hour in duration. When determining how long a course should be, many factors need to be considered. These include how detailed the content needs to be, the individual's technical background, and the level of involvement the person has in those aspects of the project. Extended training may be required for the majority of zero carbon building sub-competencies.
- Increasing an individual's interest in zero carbon building education and training is possible. Establishing common course description terminology, specific delivery formats, and by correctly identifying the target audience can all enhance the appeal. Currently, there is limited consistency in the terminology used in courses to describe for zero carbon building competencies and related sub-competencies. This lack of common terminology can make it challenging to access education and training opportunities. This challenge is further compounded by the limited use of tagging to alert an individual of the intended target audience for a course. Noting this type of information in course descriptions, or on event registration pages, can help individuals effectively identify how relevant a course offering may be in meeting their education and training needs.

5 KEY CONSIDERATIONS

As the building industry transitions toward a low-carbon future, this study highlights some immediate opportunities to address the zero carbon skills and knowledge gaps for engineers, architects and renewable energy specialists.

To bridge these gaps will require a focus on zero carbon competencies and the ability to establish accessible modes of learning to maximize the target professions ability to upskill. By addressing the gaps, the industry can be better positioned to make this transition and support the market uptake of zero carbon buildings. Many of the actions identified below can be led by or will require, collaboration among education and training providers, accreditation and professional bodies, and policy decision-makers.

Ensure Education and Training is Relevant and Accessible

Continuing education needs to be responsive to changing technologies, practices, and approaches. This is especially true for transitioning the building industry to support the market uptake of zero carbon buildings. To address the need for zero carbon upskilling, education and training providers, as well as accreditation and professional bodies, are encouraged to move on the following recommendations:

1. **Ensure education and training curricula address zero carbon building competencies.**
   Education and training offerings need to be tailored to address the competencies and sub-competencies required for zero carbon building. In addition, offerings need to address the associated educational and training gaps for engineers, architects, and renewable energy specialists. Post-secondary institutions, approved accredited training organizations, and continuous learning providers are well placed to draw on the findings of this study to ensure current and future curriculum support the application of zero carbon building competencies for Canada's current and future workforce. Industry partnerships should be established to review existing content for relevancy while helping develop new education and training offerings that target zero carbon skills and reflect the rapid pace of industry change. High-priority knowledge gaps include Zero Carbon Balance, GHG Accounting, Transition Plans Development, as well as knowledge in Thermal Energy and Cooling Demand Intensity, Embodied Carbon in construction, Adaptable Building Design, and Designing for Future Weather Conditions.

2. **Support upskilling by establishing common terminology for courses and by investing in self-assessment tools.**
   Industry groups and associations are well placed to work with accredited education and training providers to establish a recognizable and common terminology that will finding and accessing offerings related to zero carbon building competencies and sub-competencies. Accessing courses can be made easier with the use of self-assessment tools, which can suggest training and education options based on the gaps in an individual's knowledge. Self-assessment tools for zero carbon building are not yet widely available for engineers, architects, and renewable energy specialists. Such tools would need to be supported and developed by governments in collaboration with accreditation and professional bodies, as well as education and training providers.

3. **Drive enhanced professional credentialing requirements.**

   The industry professions evaluated in this study require support to respond to the increasing demand for zero carbon building skills and knowledge. This demand can be addressed with the support of accreditation bodies or certified/regulated education and training providers. These education providers can work with industry associations to incentivize members to upgrade and improve their zero carbon building knowledge. The support of professional industry associations would enable the inclusion of zero carbon building best practices as part of certification maintenance requirements, as well as provide members with the impetus to pursue life-long learning through current or future continuing education programs. These steps would also increase market demand, particularly if training providers update existing offerings and develop new education to meet continuing professional development (CPD) requirements.

4. **Invest in, develop and support multiple delivery methods and formats.**

   Individuals have different learning styles and varied opportunities to access education and training resources. In order to accommodate more people, education and training should be provided through multiple delivery methods. These methods could include free-access videos, augmented reality learning, in-person workshops and classes, online courses or mock-ups of design features. This variety will help promote the creation of content that meets the expectations of learners in an increasingly digital world. By using blended delivery formats, education providers can deliver more choice, increase learning transfer, and more effectively address zero carbon building knowledge and skills gaps.

Support and Invest in Education and Training for Zero Carbon

Achieving Canada's climate change objectives will require a concerted effort by all levels of government. A key goal will be to establish a dynamic and informed workforce able to respond to evolving market expectations and changing codes and standards. To maximize zero carbon training uptake, policymakers are encouraged to move on the following recommendations:

5. **Demonstrate leadership through government-wide learning.**

   Governments can demonstrate leadership by making zero carbon building competencies part of the core public sector training curriculum. This will facilitate comprehensive and responsive learning opportunities in areas unique to government. Public servants are on the frontline of climate change leadership. They are being challenged to quickly adopt new concepts and approaches, including ones which reflect the importance of zero carbon. Ensuring public servants are equipped with a common understanding of the importance of embodied and operational carbon to the construction and operation of buildings will strengthen Canada's capacity for innovation as well as drive the market transformation towards a zero carbon future.

6. **Address gap for in-person learning with targeted incentives.**

   While in-person training was identified as a preferred option for building-industry professionals, access to these types of zero carbon training opportunities remain limited across Canada. Limitations can be a result of not being able to deliver offerings cost-effectively due to instructor and venue location and availability, as well as market interest. Governments can support market uptake of zero carbon upskilling by directing capacity-building incentives to address this preferred delivery format gap, especially for small and mid-sized enterprises and self-employed professionals.

7. **Support the adoption of zero carbon building codes and related training and education.**

   The federal and provincial governments have agreed to start adopting increasingly more stringent model building codes with the option for a "net-zero energy ready" code by 2030.[27] However, with Canada committed to achieving net-zero emissions by 2050, governments will need to accelerate the adoption of building codes that support zero carbon buildings. Governments will be able to minimize delays and encourage the uptake and application of new codes by ensuring there are capacity-building programs in place that support the needs of professionals for zero carbon competencies and sub-competencies training and education.

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[27] Canada. Environment and Climate Change Canada (2016). *Federal Actions for a Clean Growth Economy: Delivering on the Pan-Canadian Framework on Clean Growth and Climate Change*, p 11. and National Research Council Canada (2018). *Laying the Foundation for Net-Zero Energy Ready Building Codes by 2030* 7.

6 CONCLUSION

This is the critical decade for climate action.

In the report *Global Warming of 1.5°C*, the Intergovernmental Panel on Climate Change (IPCC)[28] identified the world's carbon budget as 420 gigatonnes (Gt) of CO_2e – the maximum amount of GHGs that can be released into the atmosphere over time and still keep global warming limited to a specified level. At the world's current rate of 40 Gt of carbon per year, that budget is expected to last a little more than ten years before risking a temperature increase that will significantly alter the climate.

Zero carbon buildings represent the best opportunity for cost-effective emissions reductions. Investment in zero carbon building can keep Canada on target for its commitment to be zero emissions by 2050. At the same time, zero carbon building can spur innovation in design, building materials, and technologies, helping to create new low-carbon jobs and business opportunities. However, to accelerate the uptake and application of zero carbon buildings requires a common understanding of the importance of carbon in the building sector. It also requires the upskilling of zero carbon building competencies for engineers, architects, and renewable energy specialists.

This study demonstrates that engineers, architects, and renewable energy specialists still need to develop the competencies and sub-competencies required to respond to increasing market demand for zero carbon buildings. Targeted actions must be taken by education and training providers, accreditation and professional bodies, and policy decision-makers to minimize the knowledge and skill gaps among these professions. As a result, the industry must ensure that zero carbon building education and training resources are available, of high quality, and are delivered at the right time and in the right format(s) to facilitate upskilling.

Working together, Canada's education and training providers, accreditation and professional bodies, and policy decision-makers can provide the leadership needed to create a highly educated and empowered professional workforce – one able to support Canada's transition to a zero-carbon building future.

[28] Intergovernmental Panel on Climate Change (IPCC), ***2018: Global Warming of 1.5°C.*** *An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*, 2019 [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. In Press.

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Appendix 1: Study Methodology Analysis

Research Approach

The study included an industry survey, a desktop environmental scan of currently available training options related to zero carbon building, and interviews with education and industry experts in the areas of engineering, architecture, and construction.

Industry Survey
CaGBC administered a knowledge and skills gap online survey. The survey is provided in Appendix 3. The survey was distributed to architectural, engineering, and renewable energy professionals across Canada through CaGBC's network. The questions focused on the core competencies required for zero carbon building construction and development. The survey comprised multiple-choice and open-ended questions, and an option for individual comments was provided.

The online survey was started by 448 participants and a total of 318 fully completed responses were received from all regions of Canada, over a three-week period between March and April 2019. From the 318 responses received, through self-identification by respondents, 34 per cent were engineers, architects were 19 per cent, and renewable energy specialists were 8 per cent. The remaining 39 per cent were other professions. Results are captured in Appendix 3.

Approach to Data Analysis
To identify where zero carbon building knowledge and skills gaps exist and to what extent, the Knowledge to Job Importance, and Practical Experience ratings from the survey were compared for zero carbon building competencies. In the instance that the knowledge level was rated low and the importance to job was rated high, a skills gap was recorded.

A comparison of the difference between the mean score of personal knowledge and the mean score of job importance demonstrated areas where aggregate knowledge was lower or higher than the importance to the average respondent's job. The mean was selected to capture the overall state of knowledge and job importance in each profession, while minimizing outliers. A seven-point scale was used, with one representing no knowledge/no practical experience/no job importance, and seven representing high knowledge/high practical experience/high job importance. By comparing respondent knowledge with the importance of the core competency to their job, a reliable picture was established of where gaps exist and to what extent for zero carbon building competencies.

A cross-tabulation of the results were also generated to provide a detailed evaluation of responses based on the one to seven Likert scale. This was carried out to address whether a mean might be obscuring very polarized distributions.

Knowledge, Experience, and Job Importance
Respondents were asked to self-report on their perceived knowledge and practical experience in several core competencies required for zero carbon building, while also indicating the importance of the competency to their job. Each competency included a set of sub-competencies in order to solicit a more refined assessment of the skills and knowledge needed for zero carbon building. For each competency, the highest ranked priority gap, defined as the difference between the knowledge to job importance ratings is identified by profession, along with an overview of the results by competency. Respondents were also asked to identify their preferred format of learning. These core competencies were established by subject matter experts to reflect the knowledge and skills required to work on the design, construction, and operations of zero carbon buildings (as presented in Appendix 2).

The key competencies were grouped under the following five headings:

Zero Carbon Balance
- Zero Carbon Building Principles in General
- Greenhouse Gas (GHG) Accounting
- Calculating a Zero Carbon Balance
- Transition Plans
- Impact of Buildings on Climate Change
- Reducing Energy Demand Through Passive Design

Energy Efficiency
- Thermal Energy Demand Intensity (TEDI) and Cooling Demand Intensity
- Energy Use Intensity (EUI)
- Strategies for Reducing Heating and Cooling Energy Demand
- Strategies for Improving Energy Efficiency and Reducing Peak Demand

Renewable Energy
- Onsite Renewable Energy Generation
- Offsite Renewable Energy Generation

Low Carbon Materials
- Embodied Carbon in Construction
- Performing Life-Cycle Assessment (LCA) and Calculating Embodied Carbon

Future Weather
- Resilient Building Design
- Adaptable Building Design
- Designing for Future Weather Conditions

Environmental Scan

An online scan was conducted of available education and training related to the core competencies that were utilized for the survey. This scan identified education offerings available for competencies and sub-competencies required for the delivery of zero carbon buildings. The scan included both in-person education and training offered in Canada, as well as online education and training. The scan targeted continuing education and training opportunities for building professionals with a focus on engineers, architects, and renewable energy specialists.

Approximately 170 courses were identified and grouped into readily identifiable topics based on the zero carbon building core competencies and sub-competencies for ease of comparison and evaluation. In some instances, slightly more detailed topic groupings were established to better capture the granularity of course topics. A limitation of the scan was the capacity to segment identified courses to a building profession. This was due to the lack of course descriptions that identified the primary target audience(s). Where possible, the course overview was examined to evaluate applicability to engineers, architects, and renewable energy specialists. Some additional limitations to the scan included the following:
- In some cases, identified courses were offered in multiple delivery formats, but only one format was identified and recorded in the environmental scan;
- In-person courses identified during the scan did not include courses delivered outside of Canada;
- Most courses did not explicitly call out the target audience in the course descriptions and/or course registration pages;
- Higher education offerings were excluded from the scan, as well as papers and/or articles; and,
- The integrated design process (IDP) was included as part of the scan although not identified as a specific zero carbon building competence or sub-competency. The scan did not identify any course offerings related to the IDP specific to zero carbon buildings.

Appendix 2: Glossary of Competencies and Sub-competencies for Zero Carbon Buildings

CaGBC worked with engineers, architects, contractors, manufacturers, public and private owners and operators of large buildings, design firms, policy makers, among others, over the last five years to identify the key components and foundational practices and processes that define a zero carbon building. These efforts culminated in the establishment of the first North American standard for designing and retrofitting buildings to achieve zero carbon, referred to as the Zero Carbon Building Standard (ZCB Standard). More information on zero carbon, the ZCB Standard and the core competencies for zero carbon can be accessed at www.cagbc.org/zerocarbon. The ZCB Standard was chosen for this study as the reference document to define the core competencies and sub-competencies for zero carbon building as follows:

Zero Carbon Balance

The carbon balance is the net emissions that result from sources and sinks of carbon emissions, and it is calculated based on the embodied (i.e., emissions from the manufacturing, transport, installation, use, and end-of-life of building materials) and operational carbon (i.e., the emissions associated with energy use and the release of refrigerants during regular building operations) as well as avoided emissions. A zero carbon building achieves a balance of zero or less emissions, measured annually in terms of embodied and operational emissions. To achieve that balance, GHG emissions associated with building operations must be reduced through building design or offset through low carbon renewable energy or other verified carbon reduction measures.

Key competency considerations include:

Zero Carbon Building Principles in General: refers to the design, construction and operation principles that consider carbon as a metric and have the goal to achieve a zero carbon balance. The holistic assessment of carbon emissions needs to be incorporated from the early design stage and it is the best measure of progress towards minimizing climate change impacts from buildings.

Greenhouse Gas (GHG) Accounting: Refers to a methodology that quantifies the emissions from the operation of a building during a given period. The understanding, accounting and reporting of buildings' GHG emissions, assist businesses to benchmark their assets and to show progress over time.

Calculating a Zero Carbon Balance: The carbon balance over a specific building life-cycle, is the net emissions, calculated by adding the embodied carbon emissions plus the operational carbon emissions less the avoided carbon emissions. All the emissions across a building's life-cycle – from the construction to the maintenance, operation and end of life – are included in this calculation. In order to counterbalance these emissions, avoided emissions from investing in carbon offset projects as well as exported green power are considered. When the carbon balance is calculated to zero or better, it means that the building can be certified as zero carbon.

Transition Plans: Refers to the plan to retrofit a building and reduce its GHG emissions when any onsite combustion for space heating or hot water is used. The transition plan must indicate how the impact of onsite combustion will be mitigated over the lifetime of the building, including the way emissions derived from onsite combustion will be reduced or eliminated using specific design or energy efficiency measures. Transition plans contribute to the effort towards a combustion-free future of buildings, setting specific timeframes and actions to achieve this goal.

Impact of Buildings on Climate Change: Refers to the overall emissions associated with the building sector. Buildings' construction and operation are responsible for a high percentage of GHG emissions at a national and global level. As a result, buildings provide a unique opportunity to make significant emissions reductions and contribute to slowing down the effects of climate change.

Reducing Energy Demand Through Passive Design: Refers to the design decisions taken in order to minimize the energy demand and subsequently, the carbon emissions of a building. Passive design considerations include, good orientation and window-to-wall ratio, the use of a building's thermal mass, an efficient and airtight envelope construction, among others. Reducing energy demand through passive design is a topic also related to the thermal energy and cooling demand intensity in the energy efficiency competency.

Energy Efficiency

Energy Efficiency is the first step to reduce energy demand and associated energy costs, cut emissions, improve the operating performance of a building, and reduce the environmental impacts of energy production. Energy Efficiency is usually associated with heating, cooling, hot water, and lighting. It further focuses on meeting energy needs with the least energy use and carbon emissions while reducing the peak demand on the electricity grid.

Emphasis needs to remain first on the dual goals of minimizing embodied carbon and reducing energy demand. Improvements to the building's envelope and ventilation strategies not only reduce energy demand but also enable heating solutions that are not fossil fuel-based. Energy Efficiency is critical to ensuring the financial viability of zero-carbon designs, promotes resiliency, frees clean energy for use in other economic sectors and geographical regions, and reduces environmental impacts from energy production. Efficiency also supports grid harmonization and minimizes negative impacts on electricity grids, such as the need to meet high peak demands or absorb large amounts of renewable energy generated onsite.

Key competency considerations include:

Thermal Energy and Cooling Demand Intensity: Refers to the annual heat loss from the building envelope and ventilation, after accounting for all passive heat gains and losses. When calculated with modelling software, Thermal Energy Demand Intensity (TEDI) is based on the amount of heating energy delivered to the project that is outputted from any types of space heating equipment, per unit of gross floor area. TEDI is reported in kWh/m^2/year. The consideration of the thermal energy and cooling demand intensity in the early design of a building results in greater occupant comfort and in minimized energy demand prior to producing or procuring renewable energy.

Energy Use Intensity (EUI): Refers to the 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 gross floor area. EUI is reported in kWh/m^2/year. The EUI metric ensures that the energy efficiency of all building systems is considered holistically. EUI is reported in kWh/m^2/year.

Strategies for Reducing Heating and Cooling Energy Demand: Refers to design strategies and interventions in the envelope and mechanical systems that aim to reduce the energy demand for heating and cooling. Such strategies could include the increasing levels of thermal insulation, the integration of natural ventilation techniques, the efficient design of natural lighting, among others. These strategies ensure long-term energy performance and reduced dependence on the energy grid.

Strategies for Improving Energy Efficiency and Reducing Peak Demand: Improving energy efficiency refers to design strategies that reduce the energy demand and improve the overall building's efficiency. Peak demand is the building's highest electricity load requirement in a year and is measured and reported in kW. A high-performing building will be less dependent on the electricity grid and have lower seasonal peak demand.

Renewable Energy

Building emissions can be reduced using either onsite or offsite sources of renewable energy. Renewable Energy is referred to as a source of energy that is replenished through natural processes or uses sustainable management policies, such that it is not depleted at current levels of consumption. Examples can include solar and wind energy used for power generation and solar energy used for space and water heating. For projects where Onsite Renewable Energy is not feasible, Offsite Renewable Energy presents an additional option for emissions reductions.

Key competency considerations include:

Onsite Renewable Energy Generation: Refers to a site that is not connected to the electricity grid, and the energy that can be consumed (or stored and then consumed) onsite is considered onsite renewable energy. Integrating onsite renewable energy takes into account the grid interactions to ensure real carbon reductions. For example, energy storage, whether in the form of electrical or thermal storage, is now recognized as a valuable strategy that helps minimize grid impacts while reducing or eliminating the need for fossil fuels to meet peak heating demand. Generating onsite renewable energy helps to improve building resilience in the face of power outages, reduces overall demand from the electricity grid, minimizes environmental impacts from power generation facilities, and helps prepare for a distributed energy future.

Offsite renewable energy generation: Refers to new and virtually net-metered systems. Virtual net-metering is an arrangement with a 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 on a campus. Many buildings in dense urban areas – mid-rise or high-rise buildings – and energy-intensive building types will require some or all of the renewable energy to be procured offsite in order to achieve a zero carbon balance.

Low Carbon Materials

While the energy efficiency of buildings has improved and reduced the emissions associated with building operations, the relative embodied carbon associated with building materials has increased. Emphasis needs to be directed at reducing the carbon associated with the life-cycle embodied carbon of materials. Of particular importance are the emissions from the production of construction materials, which is referred to as upfront carbon.

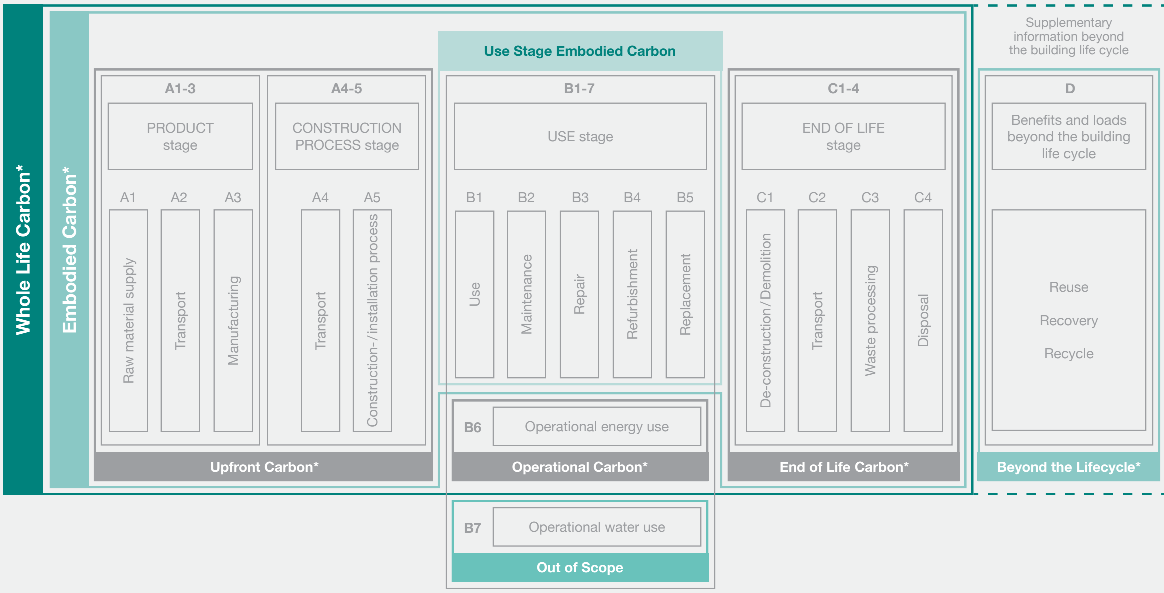
Low carbon materials are the ones with reduced carbon emissions associated with their life-cycle, such as manufacturing, transportation, construction, and end of life phases.

Key competency considerations include:

Embodied Carbon in construction: Refers to the carbon emissions associated with materials and construction processes throughout the whole life-cycle of a building. Whole-life carbon refers to the emissions from all the life-cycle stages of a building, encompassing both embodied carbon and operational carbon together (see stages A1-A5: Upfront carbon; stages B1-5: Use stage carbon; stage B6: Operational carbon; stages C1-4: End of life carbon. Stage D: Beyond the life-cycle, and stage B7: Operational water use, are supplementary stages and are not included in the assessment of the whole life carbon).

Understanding embodied carbon in construction contributes to the integration of low carbon design and materials selection, significantly reducing the emissions related to building materials and protecting against the increased need for natural resources.

Figure 6: Embodied Carbon Life-cycle Stages[29]



Performing Life-cycle Assessment (LCA) and Calculating Embodied Carbon: As defined by ISO 14040:2006, 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. This is accomplished by tracking the embodied carbon (emissions) associated with materials and construction processes throughout the whole life-cycle of a building. LCA is a performance-based approach that aims to quantify and reduce the carbon emissions associated with building materials across their whole life-cycle.

Future Weather

Over 80 per cent of today's current buildings will still be in operation by 2050, and the majority will not be designed to adapt to changing climates and the impacts of extreme weather events, such as intense forest fires, heavy flooding, damaging winds, and prolonged power outages. Building professionals will need to be well-equipped with the skills required to design, construct, and operate adaptable and resilient buildings to be zero carbon.

As average global temperatures increase, it is predicted that heating and cooling demands will change for buildings. As well, extreme weather events such as extreme heat and cold, high winds, and flooding are also expected to pose increased risks to buildings and the infrastructure on which they rely, such as electricity grids. Project teams must understand that the weather of today may not be an accurate way to model a building's performance in the future.

[29] Figure 6 originally appeared in the World Green Building Council report, *Bringing Embodied Carbon Upfront*.

Key competency considerations include:

Resilient Building Design: Refers to the design approach of a building – a new building or a deep retrofit of an existing one – that ensures livability in the event of natural disasters, loss of power, or other interruptions. Resilient (and future-proofing) building design is influenced by a wide range of regional or localized impacts including more intense storms, greater precipitation, coastal and valley flooding, longer and more severe droughts, wildfires, melting permafrost, warmer temperatures, and power outages. From buildings to communities and cities, resilient design is critical in any scale, to ensure long-term use and sustainability of the built environment.

Adaptable Building Design: Refers to adaptation measures required for a building to respond to changing conditions for short- and long-term use. Population growth, demographic changes, changes in lifestyle, technological and market evolution, are some of the parameters that may force a building to adapt to new operations over time. Adaptable and flexible design increases livability as it enables a building with at least 60-years lifetime to accommodate a range of uses. It also ensures reusability as a whole as well as for the individual components of a building. As a result, adaptable buildings last longer and can respond to changing market demands.

Designing for Future Weather Conditions: Refers to the design strategies used to address a changing natural environment (i.e., rainfalls, global temperature increase, high winds, etc.) As our climate evolves, the weather files used today are not likely to be an accurate way to model the performance of a building's design in the future. As a result, design teams must take a long-term view which keeps future weather in mind when evaluating the operational profile of a building during its early design stages.

Appendix 3: Industry Survey

Survey: Next Steps in Achieving Zero Carbon in the Built Environment

You are invited to participate in our survey “Next Steps in Achieving Zero Carbon in the Built Environment”. This survey will take approximately 10 minutes to complete. All responses will remain confidential and will only be used in aggregate form.

Survey Purpose:
This survey aims to identify gaps in the zero carbon building (ZCB) knowledge and skills of small to medium-sized enterprise employees, with a particular focus on the following sectors:
- Engineering Firms
- Architectural Firms
- Renewable Energy Firms

We also encourage individuals in the above fields who might not currently be working, or who work for larger companies, to complete this survey.

Background:
Canada has ambitious goals to reduce the amount of greenhouse gas emissions, including emissions associated with the built environment. One way in which to meet these goals is to transition to low/zero carbon buildings (ZCB). A ZCB is defined as one that is highly energy-efficient and produces onsite, or procures, carbon-free renewable energy in an amount sufficient to off-set the annual carbon emissions associated with the building. This can include different stages of a building’s life, including the design, development and operations for the new and/or existing buildings.

Which of the following best describes your current profession?
- ☐ Engineer
- ☐ Architect
- ☐ Renewable Energy
- ☐ Other (please specify)

Please indicate the size of the organization you work for based on the number of full-time equivalent (FTE) employees.
- ☐ 1-4
- ☐ 5-19
- ☐ 20-99
- ☐ 100-499
- ☐ 500+
- ☐ N/A – Not currently employed

The first part of the following questions asks you to rate your level of knowledge on the subject matter. The second part of the following questions ask you to rate your level of practical experience with the subject matter. The third part of the following questions ask you to rate the importance of the subject matter as it relates to your job.

Section B: Zero Carbon Balance

How would you rate your knowledge related to the following?

	No Knowledge						Expert Knowledge
	1	2	3	4	5	6	7
Low/zero carbon buildings principles in general							
Greenhouse gas accounting							
Calculating a zero carbon balance							
Transitions plans (e.g., A plan to retrofit a building to reduce greenhouse gas emissions)							
Impact of buildings on climate change							
Reducing energy demand through passive design							

How would you rate your practical experience related to the following?

	No Experience						In-Depth Experience
	1	2	3	4	5	6	7
Low/zero carbon buildings principles in general							
Greenhouse gas accounting							
Calculating a zero carbon balance							
Transitions plans (e.g., A plan to retrofit a building to reduce greenhouse gas emissions)							
Impact of buildings on climate change							
Reducing energy demand through passive design							

How important are the following in relation to your job?

	Not Important					Extremely Important
	1	2	3	4	5	6	7
Low/zero carbon buildings principles in general							
Greenhouse gas accounting							
Calculating a zero carbon balance							
Transitions plans (e.g., A plan to retrofit a building to reduce greenhouse gas emissions)							
Impact of buildings on climate change							
Reducing energy demand through passive design							

Section C: Energy Efficiency

How would you rate your knowledge related to the following?

	No Knowledge						Expert Knowledge
	1	2	3	4	5	6	7
Thermal energy and cooling demand intensity							
Energy use intensity							
Strategies for reducing heating and cooling energy demand							
Strategies for improving energy efficiency and reducing peak demand							

How would you rate your practical experience related to the following?

	No Experience						In-Depth Experience
	1	2	3	4	5	6	7
Thermal energy and cooling demand intensity							
Energy use intensity							
Strategies for reducing heating and cooling energy demand							
Strategies for improving energy efficiency and reducing peak demand							

How important are the following in relation to your job?

	Not Important						Extremely Important
	1	2	3	4	5	6	7
Thermal energy and cooling demand intensity							
Energy use intensity							
Strategies for reducing heating and cooling energy demand							
Strategies for improving energy efficiency and reducing peak demand							

Section D: Renewable Energy

How would you rate your knowledge related to the following?

	No Knowledge						Expert Knowledge
	1	2	3	4	5	6	7
Onsite renewable energy generation							
Offsite renewable energy generation							

How would you rate your practical experience related to the following?

	No Experience						In-Depth Experience
	1	2	3	4	5	6	7
Onsite renewable energy generation							
Offsite renewable energy generation							

How important are the following in relation to your job?

	Not Important						Extremely Important
	1	2	3	4	5	6	7
Onsite renewable energy generation							
Offsite renewable energy generation							

Section E: Low Carbon Materials

How would you rate your knowledge related to the following?

	No Knowledge						Expert Knowledge
	1	2	3	4	5	6	7
Embodied carbon in construction							
Performing life-cycle assessment and calculating embodied carbon							

How would you rate your practical experience related to the following?

	No Experience						In-Depth Experience
	1	2	3	4	5	6	7
Embodied carbon in construction							
Performing life-cycle assessment and calculating embodied carbon							

How important are the following in relation to your job?

	Not Important 1	2	3	4	5	6	Extremely Important 7
Embodied carbon in construction							
Performing life-cycle assessment and calculating embodied carbon							

Section F: Approach to Performance

How would you rate your knowledge related to the following?

	No Knowledge 1	2	3	4	5	6	Expert Knowledge 7
Resilient building design							
Adaptable building design							
Designing for future weather conditions							

How would you rate your practical experience related to the following?

	No Experience 1	2	3	4	5	6	In-Depth Experience 7
Resilient building design							
Adaptable building design							
Designing for future weather conditions							

How important are the following in relation to your job?

	Not Important 1	2	3	4	5	6	Extremely Important 7
Resilient building design							
Adaptable building design							
Designing for future weather conditions							

Please provide any additional comments you may have regarding the zero carbon building topics listed above.

Section G: Education Preferences

What is your preferred method of learning? Please select all that apply.

- ☐ Online courses
- ☐ In-person courses
- ☐ Education on the job-site
- ☐ Physical job aids or instructional guides (e.g. paper-based checklists, etc.)
- ☐ Electronic resources (e.g. online resources centre, electronic version of building codes, etc.)
- ☐ Online community of interest (e.g. individuals ask questions and/or provide guidance to others)
- ☐ Other (please specify)

Section H: Demographics - (a few last questions)

How many years of experience do you have working in the green building field?

- ☐ Less than 1 year
- ☐ 1 to 3 years
- ☐ 4 to 6 years
- ☐ 7 to 9 years
- ☐ 10 to 12 years
- ☐ 13 to 15 years
- ☐ More than 15 years
- ☐ No experience; I'm still in school

What is your age?

- ☐ 18-25 years old
- ☐ 26-35 years old
- ☐ 36-45 years old
- ☐ 46-55 years old
- ☐ 56-65 years old
- ☐ 66+ years old

Where are you located?

- ☐ British Columbia
- ☐ Alberta
- ☐ Saskatchewan
- ☐ Manitoba
- ☐ Ontario
- ☐ Quebec
- ☐ New Brunswick
- ☐ Newfoundland & Labrador
- ☐ Nova Scotia
- ☐ Prince Edward Island
- ☐ Northwest Territories
- ☐ Nunavut
- ☐ Outside of Canada
- ☐ Other

Please provide any final comments you may have regarding the questions contained within this survey.

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