SSRIA Zero Carbon Building Report

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SMART SUSTAINABLE RESILIENT INFRASTRUCTURE ASSOCIATION

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Executive Summary

Since 2016 when 175 worldwide parties agreed to the Paris Accord, focus on renewable energy sources and the reduction of greenhouse gases (GHGs) has steadily increased. Today, the number of participating parties has risen to 187, and dated goals ranging from 2020 to 2050 continue to remain prominent with codes, standards and policies being created which call for GHG and energy efficiency improvements. Many of these policies began with focus on the generation of renewable energy and an increase in building performance. However, when comparing existing policies, the lack of focus on carbon, both embodied and operational, has become much more apparent in recent times. This is especially true when considering the fact that over 50% of buildings built today will still be in use by 2050. The importance of the building sector's operational carbon and GHG emissions is more important than ever. This report serves as a market assessment and implementation forecast of both new and existing buildings to aid the SSRIA in stimulating and encouraging future low-carbon focused projects and a carbon healthy market in Alberta.

As this is a preliminary report, select building typologies were chosen based on relevance and impact; more may be pursued in future research if called for. These typologies are detailed in *Section 8: Zero Carbon Building Archetypes and Systems* in the report and in *Appendix B: Barriers of Adoption*. Alongside the detailed energy conservation measures (ECMs) relevant to each building type in Section 8, current and emerging techniques and technologies that can support carbon emission reductions in Alberta are further defined in *Section 7: Practical Techniques and Technologies to Implement Zero Carbon*. Additional support through increased advocacy, education and incentives are recommended in response to the current provincial political landscape, aligning with federal goals and drawing from well-known published codes and standards across North America. These are outlined in *Appendix A: Research Analysis* and *Appendix C: Impact Gap Analysis.*

1. Defining Zero Carbon

Defining "Zero"

A key consideration in adopting a net-zero, or "zero", building approach is to define how zero is being considered. Several definitions exist in the market today, including carbon neutral buildings, zero emissions building, low carbon buildings, high-performance buildings, and net-zero ready buildings, to name a few. While this array can be overwhelming, there are several key criteria to help distinguish them from one another, which are described in Table 1. This table will be used to describe each assessed national, sub-national, municipal, and voluntary standard in the following section. Adopting a single definition and approach to net-zero will help to ensure clarity, transparency, and objectivity in decision-making moving forward.

Table 1: Criteria for Defining Net-Zero Building Performance Standards

Energy Measurement	• Traditionally, environmental performance standards have focused on energy efficiency as the means to achieving emissions reductions. Building energy consumption can be defined in two main ways: ◦ *Site energy*: the energy that a building produces and consumes at the building site. ◦ *Source energy*: the energy that a building produces and consumes, taking into account losses in the extraction, processing and transportation of each fuel type. • *Net-zero energy ready*: this building is efficient enough that all energy consumption could be produced onsite by a renewable source. • *Energy emissions*: the greenhouse gas (GHG) emissions associated with building energy consumption. • *Energy cost*: the cost of building energy consumption.
Metric	• The metric(s) of choice will depend on the focus of the standard. Common energy use metrics include: ◦ *Thermal Energy Demand Intensity (TEDI)*: building's demand for heating and cooling only, taking passive gains and losses into account, divided by the total building area. ◦ *Total Energy Use Intensity (TEUI):* the energy required to power all heating, cooling, ventilation, lighting and other electrical needs, divided by the total building area. Within this study, TEUI is interchangeable with *Energy Use Intensity (EUI)*. • Common emissions-based metrics include: ◦ *Greenhouse Gas Intensity (GHGI):* the total amount of GHG emissions associated with a building's operational energy use.
Scope	• Typically, net-zero policies and standards focus on reducing energy or emissions associated with building operations. This is achieved by designing a building energy model, which must meet prescribed performance metrics, such as TEDI or EUI. Once constructed, the building will implement a measurement and verifications (M&V) plan to determine how well the building is meeting these metrics in operation. • Additionally, some standards are beginning to focus on the energy or carbon that is embodied within building materials. This concept, known as embodied emissions, requires a life-cycle analysis, a growing service offering in the building industry. Life-cycle analysis is the process of analyzing all energy that has been expended in a product's life. This ranges from the extraction of all base materials (e.g. wood, ore, etc.), to the processing of materials into products, to the transportation of these materials and products to factories, stores and job sites, and a product's final disposal or recycling process. The summation of this expended energy and its associated emissions, is considered a cradle-to-grave life-cycle analysis and describes the total embodied carbon within a product.

Scale	• Achieving zero energy or carbon can be addressed at the building, campus/district, or portfolio scales. Taking a building scale approach ensures greater overall reductions, while district- or portfolio-level approaches can help to target investments.
Renewable Energy	• How the zero balance can be met is determined in part by the way energy use or emissions are offset. While some standards require 100% on-site renewable energy generation, others allow off-site renewable energy sources, renewable energy credits, or carbon offsets.

Zero Carbon Working Definition

For the purpose of this report, Zero Carbon will be defined as "designing a highly energy efficient building which offsets its annual energy demand through onsite renewable energy, producing no greenhouse gas emissions". This definition purposely limits the scope to only include emissions related to building operations which is in alignment with SSRIA's main scope of activities in Alberta.

The definition above will be utilized in Section 8, where each building archetype will be developed and detailed to achieve this target.

2. Existing Zero Carbon Strategy and Policy Review

National and Sub-National Frameworks

Action on addressing climate change in the built environment is ongoing at all scales of government, including at the federal level. In signing the 2015 Paris Agreement, the Canadian Federal Government pledged to cut national emissions by 30 percent by 2030 over 2005 levels. They built upon this commitment in 2016, initiating the *Pan-Canadian Framework on Clean Growth and Climate Change* (Government of Canada, 2016) in collaboration with provinces, territories and Indigenous peoples. The purpose of the Framework is to chart a path to meet national emissions reduction targets, while bolstering the economy and building resilience to changing climate. With respect to energy efficiency, the framework requires all levels of government to adopt increasingly stringent building codes starting in 2020, and working towards "net-zero energy ready" building codes by 2030. Building codes are to take regional differences into account, and will be supported by the Federal Government through continued investment in research, demonstration, and cooperation with industry.

The BC Energy Step Code

The first of these provincial net-zero energy-ready building codes was developed by the Province of British Columbia (BC). The Province's 2008 *Climate Action Plan* set out a greenhouse gas emissions reduction target of 80% below 2007 levels by 2050, including emissions reductions in the building sector. Developed in 2016, the creation of the BC Energy Step Code provides a performance-based pathway to net-zero energy-ready buildings and a single, consistent, cross-Province solution to the patchwork of different building standards that was previously offered by BC municipalities (Government of British Columbia, 2017). While the net-zero energy-ready portion of the Step Code will not be mandated into the BC Building Code until 2032, local governments have the option to voluntarily adopt the Step Code as a requirement or incentive to the BC Building Code for new buildings.

The BC Energy Step Code focuses on achieving emissions reductions by setting energy performance targets for new Part 9 (single-family residential) and Part 3 (multi-unit residential and commercial) buildings. Part 9 buildings are required to meet increasingly stringent targets for mechanical energy use intensity (MEUI) and thermal energy demand intensity (TEDI), while Part 3 buildings are required to meet set levels of performance in Total Energy Use Intensity (TEUI) and TEDI. Both Part 9 and Part 3 buildings are also required to submit energy models and subject completed projects to an airtightness test. While a GHG Intensity target was proposed for adoption during early stages of Step Code development, it was ultimately excluded from performance requirements. However, the highest steps of the new code require buildings to achieve a net-zero energy-ready level of building performance, and accept Passive House as an alternative compliance pathway.

Policy	Source	Scale	Metric(s)	Scope	Renewable Energy
BC Energy Step Code	Energy	Building	· TEDI (kWh/m2/year) · Total EUI (kWh/m2/year) · Airtightness	Operations	Off-site allowed

Province of Ontario & Infrastructure Ontario

To date, no other provinces have yet to adopt a code on par with the BC Energy Step Code. In Ontario, the previous Provincial government articulated a commitment to achieve net-zero carbon/carbon neutral for small buildings by 2030 in its *Climate Change Action Plan*, along with a commitment to make all new buildings zero energy-ready by 2030 (Government of Ontario, 2015). Part 12 of the Ontario Building Code (OBC) is currently divided into SB-10 for large buildings and SB-12 for houses of three stories or less. January 2017 updates to the SB-12 included a prescriptive target of a 15% increase in energy efficiency in new homes over the previous requirements. Other SB-10 updates included a compliance path that targets a 13% improvement over the current energy efficiency for large buildings. As in British Columbia, these updates do not target carbon specifically, but move the building code baseline closer to achieving a net-zero energy-ready level of performance.

In addition to prescribing more stringent building codes, the Province of Ontario has set requirements for its own ministries with operational control of government facilities. Emissions reduction targets were set at 19% below 2006 levels by 2014, and the upcoming target of 27% below 2006 levels by 2020. Of note is the Ontario Ministry of Infrastructure's real estate operator Infrastructure Ontario (IO), which has reduced emissions levels from its facilities by 48% since 2006 (Government of Ontario, 2017). IO has outlined three steps to achieve carbon neutrality in its building stock: 1) right-sizing its building portfolio, 2) improving building energy efficiency, and 3) employing low-carbon energy sources. These three steps are part of the previous government's commitment to bring Infrastructure Ontario's building portfolio to zero carbon/carbon neutral by 2030.

Policy	Source	Scale	Metric(s)	Scope	Renewable Energy
Infrastructure Ontario	Emissions	Portfolio	· Not available	Operations	Off-site and RECs allowed

Public Services and Procurement Canada (PSPC)

Public Services and Procurement Canada (PSPC) is the second largest contributor to federal government GHG emissions from building operations, having a real estate portfolio of almost 300 facilities and structures. Consistent with the 2016 to 2019 *Federal Sustainable Development Strategy*, the department has committed to achieve carbon neutrality across its Crown-owned real property portfolio by 2030 (Government of Canada, 2015). In pursuit of this goal, departmental undertakings include: implementing building automation, deep energy retrofits, and lighting upgrades; fuel switching; optimizing space utilization; and modernizing the five district energy plants used to heat and cool over 80 buildings in Ottawa's National Capital Region. To evaluate its progress, PSPC will be tracking GHG emissions per fiscal year and GHG offsets/renewable energy credits applied per fiscal year.

Policy	Source	Scale	Metric(s)	Scope	Renewable Energy
PSPC Sustainable Development Strategy: 2017 to 2020	Emissions	Portfolio	· GHGI (tCO2e/m2/year)	Operations	GHG offsets/ renewable energy credits allowed

California's Building Energy Efficiency Standards Program

South of the border, several of the State of California's actions are also noteworthy. In 2007, California set a goal of achieving zero net energy levels of performance in all new commercial construction by 2030. In 2015, the state launched its *Zero Net Energy Action Plan* to ensure that all new homes will be net zero energy by 2020 (California Public Utilities Commission, 2015).

California's *Building Energy Efficiency Standards* contain energy and water efficiency requirements for new construction and major renovation projects, and are divided into three basic sets: 1) A basic set of mandatory requirements that apply to all buildings; 2) A set of tailored performance standards (or "energy budgets") that vary by climate zone and building type that provide flexibility in how energy efficiency in buildings can be achieved; and 3) An alternative set of prescriptive packages that provide a recipe or a checklist compliance approach (California Public Utilities Commission, 2012). The 2019 Energy Standards update represents a major step towards meeting the Zero Net Energy (ZNE) goal by the year 2020 and is the last of three updates to move California toward achieving that goal (California Public Utilities Commission, 2018).

Policy	Source	Scale	Metric(s)	Scope	Renewable Energy
California Building Energy Efficiency Standards	Energy	Building	· Total EUI (kWh/m2/year)	Operations	Off-site allowed

Massachusetts' Stretch Code

A second state-level approach worth noting can be found in the State of Massachusetts. Since 2008, the Zero Net Energy Buildings Task Force and Zero Net Energy Building Advisory Council have worked to create a pathway toward zero net energy buildings in the state, with an overarching aim of putting the private sector on a path toward 1) the broad marketability of zero net energy commercial and residential buildings by 2020 and 2) the universal adoption of zero net energy practices for new commercial and residential construction by 2030 (Massachusetts Zero Net Energy Buildings Task Force, 2009). In addition, Massachusetts offers a Stretch Code to municipalities who want to implement more stringent energy efficiency provisions for new construction and major renovation projects within its jurisdiction (Government of Massachusetts, 2019). Once adopted, the Stretch Code becomes the new mandatory base code for that municipality. As of November 2018, 250 municipalities have adopted the Stretch Code and many building code officials have received free training (Government of Massachusetts, 2019).

Policy	Source	Scale	Metric(s)	Scope	Renewable Energy
Massachusetts Stretch Code	Energy	Building	· Total EUI (kWh/m2/year) · HERS rating	Operations	Off-site allowed

Municipal Actions

Finally, some local governments are also working to require and evaluate increasingly higher performance among their communities' building stock. As above, many of these focus on energy efficiency; however, some are beginning to focus more exclusively on emissions reductions.

The City of Vancouver's Zero Emissions Building Plan

Vancouver has committed to becoming the 'Greenest City' in the world by 2020. In support of this goal, the City has outlined energy use and GHG emission reduction targets in existing buildings by 20% over 2007 levels by 2020, and now requires all new buildings built from 2020 onward to be carbon neutral in operations (City of Vancouver, 2016). In support of this goal, the *Zero Emissions Building Plan* sets new performance thresholds for major building types in Vancouver every 5 years, to eventually reach zero emissions/carbon neutral in new buildings by 2030 (City of Vancouver, 2016). New developments are required to reach select levels of performance in three primary metrics:

- Total Energy Use Intensity (TEUI), to encourage higher efficiency buildings and lower utility costs;
- Thermal Energy Demand Intensity (TEDI), to encourage better building envelopes, improve occupant comfort and enhance resilience; and
- Greenhouse Gas Emissions Intensity (GHGI), to encourage low-carbon fuel choices and reduce building emissions.

The emphasis on total energy use, thermal demand reduction and GHGI encourages a passive design-first approach coupled with high efficiency active systems, such as heat recovery and improved airtightness.

Policy	Source	Scale	Metric(s)	Scope	Renewable Energy
Vancouver Zero Emissions Building Plan	Emissions	Building	· TEDI (kWh/m2/year) · Total EUI (kWh/m2/year) · GHGI (t CO2e/m2/year)	Operations	Off-site allowed

The City of Toronto's Zero Emissions Building Framework

The City of Toronto has committed to an ambitious set of City-wide energy and greenhouse gas (GHG) reduction targets, including a goal of reducing GHG emissions by 80% of 1990 levels by 2050. As a part of the Toronto Green Standard, the *Zero Emissions Building Framework* comprises a full set of targets for the five most common building archetypes that require increasing levels of performance over time (City of Toronto, 2017). As in Vancouver, four tiers of performance were developed to take the building industry from today's building practices to a near-zero emissions level of performance by the year 2030. Tier 4 targets represent a near-zero level of emissions performance, at which point fuel switching is promoted to foster a shift away from natural gas towards electricity and renewable energy sources. The standard uses the same combination of metrics as Vancouver: TEUI, TEDI, and GHGI.

Policy	Source	Scale	Metric(s)	Scope	Renewable Energy
Toronto Zero Emissions Building Framework	Emissions	Building	· TEDI (kWh/m2/year) · Total EUI (kWh/m2/year) · GHGI (t CO2e/m2/year)	Operations	Off-site allowed

The City of Seattle's Sustainable Buildings and Sites Policy

This policy requires that new City-funded projects and major renovations with over 5,000 ft^2 of occupied space achieve a LEED Gold Rating (Staley & Mallory, 2011). For energy efficiency, these projects must achieve an EUI that is a minimum of 15% more efficient than a baseline building designed to the 2009 Seattle Energy Code. In addition, these municipal projects must meet additional water, waste, and bicycle parking requirements. Projects that are under 5,000 ft^2 or not eligible for LEED must complete the Capital Green checklist instead.

Policy	Source	Scale	Metric(s)	Scope	Renewable Energy
Seattle Sustainable Buildings and Sites Policy	Energy	Building	· Total EUI (kWh/m2/year)	Operations	Off-site allowed

Washington, DC's Clean Energy DC Omnibus Amendment Act of 2018

The District of Columbia's Clean Energy DC Act sets a goal of cutting greenhouse gas emissions in DC by 50% (District of Columbia, 2018). Implemented by the Department of Energy and the Environment (DOEE), the Act requires DC's electricity to be generated using 100% renewable energy sources by 2032. It also creates strict energy efficiency standards for new buildings, requiring net-zero construction for residential buildings by 2022 and commercial buildings by 2026. DC will also allow alternative compliance through the International Living Future Institute's (ILFI) Living Building Challenge and Passive House building standards for those developers seeking visible certification.

Policy	Source	Scale	Metric(s)	Scope	Renewable Energy
Washington DC's Clean Energy DC Omnibus Amendment Act of 2018	Emissions	Building	· Total EUI (kWh/m2/year)	Operations	Off-site allowed

Voluntary Standards

In cases where low- and zero-energy and emissions buildings are not mandated by a local jurisdiction, it may be more appropriate to look at third-party certified voluntary standards to demonstrate leadership in green building practices. In addition to promoting higher building standards, participating in these voluntary programs makes an explicit statement about the values of an organization and offers increased visibility for projects. The standards and certifications below offer different pathways for achieving low and zero-energy.

US Green Building Council's LEED v4 BD+C

Developed by the US Green Building Council, LEED is a framework for identifying, implementing, and measuring green building and neighborhood design, construction, operations, and maintenance. LEED is a voluntary, market-driven, consensus-based tool that serves as a guideline and assessment mechanism. LEED rating systems address commercial, institutional, and residential buildings and neighborhood developments. While it does not demand a net-zero level of energy performance, LEED v4 BD+C requires at least 5% energy cost savings from ASHRAE 90.1-2010 standards and will receive recognition up to a reduction of 50%.

Policy	Source	Scale	Metric(s)	Scope	Renewable Energy
USGBC LEED V4 BD+C	Energy cost	Building	· Total EUI (kWh/m2/year)	Operations and embodied	On-site, off-site, and RECs allowed

Canada Green Building Council's Zero Carbon Building Standard

Launched in 2017, the CaGBC's voluntary Zero Carbon Building Standard is the first of its kind in Canada. The program specifically targets the achievement of zero carbon commercial, institutional and multi-family buildings, which it defines as buildings that offset their annual carbon emissions associated with operations using either on-site renewable energy generation or by procuring carbon-free renewable energy. Both new and existing buildings under the program must also report their energy use intensity (TEUI), peak energy demand, and embodied carbon. New construction projects must additionally hit a target for Thermal Energy Demand Intensity (TEDI) to ensure that projects are doing all they can to reduce energy demand before adding renewable energy or purchasing offsets. To demonstrate the broad applicability of the standard, CaGBC is currently running a two-year pilot with 16 zero carbon building projects from across the country. These building types range from offices and multi-unit residential, to schools and institutional developments. The outcomes will inform further refinement of the Standard and the development of tools, resources, and education for the broader building market.

Policy	Source	Scale	Metric(s)	Scope	Renewable Energy
CaGBC ZCB	Emissions	Building	· GHGI (tCO2e/m2/year) · TEDI (kWh/m2/year)	Operations and embodied	Off-site and RECs allowed

ILFI Zero Energy Certification

The International Living Future Institute's (ILFI) Zero Energy Building (ZEB) Certification was created to allow projects to demonstrate zero energy performance, building an advanced cohort of projects with the integrity of third-party performance certification. For zero energy, they state: "One hundred percent of the building's energy needs on a net annual basis must be supplied by on-site renewable energy. No combustion is allowed." This program:

- certifies that the building is truly operating as claimed, harnessing energy from the sun, wind or earth to produce net annual energy demand through a third-party audit of actual performance data,
- provides a case study platform for your project to inform and accelerate other zero energy efforts throughout the world,

- celebrates a significant accomplishment, and differentiates both the building and those responsible for its success in this quickly evolving market.

Policy	Source	Scale	Metric(s)	Scope	Renewable Energy
ILFI Zero Energy Certification	Energy	Building	· Total EUI (kWh/m2/year)	Operations	On-site, with specific off-site exceptions

Passive House Canada

The voluntary Passive House building performance standard is a rigorous performance standard that encourages ultra-high levels of energy efficiency by imposing rigorous standards for heating, cooling, airtightness and energy use in all building types. Passive House Canada administers the program here in Canada, which is identical to the international standard. Passive House Canada provides several resources, training and courses for the achievement of the standard. Approximately 40 projects have been constructed to the Passive House standard in Canada, with a majority found in British Columbia and Ontario.

Policy	Source	Scale	Metric(s)	Scope	Renewable Energy
Passive House	Energy	Building	· Airtightness · Heating energy demand · Cooling energy demand · Primary energy demand	Operations	Off-site allowed

3. General and Local Barrier Identification

Challenges of Implementation

While the implementation of an energy step code will provide many benefits to the building sector, including increased building energy efficiency and resiliency, reduction in greenhouse gas production, more comfortable occupant spaces, and reduced long-term energy costs, there are multiple barriers which must be considered. These challenges can range from general factors such as industry resistance to more specific Alberta-based issues like the emission intensity of the electric grid.

Common Barriers

Typical barriers which appear when more stringent optional energy codes are introduced have been discussed by Laustsen (Laustsen, 2008), and include:

- Focus on capital and incremental costs, but not future costs,
- Insufficient efficiency awareness among consumers and designers,
- Cost structures and lack of expertise,
- Building performance gap,
- Split incentives where costs are covered by builders but the rewards benefit owners,
- Energy is invisible and only appears as comfort, and
- Building codes typically set minimum standards.

These industry, financial, and general barriers are common roadblocks throughout almost all energy efficiency policy implementations. Additionally, the more drastic the change, the more resistance these barriers will demonstrate. To help mitigate these challenges, it is suggested that multiple strategies be implemented, with a focus on providing training and increasing industry expertise, developing and providing financial incentive programs such as the newly implemented Alberta PACE program (Government of Alberta, 2018), developing case studies to increase awareness and confidence, and to allow for adequate time and flexibility for governments to adapt.

Alberta Barriers

In addition to these common barriers, many challenges exist with the Alberta market that can have an effect on the development of an energy step code.

Political

While the implementation of energy efficiency strategies may make sense from an environmental and long-term financial perspective, these goals don't always align with political interests. Therefore, it is important to continue research and development around zero carbon buildings and the energy step code, as long-term ownership of buildings will continue into the future and provide case studies for further uptake. Additionally, building policies and standards can help create stability in times of uncertainty, creating a strong foundation for future building design. A lack of governmental energy efficiency incentives may also provide short-term barriers for zero carbon building development.

Energy Cost

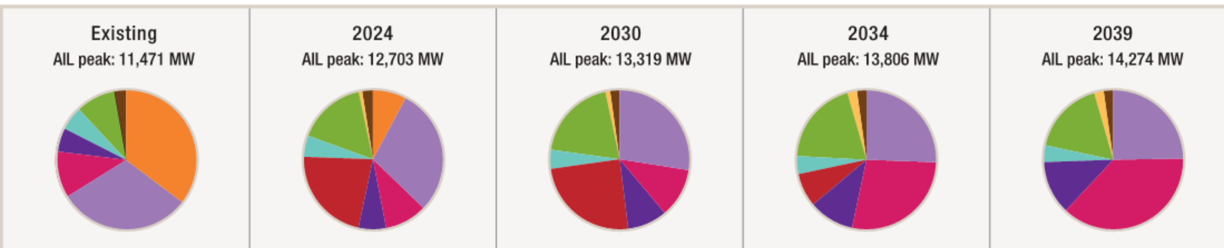
Energy costs within Alberta can also provide a barrier to implementation of zero carbon technologies. Since natural gas costs are so much lower than electricity costs (over 5x cheaper in 2019 (ENMAX, 2019)), long-term owners may be more prone to implementing natural gas based equipment. This creates a barrier around installation of electrical equipment and electrification of a building, which is necessary to achieve zero carbon.

Alberta's Climate

Alberta's climate can also provide a barrier to creating a zero carbon building due to the province's cold winter temperatures. Since technologies which are commonly used to create zero carbon buildings can occasionally struggle to meet heating needs in extremely cold temperatures, building designers may be unwilling to completely rely on these systems. Although cold weather heating technology is improving with low-temperature heat pump systems, full adoption of these mechanical systems may provide a barrier to implementation of zero carbon buildings.

Grid Emission Intensity

Another barrier to the successful implementation of zero carbon buildings is the greenhouse gas emissions intensity of Alberta's electric grid. To implement a zero carbon building, all building systems must shift away from combustion and become 100% electric, ensuring compatibility with solar PV, or other, renewable sources of electricity. However, a significant chance exists that zero carbon buildings will be constructed before the addition of on-site solar PV panels. In this case, the building must draw all energy from the electric grid. The Alberta Electric Systems Operator (AESO) 2019 Long-term Outlook Figure 1 shows existing Alberta electricity generation mixes projected out to 2039, with coal-fired energy reduced to 0 MW by 2030 (AESO, 2019).



	Existing %	Existing MW	2024 %	2024 MW	2030 %	2030 MW	2034 %	2034 MW	2039 %	2039 MW
Coal-fired	36%	5,723	8%	1,421	0%	0	0%	0	0%	0
Cogeneration	31%	4,937	30%	5,319	28%	5,499	26%	5,589	25%	5,679
Combined-cycle	11%	1,748	10%	1,748	11%	2,227	28%	6,059	37%	8,454
Simple-cycle	6%	921	6%	1,138	9%	1,835	11%	2,300	13%	2,903
Coal-to-gas	0%	0	22%	4,009	25%	4,890	8%	1,729	0%	0
Hydro	6%	894	5%	894	5%	894	4%	894	4%	894
Wind	9%	1,445	16%	2,904	19%	3,854	20%	4,272	17%	3,931
Solar	0%	15	1%	131	1%	231	2%	481	2%	481
Other	3%	423	2%	423	2%	423	2%	473	2%	473
Total capacity		16,106 MW		17,987 MW		19,853 MW		21,797 MW		22,815 MW

Figure 1: AESO Reference case grid electricity composition

While AESO describes many scenarios of how the electric grid will evolve, this reference case shows a business-as-usual scenario which can be considered. If the goal of creating zero carbon buildings, and an energy step code, is to reduce greenhouse gas emissions, the deployment of this policy must be carefully timed with the greening of Alberta's electric grid. Otherwise, it will cause new net-zero buildings to draw large amounts of electricity from a high-emissions grid, and likely increase the building sector's emission rates.

Solar Potential

Another challenge in the implementation of a net-zero energy ready buildings is the solar potential of a region. Due to the size of Alberta, it features a large range of solar potential values which will directly affect the size of solar PV system which must be installed to create a net-zero building, as shown in Figure 2. Municipalities with lower solar potential, such as Fort McMurray, will need to install a higher number of solar panels to get the same output as Medicine Hat, which has a higher solar potential. Additionally, this is compounded by the fact that colder regions will typically use more energy in heating. This combination of lower solar potential and larger amounts of energy required for heating may provide a barrier in the implementation of net-zero energy buildings in colder climate zones.

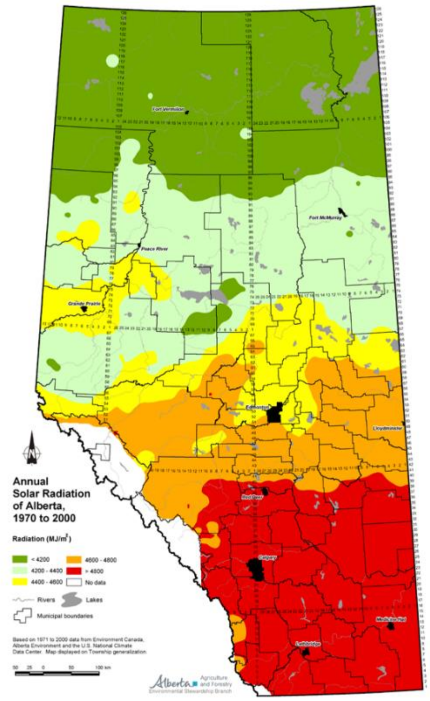


Figure 2: Alberta Solar Potential

4. Implementation Strategies for Zero Carbon

General Approaches to Decarbonization

Opportunities to decarbonize are determined by several factors, such as: the nature of the organization, operational practices, building stock, onsite energy infrastructure, and other considerations. However, the following approaches describe actions which can be taken to implement zero carbon strategies.

High Efficiency Buildings

Designing a high efficiency building is the backbone of successfully implementing a zero carbon building strategy, and represents the reduction of energy necessary to power the building when compared to the required energy code. This is typically achieved through the integration of envelope, mechanical, and electrical systems and techniques to achieve a building which will consume a minimal amount of energy.

Renewable Energy Implementation

The implementation of on-site renewable energy systems such as solar photovoltaic (PV), solar thermal, and geothermal technologies are important factors in achieving zero carbon buildings. Since these systems generate zero emission electricity and/or heat, when combined with high efficiency buildings, they provide the typical path to a zero carbon building. Since these renewable systems are utilized on-site, they allow for control of the building energy source and provide resilience from the electricity grid.

Electrification of Building Systems

Shifting from combustion-based technologies to systems powered by renewable electricity, represents a massive opportunity to implement zero carbon buildings. However, while this approach may reduce on-site carbon emissions, it is contingent on the electric grid becoming a low-carbon source of power. For the full electrification of building systems to approach zero carbon within Alberta, the grid will have to significantly reduce its high carbon emissions factor.

Renewable Energy Credits and Carbon Offsets

Purchasing renewable energy credits (RECs) or carbon offsets can contribute to offsetting carbon generated by a building through indirect means. A REC directly supports operating renewable energy projects and the development of new renewable energy.

Fuel Switching from Natural Gas to Biogas

Substitution of natural gas consumption to biogas would allow the decarbonization of the thermal energy used for in-building heating equipment. Currently, sources for cost-effective biogas delivery in Alberta are limited. Biogas conversion should be explored in the future if availability increases and costs significantly decline. This strategy can serve as a transitional decarbonization strategy as the electric grid moves to a decarbonized system powered by renewable electricity and lower emissions intensive power sources.

Carbon Capture

Carbon capture technologies are emerging, though still at the early stages of development. However, it would make sense for the SSRIA to keep apprised of the technology as it advances to assess whether carbon capture would have viability in the future.

Policy Based Decarbonization

Implementation of a Net-Zero Framework

In 2016, the Province of Alberta adopted the National Energy Code for Buildings (NECB) 2011 and Section 9.36 for Part 9 (residential) buildings for all new buildings per the Alberta Building Code (ABC). On February 15th 2019, Alberta announced the adoption of NECB 2017 (Alberta Municipal Affairs, 2019) from April 1st 2019 onwards. Before the adoption of NECB, there were no energy efficiency requirements for new buildings in Alberta. Whilst NECB represents minimum levels of energy performance rather than net-zero energy, this demonstrates that the principle of enforced energy codes can work in Alberta and the adoption of NECB 2017 shows that updates can be accommodated.

What is an Energy Step Code?

An energy step code is a tiered approach to enhancing current building codes to meet more stringent future energy building standards. This strategy creates consistency for new building's energy performance by providing specific and measurable quantitative goals. Within the step code, a number of tiers (or steps) are created which incrementally increase in energy performance, leading to net-zero energy ready buildings, which is considered one of the highest levels of building energy efficiency. This approach is beneficial to industry as it provides simple and consistent energy targets for new buildings, and multiple energy tiers ensure builders can designate specific building types to meet particular steps.

Implementation of an Energy Step Code

There are many different avenues in which a step or stretch energy code could be implemented. Geographical and technical factors ensure that a step code cannot follow identical implementation paths, however, there are common actions which can lead to successful strategy execution (Frappe-Seneclauze, Russell, & Tam Wu, 2015):

- Declare a goal to require all new buildings be net-zero energy ready by 2030, which aligns with the Pan-Canadian Framework on Clean Growth and Climate Change.
- Declare a goal to require all existing buildings to be net-zero energy ready by a desired date.
- Research and develop the energy tiers necessary to implement a step or stretch code, charting a course from current energy building codes to net-zero energy ready ones.
- Conduct pilot projects to enhance industry receptiveness and determine energy feasibility.
- Implement the energy step code into governmental policy and the building code, requiring all new buildings to be net-zero energy ready by 2030.

5. Alberta Implementation of Zero Carbon Strategies

Current State of Affairs

Government of Alberta Climate Goals

In November of 2015, the Government of Alberta implemented a strategy to reduce carbon emissions and create opportunities to diversify the economy, known as the *Climate Leadership Plan* (Government of Alberta, 2015). The four key policy initiatives which were introduced from this strategy included:

- implementing carbon pricing on greenhouse gas emissions,
- phasing out coal-generated electricity by 2030 while generating 30% of electricity using renewables,
- capping oil sands emissions, and
- reducing methane emissions.

The current provincial government have decommissioned the carbon pricing strategy for residential and commercial buildings, though the federal government continues to require some form of carbon pricing and, as such, the Alberta Government is foccussed on large industry emitters through the *Carbon Competitiveness Incentive Regulation* to meet these federal targets. Currently, the Government of Alberta has yet to develop a net-zero, step, or stretch code framework for new building development beyond the Energy Code requirements described in the Alberta Building Code.

Alberta Infrastructure

As mandated in Alberta Infrastructure's *4th Edition Technical Design Requirements*: Green Building Standards, all Tier 1 (new buildings and major renovations) Government owned buildings are required to be LEED v4 Silver certified (Alberta Infrastructure, 2018). Within this LEED v4 certification, all new buildings must achieve 12 points in the credit EAc2: Optimize Energy Performance, which corresponds to a 29% energy cost savings from the ASHRAE 90.1-2010 baseline. This is with the exception of hospitals and healthcare centres, which must achieve 11 points and a 22% energy cost reduction. Additionally, each new building must undergo an ILFI Living Building Challenge feasibility study and a net-zero analysis. However, this net-zero analysis is to demonstrate that a net-zero energy building was considered, but not necessarily pursued, and does not have any prescriptive requirements.

City of Calgary

After conducting extensive research and stakeholder workshops throughout 2017, the City of Calgary released their *Climate Resilience Strategy: Mitigation and Adaptation Action Plans* in late 2018 (City of Calgary, 2018). The City acknowledges the federal government and Natural Resources Canada's (NRCan) commitment to implementing model net-zero energy codes for existing buildings by 2022, with the expectation that all new buildings will be net-zero energy ready by 2030 (Government of Canada, 2016). While the City will not implement more stringent building energy requirements beyond the provincially required codes, it has committed to supporting enhanced energy performance through incentives and financial access.

The City of Calgary also received an investment of $22 million, through the Low Carbon Cities Canada program and administered by Alberta EcoTrust, to develop low carbon solutions for the region.

City of Edmonton

The City of Edmonton published an *Energy Transition Strategy* in August of 2015 (City of Edmonton, 2015), which was designed to manage risks induced by climate change and to increase sustainability within all sectors. Net-zero buildings are briefly mentioned within the Leadership section of the Strategy as being an innovation which the City will support, but with no clear guidance on how this will be accomplished.

The City of Edmonton also received an investment of $22 million, through the Low Carbon Cities Canada program and administered by Alberta EcoTrust, to develop low carbon solutions for the region. The City is also currently updating their strategy (to be released in October 2020) and one of the six climate shifts for the municipality, and that will be the basis of the strategy, is achieving emission neutral buildings.

Implementation in Alberta

Although the strategies mentioned in *Section 4: Implementation Strategies for Zero Carbon* may all see implementation within Alberta at some point in the future, some require significant amounts of effort, while other can be implemented within a shorter timeframe. Policy-based strategies may require new or existing buildings to achieve zero carbon or become zero carbon "ready" in the future, but this timeframe is somewhat uncertain. The Canadian Government has committed to all new buildings being net zero ready by 2030 (Government of Canada, 2016), but it is unknown how the National Energy Code for Buildings (NECB) will be updated to reflect this. Therefore, policy-based zero carbon strategies should be considered to have long-term implications.

When considering the various technological based zero carbon strategies, certain technologies will have a much greater impact in Alberta than others. These strategies can be categorized into four different groups:

1. New Building Construction,
2. Existing Building Retrofits,
3. Onsite Renewable Energy, and
4. Building Electrification.

To achieve a comprehensive zero carbon building framework, strategies from all four categories must be implemented. However, different strategies will have varying effectiveness when considering Alberta's energy context. As noted in Figure 1, Alberta currently produces a significant amount of its electricity with coal and natural gas. According to AESO 2019 Long-term Outlook projections, the Alberta grid will not divest itself of coal until at least 2030, ensuring a high electric grid emissions factor until that time period.

Therefore, zero carbon strategies which focus on building design and controllable on-site factors are important in the short-term. These strategies include:

- High Efficiency Buildings,
- On-site Renewable Energy Systems, and
- On-site Fuel Switching from Natural Gas to Biogas.

Once the grid has become decarbonized in the long-term, focus should turn to the following strategy:

- Electrification of Building Systems.

Barriers to Adoption

The concept of barriers is used to describe the obstacles that hinder the planning and implementation of climate change adaptation and adoption of concepts such as zero carbon. *Barriers of Adoption* are defined here as obstacles that can be overcome with applied effort, management, change of thinking, prioritization of strategies, and related shifts in policies, resources, building code, etc. The focus of this report is to identify barriers of adoption that can be overcome to achieve short term goals of the SSRIA and as defined in Figure 3 below, with an eventual impact to longer term goals in the future.

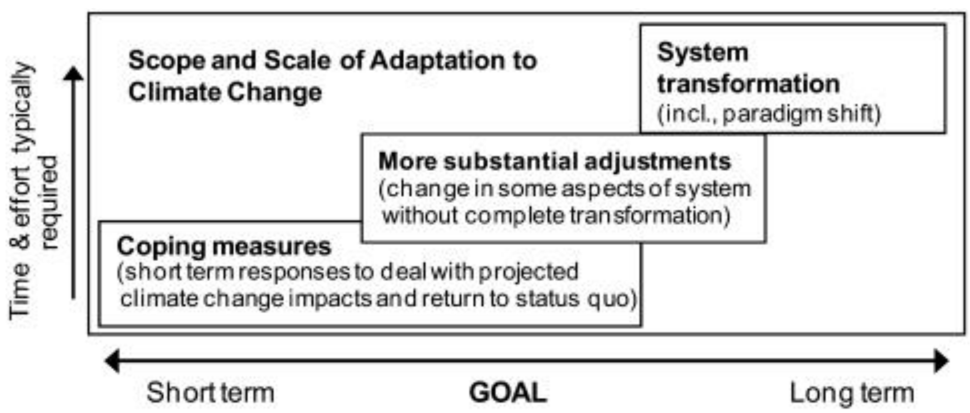


Figure 3: "A framework to diagnose barriers to climate change adaptation"
Susanne C. Moser and Julia A. Ekstrom

Adoption as related to decision-making is confronted with barriers for public and private sectors and, combined with other restricting factors, such as availability of technology, can further reduce the desired level of adaptation. Further definition of key focus areas are noted below and a 'high', 'medium', 'low' analysis of each building typology can be found in *Appendix B: Barriers of Adoption*.

Cost

Cost can be divided into two categories: the soft costs that occur when analysing and developing strategies, and the hard costs that occur with new builds and replacement of long-lived capital in retrofits.

Economic strategies typically focus on choosing the most cost-effective projects, but there are other indirect costs to decision-making that need to account for impacts on equity, health, and the cost of doing nothing, among others.

Regulatory & Government

A study from BC found five major barriers to the adoption of climate change strategies: inadequate collaboration between organizations and individuals, an absence of senior level political leadership, a lack of public awareness, insufficient financial and staff capacity within departments, and misalignment of policies within and between levels of government. These barriers can also be found within the AB government structure and outreach to constituents. While there has been some progress towards an updated regulatory environment, the provincial government is stuck in a cycle of shifting priorities with each new political party in office and no clear message on a long-term path forward.

Policy & Municipal

Typically public decision-makers remove the barriers listed above, but they themselves face similar barriers such as insufficient knowledge or resources in the area of climate change. Moreover, most adaptation measures require high coordination between different governance levels, with coordinated support, easement of regulatory and policy barriers, and incentives to supplement programs.

Currently, our largest municipalities seek funding from federal agencies, are reluctant to implement strong policies due to provisional political positioning, and rely on organizations like the SSRIA to fill in the gaps.

Understanding & Awareness

Uncertainty represents one of the largest barriers to the adoption of zero carbon where future demographics, technologies and economics, and future climate change conditions are unknown and difficult to predict with any accuracy. In addition, social and cultural factors lead to inconsistent decision-making through half-information and misunderstanding.

Understanding and awareness are essential elements of overcoming these barriers. They help people understand and address the impact of carbon emissions, encourage changes in their attitudes and behaviour, and help them adapt to climate change related trends. The SSRIA is well positioned to demonstrate the value of adaptation - shifting attitudes, and increasing knowledge across building industry sectors, governmental organizations, and for building occupants.

Impact Gap Analysis

The Impact Gap Analysis of this report reviews key areas of influence where the SSRIA and its funded projects should focus efforts to maximize GHG emissions reductions. The analysis identifies areas of priority as 'high', 'medium', and 'low', recommending the strategies and typologies identified as 'high' as areas that will net the most impact, whether through direct GHG emissions reductions or indirect advancement of the concepts towards a zero carbon future. The report draws from published policies, programs and standards that influence carbon emission strategies today and a comprehensive list can be found in *Appendix A: Research Analysis*. Further, the impact gap analysis focusses on four key areas of influence as defined below and in *Appendix C: Impact Gap Analysis*.

Advocacy

Advocacy continues to be an active area municipally, provincially and federally. The key focus should be on next steps – taking action based on the research and leveraging organizations willing to act on their advocacy efforts to date. Recent government changes in AB suggest the SSRIA should continue advocacy efforts at the provincial level, and partner with municipalities and specific branches of government to amplify efforts (such as Alberta Innovates and Alberta EcoTrust).

Education

While there are many programs and educational offerings, the depth of programming needs to be increased to addressed industry across sectors and disciplines. We recommend combining efforts with institutions and other oganizations to leverage and share lessons learned from SSRIA-funded and other projects to continue to build awareness and influence market uptake.

Incentives

While there are several grants and other funding programs, few traditional incentives exist across Canada, very little in Alberta, if at all. Priority should be placed on direct GHG operational impacts –

incentivize building owners, operators, and occupants to engage in programs and actively reduce emissions. Consider linking educational components for incentive recipients to understand the impacts of the strategies they are implementing.

Policy

The policy and regulatory environment in Alberta tends towards older, less robust strategies that require updating and or development to ensure better adoption and application of strategies for long term success. A focus on large buildings is recommended where there is little to no policy in place to address this area that has large impact potential.

6. Timeline to 2050 for Alberta to Implement these Strategies

The timeline to 2050 for Alberta to implement these strategies can be broken down into two categories, short-term and long-term implementation. Short-term implementation considers the timeframe from 2020-2030 and reflects strategies which will have the most amount of impact within the next decade. Long-term implementation considers the timeframe of 2030-2050 and highlights strategies which will have a greater impact over that 20-year period.

Short-term Timeline to 2030

To create the most impact within the short-term timeframe of 2020-2030, focus must first be put on strategies which encourage energy efficiency in new building construction. The knowledge base around high efficiency buildings is increasingly expanding in the building and design industry, and effort must be put into implementing these strategies as soon as they are determined feasible.

Additionally, as existing building systems are required to be replaced over the short-term, effort should be put into high efficiency retrofit strategies. System replacement strategy will be determined by component lifespan and the time in which it requires replacing. For example, if a boiler requires replacement in 2020, it may make more sense to implement a high-efficiency natural gas boiler over an electric boiler, since the Alberta grid will still be producing significant emissions until 2030. However, if windows need replacing, it makes sense to implement the highest efficiency windows possible.

This is shown in Figure 3, which highlights the need for high effort and investment within New Building Construction for zero carbon strategies from 2020 onwards, while Existing Building Retrofits will require moderate investment until 2030 and high effort and investment afterwards.

While Renewable Energy is important to a zero carbon building strategy, it has less overall impact than high efficiency building strategy investment. Therefore, it should receive moderate investment and effort until 2035, after which it should receive high investment as high efficiency buildings become increasingly standard.

Long-term Timeline to 2050

When considering the long-term timeline from 2030-2050, continued emphasis must be put on New Building Construction, Existing Building Retrofits, and Renewable Energy. High levels of effort and investment must be made in these areas, as they are critical to achieving comprehensive zero carbon buildings.

However, as Alberta's electric grid continues to decarbonize, focus must be put on the electrification of building systems. With the growing availability of low emissions electricity in the grid, mechanical systems can be fully converted from fossil fuel-based systems to electric, reducing emissions output significantly. As these high efficiency buildings achieve full electrification, power will be supplied from on-site Renewable Energy systems and the low carbon electric grid, achieving zero carbon building status.

This is shown in Figure 3, as Building Electrification doesn't become a major priority until 2035-2040, where moderate investment begins. Through the 2040s, investment in building electrification should continue to increase as the grid reduces it's emissions intensity until buildings are fully electrified through 2050.

Implementation Timeline

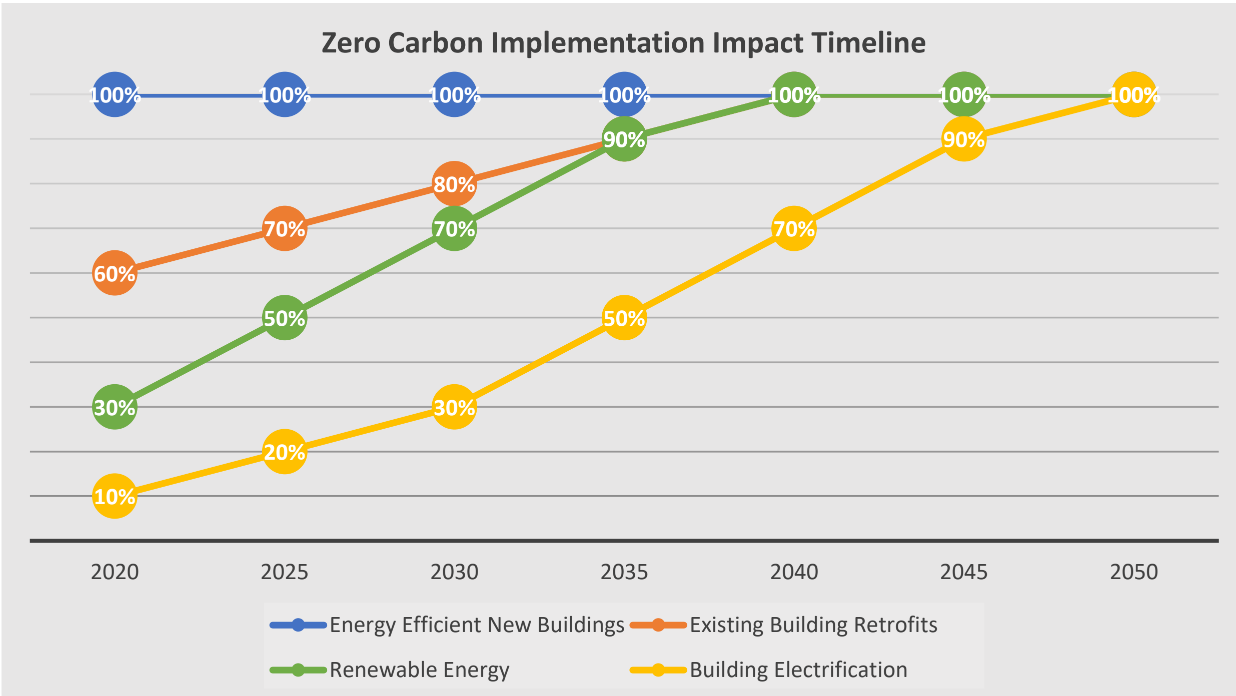


Figure 3: Zero Carbon Building Implementation Timeline to 2050 for Alberta

Energy Efficient New Buildings: This strategy describes the implementation of energy efficient systems within new building construction. As of 2019, the technology and building techniques exist to design and implement a highly energy efficient new building.

Existing Building Retrofits: This strategy describes the renovation and retrofitting of existing buildings with energy efficient technology and equipment. This should be implemented over time as equipment reaches its end of life.

Renewable Energy: This strategy describes the addition of onsite renewable energy technologies to generate energy and offset energy consumption of the building.

Building Electrification: This strategy describes the electrification of a building as the final step to achieve a zero carbon building. This strategy is contingent on two key events, the addition of renewable energy to the building and the decarbonization of Alberta's electric grid.

7. Practical Techniques and Technologies to Implement Zero Carbon

Theory of Zero Carbon Buildings

Three stages of Zero Carbon Building design:

1. **Passive Design:** applying heating, cooling, and ventilation design principles, such as building orientation, window placement/size, and using natural air currents to lower energy demands and increase building energy efficiency as a first step.
2. **Active Design:** installation of high efficiency mechanical and electrical systems which actively use power to operate components such as HVAC and lighting. This allows users to fine tune control of interior conditions and comfort.
3. **Renewable Energy:** the addition of renewable energy systems such as solar, wind, geothermal, and more; used to support building and site energy demands and reducing operations emissions.

ECMs that deal with Architectural design aspects are known to be "passive measures", which are assessed first in the design process. These passive ECMs typically have longer lifespans than mechanical and electrical systems and can determine the success of a building design achieving energy efficiency. This is followed by "active measures", which are ECMs that fall under Mechanical and Electrical design aspects. These systems are implemented after fully optimizing the passive architectural design.

Energy Modelling Energy Conservation Measures

The following ECMs are used in energy modelling, which is typically the method used to determine the initial EUI and TEDI of a building.

Discipline	Energy Conservation Measure
Architectural	Window-to-Wall Ratio (WWR)
	Infiltration Rate (Air Tightness)
	Wall R-Value
	Window R-Value and Type
	Roof R-Value
	Foundation Walls R-Value / Slab-on-Grade or Perimeter Insulation R-Value
	Orientation
	Massing and Articulation
	Thermal Bridging
Electrical	Interior Lighting Power
	Exterior Lighting Power
	Lighting and Equipment Control Systems
Mechanical	Boiler type and efficiency
	Chiller type and efficiency
	Circulation pumps type and efficiency
	Downstream HVAC systems (Air Handlers, Fan Coils, Radiation Heating)

	Furnace efficiencies
	Energy/Heat Recovery
	Domestic Hot Water
	Temperature Setpoints and Scheduling
	Heating/Cooling Controls
	Ventilation Controls
	Fan Power
	Equipment sequence of operations
	Wright-sizing (i.e. accurate ventilation rates)

Zero Carbon Techniques and Technologies

The following zero carbon techniques and technologies represent both existing and emerging strategies being implemented in many jurisdictions across Canada. This is not an exhaustive list and as techniques and technologies develop, this list will evolve with them. Each strategy review includes comments on the relevance and/or success within the Alberta market to date.

Zero Carbon Techniques

Building Massing

A building's massing represents its general shape and size, typically represented in 3 dimensions, creating a visual understanding of its interior and exterior spaces. When massed, a building is simplified to bring focus to its overall shape and placement of windows and walls.

When designing a zero carbon building, understanding the massing and space of a building is key in planning for ventilation, energy use, health and comfort. Buildings with simplified massing and lower amounts of vertical walls will be more energy efficient, as they are less prone to heat loss through the envelope.

Envelope Design (Insulation, Thermal Bridging) and Air Tightness

A building's envelope, or exterior wall system, physically separates its interior conditioned environment from the exterior unconditioned environment. How effectively it does so will depend on the wall system's design and construction. By selecting proper materials, high performance wall assemblies can be created with better insulation (R-values), air tightness, and less thermal bridging. This leads to a smaller thermal energy demand intensity (TEDI) as less heat is lost through the building envelope and ventilation system.

A building's envelope is one of the key contributors to a successful zero carbon design. By using high performing assemblies, a building's need to heat or cool itself will typically decrease which will directly correlate to a decrease in its energy need and usage. Considerations for windows, doors, roof and slab components will all impact the overall performance of the building envelope.

Equally important is the concept of air tightness. Air tightness determines the amount of air that can enter or leave a building through the envelope, typically through wall pentrations and connections. The air tightness of a building's envelope can have a significant impact on it's energy efficiency.

Window-to-Wall Ratio (WWR) and Distribution

This variable is important to not only fire safety but building energy efficiency as well. Dividing a wall's total area by the total area of glazing on said wall, we can determine it's WWR. Window-to-wall ratio contributes to many aspects of a building's energy performance such as solar gain, daylighting, and ventilation.

Curtain wall systems need special consideration when designing high performing buildings. As they are predominantly made of glass and metal framing, and typically span large sections of a wall, these systems can decrease building energy performance by means of thermal bridging, excesive heat gain which leads to the need for cooling, and in some cases, moisture control problems. While curtain wall systems can be designed to be energy efficient, they remain more expensive and less efficienct in comparison to a typical wall system with inset windows. Despite this, they remain popular in commercial and industrial design.

Zero Carbon Technologies

The listed technologies support zero carbon principles in that they all perform more efficiently than other systems within their scope. By passively harnessing and using renewable resources, they produce little to no waste, run more efficiently, consume less resources, or all of the above.

CHPs

Combined heat and power units, or CHPs, are efficient mechanical engines which primarily focus on the generation of electricity. As a secondary energy source, excess heat is created through the combustion of fuel, which can be captured and used in lower temperature heating processes. Typically, this heat can be utilized in a building's domestic hot water system.

Micro CHPs are a smaller scale version of this technology and are currently being tested for their viability in residential use. Full-scale units have shown to perform well both within Alberta and the rest of Canada. Interest in this technology has been growing within both building sectors and is anticipated to continue growing as fuel switching and other renewable energy initiatives increase in number and relevance.

Geo-Exchange

Also known as ground source heat pumps, these systems work by using naturally occurring temperatures below ground. As the sun warms the earth's surface, thermal energy is stored below ground; this temperature can either become warmer or cooler than surface temperature depending on the time of the year and conditions at that time. A geo-exchange system will tap into that preserved thermal energy and collect it via a geothermal heat pump or similar device, which then will distribute that heat into a building's heating system.

Despite being an older technology, geo-exchange systems have encountered some problems in implementation. To date, their performance has been recorded as below average to acceptable when compared to some more efficient systems such as HRVs. Despite this, they remain a viable technology that should receive more stringent testing prior to usage. Furthermore, location and climate should be greatly considered prior to usage, and if selected, proper installation of the system can greatly increase effectiveness. Alberta's current grid system also plays a role in the performance of this technology in that electrical supply and demand can sometimes be limited based on location.

Heat Pumps

By harnessing local temperatures and collecting heat through it's closed loop, a heat pump is considered one of several low-carbon systems. It works by using a refrigerant liquid which condensates or evaporates through coils at different sections of the system. During the evaporation stage, heat is absorbed through it's surroundings and captured, where it is later released when the liquid is pressurized in another coil.

As they do not produce emissions through combustion and are electricity based systems, heat pumps are often highly considered in zero carbon design. However, this technology will not reduce Alberta's carbon emissions until the province's grid is decarbonized due to the fact that these systems run on electricity. An additional option is utilizing on-site renewable production, such as solar PV, to support the heat pump. This technology is currently becoming more common within Alberta.

Low Temperature Heating Distribution Systems

With an increase in high performance wall systems, the need for more efficient heating systems also increases. Low temperature heating systems distribute heat by consistently running at a lower temperature; this leads to less energy consumed to generate heat when compared to traditional systems which have spikes of high heat output. These systems are also more thermodynamically efficient by facilitating the use of a broad range of heating technologies that are not available to buildings with lower performing envelopes. These technologies include air and ground source heat-pumps and condensing boilers.

This is a relatively new concept being implemented in Alberta. There is interest in applying this concept to campus type developments that have existing distribution systems and can easily transition.

Solar PV

Solar has been used as a renewable energy source for decades. A solar photovoltaic system (PV) uses panels filled with silicone semi-conductors to collect and convert photons into usable electricity. Solar PV panels are the most commonly seen and used solar technology today. As a renewable source of energy, solar PV offers an energy source without the production of emissions and waste.

With some of the highest annual sun lighting hours in the country, Alberta is generally considered ideal for solar energy generation. This is especially true for on-site residential generation as the cost of solar equipment has decreased with the market's increased interest. Several incentive and rebate programs have also appeared around solar over the last couple decades, however these programs tend to change over time.

Solar Thermal

Similar to solar PV, solar thermal systems also collect solar energy, but instead of creating electricity, solar thermal systems collect solar heat energy, which can be utilized in a building's heating system.

While solar thermal equipment has advanced quite rapidly in recent years, it's uptake within Alberta, or across Canada in general, is slower than solar PV. However, it has shown success in efficient heating supply, especially in the case of heated loop concrete floor systems in both residential and commercial scopes. In some cases, solar thermal systems generated more heat than was needed when installed in an ideal location such as an unobscured south-facing façade or fence.

Heat/Energy Recovery Ventilation

Heat recovery ventilator systems, or HRVs, recover heat created in the interior of the building and use it to heat fresh supply air coming from the outside. This increases the efficiency of the building's mechanical system, as it reduces the amount of heat required to be produced by heating system. These systems are especially efficient in existing buildings with low air tightness. Since these existing buildings experience increased air transfer with exterior temperatures, HRVs can provide significant value in reucing energy usage. Additionally, in cold climates, HRVs are an excellent solution as they are practically impenetrable if installed correctly.

An energy recovery ventilator system, or ERV, will also maintain humidity within the interior space of the building when an HRV would simply heat incoming supply air with no humidity preservation. To this extent, ERVs are typically more recommended to Alberta's cold and dry conditions so as to maintain internal humidity. More recently, both systems have become more common in residential and commercial practice, and are becoming more widely available throughout all markets across Canada.

Wind

Like solar energy, wind can be naturally harnessed to generate energy. Technology to support this has greatly improved especially in past few decades, and the presence of wind farms in southern Alberta is still prominent given the large areas of wind activity. Both government and private interest have aided in the growth of wind energy, and Alberta is one of the largest wind markets in Canada according to CanWEA (Canadian Wind Energy Association).

Southcenter Mall in Calgary, Calgary's C-Train, and various other large operations have opted into using wind generated energy, and windfarms continue to grow in the province. Unlike solar, no incentives have been offered through the government though the price of wind technology has decreased with an increase in market interest.

8. Zero Carbon Building Archetypes and Systems

To understand how zero carbon buildings can be achieved, eight building archetypes were considered:

1. Single Family Home: Includes both attached and detached single family residential buildings, up to 3 stories.
2. Mid-Rise Residential: Multi-family housing up to 6 stories for low-rise and up to 10 stories for mid-rise. Includes multi-use buildings.
3. High-Rise Residential: Multi-family housing 11 stories or more. Includes multi-use buildings.
4. High-Rise Commercial: Office building greater than 6 stories. Includes multi-use spaces.
5. Educational (K-12 schools): Educational facilities supporting grades K to 12. Universities and colleges were omitted due their unique needs.
6. Warehouse: Large facilities used for the storage of goods and equipment, up to 2 stories.
7. Fire Hall: Facilities supporting fire engines and other fire prevention equipment and operations.
8. Healthcare Clinics & Administration: Includes all healthcare and medical clinics, and related administration services, up to 3 stories. Hospitals were omitted.

The following table describes how each Building Archetype was considered. Building systems were split into four main categories, Building Envelope, Mechanical, Electrical, and Renewable Energy. Within each category, building items were identified which have a large impact on that particular archetype's energy usage. Average lifespans for each building item were identified, although it should be noted that these are highly dependant on system type and the specific material being used in construction for each item. For each building item, a zero carbon energy conservation measure (ECM) was assigned. While each of these measures will individually increase the building's energy efficiency and performance, to achieve a zero carbon building all measures must be implemented in the building design.

Building System Category		
Building Item	Building Item Lifespan	Building Item Zero Carbon ECM

While the following archetype descriptions detail how a new building should be designed to achieve zero carbon, these tables can be utilized for existing building retrofits as well. When considered in the context of the zero carbon strategy implementation timeline and the theory of zero carbon buildings, these building item ECMs provide a target retrofit strategy.

For example, if an existing building requires an envelope upgrade, such as new windows, it makes sense to install the most energy efficient windows possible. Due to the long window lifespan, implementing highly efficient windows will not only reduce energy usage in the short-term, but provide the foundation for a zero carbon building in the long-term. The same concept is true with electrical systems, such as interior lighting, where it makes sense to implement the most energy efficient item possible.

However, if a mechanical system needs replacing, it is highly dependant on which timeframe this will occur. If a system is due for replacement in the short-term, it may make sense to install a fuel-based system that relies on biogas or natural gas. Since this system may only have around a 20-year lifespan and the Alberta electric grid has not decarbonized, it would likely produce fewer emissions than an electric system. However, if the system is due to be replaced in the long-term and the Alberta grid has begun significant decarbonization, an electric system will be necessary to achieve zero carbon.

While the following archetype tables provide an outline of the target systems necessary to achieve zero carbon, it is important to note that all existing buildings are different and will have varying requirements to meet zero carbon. Each existing building must be assessed individually to understand its unique path to become a zero carbon building.

Single Family Home

Building Envelope ECMs		
Massing	NA	Simplified. Reduce number of corners and perforations in architectural design
Walls	40	Effective R-Value of R40-R60 (hr·ft^2·°F)/Btu; Airtight below 0.5 cfm/ft^2
Roofs	20	Effective R-Value of R60-R80 (hr·ft^2·°F)/Btu
Windows	40	Effective R-Value of R4 to R6 (hr·ft^2·°F)/Btu high-performance triple glazed
Windows SHGC	NA	Optimized for summer shading and winter passive heating
WWR	NA	< 30%
Thermal Bridging	NA	Thermally broken window frames and doors
Slab on Grade	75	Insulate perimeter with minimum R10 for 4ft vertical
Mechanical Systems ECMs		
System Description	20	VRF Heat pump for heating/cooling linked to central HRV unit.
Fans	20	NEMA high efficiency motors with low specific fan power: Fan Coil Units < 0.37 W/cfm; MUAs < 0.7 W/cfm
Ventilation	20	Must never exceed code minimum and minimize ventilation duct run
Energy Recovery	20	Full recovery of all non-toxic exhaust with minimum 80% sensible effectiveness. Recommended: drain water heat recovery
Electrical Systems ECMs		
Interior Lighting	10	50% less than NECB 2017 (including suites)
Exterior Lighting	10	70% less than NECB 2017 while maximizing spacing between lighting fixtures
Renewable Energy Systems		
Requirement	NA	Total annual energy use to be supplied via renewables
Readiness	NA	Arrange building geometry to accommodate solar PV, system auxiliaries, and connection points.
Solar PV	25	Orient panels south, optimize tilt for efficiency, and cover maximum area possible

Mid-Rise Residential

Building Envelope ECMs		
Massing	NA	Simplified. Reduce number of corners and perforations in architectural design
Walls	40	Effective R-Value of R30-35 (hr·ft²·°F)/Btu; Airtight below 0.5 cfm/ft²
Roofs	20	Effective R-Value of R40-R50 (hr·ft²·°F)/Btu
Windows	40	Effective R-Value of R4 to R6 (hr·ft²·°F)/Btu high-performance double or triple glazed
Windows SHGC	NA	Optimized for summer shading and winter passive heating
WWR	NA	< 30%
Thermal Bridging	NA	Thermally broken window frames and balcony doors. Insulate all structural penetrations (i.e. balcony slabs)
Foundation Walls	75	R-Value > R10 (hr·ft²°·F)/Btu on first below grade wall
Mechanical Systems ECMs		
System Description	20	4-Pipe FCUs with CHW and HW coils with in-suite HRV. Central DOAS with HRV for corridor and non-residential ventilation.
Heating	20	Heating Source: Electric or efficient condensing natural gas boiler, depending on grid decarbonization (grid emissions factor) and onsite renewable energy generation. Decouple heating from ventilation and minimize pipe/duct runs
Cooling	20	Glycol Fluid Cooler or Air-cooled chillers with HRV economizer
Fans	20	Variable Flow, NEMA high efficiency motors with low specific fan power: Fan Coil Units < 0.37 W/cfm; MUAs < 0.7 W/cfm
Ventilation	20	Must never exceed code minimum and minimize ventilation duct run
Energy Recovery	20	Full recovery of all non-toxic exhaust with minimum 80% sensible effectiveness for in-suite HRV and DOAS. Recommended: Chiller condenser heat recovery. Run-around glycol heat recovery for parkade (subject to budget) 40% effectiveness
Pumps	15	Variable Speed
Electrical Systems ECMs		
Interior Lighting	10	50% less than NECB 2017 (including suites)
Exterior Lighting	10	70% less than NECB 2017 while maximizing spacing between lighting poles
Lighting Controls	10	Occupancy sensors in circulation/transient spaces. Daylight sensors in daylit areas. Lighting fixtures connected to daylight sensors must be addressable
Renewable Energy Systems		
Requirement	NA	Total annual energy use to be supplied via renewables
Readiness	NA	Arrange building geometry to accommodate solar PV, system auxiliaries, and connection points.
Solar PV	25	Orient panels south, optimize tilt for efficiency, and cover maximum area possible

High-Rise Residential

Building Envelope ECMs		
Massing	NA	Simplified. Reduce number of corners and perforations in architectural design
Walls	40	Effective R-Value of R30-35 (hr·ft²·°F)/Btu; Airtight below 0.5 cfm/ft²
Roofs	20	Effective R-Value of R40-R50 (hr·ft²·°F)/Btu
Windows	40	Effective R-Value of R4 to R6 (hr·ft²·°F)/Btu high-performance double or triple glazed
Windows SHGC	NA	Optimized for summer shading and winter passive heating
WWR	NA	< 30%
Thermal Bridging	NA	Thermally broken window frames and balcony doors. Insulate all structural penetrations (i.e. balcony slabs)
Foundation Walls	75	R-Value > R10 (hr·ft²°·F)/Btu on first below grade wall
Mechanical Systems ECMs		
System Description	20	Low-temp WLHPs (2-speed compressors) interlocked with in-suite HRV. Central DOAS with HRV for corridor and non-residential ventilation.
Heating	20	Heating Source: Electric or efficient condensing natural gas boiler, depending on grid decarbonization (grid emissions factor) and onsite renewable energy generation. Decouple heating from ventilation and minimize pipe/duct runs
Cooling	20	Glycol Fluid Cooler or Air-cooled chillers with HRV economizer
Fans	20	NEMA high efficiency motors with low specific fan power: Fan Coil Units < 0.37 W/cfm; MUAs < 0.7 W/cfm
Ventilation	20	Must never exceed code minimum and minimize ventilation duct run
Controls	20	Demand Controlled Ventilation based on BMS schedule or CO2 Sensors.
Energy Recovery	20	Full recovery of all non-toxic exhaust with minimum 80% sensible effectiveness for in-suite HRV and DOAS. Recommended: Chiller condenser heat recovery. Run-around glycol heat recovery for parkade (subject to budget) 40% effectiveness
Pumps	15	Variable Speed
Electrical Systems ECMs		
Interior Lighting	10	50% less than NECB 2017 (including suites)
Exterior Lighting	10	70% less than NECB 2017 while maximizing spacing between lighting poles
Lighting Controls	10	Occupancy sensors in circulation/transient spaces. Daylight sensors in daylit areas. Lighting fixtures connected to daylight sensors must be addressable
Renewable Energy Systems		
Requirement	NA	Maximize on-site renewable energy potential (solar PV) and supplement additional consumption requirements via off-site renewable energy connection or purchase of renewably generated electricity from the grid.
Readiness	NA	Arrange building geometry to accommodate solar PV, system auxiliaries, and connection points.
Solar PV	25	Orient panels south, optimize tilt for efficiency, and cover maximum area possible

High-Rise Commercial

Building Envelope ECMs		
Massing	NA	Simplified. Reduce number of corners and perforations in architectural design
Walls	40	Effective R-Value of R25 (hr·ft²·°F)/Btu; Airtight below 0.5 cfm/ft²
Spandrels	40	R-Value of R5 to R7 (hr·ft²·°F)/Btu;
Roofs	20	Effective R-Value of R30-R40 (hr·ft²·°F)/Btu
Windows	40	Effective R-Value of R4 to R6 (hr·ft²·°F)/Btu high-performance double or triple glazed
Windows SHGC	NA	Optimized for summer shading and winter passive heating
WWR	NA	< 50%
Thermal Bridging	NA	Thermally broken curtain wall system
Foundation Walls	75	R-Value > R10 (hr·ft²°·F)/Btu on first below grade wall
Mechanical Systems ECMs		
System Description	20	DOAS with perimeter hydronic or electric radiant ceiling panels. System must be linked to ERVs
Heating	20	Heating Source: Electric or efficient condensing natural gas boiler, depending on grid decarbonization (grid emissions factor) and onsite renewable energy generation. Decouple heating from ventilation and minimize pipe/duct runs. Eliminate reheat coils.
Cooling	20	Cooling delivered by DOAS as economizer with Glycol Fluid Cooler or Water-cooled chillers for summer season
Fans	20	Variable Flow NEMA high efficiency motors with low specific fan power: AHUs < 0.9 W/cfm; FCUs < 0.37 W/cfm
Ventilation	20	Must never exceed code minimum and minimize ventilation duct run. Displacement ventilation to increase ventilation effectiveness
Controls	20	Demand Controlled Ventilation based on BMS schedule or CO_2 Sensors.
Energy Recovery	20	Full recovery of all non-toxic exhaust with minimum 80% sensible effectiveness. Recommended: Chiller condenser heat recovery. Run-around glycol heat recovery for parkade (subject to budget) 40% effectiveness
Pumps	15	Variable Speed
Electrical Systems ECMs		
Interior Lighting	10	50% less than NECB 2017 (including suites)
Exterior Lighting	10	70% less than NECB 2017 while maximizing spacing between lighting poles
Lighting Controls	10	Occupancy sensors in circulation/transient spaces. Daylight sensors in daylit areas. Lighting fixtures connected to daylight sensors must be addressable
Renewable Energy Systems		
Requirement	NA	Total annual energy use to be supplied via renewables
Readiness	NA	Arrange building geometry to accommodate solar PV, system auxiliaries, and connection points.
Solar PV	25	Orient panels south, optimize tilt for efficiency, and cover maximum area possible

Education (K-12 Schools)

Building Envelope ECMs		
Massing	NA	Simplified. Reduce number of corners and perforations in architectural design
Walls	40	Effective R-Value of R35 (hr·ft²·°F)/Btu; Airtight below 0.5 cfm/ft²
Roofs	20	Effective R-Value of R40-R50 (hr·ft²·°F)/Btu
Windows	40	Effective R-Value of R4 to R6 (hr·ft²·°F)/Btu high-performance double or triple glazed
Windows SHGC	NA	Optimized for winter passive heating
WWR	NA	< 30%
Thermal Bridging	NA	Thermally broken window frames and doors
Slab on Grade	75	Insulate perimeter with minimum R10 for 4ft vertical
Mechanical Systems ECMs		
System Description	20	DOAS with in-slab heating or hydronic baseboards at perimeters. System must be linked to ERVs
Heating	20	Heating Source: Electric or efficient condensing natural gas boiler, depending on grid decarbonization (grid emissions factor) and onsite renewable energy generation. Decouple heating from ventilation and minimize pipe/duct runs. Eliminate reheat coils.
Cooling	20	Cooling delivered by DOAS as economizer with DX coil for peak days
Fans	20	Variable Flow NEMA high efficiency motors with low specific fan power: AHUs < 0.9 W/cfm;
Ventilation	20	Must never exceed code minimum and minimize ventilation duct run. Displacement ventilation to increase ventilation effectiveness
Controls	20	Demand Controlled Ventilation based on BMS schedule or CO2 Sensors.
Energy Recovery	20	Full recovery of all non-toxic exhaust with minimum 80% sensible effectiveness
Pumps	15	Variable Speed
Electrical Systems ECMs		
Interior Lighting	10	50% less than NECB 2017 (including suites)
Exterior Lighting	10	70% less than NECB 2017 while maximizing spacing between lighting poles
Lighting Controls	10	Occupancy sensors in circulation/transient spaces. Daylight sensors in daylit areas. Lighting fixtures connected to daylight sensors must be addressable
Renewable Energy Systems		
Requirement	NA	Total annual energy use to be supplied via renewables
Readiness	NA	Arrange building geometry to accommodate solar PV, system auxiliaries, and connection points.
Solar PV	25	Orient panels south, optimize tilt for efficiency, and cover maximum area possible

Warehouse

Building Envelope ECMs		
Massing	NA	Simplified. Reduce number of corners and perforations in architectural design
Walls	40	Effective R-Value of R30-R35 (hr·ft²·°F)/Btu; Airtight below 0.5 cfm/ft²
Roofs	20	Effective R-Value of R50-R70 (hr·ft²·°F)/Btu
Windows	40	Effective R-Value of R3 to R4 (hr·ft²·°F)/Btu high-performance double or triple glazed
Windows SHGC	NA	Optimized for summer shading and winter passive heating
WWR	NA	< 5%
Thermal Bridging	NA	Thermally broken insulated metal panels, OH doors, and curtain wall systems
Slab on Grade	75	Insulate perimeter with minimum R10 for 4ft vertical. Refrigerated: full under slab R10-15
Mechanical Systems ECMs		
System Description	20	Large Warehouse: Ventilation Units comprised of an efficient natural gas or electric furnace (depending on grid decarbonization and emissions intensity) and integrated HRV. Small Warehouse: in-floor heating linked to an overhead HRV. Heating Source: Electric or efficient condensing natural gas boiler, depending on grid decarbonization (grid emissions factor) and onsite renewable energy generation.
Heating	20	Decouple heating from ventilation and minimize pipe/duct runs. More radiant heaters of less capacities spaced optimally.
Cooling	20	Economizer only via MUA with ceiling fans to avoid air stratification
Fans	20	Variable Flow NEMA high efficiency motors with low specific fan power: AHUs < 0.9 W/cfm; FCUs < 0.37 W/cfm
Ventilation	20	Must never exceed code minimum and minimize ventilation duct run. Displacement ventilation to increase ventilation effectiveness
Controls	20	Units must be linked to Unit Heaters (or radiant heaters) for sequencing. Demand Controlled Ventilation based on BMS schedule or CO2/CO Sensors.
Energy Recovery	20	Full recovery of all non-toxic exhaust with minimum 80% sensible effectiveness.
Pumps	15	Variable Speed
Electrical Systems ECMs		
Interior Lighting	10	50% less than NECB 2017 (including suites)
Exterior Lighting	10	70% less than NECB 2017 while maximizing spacing between lighting poles
Lighting Controls	10	Occupancy sensors in circulation/transient spaces. Daylight sensors in daylit areas. Lighting fixtures connected to daylight sensors must be addressable
Renewable Energy Systems		
Requirement	NA	Total annual energy use to be supplied via renewables
Readiness	NA	Arrange building geometry to accommodate solar PV, system auxiliaries, and connection points.
Solar PV	25	Orient panels south, optimize tilt for efficiency, and cover maximum area possible

Fire Hall

Building Envelope ECMs		
Massing	NA	Simplified. Reduce number of corners and perforations in architectural design
Walls	40	Effective R-Value of R30-R35 (hr·ft²·°F)/Btu; Airtight below 0.5 cfm/ft²
Roofs	20	Effective R-Value of R40-R50 (hr·ft²·°F)/Btu
Windows	40	Effective R-Value of R4 to R6 (hr·ft²·°F)/Btu high-performance double or triple glazed
Windows SHGC	NA	Optimized for summer shading and winter passive heating
WWR	NA	< 30%
Thermal Bridging	NA	Thermally broken OH doors and windows
Slab on Grade	75	Insulate perimeter with minimum R10 for 4ft vertical
Mechanical Systems ECMs		
System Description	20	DOAS with perimeter hydronic or electric radiant ceiling panels. System must be linked to ERVs
Heating	20	Heating Source: If hydronic, electric or efficient condensing natural gas boiler, depending on grid decarbonization (grid emissions factor) and onsite renewable energy generation. Decouple heating from ventilation and minimize pipe/duct runs. Eliminate reheat coils.
Cooling	20	Cooling delivered by DOAS as economizer with Glycol Fluid Cooler or Air-cooled chillers for summer season
Fans	20	Variable Flow NEMA high efficiency motors with low specific fan power: AHUs < 0.9 W/cfm; FCUs < 0.37 W/cfm
Ventilation	20	Must never exceed code minimum and minimize ventilation duct run. Displacement ventilation to increase ventilation effectiveness
Controls	20	Demand Controlled Ventilation based on BMS schedule or CO2 Sensors.
Energy Recovery	20	Full recovery of all non-toxic exhaust with minimum 80% sensible effectiveness.
Pumps	15	Variable Speed
Electrical Systems ECMs		
Interior Lighting	10	50% less than NECB 2017 (including suites)
Exterior Lighting	10	70% less than NECB 2017 while maximizing spacing between lighting poles
Lighting Controls	10	Occupancy sensors in circulation/transient spaces. Daylight sensors in daylit areas. Lighting fixtures connected to daylight sensors must be addressable
Renewable Energy Systems		
Requirement	NA	Total annual energy use to be supplied via renewables
Readiness	NA	Arrange building geometry to accommodate solar PV, system auxiliaries, and connection points.
Solar PV	25	Orient panels south, optimize tilt for efficiency, and cover maximum area possible

Healthcare Clinic/Administration

Building Envelope ECMs		
Massing	NA	Simplified. Reduce number of corners and perforations in architectural design
Walls	40	Effective R-Value of R30-R35 (hr·ft²·°F)/Btu; Airtight below 0.5 cfm/ft²
Roofs	20	Effective R-Value of R40-R50 (hr·ft²·°F)/Btu
Windows	40	Effective R-Value of R4 to R6 (hr·ft²·°F)/Btu high-performance double or triple glazed
Windows SHGC	NA	Optimized for summer shading and winter passive heating
WWR	NA	< 30%
Thermal Bridging	NA	Thermally broken curtain wall system
Slab on Grade	75	Insulate perimeter with minimum R10 for 4ft vertical
Foundation Walls	75	R-Value > R10 (hr·ft²°·F)/Btu on first below grade wall
Mechanical Systems ECMs		
System Description	20	DOAS with Active Chilled Beams (vent/cooling) with perimeter radiant heating. System must be linked to ERVs
Heating	20	Heating Source: Electric or efficient condensing natural gas boiler, depending on grid decarbonization (grid emissions factor) and onsite renewable energy generation. Decouple heating from ventilation and minimize pipe/duct runs. Eliminate reheat coils.
Cooling	20	Cooling delivered by DOAS by economizer through chilled beams with Glycol Fluid Cooler or Air-cooled chillers for summer season
Fans	20	Variable Flow NEMA high efficiency motors with low specific fan power: AHUs < 0.9 W/cfm;
Ventilation	20	Must never exceed code minimum and minimize ventilation duct run.
Controls	20	Demand Controlled Ventilation based on BMS schedule or CO2 Sensors.
Energy Recovery	20	Full recovery of all non-toxic exhaust with minimum 80% sensible effectiveness. Recommended: Chiller condenser heat recovery. Run-around glycol heat recovery for parkade (subject to budget) 40% effectiveness
Pumps	15	Variable Speed
Electrical Systems ECMs		
Interior Lighting	10	50% less than NECB 2017 (including suites)
Exterior Lighting	10	70% less than NECB 2017 while maximizing spacing between lighting poles
Lighting Controls	10	Occupancy sensors in circulation/transient spaces. Daylight sensors in daylit areas. Lighting fixtures connected to daylight sensors must be addressable
Renewable Energy Systems		
Requirement	NA	Total annual energy use to be supplied via renewables
Readiness	NA	Arrange building geometry to accommodate solar PV, system auxiliaries, and connection points.
Solar PV	25	Orient panels south, optimize tilt for efficiency, and cover maximum area possible

APPENDIX A: Research Analysis

ZERO CARBON INITIATIVES IN EXSISTING POLICIES, PROGRAMS & STANDARDS												
POLICIES, PROGRAMS & STANDARDS	DOCUMENT TYPE	AUTHOR	BRIEF SUMMARY	SOURCES	ADDRESSED BUILDING TYPOLOGIES	DIRECT LINK TO ALBERTA?	TARGETS (LIST)	POLICY & ORGANIZATION ALLIGNMENT (LIST)	CLEAN ENERGY INITITIVES (LIST)	CARBON OFFSETS (YES OR NO)	ENERGY EFFICIENCY (LIST)	ENERGY CONSERVATION (LIST)
BC ENERGY STEP CODE	Standard	Energy Step Code Council and Safety Standards Branch	Began in April 2017. An optional provincial standard for municipalities to adopt in BC. If adopted, buildings can be designed and built to 4 increased steps from the baseline BC building code, with step 1 being mandatory.	https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/construction-industry/building-codes-and-standards/guides/bcenergystepcode_guide_v1.pdf	All typologies. New construction only. Retrofit standard being written.	Potential to influence Alberta in the future.	"Net-zero energy ready" by 2032. Targets must aim to lower GHGs and increase energy efficiency from the baseline BC Building Code. Includes building envelopes and certain mechanical systems.	Pan-Canadian Framework on Clean Growth and Climate Change	Varies between municipalities. Many regions have created a requirement for on-site renewables, others required new construction to be connected to renewable district energy systems. Requires a new building to provide whole building energy modelling using approved energy modeling software.	N/A	Varies between municipalities. Many regions call for increased minimum R-values, higher performance windows, etc.	Varies between municipalities.
PSPC SUSTAINABLE DEVELOPMENT STRATEGY: 2017-2020	Policy	The Department of Canadian Heritage	Began in 2017. A response to Canada's FSDS (Federal Sustainable Development Strategy), this document details the Department of Canadian Heritage's goals in support of a low carbon government.	https://www.canada.ca/en/canadian-heritage/corporate/publications/plans-reports/sustainable-development-strategy-2017-2020.html	Commercial office. New and retrofit construction.	Yes.	Follows the 2030 UN Agenda for Sustainable Development. Reduce GHG emission of government fleet and buildings 40% below 2005 levels by 2030, or as early as 2025. FSDS Goal 12: promote public procurement practices that are sustainable, in accordance with national policies and priorities. FSDS Goal 13: climate action. Also expressing support of North America Climate, Clean Energy and Environment Partnership.	UN's 2030 Agenda for Sustainable Development FSDS DSDS (Department Sustainable Development Strategy Federal Policy on Green Procurement	Supports and enforces North America Climate, Clean Energy and Environment Partnership.	N/A	Committed to the improvement in energy efficiency of all of the department's buildings. Renew BOMA certification on one of their bigger buildings.	N/A
CALIFORNIA BUILDING ENERGY EFFECIENCY STANDARDS	Standard	California Energy Commission	Began in 1978 (updated every 3 years.) Building standards mandatory for all of California for both residential and nonresidential construction. The newest version goes into effect in January 2020.	https://ww2.energy.ca.gov/title24/2019standards/	All typologies. New and retrofit construction.	No.	The current 2019 version is a large step towards their 2020 goal of Net Zero Energy. Requirements for all construction regarding energy and water efficiency, and indoor air quality.	ASHRAE 90.1 2017	A building meets performance standards if it does not consume more energy than was budgeted through compliant energy modeling software. Community shared renewable systems can be requested and reviewed by the Commission. In 2020, solar panels will be a requirement on new residential construction.	N/A	Higher performing R-values for most assemblies. Higher performing U-values for glazing. Higher insulation regulation around piping, ventilation, and other systems. Minimum performance metrics for heat pumps. And more.	The ability to use batteries to store excess solar energy is an option but needs to be approved. This can be used individually or as a community. Movement sensors have some regulations and min./max. requirements. Time-switch lighting must have back-up controls in the case of power interruption. Controls for hot water distribution must be capable of automatically turning off and be equipped with automatic temperature control. And more.
MASSACHUSETTS STRETCH CODE	Standard	Office of Public Safety and Inspections	Began in 2012. Similar to the BC step code, the Massachusetts Stretch Code is an optional code for municipalities to enforce regionally. It is a prescriptive method.	https://www.mass.gov/handbook/eighth-edition-of-the-ma-state-building-code-780	All commercial. Mid to high residential. New and retrofit construction.	No.	To lower consumption requirements, modernize building envelope, ventilation, insulation systems and other measures. Promote cost savings for builders, owners, and residents through offsets and improved efficiency.	IECC 2015 ASHRAE 90.1-2013	On-site renewable energy minimums are enforced. Offers approved alternative energy performance methods.	Yes.	Energy modeling through approved software is required. HVAC systems must be certified and tested. All fuel burning appliances and systems must be officially and clearly labelled..	N/A
TORONTO ZERO EMISSIONS BUILDING FRAMEWORK	Policy	City of Toronto	Written in 2017. An action plan acting on Toronto's Green Standard in improving goals for higher performance levels in new construction to reduce GHG impact, improve densification, retrofitting poorer-performing buildings, increasing occupant comfort, and encourage industry capacity for high performance design and construction.	https://www.toronto.ca/wp-content/uploads/2017/11/9875-Zero-Emissions-Buildings-Framework-Report.pdf	All typologies. New and retrofit construction.	Potential to influence Alberta in the future.	Reduction GHG emissions by 80% of 1990 levels by 2050. Reduce demands on provincial power generation infrastructure and reduce emissions. Increase renewable and district energy generation across the city.	Provincial requirements 2017 Ontario Building Code LEED NC 2009	Optional on-site renewable energy is mentioned with a minimum site coverage of 5% of total building's energy load. Pledged to increase support to city renewable and district energy. Fuel switching is mentioned. Sub metering is optional and encouraged to better measure energy usage. District energy connections.	N/A	Air tightness testing requirements are called for. Building labeling and disclosure. Offset poor building performance with the removal or performance improvement of balconies. Building commissioning to ensure buildings are operating as intended.	Model peak energy demand intensity. Required energy modeling. Peak energy and demand response measures. Prevent use of light through passive design. And more.
VANCOUVER ZERO EMISSIONS BUILDING FRAMEWORK	Policy	City of Vancouver	Written in 2016. Focused on the greater Vancouver area, this plan details 4 actions strategies to ensure that all new buildings emit no GHGs by 2030, and no operational GHG emissions by 2025.	https://vancouver.ca/files/cov/zero-emissions-building-plan.pdf	All typologies. New construction only.	Potential to influence Alberta in the future.	Zero emissions by 2030. Zero emissions of new construction by 2025. Focuses TEDI targets.	BC Provincial Energy Efficiency Working Group Passive House is greatly referenced throughout the whole policy. Building Bylaw Rezoning Policy for Green Buildings City of Toronto Green Standard	Entirely focused on renewable energy including but not limited to: High performance building envelopes TEDI Embodied carbon Energy Modelling	Yes; on-site solar is only mentioned.	Design aspects including but not limited to WWR, assembly R-values, ventilation rates, and more will need to demonstrated to prove a building has met the policy's requirements.	Time-stepped limits for TEDI are required
SEATTLE SUSTAINBLE BUILDINGS AND SITES POLICY	Policy	City of Seattle	Written in 2011. This citywide policy focuses on improving the environmental, economic and social health quality of the city through its new and retrofitting building projects.	https://www.seattle.gov/environment/climate-change/buildings-and-energy/city-facilities/sustainable-buildings-and-sites	All typologies. New and retrofit construction.	No.	No dates listed. Targeting improve all present and future construction and Maintenance to improve overall city quality of living and efficiency.	LEED (for new construction, additions and major retrofits) Capital Green Seattle Energy Code	Requires following LEED energy requirements. Energy modeling and aiming for 2030 Challenge goals is only strongly recommended.	Yes; Ideal Green Parks program only mentioned.	LEED performance metrics.	N/A
WASHINGOTN DC'S CLEAN ENERGY DC OMNIBUS AMENDMENT ACT OF 2018	Policy	Government of the District of Columbia	Draft written in 2016, full document in 2018. The District of Columbia's energy and climate action plan. It focuses on GHG emissions from buildings, energy infrastructure and transportation systems with an aim to be improved by 2032.	https://doee.dc.gov/cleanenergydc	All typologies. New construction by 2021. Retrofits by 2026 or sooner.	No.	Decrease emissions levels by 2032 to be below recorded levels in 2006. Carbon neutrality by 2050.	LEED The District's 2050 carbon neutrality commitment. Plans to offer future alternative paths into LEED, Enterprise Green Communities, Passive House, and Living Building Challenge.	Future plans to modernize district systems to be more renewable. Add solar minimum requirements to building code.	Yes.	Window performance increases. General building performance increases to improve efficiency to reach 2050 goals.	N/A
USGBC LEED V4 BD+C	Standard	USGBC	Version 4 began in 2016. LEED practices focused on the new construction of commercial projects. Many sections pertain to energy and emissions, alongside water, materials and more.	https://www.usgbc.org/sites/default/files/LEED%20v4%20BDC_07.25.19_current.pdf	Commercial and institutional typologies. New construction only.	Yes.	Energy modeling. Water usage, sourcing, and treatment. Location and transportation. Densification. Renewable energy production. Offsets. And more.	LEED aims to align with various standards, policies, and reporting programs worldwide and mentions the following: Organization for Economic Co-operation and Development (OECD) UN Global Compact: Communication of Progress SIO 26000:2010 Guidance on Social Responsibility	Construction pollution prevention. Minimum/optimized energy performance. Renewable energy production. Green power. Pollution prevention. And more.	Yes.	Rainwater management. Heat island reduction. Building-level water metering. Building life-cycle impact reduction. Indoor air quality performance and monitoring. Thermal comfort. Daylighting. And more.	Light pollution reduction. Cooling tower water use. Demand response. Public transit and site accessibility. And more.
USGBC LEED V4 O+M	Standard	USGBC	Version 4 began in 2016. Similar to BD+C above, this standard focuses on existing buildings and their operations.	https://www.usgbc.org/resources/leed-v4-building-operations-and-maintenance-current-version	Commercial and institutional typologies. Operations and maintenance only.	Yes.	Energy modeling. Water usage, sourcing, and treatment. Location and transportation. Densification. Renewable energy production. Offsets. And more.	LEED aims and encourages to align with various standards, policies, and reporting programs worldwide and mentions the following: Organization for Economic Co-operation and Development (OECD) UN Global Compact: Communication of Progress SIO 26000:2010 Guidance on Social Responsibility	Construction pollution prevention. Minimum/optimized energy performance. Renewable energy production. Green power. Pollution prevention. And more.	Yes.	Rainwater management. Heat island reduction. Building-level water metering. Building life-cycle impact reduction. Indoor air quality performance and monitoring. Thermal comfort. Daylighting. And more.	Light pollution reduction. Cooling tower water use. Demand response. Public transit and site accessibility. And more.
CAGBC ZERO CARBON BUILDING STANDARD	Standard	CaGBC	Began in 2017. A Canadian standard written by the CaGBC focusing carbon initiatives for commercial buildings. Uses the ENERGY STAR Portfolio Manager metrics and focuses energy demand and use aiming to lower emissions.	https://www.cagbc.org/cagbcdocs/zerocarbon/CaGBC_Zero_Carbon_Building_Standard_EN.pdf	Commercial only. Residential standard being written. New and retrofit construction.	Yes.	All new buildings to be zero carbon by 2030. All buildings to be zero carbon by 2050.	Pan-Canadian Framework on Clean Growth and Climate Change Energy Star Portfolio Manager	New construction projects require on-site renewables. Considering the embodied and life-cycle carbon of materials during the design stage. Categorizes emissions into 4 categories: direct, indirect, biomass, and avoided emissions	Yes.	Improving building efficiency with high focus on building envelopes and ventilation. TEDI. EUI.	Considering and planning for peak demand energy times by storing excess energy or using other methods.
CHBA NET ZERO ENERGY LABEL	Standard	CHBA	Began 2016. The CHBA NZE Label is a certification program for homes that certifies they meet the Technical Requirements modelled and constructed to produce as much energy as it consumes on an annual basis. This includes using NRCan's EnerGuide Rating System's energy performance rating.	https://www.chba.ca/CHBA/HousingCanada/Net_Zero_Energy_Program/NZE_Qualified_Homes/CHBA/Housing_in_Canada/Net_Zero_Energy_Program/NZE_Qualified_Homes.aspx?hkey=6dfe0bb7-cd34-4395-9052-64219fe31a99	Residential. Operational certification.	Yes.	No dated targets. To achieve net zero certification where a home produces as much energy as it consumes on an annual basis.	NRCan EnerGuide Rating System ENERGY STAR R-2000	Generated energy must be produced on-site. Storage of energy to be used later is also allowed. Solar PV and wind turbines are explicitly defined and explained.	N/A	Ducts of varying uses have minimum R-values they must meet.	Storing excess generated power to be used at a later time.
ILFI ZERO ENERGY CERTIFICATION	Certification Program	ILFI	Began in 2011. Focuses on tracking the performance of a building over the course of 1 year, verifying that 100% of its net-annual energy needed is produced on-site, with no combustion allowed. Paid certification.	https://living-future.org/zero-energy/certification/#overview	All typologies. Operational certification only.	Yes.	Proving the building in question truly operates as claimed by means of using the sun, wind, and earth to produce annual net energy demand.	N/A	Full on-site energy generation to offset net annual energy consumption, exactly like traditional net zero practices.	Yes; only on-site was mentioned.	N/A; this certification program mainly monitors and benchmarks a building's performance. ILFI's other program, the Living Building Challenge, goes into building efficiency greatly.	Surplus generated energy may be applied toward a portion of the embodied carbon offset.
PASSIVE HOUSE	Standard	Passive House Canada	Canadian chapter began in 2013, Passivhaus in 1990s. Passive House is a sustainable building standard focused on the energy and performance of a building, with strong attention to mechanical systems and building assemblies. Lowered energy use is a key goal.	https://www.passivehousecanada.com/about-passive-house-canada/	All typologies. New and retrofit construction.	Yes.	Proving the building in question truly operates as claimed by means of using the sun, wind, and earth to produce annual net energy demand.	N/A	The use of solar or wind are not a requirement, but strongly recommended, with much training and focus around the installation of systems for peak performance.	N/A	Extremely high and efficient assemblies and mechanical systems. Thanks to passive heating and cooling, there is a much lower energy demand on these types of buildings.	Not a requirement, but calculations for energy use and storing are optional and encouraged.
PAN-CANADIAN FRAMEWORK ON CLEAN GROWTH AND CLIMATE CHANGE	Policy	Federal Canadian Government	Written in 2016. A response to the 2015 Paris Agreement, this policy details Canada's commitment to achieving all of the 2030 and 2050 goals listed in the agreement.	http://publications.gc.ca/site/eng/9.828774/publication.html	All typologies. New and retrofit construction.	Yes.	To meet or exceed of a 30% GHG reduction by 2030 based on 2005 levels.	2015 Paris Agreement Various provincial policies, such as Vancouver's Declaration on Clean Growth and Climate Change and Quebec's Summit on Climate Change 2015.	Recognizing and supporting renewable energy steps provinces may have already taken, including all types from carbon pricing to hydroelectric and more. Cleaner electricity, wind power, coal phase-out programs, and solar are all mentioned and reinforced. Several systems are also mentioned with a need to be improved and modernized, such as electrical grid systems. And more.	Yes.	There is a call to make buildings more energy efficient overall. Retrofitting buildings, including fuel switching if needed. Improving efficiency of appliances. Supporting energy efficient codes and practices in Indigenous communities. And more.	Expanding, updating, and modernizing electrical grid storage systems.
ASHRAE VISION 2020	Policy	ASHRAE Vision 2020 Ad Hoc Committee	Written in 2008. This document explains ASHRAE's commitment to aiding the market in achieving Net Zero Energy Buildings by 2030 by providing tools by 2020.	https://www.ashrae.org/File%20Library/About/Strategic%20Plan/ASHRAE-Vision-2020-color.pdf	All typologies. New and retrofit construction.	Yes.	All buildings to be Net Zero Energy by 2030. To provide consistent and stable market tools by 2020 to achieve the above goal.	American Society of Heating, Refrigerating and Air-Condition Engineers American Institute of Architects USGBC Illuminating Engineering Society of North America	The committee is committed to researching renewable energy systems. The document includes guides which offer strategies for on-site renewable energy concepts.	Yes; may cover no more than 50% of the building's net energy.	The document calls for the building contractors to implement and follow-through with energy-efficient designs, including trading trades in proper implementations skills. Increase and support incentive and restructuring relationships between building energy and source energy. Building envelope should be designed to minimize loads on HVAC and lighting loads.	Quantifying building attributes, both new and operational, to better understand building's consumption rates and conservation efforts needed. Buildings which generate potable water should be able to use that as credit against their water metering.
ENERGUIDE RATING SYSTEM	Rating System	NRCan	Began in, this version written in 2015. A national system for the purpose of assessing and depicting the energy performance of houses.	https://www2.nrcan-rncan.gc.ca/oee/nh-mn/documents/eg/tech/EnerGuide%20Rating%20System%20Technical%20Procedures%20Version%2015.1.pdf	Residential, low-rise only. Operational certification.	Yes.	No dated targets. Targets include helping industry, home-owners, and stakeholders become energy literate. Provide readily available energy performance information that is widely used. Facilitate energy performance advancements in and existing low-rise housing.	R-2000	Renewable energy systems, examples included solar domestic water heater and PV panels, must be documented and photo graphed for assessment. Various sections of the guide include upgrade considerations and recommendations including but not limited to ventilation, mechanical systems, and hot water systems.	N/A	Building envelope upgrade recommendations go into fair detail, especially when considering air sealing, R-values of various assemblies, and windows and doors.	N/A
ENERGY STAR PORTFOLIO MANAGER	Benchmarking Certification Program	Energy Star	Began in 1999 (in the USA) Initial launched by the U.S. Environmental Protection Agency, this benchmarking program quantifies and measure commercial buildings and quickly became the industry standard, which it remains today.	https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/use-portfolio-manager/learn-how-portfolio-manager	All typologies. Operational metering.	Yes.	To measure new and existing buildings on various metrics to compare them to a benchmark and quantify their performance.	N/A	N/A	N/A	Portfolio Manager measures the following metrics: GHG emissions (carbon footprint) 1-100 water score 1-100 overall energy score Annual occupancy Ventilation Illumination And more.	N/A
UNIVERSITY OF ALBERTA SUSTAINBILITY PLAN 2016-2020	Policy	University of Alberta Sustainability Council	Written in 2016. A response to the 2015 Paris Agreement, this policy details Canada's commitment to achieving all of the 2030 and 2050 goals listed in the agreement.	https://issuu.com/officeofsustainability/docs/sustainability_plan_2016-2020__sing	Institutional or other campus facilities; this document explains campus sustainability goals.	Yes; in that the university is in Alberta.	Reduce the university's GHG emissions by 17% below 2005 levels by 2020. The plan is to strive towards 5 goals: Leadership Education and Research Operations and Infrastructure Community and Culture Health and Well-being	The Way We Green: The City of Edmonton's Environmental Strategic Plan 2011 Statement of Action, G8 University Summit 2010 The Sustainability Tracking, Assessment and Rating Systems (STARS)	Embed social, economic and environmental sustainability into the development and care of the university's indoor and outdoor spaces.	N/A	Nothing was directly mentioned towards building assemblies or components, but as mentioned before, UofA does report to STARS periodically to be re-assessed.	N/A
UNIVERSITY OF CALGARY 2019 CLIMATE ACTION PLAN	Policy	University of Calgary Sustainability Resource Centre	Written in 2019. This document provides a roadmap to the university's sustainability, and focuses 3 mains points: Framework for advancing sustainability education and research Framework on engagement for sustainability Framework on sustainability in administration and operations	https://www.ucalgary.ca/sustainability/strategy/climate-action-plan	Institutional or other campus facilities; this document explains campus sustainability goals.	Yes; in that the university is in Alberta.	GHG emissions to be 35% lower than 2008 levels by 20025 50% lower than 2008 levels by 2030 97% lower than 2008 levels by 2050	The University of Calgary's Eyes High Strategic Vision and Strategy 2011 The Brundtland Report (UNWCED 1987) STARS Paris Agreement 2015 Pan-Canadian Framework on Clean Growth and Climate Change Government of Canada Clean Fuel Standard 2020	Promote research opportunities within the operations group on campus, including the Energy Management Strategy. Reduce energy demands through retrofits. Use higher amounts of renewable energy. Decarbonize the district energy system.	N/A	Develop ultra-energy efficient and net-zero carbon construction. Drastic reduction of energy demand through a four-tiered energy retrofit program for existing buildings, as well as continued renewal and repurposing to improve space utilization. Minimize external energy demands by reducing energy demand within the buildings, Fuel-switching.	Energy storage. The use of renewable fuels such as biomass (BM) or renewable natural gas (RNG) to address peak heating demand only during the coldest months of the year.
CALGARY CLIMATE RESILIENCY STRATEGY	Policy	City of Calgary	Written in 2018. The city's plan and commitment to supporting climate change and reducing GHG emissions through various industries including construction and building maintenance.	https://www.calgary.ca/UEP/ESM/Pages/Climate-change/Climate-Actions.aspx	Residential, commercial, and industrial . New and retrofit construction.	Yes.	80% GHG reduction by 2050.	Pan-Canadian Framework on Clean Growth and Climate Change Alberta Climate Leadership Plan Natural Resources Canada	On-site and neighborhood scale renewable and low carbon energy systems. Supporting low carbon economy. Lower promoting renewable energy bills, one aim is to lower Calgarian's utility bills. Buildings should report energy usage in the future.	Yes; in partnership with the Province.	A core part of the city's climate mitigation plan is to adapt to large infrastructure upgrades including a strong focus on applying energy performance standards in new and existing buildings. The policy lists forecasted GHG emissions per building typology, such as a reduction of 129 Mt in the residential sector by 2050. Support energy step-codes. Prepare Calgary to implement a new retrofit code. And more.	Conservation through improved building envelopes. Redesigning utility bills to promote energy conservation. To build and design for heat wave peak demand loads as they require more air conditioning typically. Water storage capacity will be an increasing priority.
CLIMATE RESISTANT EDMONTON	Policy	City of Edmonton	Written in 2018. The city's plan to reduce GHG emissions.	https://www.edmonton.ca/city_government/environmental_stewardship/ghg-emissions-reduction-plan.aspx	All typologies. New and retrofit construction.	Yes.	3 scenarios were assessed and what path the city would need to take either: 30% below 2005 levels by 2030 50% below 2005 levels by 2030 Or Carbon neutral by 2030.	Pan-Canadian Framework on Clean Growth and Climate Change The Paris Agreement Edmonton's Declaration's commitments for GHG planning and reporting Alberta's Climate Leadership Plan Renewable Electricity Plan	Continue to motivate new local renewable energy generation to increase resilience to grid disruptions. Edmonton's Solar Program.	Yes.	Energy performance monitoring for buildings will be a future focus.	Monitor the need for energy storage units for vehicles for the future.
ALBERTA CLIMATE LEADERSHIP PLAN	Policy	Government of Alberta	Began in 2015, current version from 2018. A made-in-Alberta strategy to reduce carbon emissions while diversifying the economy, creating jobs, and protecting the health environment within the province.	https://open.alberta.ca/dataset/da6433da-69b7-4d15-9123-01f76004f574/resource/b42b1f43-7b9d-483d-aa2a-6f9b4290d81e/download/clp_implementation_plan-jun07.pdf	General infrastructure funding; no specific typologies were explicitly mentioned. New and retrofit construction.	Yes.	Phase out all coal-generated electricity by 2030. Provide 30% of Alberta's energy through renewable sources by 2030. Reduce methane emissions from upstream oil and gas production by 45% from 2014 levels by 2025.	Energy Efficiency Alberta The Indigenous Climate Leadership Initiative The Carbon Competitiveness Incentive Regulation Alberta Climate Change Office	Carbon Levy of \$20 per ton CO_2e in 2017 and \$30 in 2018.	N/A	ICLI supports retrofitting indigenous communities with better performing renovations, solar, energy audits, and more.	N/A

APPENDIX B: Barriers of Adoption

BUILDING TYPOLOGY ASSESSMENT						
BUILDING TYPOLOGY		DESCRIPTION	BARRIERS OF ADOPTION			
			Cost	Regulatory & Government	Policy & Municipal	Understanding & Awareness
RESIDENTIAL	SINGLE FAMILY	Includes both attached and detached single family residential buildings, up to 3 stories.	High Individual preferences for homes still dominate the strategies being applied to this residential typology. Costs for zero carbon are perceived as too high for homeowners to bear at this time.	High While some energy requirements exist in the current NECB, more code requirements should be added. This typology would also benefit greatly from government subsidized incentives.	High While some energy requirements exist in some municipalities, more requirements should be added. This typology would also benefit greatly from municipal subsidized incentives.	Medium Some municipalities are actively engaging their communities and others less so.
	MID-RISE	Multi-family housing up to 6 stories for low-rise and up to 10 stories for mid-rise. Includes multi-use buildings.	Medium Mid-rise buildings hover between affordable and costly strategies to achieve zero carbon goals. Local bylaws and regulations can often impact decision-making.	High While some energy requirements exist in the current NECB, more code requirements should be added for low-rise. This typology would also benefit greatly from government subsidized incentives.	High While some energy requirements exist in some municipalities, more requirements should be added. This typology would also benefit greatly from municipal subsidized incentives.	Medium Some municipalities are actively engaging their communities and others less so.
	HIGH RISE	Multi-family housing 11 stories or more. Includes multi-use buildings.	Low This typology can typically invest in strategies for a lower cost/ft2 than other residential building types.	Medium The current and future NECB will address many issues. This typology would also benefit from government subsidized incentives.	Medium The current and future NECB will address many issues. This typology would also benefit from municipal subsidized incentives.	Medium Some municipalities are actively engaging their communities and others less so.
COMMERCIAL	OFFICE	Facilities supporting office work and operations, 3+ stories.	Low This typology can typically invest in strategies for a lower cost/ft2 than other building types.	Low Minimal impact to building to zero carbon in this typology. This typology would also benefit from government subsidized incentives.	Low Minimal impact to building to zero carbon in this typology. This typology would also benefit from government subsidized incentives.	Low Much education is aimed at this building typology.
	WAREHOUSE	Large facilities used for the storage of goods and equipment, up to two stories.	Medium This typology is gaining momentum as a key area that benefits from high performing envelopes and large solar PV roof installations.	Low Minimal impact to building to zero carbon in this typology. This typology would also benefit from government subsidized incentives.	Low Minimal impact to building to zero carbon in this typology. This typology would also benefit from government subsidized incentives.	Low Much education is aimed at this building typology.
INSTITUTIONAL	EDUCATIONAL	Educational facilities supporting grades K to 12. Universities and colleges were omitted due their thier unique needs.	Medium Much work has been done to understand what is required to achieve zero carbon in educational facilities. The next step is to target new builds. Note: retrofits of existing educational facilities drive the costs to Medium in this analysis.	Medium Current government policies are restricting movement forward in this typology.	Low Municipalities have low influence over this specific typology.	Medium Some education has been developed for this building typology but excludes general public awareness.
	HEALTHCARE	Includes clinics, assisted care, and other smaller facilities. Hospitals were omitted due to their size and unique needs.	Medium Strategies from residential and commercial building typologies can be adopted easily to meet these building types.	Medium Current government policies are restricting movement forward in this typology.	Low Municipalities have low influence over this specific typology.	Medium Some education has been developed for this building typology but excludes general public awareness.
CIVIC	FIREHALL	Facilities supporting fire engines and other fire prevention equipment and operations.	Medium Strategies from residential and commercial building typologies can be adopted easily to meet this building type.	Low Minimal impact to building to zero carbon in this typology.	Medium The current and future NECB will address many issues. This typology would also benefit from municipal subsidized incentives.	Medium Some municipalities are actively engaging their communities and others less so.

APPENDIX C: Impact Gap Analysis

BUILDING TYPOLOGY		PRIORITIZATION MATRIX											
		NEED FOR ADVOCACY			NEED FOR EDUCATION			NEED FOR INCENTIVES			NEED FOR POLICY		
		Alignment with National Goals	Focus on Resilience	GHG Reductions from Operations	Alignment with National Goals	Focus on Resilience	GHG Reductions from Operations	Alignment with National Goals	Focus on Resilience	GHG Reductions from Operations	Alignment with National Goals	Focus on Resilience	GHG Reductions from Operations
RESIDENTIAL	SINGLE FAMILY	Low Several documents explicitly advocate for this typology to align with national goals.	Low Several documents explicitly advocate for increased resilience of this typology.	Low Several documents explicitly advocate for an operational GHG reduction from this typology.	Medium Only some documents educate aligning this typology with national carbon goals, and it is typically less complicated to build.	High Some documents educate resiliency within this typology, but given its demand and vulnerability to damage more should be made.	Low Some documents explicitly educate decreasing this typologies operational GHGs, and it is typically less complicated to build.	Low	Low	High	Medium Several documents explicitly align this typology with national goals, but given its demand more policies could be written that are more regionally specific (i.e.: city specific.)		
	MIDRISE MULTI-FAMILY	Medium Many documents advocate all general typologies, where this typology is included, to align with national goals.	Medium Many documents advocate for an increase in resilience for all general typologies, where this typology is included.	Medium Many documents advocate for a decrease in operational GHG emissions of all general typologies, where this typology is included.	Medium Only some documents educate aligning this typology with national carbon goals, and it is moderately less complicated to build.	Medium Some documents educate resiliency within this typology, but more should be made as this typology should be used more in the future in response to densification.	High Some documents educate decreasing this typology's GHGs, but more should be made as this typology typically generates more GHGs.	Low	Low	High	Low Many policies address all general typologies, where this typology is included, to align with national goals.	Medium Several policies cover the need for resilience in this typology, however more could be made as it can be a broad typology.	Medium Some documents educate how to reduce GHG emissions from general typologies which would include this one, but it is also a large producer of emissions and should be explained more thoroughly.
	HIGH RISE MULTI-FAMILY	Medium Many documents advocate all general typologies, where this typology is included, to align with national goals.	Medium Many documents advocate for an increase in resilience for all general typologies, where this typology is included.	Medium Many documents advocate for a decrease in operational GHG emissions of all general typologies, where this typology is included.	High Some documents educate aligning this typology with national carbon goals, but because it is typically more complicated to build more education should be provided.	High Some documents educate resiliency within this typology, but more should be made as this typology should be used more in the future in response to densification, and it is typically more difficult to build.	High Some documents educate decreasing this typology's GHGs, but more should be made as this typology typically generates more GHGs.	Low	Low	High	Low Many policies address all general typologies, where this typology is included, to align with national goals.	Medium Several policies cover the need for resilience in this typology, however more could be made as it can be a broad typology.	Medium Some documents educate how to reduce GHG emissions from general typologies which would include this one, but it is also a large producer of emissions and should be explained more thoroughly.
COMMERCIAL	OFFICE	Medium Many documents advocate all general typologies, where this typology is included, to align with national goals.	Medium Many documents advocate for an increase in resilience for all general typologies, where this typology is included.	Medium Many documents advocate for a decrease in operational GHG emissions of all general typologies, where this typology is included.	High Some documents educate aligning this typology with national carbon goals, but because it is typically more complicated to build more education should be provided.	Medium Some documents educate resiliency within this typology, but more should be made to respond to varying needs within this typology.	High Some documents educate how to reduce GHG emissions from general typologies which would include this one, but it is also a large producer of emissions and should be explained more thoroughly.	Low	Low	High	Low Many policies address all general typologies, where this typology is included, to align with national goals.	Medium Several policies cover the need for resilience in this typology, however more could be made as it can be a broad typology.	Medium Some documents educate how to reduce GHG emissions from general typologies which would include this one, but it is also a large producer of emissions and should be explained more thoroughly.
	WAREHOUSE	Medium Many documents advocate all general typologies, where this typology is included, to align with national goals.	Medium Many documents advocate for an increase in resilience for all general typologies, where this typology is included.	Medium Many documents advocate for a decrease in operational GHG emissions of all general typologies, where this typology is included.	High Some documents educate aligning this typology with national carbon goals, but because it is typically more complicated to build more education should be provided.	Medium Some documents educate resiliency within this typology, but more should be made to respond to varying needs within this typology.	High Some documents educate how to reduce GHG emissions from general typologies which would include this one, but it is also a large producer of emissions and should be explained more thoroughly.	Low	Low	High	Low Many policies address all general typologies, where this typology is included, to align with national goals.	Medium Several policies cover the need for resilience in this typology, however more could be made as it can be a broad typology.	Medium Some policies cover the reduction of GHG emissions from general typologies which would include this one.
INSTITUTIONAL	EDUCATIONAL	High There is little to no advocacy for this typology to align with national goals.	High There is little to no advocacy for this typology to increase it's resilience.	High There is little to no advocacy for a decrease in operational GHG emissions for this typology.	High Little to no documents educate how to align this typology with national carbon goals.	High Little to no documents educate how to make this typology more resilient outside of general knowledge applicable to most typologies.	High Little to no documents educate how to reduce GHG emissions from this typology, and it is also a large producer of emissions.	Low	Low	High	High Little to no policies cover this typology.		
	HEALTHCARE	High There is little to no advocacy for this typology to align with national goals.	High There is little to no advocacy for this typology to increase it's resilience.	High There is little to no advocacy for a decrease in operational GHG emissions for this typology.	High Little to no documents educate how to align this typology with national carbon goals.	High Little to no documents educate how to make this typology more resilient outside of general knowledge applicable to most typologies.	High Little to no documents educate how to reduce GHG emissions from this typology, and it is also a large producer of emissions.	Low	Low	High	High Little to no policies cover this typology.		
CIVIC	FIREHALL	High There is little to no advocacy for this typology to align with national goals.	High There is little to no advocacy for this typology to increase it's resilience.	High There is little to no advocacy for a decrease in operational GHG emissions for this typology.	High Little to no documents educate how to align this typology with national carbon goals.	High Little to no documents educate how to make this typology more resilient outside of general knowledge applicable to most typologies.	High Little to no documents educate how to reduce GHG emissions from this typology, and it is also a large producer of emissions.	Low	Low	High	High Little to no policies cover this typology.		