STANDARDS RESEARCH

The Circular Built Environment in Canada: A Review of the Current State, Gaps and Opportunities

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Executive Summary

The construction industry is a major consumer of natural resources and imposes significant impacts on the environment. A circular built environment (CBE) is necessary to manage the increasingly limited supply of natural resources, minimize waste and achieve carbon-emission reductions, while providing the housing and infrastructure society needs.

CBE proposes an alternative to the current linear economy of "take-make-use-dispose." It is a restorative and regenerative system in which the goal is to recapture the value of existing buildings, increase their durability, and create new buildings whose materials can be used, and reused, long into the future.

CBE is at an early stage of adoption in Canada. Barriers to CBE include transitional costs, lack of awareness, industry fragmentation, supply chain complexities and inconsistent regulations. Bringing CBE into the mainstream will require collaboration across government, business and academia. Standards can play an important role in the adoption of circularity by providing the language we use to identify it, guidance for policies and regulations, and examples to ease adoption.

Through a literature review, interviews with industry leaders and two roundtable workshops, this study sought to explore the current state of CBE in Canada, identify gaps and recommend a path forward.

The following are actions that can be taken across the construction sector:

- Create a national waste management framework with aligned metrics, definitions and targets across regions and provinces.
- Include embodied carbon requirements and references in codes and policies.
- Incorporate CBE criteria and how to use reclaimed materials in design standards for the key structural materials referenced in the National Building Code of Canada (NBC). These include steel, concrete, wood and masonry.
- Simplify certification of salvaged materials for reuse (not downcycling).
- Create a pan-national network of markets for reused materials through increased disposal fees.
- Commit to a national building information modelling (BIM) mandate to facilitate project data management and reporting.
- Extend net-zero policy roadmaps to cover waste/resource efficiency and other benefits circular practices offer.

Gaps were identified and recommendations were made in the following six categories.

1. **Definitions:** Standardized definitions can alleviate an inconsistent use of terminology for circularity in Canada. These definitions are needed to provide aligned perceptions. Additional education and outreach can inform the industry on the value of circularity.
2. **Standards:** Metrics and guidance can be incorporated into standards to assist in setting goals and establish a pathway to achieve them. Research for standards provides the technical legitimacy to encourage their adoption and the specifications for implementation. Research into reuse of structural materials was specifically identified as a need to encourage a CBE.

3. **Data, metrics and indicators:** Data is needed to understand where the greatest need lies and where gains can be made quickly. Material specifications in environmental product declarations (EPDs) can be more consistent and accessible, and life cycle assessments (LCAs) can be created in a more consistent manner for comparison. Waste diversion and recycling rates can be analyzed across regions to identify where more resources can be allocated for reuse or material diversion activities. A circularity index could be developed from this data to identify excellence and best practices in CBE.
4. **Governance:** National codes should add guidance on the alteration, change of use and deconstruction of existing buildings, as well as on the use of salvaged materials. Governance can also provide guidance on use of prefabricated components designed for disassembly, to remove the burden of alternative compliance pathways in project approval.
5. **Technical issues:** Technical issues such as choice of material, design of a structure, and how components are connected are key to adoption of CBE. There is a gap in accessibility of this information and guidance on how to use it.
6. **Market barriers:** Market barriers exist for circular practices. The extra effort required impedes action to find materials for reuse, design for deconstruction, or consider the full life-cycle cost instead of the immediate construction or repair costs. Procurement and contracts need updated models and templates.

CBE will play a crucial role in mitigating embodied emissions as Canada collaborates with other nations to minimize the carbon footprint of buildings and address the impacts of climate change. Establishing a CBE necessitates a paradigm shift in approach to material usage, encompassing considerations such as extraction, design, reuse and diversion from landfills. Although this transformation will require time, the process can be expedited by leveraging existing examples of techniques from within Canada and internationally, and by embracing innovative methods that may emerge as momentum for CBE gains traction.

Although new buildings can be built to include "green" and energy-efficient methods, it can still take 10 to 80 years to recover from impacts of construction due to the embodied carbon within building materials [2].

1 Introduction

Globally, the construction industry is the largest consumer of raw materials and accounts for 25–40% of the world's carbon emissions [1]. Although new buildings can be built to include "green" and energy-efficient methods, it can still take 10 to 80 years to recover from impacts of construction due to the embodied carbon within building materials [2]. Embodied carbon emissions include emissions resulting from the manufacturing, transportation, installation, maintenance and disposal of building materials. The World Economic Forum estimates that less than one third of construction and demolition waste is currently recovered [3].

In 2017, the Organisation for Economic Co-operation and Development (OECD) stated that "Canada is among the most material-intense economies in the OECD" [4]. Meanwhile, the Conference Board of Canada ranked Canada 15th out of 17 countries for the amount of municipal solid waste it sends to landfills [5]. Overall, only 6% of materials entering Canada's economy come from recycled sources, whereas almost three-quarters of materials used are wasted [6].

Canada's construction industry generates a huge amount of waste, comprising over four million tonnes or 12% of the solid waste stream generated [7]. Of this, only 750,525 tonnes (about 18%) was diverted from landfills in 2020 [8]. Wood represents about 30% of the total volume of construction waste that goes to landfill [9]. Natural Resources Canada estimates that unrecovered wood waste in Canada's municipal solid waste (MSW) and construction, renovation and demolition (CRD) waste streams amounts to roughly 1.75 million metric tonnes annually [10].

Moving from the linear take-make-waste economy to a circular economy holds great promise for reducing the environmental impacts of construction. A definition of the "circular economy" is currently being proposed by technical committee ISO/TC 323 as "an economic system that uses a systemic approach to maintain a circular flow of resources, by recovering, retaining or adding to their value, while contributing to sustainable development" [11] [12]. A circular built economy (CBE) envisions a future where buildings are designed, planned, built, operated, maintained and deconstructed in a manner in which waste is a resource that is not discarded to landfills. Buildings, and the materials and components that go into them, would be designed and produced to be more durable, utilized at their highest value at all times, and repaired, refurbished, disassembled and reused in perpetuity.

The successful implementation of a circular construction economy will require a change of mindset – one that finds value in used products and economical methods to turn discarded items into new products. It creates opportunities for new businesses that provide materials and products that reduce emissions and the costs of extracting and transporting raw materials. Figure 1 presents a simplified view of the CBE, and examples of circular strategies that can be employed at each stage of a building's life cycle.

Businesses that are moving towards circular models are benefitting from energy savings, cost reductions, and improved consumer and investor relationships [13]. For example, the global construction waste recycling market size was valued at approximately US$28.97 billion in 2022. The market is expected to grow above a compound annual growth rate (CAGR) of 5.4% and is anticipated to reach over US$41.88 billion by 2030 [14].

While the market for circular economy solutions in Canada has potential, and interest is growing in certain areas such as waste minimization, little has been done so far to encourage upstream circular strategies, such as circular inputs and product-as-a-service business strategies. Regulatory changes, market barriers, technical challenges and consumer engagement must be addressed simultaneously as a system to reach the goals of a CBE [15]. However, mapping the full circular economy for the built environment is a complex process – there are many circles within circles.

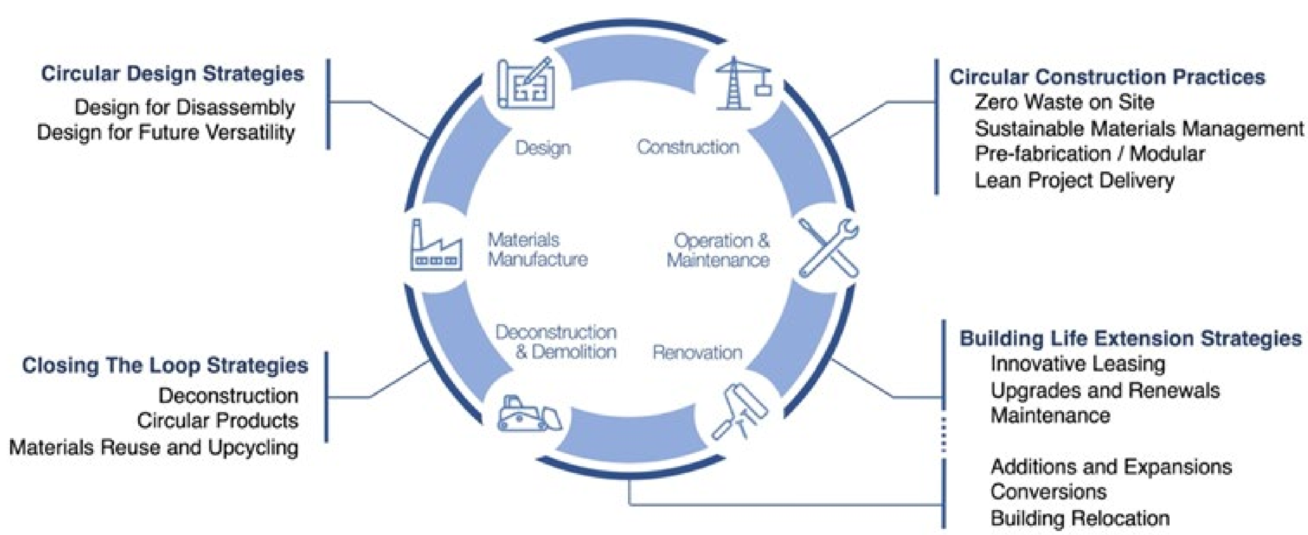
The purpose of this research is to explore the current state of the CBE ecosystem in Canada, highlight gaps based on an analysis of national and international activities, best practices, standards and regulations, and propose ideas for actions that can be taken to help accelerate the adoption of circular practices in Canada's built environment.

2 Methods

This study involved a literature review and environmental scan including standards, academic, technical and government documents. Sources were identified based on recommendations from project collaborators, and through an internet search using keywords such as circularity, circular economy, circular built environment, embodied carbon, construction waste, reducing, reusing, upcycling, recycling and Canada.

Standards relevant to the CBE were identified through a review of building codes, policies, leading voluntary programs, related documents and interviews with industry leaders.

Figure 1: The circular built environment (CBE) and examples of strategies. Source: Scius.



Review criteria included:

- The presence of circular policies and regulations, and the standards that support them (e.g. energy efficiency and embodied carbon, take a "renovation first" approach, retrofit codes)
- Standards that aim to close material chain loops and enable sustainable materials management (e.g., secondary materials, deconstruction)
- Standards that address building performance over the entire life cycle
- Standards that address scarcity (e.g., material, energy) and resource efficiency
- Standards that encourage extended producer responsibility (EPR)
- Standards that address the principles of circular design (e.g., low carbon, versatility, durability, adaptive reuse, disassembly)
- Circularity in existing buildings and infrastructure such as life extension of buildings and components
- Innovation in construction that fosters circular thinking and actions (e.g., data collection and reporting, digital tools)

This evaluation was undertaken to determine where principles of CBE are incorporated into existing standards, noting any gaps and opportunities to better include for CBE, as well as where new standards could be established to strengthen circular practices. The research also involved examining policies and voluntary programs in Canada and internationally, considering the degree to which they advanced circular practices.

This work was informed by 20 semi-structured interviews with local and international researchers and experts from different sectors to validate, refine and update the information collected. Two technical roundtable workshops were convened of approximately 50 people each, from various professions related to the built environment in Canada.

The interviews sought to identify current actions to incorporate circularity and how standards and codes interact with those efforts, as well as recommendations for how policies and regulations might be adapted for circularity, how to limit construction waste and recycle more, and how standards could support innovation and system change. Examples from other jurisdictions around the world that have implemented an approach that could be considered in Canada were also sought.

The roundtable workshops explored the tools and strategies that are currently being used to foster circular practices and discussed implementation challenges. They then explored ideas for market mechanisms, policies, regulations and technical solutions that could limit waste, and prioritized those that could be started quickly.

3 The Policy Environment for Buildings in Canada

Policies and regulations apply to buildings throughout their life cycle from land use, planning and development, through to demolition and the management of construction waste. When it comes to circular building practices, the policy environment for buildings in Canada has not developed uniformly. For example, there are various building code-related initiatives underway to support circular practices such as retrofits. However, little is happening in terms of land use and development policies that hamper the adoption of strategies such as existing-building alterations, expansions or conversions.

3.1 Land Use and Development

Land use, planning and development policies govern the selection of building locations and their intended use. These policies can have an influence on building alterations, expansions and conversions that prevent complete demolition. Land use policies can also influence whether buildings are preserved and nature protected through densification and infill projects, or drive developers to build on greenfield land.

While key informants indicated that there is little ongoing work in Canada to orient land use and development policies towards circularity, there are some interventions that could be considered. In particular, policies could be updated to allow a greater mix of uses such as:

- Commercial uses in residential areas
- Allowing the conversion of older structures to alternative uses or mixing uses within a single building
- Permitting potentially non-conforming properties to be retained and re-used (for example, older buildings may not meet parking requirements)
- Addressing zoning policies that permit new developments that are much larger than what currently exists, threatening otherwise serviceable small buildings with demolition [16]

3.2 Building Codes and Regulations

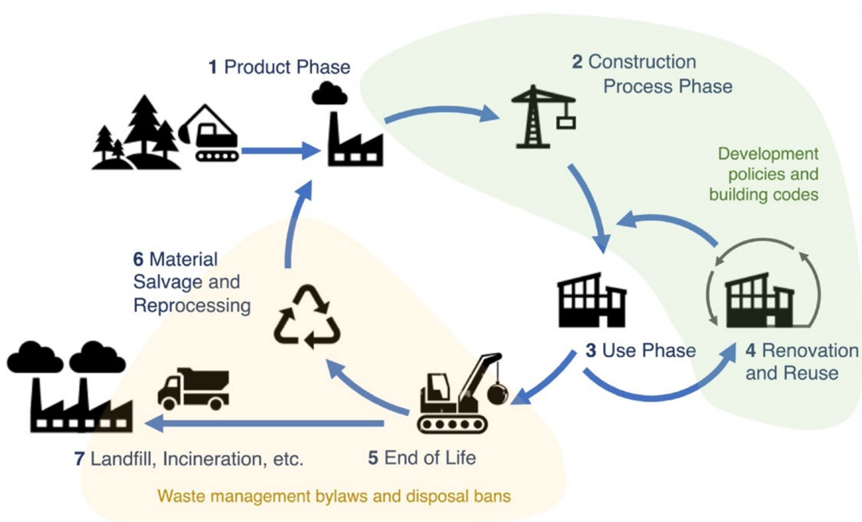
Minimum standards for the construction of buildings are specified in building codes, bylaws and regulations. Codes are regularly reviewed and revised to remain responsive to current and emerging issues, new technologies, materials and construction practices.

The introduction of new regulations, codes, standards and practices can take time. In the past, voluntary programs, pilots and emerging policies have played an important role in signaling future intentions to industry to invest in skills development, build up supply chains and educate participants. For example, the LEED green building rating system is a voluntary market-led system that exemplifies leadership in sustainable building design, construction and operation [17]. Over the years, many standards and practices that LEED introduced to the Canadian construction industry such as ASHRAE 90.1 – *Energy Standard for Sites and Buildings Except Low-Rise Residential Buildings* [18] have subsequently been incorporated by reference into building codes.

Codes and regulations are primarily imposed on the built environment during the construction phase. Regulations are imposed at end of life through waste management legislation, although building codes do not currently address end-of-life processes. Depending on local controls, which may be provincial/territorial, regional or municipal, construction waste management regulations can establish requirements related to the proper handling and disposal of certain materials or impose disposal bans.

Figure 2 illustrates the scope of building codes and regulations overlaid on a simplified materials flow diagram for buildings.

Figure 2: The scope of development and building codes, standards and regulations overlaid on the simplified materials flow diagram for buildings



3.2.1 National Building Code of Canada

The National Building Code of Canada (2020) (NBC) provides technical specifications for the design and construction of new buildings, and for the demolition, alteration and change of use of existing buildings. The NBC – along with the National Energy Code for Buildings (NECB), National Plumbing Code, National Fire Code and others – serves as a model code that is legally adopted by provinces and territories, charter cities and First Nations. It is then administered by authorities having jurisdiction (AHJs).

The National Research Council Canada (NRC) is currently exploring new low-carbon requirements and is working collaboratively to implement these through standards, specifications, guidelines and publications, notably:

- Developing new language for forthcoming updates to National Model Codes that will enable the regulation of operational and life-cycle carbon emissions, respectively. Specifically, technical requirements for operational carbon emissions will be introduced in the 2025 version. Technical requirements for embodied carbon emissions will be introduced in the 2030 version. This work will inform the application to alterations to existing buildings, which will follow.
- Developing a low-carbon guideline that considers life-cycle greenhouse gas (GHG) emissions in federally funded construction projects.
- Revitalizing the National Master Construction Specification (NMS) to include low-carbon solutions.
- Developing and implementing a new suite of performance-based requirements in the National Model Codes.
- Enabling the digitalization of the National Model Codes and the NMS.

3.2.2 Retrofits

Currently, there is no national retrofit code and no related provincial/territorial regulations in use in Canada. At the local level, the City of Vancouver has created regulations for upgrading existing buildings. This is the only retrofit regulation currently in use in Canada.

3.2.2.1 National Retrofit Code

The National Building Code applies to new buildings, building alterations, changes of use and building removal. However, there are unique considerations for existing buildings. The Joint Task Group on the Alterations to Existing Buildings (JTG AEB) is expected to publish a model national retrofit code by 2030, which is envisaged as "a model code for existing buildings to help guide energy efficiency improvements during renovations, with the goal that all provinces and territories adopt it [19]." It has been recommended that this new code be a part of the National Model Code and not a separate set of guidelines, and that the provinces and territories adopt it without deviations to better support practitioners who operate nationally [20]. To date, the JTG AEB has developed a set of eight principles to guide the development of the technical requirements:

1. Close the performance gap between new and existing buildings.
2. Maintain life safety and overall building performance, not making the building worse than the existing one.
3. Avoid negative unintended consequences of alterations.
4. Ensure the building cannot be left in an unsafe state.
5. Apply SMART principles (specific, measurable, achievable, relevant and timely).
6. Encourage alterations to existing buildings without undue burden.
7. Preserve heritage buildings.
8. Complement other programs and tools.

Definitions of repairs, and minor and major alterations, will also be incorporated into the new retrofit code. Initially, the retrofit code will focus on energy efficiency.

3.2.2.2 Provincial Retrofit Codes

There are efforts underway to develop retrofit codes in various jurisdictions in Canada. For example, a retrofit code was proposed in BC's 2020 Climate Change Accountability Report [21]. BC's Existing Buildings

Renewal Strategy aims to develop more energy-efficient, water-efficient and cleaner buildings [22]. The release of BC's retrofit code has been proposed for 2025 [23].

3.2.2.3 Vancouver Building Bylaw PART 11 – Existing Buildings

The Vancouver Building Bylaw (VBBL) differs significantly from the National Building Code when it comes to existing buildings. Part 11 of the bylaw is a tiered approach to building regulations that reflects the practical need to retrofit or adapt buildings in stages [24]. The VBBL Upgrade Mechanism Model provides a framework for building owners and designers to establish the required level of upgrade for the existing portion of a building, as a function of the project types and the related categories of work. In particular, the bylaw considers fire and life safety, occupant health, structural and non-structural safety, accessibility for persons with disabilities, and water efficiency.

The bylaw also stipulates that any major extension of an existing building's original design life shall require upgrading to an acceptable level. An alteration to an individual suite within an existing building will not trigger upgrades within any other suites, except where the alteration creates a non-conformity with the VBBL.

Depending on the type of work envisaged, envelope upgrades may also trigger the requirement to comply with VBBL Part 10 Energy and Water Efficiency. Part 11 aims for a balance between upgrading building performance where possible to an acceptable level, while avoiding incentivizing the demolition of buildings by triggering required, significant upgrades. There are also exceptions where upgrades may provide significant hardship to the owner.

In practice, VBBL Part 11 is a framework that requires significant negotiation and collaboration between building officials, owners and professionals.

The potential solutions are often highly customized, and therefore can be time consuming and expensive. They rely on extensive up-front investigation by experienced designers and builders, as an existing building's records can often be poor, incomplete or nonexistent.

These front-end factors for retrofits are a result of the linear approach to building life cycles of the modern-day building stock. Circular practices cannot be limited to new builds – existing buildings will also require innovative practices and approaches that consider some of the challenges.

3.3 Construction Waste Disposal Regulations

The regulatory landscape surrounding construction, renovation and demolition (CRD) waste management in Canada is complex and driven by a variety of goals that include environmental protection, corporate responsibility, GHG emissions reduction, and strengthening diversion markets and infrastructure. The handling and disposal of construction waste is primarily regulated at the provincial or local level, and each region has its own priorities and approaches. This has resulted in a range of different scopes, definitions, activities and a lack of harmonization of CRD management practices across the country.

To streamline the identification and separation of waste materials on-site, the infrastructure must be in place to collect and transport the separated materials, and a secondary use must be identified so that the materials have somewhere to go. Workers need to be trained on what material goes where, as well as the levels of acceptable contamination. Often, materials are not easily separated when pieces are glued together or otherwise connected in a way that would add extra labour to pull them apart.

Industry insight

On-site source separation is challenging due to lack of worker awareness, insufficient volumes of generated materials to cover transportation costs and distances to recycling centres. The infrastructure at the recycling facility also affects the uptake if, for example, there is only one weighing station. Each bin would have to be brought in separately, adding to the time and labour required to bring in the recycled materials. The investment in these efforts does not have sufficient return to make it cost-effective for many projects.

Table 1 presents examples of construction waste-management policy levers in Canada to illustrate the range of actions planned or in use. In the absence of standards, each jurisdiction is developing their own approaches and requirements.

3.4 Circular Built Environment Policies in Canada

There have been early efforts to establish frameworks for CBE in Canada generally, but few have addressed buildings in detail. Coordinating the actions of municipalities will ease the transition to a circular economy, particularly as municipalities are often more directly involved with waste management services. Most of the leading-edge activities are taking place in Quebec. Key examples include:

- ***Québec circulaire*** is arguably the most comprehensive effort in Canada to advance circular practices at the provincial level [35]. It is not construction specific, but there are several organizations involved with a strong interest in the built environment. Broad industry and government engagement over several years has resulted in an analytical model and benchmark report. There has also been investment in research and development (R&D).
- The ***Centre for Intersectoral Studies and Research in Circular Economy (CERIEC)*** at the École de technologie supérieure (ÉTS) launched a "living lab" in 2021 that aims to address the obstacles standing in the way of circularity for targeted material flows in the Québec construction sector. The goal is to co-create solutions aimed at integrating and mainstreaming circular economy strategies via a series of pilot projects [36].

Table 1: A selection of construction waste-management policy levers and examples to illustrate the diversity of approaches across Canada

Policy Lever	Example
Waste disposal bans	**Richmond County, Nova Scotia** has imposed a ban on the disposal of treated wood [25]. The most common types of disposal bans across Canada include those on hazardous materials (asbestos, batteries, biomedical waste, antifreeze, flammable materials, pharmaceuticals, mercury-containing thermostats), clean or treated wood, electronics, gypsum and tires.
CRD material handling permits	**Nova Scotia** requires approval to transfer, store and process construction and demolition debris, and bans treated wood waste [26].
Extended producer responsibility (EPR)	**Ontario** plans to transition existing waste diversion programs to a new producer responsibility framework without disruption of services (not construction specific) [27]. **Quebec** has implemented EPR-based regulations designed to modernize the curbside recycling system. While not designed for CRD waste, the regulation is an example of how to impose financial conditions on suppliers of products that create waste to pay for the collection and processing of that waste. The Quebec program targets companies that supply containers, packaging and printed matter [28].

Policy Lever	Example
Salvage and recycling regulations	Each of Metro Vancouver's 22 municipalities have their own set of bylaws and processes that govern construction and demolition activities, including salvage and recycling requirements. The most demanding policies are: The **City of Richmond** Demolition, Moving or Salvage Program is applicable to all single-family homes and requires a minimum recycling requirement of 70% [29]. The **City of Vancouver** requires a demolition permit for all buildings [30]. For houses, it stipulates the following deconstruction and recycling obligations: ▪ Pre-1950 single-family homes – minimum recycling rate of 75% ▪ Single-family homes with character status – minimum recycling rate of 90% ▪ Pre-1910 and heritage listed homes – salvage of three tonnes of wood The **City of Burnaby** and the **City of Surrey** both have minimum diversion rates of 70% for demolition waste [31] [32]. The **District of North Vancouver's** Demolition Waste Reduction Bylaw applies to the removal of single-family homes constructed before 1950 and requires salvaging 3.5 kg (2.6 board feet) of reclaimed lumber per square foot of finished floor space during demolition [33]. The **City of Port Moody** requires that a Waste Management Plan accompany both Building Permit Applications and Demolition Permit Applications [34]. Also, 70% of all recyclable materials generated on-site must be recycled prior to project completion. Since the implementation of this bylaw, demolition projects have achieved an 85% diversion rate, while construction and renovation projects have achieved a 76% diversion rate. Overall, there has been an impressive 84% diversion rate for all CRD waste.

- The ***Québec Circular Economy Research Network (RRECQ)*** is leading the co-creation of a roadmap for the transition to a circular economy in Quebec by 2050. This highly collaborative effort is underpinned by a substantial engagement process that will help to map an ecosystem of players, social economy, information/data, policies/legislation, education/research and entrepreneurship/employment. It will also consider resource management and the tightening or integration of material flows, as well as business models, sectors/value chains, strategies, production/consumption, rebound effect and transition levers/challenges.
- ***Ville de Montréal*** has published a circular economy framework that guides civic action [37]. Although quite high-level and not construction-specific, the framework was developed with broad cross-sector collaboration. The action checklist presents 12 key policy approaches to help governments promote, facilitate and catalyze the development of the circular economy. It also presents a suite of indicators and benchmarks of Montreal's current progress to a circular economy.

Examples of other initiatives that are taking place across the country include:

- The ***Province of Ontario*** released the ***Strategy for a Waste-Free Ontario: Building the Circular Economy in 2017 [27].*** It provides road map for producers to manage the end of life of products. and revises existing programs for waste diversion of materials such as electronics, hazardous waste and tires.
- The ***City of Richmond Circular City Strategy*** has been developed to guide it in achieving a 100% circular economy by 2050 [38]. The strategy seeks to minimize waste and decrease dependence on natural raw materials through reuse and collaboration in ecosystem services, food systems, business resources, transportation, the built environment and consumer materials.

"There is relatively little being done to specifically encourage renovations and retrofits beyond the well-established energy efficiency programs such as EnerGuide"

- The ***Circular Cities and Regions Initiative (CCRI)***, a program developed by the National Zero Waste Council, supports local governments to accelerate circular economy solutions with advisors and a peer-to-peer network [39]. Since launching in 2021, the CCRI has led a national dialogue on circular economy best practices and achieved measurable impact in 25 cities and regions across the country through its Peer-to-Peer (P2P) Network. The participating communities went through an immersive year of knowledge sharing and capacity building, and are now taking the next steps to develop their own circular economies. The next intake for the CCRI P2P Network is expected to happen in 2024.
- The ***Final Report Baselining for a Circular Toronto*** outlined the current state of circularity in the city, along with goals to identify materials in the existing building stock and promote high-value recycling and material recovery [40].
- The ***District of Squamish*** developed a ***Circular Economy Roadmap*** that includes the built environment as a thematic area of exploration [41]. Strategic pillars within that theme include embracing circularity in design; education and awareness; cross-sector collaboration; policy, incentives, procurement, and regulation; and changing the business models, processes, supply chain and technology innovation.

4 Emerging Policies, Voluntary Programs and Market Mechanisms in Canada

Policymakers use a range of levers to introduce standards and practices that are new to the building industry and to support market adoption. To advance the CBE, several jurisdictions have published strategies that frame a regulatory roadmap towards embodied carbon regulations. A few have gone further and are implementing embodied carbon policies that require life-cycle assessment (LCA). Some have also established measures that promote low-carbon materials. Others leverage voluntary programs, offering policies as optional pathways to compliance supported by development incentives (such as allowing more developable floor area, rebates, reduction in fees, etc.) or pilot the policy through "early adopter" communities.

There are standards and guidelines referenced in voluntary green building programs that may find their way into future building codes. However, there is relatively little being done to specifically encourage renovations and retrofits beyond the well-established energy efficiency programs such as EnerGuide [42]. A unique consideration for policies geared towards advancing CBE is the need to consider the entire supply chain and to take a life-cycle approach.

This section identifies emerging government-led initiatives that are supporting the advancement of the circular built environment. Given that policies and regulations alone may not drive building owners to proactively undertake upgrades outside of their desired scope when altering homes or buildings, this section also includes market mechanisms that can help to encourage circular strategies for buildings.

Emerging CBE policies are largely focused on limiting both embodied and operational carbon emissions from buildings. Operational energy efficiency is covered under the National Energy Code and many jurisdictions across Canada have committed to net zero goals. However, governments are starting to require embodied carbon reporting for new buildings. Using LCA and stating a goal of lower embodied carbon, designers can compare the carbon emissions inherent in different design options.

Industry insight

Awareness of embodied carbon emissions can result in renovating or repurposing a building rather than demolishing and rebuilding it. LCA is thus a useful tool for broadening industry understanding of embodied carbon, thereby fostering more circular practices.

4.1 Sustainability Reporting

The Canadian Securities Administrators plans to start requiring environmental, social and governance (ESG) reporting and climate disclosures from large Canadian banks, insurance companies and federally regulated financial institutions in 2024 [43]. While not directly related to the building industry, the financial community is a key influencer of the construction industry and these ESG reporting requirements could be pushed down to borrowers.

ESG reporting requirements are now in effect for publicly traded companies [44]. This will impact institutional property owners such as pension funds and real estate investment trusts (REITs) in particular.

There are several ESG reporting frameworks and standards to evaluate corporate operational performance to help with risk management and as a market differentiator [45].

While CBE is not specifically considered in leading ESG reporting programs yet, some building owners are looking into the whole-life carbon profile of their assets, managing waste generation and recycling rates, tightening supply chains and other environmental considerations. This suggests that ESG reporting may be a potential avenue for integrating CBE principles in the future.

4.2 Embodied-Carbon Policies

Embodied-carbon policies offer a good first step towards CBE. Following the carbon emissions trail through the life cycle of a building can serve as a useful proxy for circularity, at least during the early days of CBE adoption. Indeed, increasingly, designers are finding that an efficient building (e.g., meets operational energy efficiency and carbon emission targets such as net zero and passive house) needs to be built using processes that minimize waste, while maximizing quality and performance.

There are several embodied-carbon policies in development or in the process of implementation. For a full analysis, refer to UBC's Policy Review of Carbon-Focused Life Cycle Assessment [46]. One of its key findings is the need to create a database of project information that can be used to establish policy targets and benchmarks for embodied carbon and other environmental impacts. Recent research also explores how LCA can be useful for evaluating the carbon benefits of existing buildings [47].

Industry insight

Embodied carbon is easier to understand than circularity and can serve as a proxy for CBE in procurement policies. So long as there are embodied carbon limits imposed, effort will be made to minimize the environmental impacts of materials.

4.2.1 City of Vancouver Green Building Policy

The City of Vancouver is the first jurisdiction in North America to incorporate embodied carbon requirements into regulations. The goal was to reduce carbon emissions from materials and construction by 2025 and achieve a 40% reduction by 2030.

As of October 2023, the Vancouver Building By-Law (VBBL) sets embodied-carbon emissions reduction minimums of 10% for all new Part 3 buildings[1], and 20% for new low-rise buildings that can build with wood or mass timber [48]. It requires developers to either 1) demonstrate that they have sustainably sourced wood, concrete or steel; 2) disclose the chemical ingredients of building products; or 3) achieve 75% construction waste diversion [49]. An accompanying Embodied Carbon Strategy report promotes the idea that when buildings are scheduled to be replaced, they can be disassembled in a way that allows their materials to be used again in new buildings that are carbon positive and seismically resilient [66].

4.2.2 City of Toronto Green Standard

The Toronto Green Standard (TGS) represents Toronto's sustainable design and performance requirements for new private and city-owned developments [50]. TGS Version 4 limits GHG emissions from newly constructed buildings and requires City-owned buildings to be net zero. New City-owned buildings must also limit upfront embodied-emission intensity for major structural and envelope systems to below 350 kg CO_2e/m^2. This requirement is now a Tier 2 (optional) requirement in the TGS v4 for buildings that are not owned by the City. Future versions of the TGS may include performance requirements for embodied emissions in building materials such as concrete, steel and insulation in small and large buildings [51].

4.3 Low-Carbon Materials Policies

Policies that promote the use of low-carbon materials contribute to CBE not only by imposing fewer climate impacts, but also by encouraging the use of salvaged or reclaimed materials. Policies that steer project teams towards, or away from, certain materials are becoming more common in Canada. These policies have economic roots in promoting local materials, but also contribute toward achieving low-carbon goals. Some procurement policies are starting to include requirements about clean, healthy, low-carbon materials.

4.3.1 Wood First Policies

Wood harvested from forests that are managed sustainably is considered a low-carbon structural material because forests sequester carbon. Also, wood product manufacturing processes are less energy-intensive than for cement or steel production. Compared to other options, wood can be a light, adaptable and malleable material that can lend itself to easy salvage and reuse. Indeed, the first companies in Canada to offer deconstruction and reclamation services focus on wood products [52].

Wood First policies are in effect in several provinces, and policies directed towards other materials are now emerging. BC and Quebec were the first to implement a Wood First policy in 2009, with Ontario following in 2012. While the Quebec Wood Charter is generally more focused on promoting the use of wood through investments in non-residential projects, training and R&D, the Ontario Wood First Act was geared towards amending the Ontario Building Code to allow six-storey wood-frame buildings [53] [54]. However, the BC Wood First Act went further [55]. It not only raised the permissible height of wood frame buildings, but it also requires provincially funded projects to use wood as the primary construction material. BC recently expanded its prioritization of timber with the launch of the Mass Timber Action Plan in 2023 [56].

Wood First policies generally require project teams to consider wood as the priority material for publicly funded projects. Inevitably, not every project can use wood due to regulatory or functional constraints. In these cases, a report is submitted demonstrating how wood was considered, but not feasible. Under a hypothetical Renovation First policy, a similar decision-making process could be applied to encourage project teams to consider renovations where an existing building is threatened with demolition.

1 Part 3 buildings include everything except homes and small structures, which are covered under Part 9. For more information, see Section 3.2.1.

4.3.2 City of Langford Low-Carbon Concrete Policy

Langford, BC is the first jurisdiction in Canada to adopt a low-carbon concrete policy, with a view to accelerating the deployment of technologies to decarbonize the built environment [57]. All concrete supplied to municipal projects, and all other projects greater than $50m^3$, must be produced using post-industrial carbon mineralization technologies, or an equivalent that offers concrete with lower embodied carbon.

4.4 Green Procurement Policies

Public and private sector organizations can use their purchasing power to procure goods, services and works with a reduced environmental impact. While low-carbon material policies can be referenced in procurement requirements, there are also opportunities for owners to specify performance goals or actions such as benchmarking and reporting. An example of this is conducting a whole building LCA or creating a building materials inventory.

4.4.1 Federal Policy on Green Procurement

Nationally, the Policy on Green Procurement references the Standard on Embodied Carbon in Construction, which requires the disclosure and reduction of the embodied carbon footprint of structural materials used in major federal construction projects [2] [58] [59]. This standard only addresses structural materials (i.e., wood, concrete and steel) and sets minimum requirements for how project teams must disclose and reduce the embodied carbon of major construction projects. All new major federal projects must also conduct a climate change risk assessment that incorporates both current and future climate conditions. Designing for climate resilience is an important consideration in the context of CBE, as it supports the development of durable buildings that can better withstand extreme weather events.

4.4.2 Civic Green Procurement Programs

At the municipal level, several large cities, such as Montreal, QC, and smaller communities such as the city of Richmond, BC and the Village of Cumberland, BC, have adopted green public procurement programs. Notably, the City of Toronto is working toward an aspirational goal of making Toronto the first municipality in Ontario with a circular economy and is working on a series of circular procurement pilots [60].

4.5 Deconstruction Policies

While waste disposal policies have been in place for some time, deconstruction is an emerging concept. Deconstruction policies are important levers in advancing CBE because they encourage builders to dismantle structures with the goal of maximizing reuse and recycling the constituent materials rather than demolition [61].

4.5.1 City of Vancouver Voluntary Advanced Deconstruction Permit

Deconstruction permits can be obtained from the City of Vancouver for one- and two-family homes to provide incentives to take the time required for deconstruction. Previous bylaws required demolition and building permits to be issued simultaneously. With the Voluntary Advanced Deconstruction Permit, applicants commit to completing a compliance report detailing diversion rates for reuse, recycling or recovery of 75% of non-hazardous materials and providing receipts from receiving facilities [62]. The incentives are a 50% discount on disposal of residuals from deconstruction at the Vancouver Landfill and early release of the deconstruction permit, providing a two-week scheduling advantage.

4.6 Voluntary Programs and Tools

Voluntary programs serve as important pathways for new policies and standards to gain market acceptance and adoption. There are several programs, community initiatives and voluntary schemes that are designed to catalyze a circular economy for the built environment.

2 Up until December 31, 2024, major projects are defined as valued over $10 million. After that date, the limit drops to any project worth over $5 million.

"In practice, NMCS and other specifications play an important role in defining how building components, elements and systems are sourced, built, installed, commissioned, operated and treated at end of service."

4.6.1 National Master Construction Specification

Although architects, engineers and builders are not required to use National Master Construction Specification (NMCS), it is a key reference document that contains over 100 design master specifications. It also contains 750 construction master specifications, affecting every aspect of a construction project from project definition and procurement to construction and commissioning [63]. How specifications fit within the framework of construction documentation for a project is described in Appendix E of the Royal Architectural Institute of Canada Handbook of Practice for Architects [64]. Currently, the Government of Canada is using it as a tool to advance the goals of its Policy on Green Procurement, using measurable performance targets and prescriptive procedures.

The NMCS references many commonly used standards in Canada to provide detailed information about the required performance, means and methods. In practice, NMCS and other specifications play an important role in defining how building components, elements and systems are sourced, built, installed, commissioned, operated and treated at end of service. Specifications therefore can have significant impacts on a project's outcomes. However, there is no standard language in the NMCS that relates to deconstruction, disassembly, salvaged materials and how to incorporate them into new projects, or circular strategies. There have been efforts to create model specifications for deconstruction and disassembly of existing buildings that can be incorporated into the NMCS format. A few examples are listed below:

- Province of Manitoba: Model Specifications for Dismantling and Salvage of Existing Structures [65]
- King County, Washington, US: Design specifications and waste management plans for Construction Waste Management [66] and Building Deconstruction and Salvage [67]
- Building Material Reuse Association (BMRA), US: Model Guide Specification for Deconstruction of Buildings [68]

4.6.2 Green Building Rating Systems

Green building rating systems and other voluntary programs act as catalysts to prime the market. Some, like LEED and BOMA BEST, are more commonly used than others. They are frequently leveraged by municipal governments as a way to demonstrate compliance with local policies.

4.6.2.1 LEED

The LEED Green Building Rating System is the leading holistic green building rating system in Canada and globally. It includes criteria for sustainable sites, energy and climate, water efficiency, materials and occupant health. It offers programs specifically for new construction and major renovations, houses, interior design and fit-outs, and for operations and maintenance. It references voluntary standards and guidelines that could become standards over time [17]. For example, LEED has included credits for LCA for some time, which promoted adoption and gave the City of Vancouver, and others, the confidence to move forward with LCA regulations.

LEED offers a credit for incorporating strategies to increase the useful life of a project or the spaces therein. It encourages designers to enhance the flexibility of spaces, increase the potential for adaptive use, and make it easy to salvage and recycle building materials over the building's service life. To achieve the credit, at least 50%, by cost, of non-structural materials must be tagged using radio frequency identification or other permanent labels that describe the material's origin, properties and date of manufacture, in compliance with CSA Z782-06, *Guideline for Design for Disassembly and Adaptability in Buildings*.

Industry insight

"The challenge with LEED is that designers pursuing LEED can choose from a list of several credits to gain enough to achieve the rating, so there is no guarantee that the measures relating to circularity will be pursued."

4.6.2.2 BOMA BEST

The Building Owners and Managers Association (BOMA) BEST suite of holistic sustainability certification programs and building management tools promote energy efficiency, occupant health, and low-carbon performance in existing commercial and multi-family buildings [69]. This program helps owners to keep their properties economically viable and thus extend their service lives as long as possible.

4.6.2.3 Living Building Challenge

The Living Building Challenge is an extremely challenging holistic green building program [70]. Its 10 core imperatives include requirements for embodied carbon, use of responsible materials and net positive waste. Of relevance to CBE, projects must demonstrate a 20% reduction in the embodied carbon of primary materials compared to an equivalent baseline. Retained materials in existing building projects can be counted against the required 20%. Credit is also given for projects that divert 80% of construction waste from landfill, plan for adaptive reuse, deconstruction and durability, and prepare a Materials Conservation Management Plan that demonstrates how material usage is optimized over the building's life cycle.

4.6.2.4 CAGBC Zero Carbon Building Standards

The Canada Green Building Council (CAGBC) has developed zero-carbon certification standards for both new buildings and retrofits that consider the embodied carbon impacts of new structural or envelope materials and refrigerants [71].

4.6.2.5 TRUE

TRUE is a certification program for zero-waste performance available through the Canada Green Building Council [72]. It offers a whole-system approach aimed at changing how materials move through the construction value chain. TRUE encourages the redesign of material life cycles so that all products can be reused.

4.6.2.6 Zero Waste Construction Canada

Formal validation of zero waste efforts in Canadian construction projects can be achieved through certification provided by Zero Waste Construction Canada [73]. The program is designed to help project teams identify and realize opportunities to avoid waste and manage materials during design, construction and at the end of a building's life.

4.7 Market Mechanisms

Extensive changes to existing patterns of production and consumption are needed to bring CBE to the mainstream. Regulations alone may not be sufficient to shift to CBE without adversely affecting Canada's real estate and construction economies. Market mechanisms can help to minimize or reallocate costs and drive the necessary changes in behaviour that will result in new products, practices and markets. These mechanisms may include:

- novel forms of leasing and "product as a service"
- networks, marketplaces and collaborative platforms
- financial incentives such as subsidies, fees and taxes

4.7.1 Innovative Leasing and Product as a Service

Sustainability-minded building owners, landlords and tenants can drive change in the market through innovative leasing models such as green leases, asset leasing, and "on-demand" space [74]. Green leases, such as the REALPAC National Standard Lease (2021) template for single office building projects, consider the trajectory towards zero-carbon operations and climate resiliency, and include sustainability measures such as energy efficiency and waste management [75]. As yet, there has been little standardization for short, flexible leasing structures that support CBE.

"Product as a service" (PaaS) schemes, which include supply, maintenance and replacement services, remove the upfront capital cost to customers, while helping them acquire higher quality, more durable products.

PaaS schemes tend to establish long-term relationships between the customer and the supplier. This is because these products are expected to have longer life cycles, come with reconditioning options and employ waste minimization strategies. Anything can be supplied in the form of PaaS, including IT equipment [76], solar panels [77] and elevators [78]. In each case, suppliers are expected to care for the product and keep it operating at its highest level of efficiency for the duration of the relationship. When the customer no longer needs the product, the supplier takes it back, refurbishes it or replaces it. In Canada, PaaS is a largely unregulated field. Options are offered on an ad hoc basis and each supplier operates on different terms.

4.7.2 Networks, Marketplaces and Collaborative Platforms

The market rationale for a transition to a circular economy in the built environment is becoming increasingly compelling. Rising climate costs, the price of carbon, resource scarcity, labour shortages, and demand for housing and infrastructure are just a few examples. However, advancing a CBE depends on the development of markets for used elements, products and materials. There are several organizations in Canada with online marketplaces where used construction resources can be traded. These markets are foundational to the success of a circular construction economy, but those that exist operate at a small scale and without standardization of products and services.

4.7.2.1 Habitat for Humanity ReStores

Habitat for Humanity operates ReStores across Canada, which receive and sell used building materials [79]. The City of Vancouver set up the Rebuild Hub deconstruction and salvage network as a virtual platform to re-sell used building materials, with all proceeds going towards Habitat for Humanity's affordable housing projects [80].

4.7.2.2 Ontario Materials Marketplace

The Ontario Materials Marketplace provides an online centre to buy and sell materials locally. Users identify what they have available and what they need, with the technology platform providing a connection to alert them to recommended opportunities [81].

4.7.2.3 Hyon

Hyon is an asset management software company in Saskatchewan that provides an online marketplace for used goods such as office equipment [82]. The technology provides a platform for companies to calculate the financial and environmental impact of engaging in the secondary goods marketplace.

4.7.3 Financial Incentives

Financing mechanisms can help owners overcome real (or perceived) costs to adopting circular practices. In addition to the capital costs for "circular" materials and processes, there may be additional planning, detailed modelling, research and analysis needed for the first few projects, as well as education and training.

4.7.3.1 Gas Tax Fund

The federal Gas Tax Fund (GTF) is administered through the Federation of Canadian Municipalities (FCM) and provides long-term funding to local governments to build and upgrade civic buildings and infrastructure [83]. All projects require an asset management plan to receive funding. FCM also manages the $110-million Municipal Asset Management Program (MAMP), which can partly pay for building improvements [84]. These programs do not specifically refer to circularity as a priority, but they are heavily focused on reduction of carbon emissions and climate resiliency. To date, funded projects are in line with the ISO 55000 Asset Management guidelines [85].

4.7.3.2 Toronto Green Standard Refunds

The City of Toronto refunds development charges of non-city-owned projects that volunteer to pursue Tier 1 of the voluntary Toronto Green Standard [86]. A partial refund for Tiers 2 to 4 was increased in 2022 to accelerate adoption of the standard.

4.7.3.3 Township of Douro-Dummer Embodied Carbon Incentives

The township of Douro-Dummer in Ontario offers permit applicants the opportunity to apply for a block grant of $10,000 per house through the City Policy Framework for Dramatically Reducing Embodied Carbon for projects whose embodied carbon emissions are below a fixed target [87]. The objective is to reward builders for meeting an embodied carbon limit of 75 $kgCO_2e/m^2$.

4.7.3.4 Downtown Calgary Development Incentive

The Downtown Calgary Development Incentive Program was set up by the City of Calgary to offer owners of downtown office buildings $75/square foot, up to a maximum of $10 million per property, to convert to residential buildings [88]. The funding mandate has now been fulfilled and the City of Calgary is evaluating its impact.

5 CBE Standards in Canada

There are many hundreds of standards referenced in building codes and specifications, and many more in voluntary programs. A total of 54 standards were identified for their potential to incorporate CBE considerations, of which 16 are in common use by building industry practitioners and regulators because they are referenced in building codes (Table 2).

There is a relatively large number of standards in development, or that serve as guidelines or are referenced in emerging policies and voluntary programs (Table 3). Several are international standards that support circularity in the built environment where there is currently no Canadian counterpart.

Table 2: Standards in common use in Canada that could incorporate CBE

ASHRAE 90.1-2022, Energy standard for sites and buildings except low-rise residential buildings
CSA O86:19, Engineering design in wood
CSA S16:19, Design of steel structures
CSA A23.3:19, Design of concrete structures
CSA Z240 MH Series-16, Manufactured homes
CSA S269.1 (2016), Falsework and formwork
CSA S304-14 Design of masonry structures
CSA A440:22, North American fenestration standard/Specifications for windows, doors and skylights

CSA A277-16, Procedure for certification of prefabricated buildings, modules, and panels
CSA A660-10 (R2019), Certification of manufacturers of steel building systems
C22.2 NO. 236-15, Heating and cooling equipment (Bi-national standard with UL 1995)
CSA SPE-17:22, HVAC guide for part 9 homes
CSA-F326-M91, Residential mechanical ventilation systems
CSA C873 SERIES:15 (R2020), Building energy estimation methodology
CSA Z252-21, Process for delivery of volumetric modular buildings
CSA Z5001-2020, Existing building commissioning for energy using systems

Table 3: Standards in development or in limited use in Canada that could incorporate CBE

ANSI/ASHRAE Standard 228, Standard method of evaluating zero net energy and zero net carbon building performance
ASHRAE 189.1: International green construction code
ASTM WK62996 Guide for property resilience assessment
BES 6001, Responsible sourcing of construction products
BS EN 15978-1 Sustainability of construction works - Methodology for the assessment of performance of buildings.
BS EN ISO 19650, Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling.
CSA S478:19, Durability in buildings
CSA Z762-95 (R2016), Design for the environment (DFE)
CSA Z782-06, Guideline for design for disassembly and adaptability in buildings
CSA Z783-12 – Deconstruction of buildings and their related parts
CAN/CSA-ISO 14025:07 Environmental labels and declarations — Type III environmental declarations — Principles and procedures
CAN/CSA-ISO 14040:06 (R2021), Environmental management - Life cycle assessment - Principles and framework
CAN/CSA-ISO 14044:06 (R2021), Environmental management - Life cycle assessment - Requirements and guidelines

EPA Framework for the assessment of environmental performance standards and ecolabels for federal purchasing
IEC 63092, Photovoltaics in buildings
ISO 10845, Construction procurement
ISO 14090:2019, Adaptation to climate change — Principles, requirements and guidelines
ISO 15392:2019, Sustainability in buildings and civil engineering works — General principles
ISO 15686 series, Buildings and constructed assets — Service life planning
ISO 16745-1/2:2017 Sustainability in buildings and civil engineering works — Carbon metric of an existing building during use stage — Part 1: Calculation, reporting and communication
ISO 20887:2020, Sustainability in buildings and civil engineering works – Design for disassembly and adaptability – Principles, requirements and guidance
ISO 21929-1:2011 Sustainability in building construction — Sustainability indicators — Part 1: Framework for the development of indicators and a core set of indicators for buildings.
ISO 21930:2017, Sustainability in buildings and civil engineering works – Core rules for environmental product declarations of construction products and services
ISO 21931-1:2022 Sustainability in buildings and civil engineering works — Framework for methods of assessment of the environmental, social and economic performance of construction works as a basis for sustainability assessment — Part 1: Buildings
ISO 22057:2022, Sustainability in buildings and civil engineering works – Data templates for the use of environmental product declarations (EPDs) for construction products in building information modelling (BIM)
ISO 50001:2018, Energy management
ISO 55000:2014, Asset management — Overview, principles and terminology
ISO/CD 59004 Circular economy — Terminology, principles and guidance for implementation
ISO/CD 59010 Circular economy — Guidance on the transition of business models and value networks
ISO/CD 59014 Secondary materials — Principles, sustainability and traceability requirements
ISO/WD 59020 Circular economy — Measuring circularity framework
ISO/CD 59040 Circular economy — Product circularity data sheet
ISO/TC 323 Circular Economy

PAS 2080:2016, Carbon management in infrastructure
SPE-890-15 A Guideline for accountable management of end-of-life materials
Zero carbon building standards

Figure 3 provides graphical representation of how the standards that are in common use (dark blue) and those that are in development or in limited use (light blue) relate to the building life cycle. It shows how efforts to develop standards have focused on materials manufacture and construction processes, with relatively few that address end of life and material salvage and reprocessing.

6 Other Activities Supporting Circularity in Canada

The CBE landscape is evolving rapidly and there are a number of initiatives in development or underway that play an important role in advancing CBE in Canada. While a survey of all the academic research related to CBE in Canada is outside the scope of this report, it is important to highlight the NRC's recently launched decarbonization platform, which could be a powerful enabler of change. NRC has received a $180 million investment over the next seven years to harmonize and modernize building codes, and address knowledge and data gaps in the development and specification of low-carbon materials, products, services and practices. It will also be used to develop solutions that increase construction sector productivity through digitalization [89]. This major program of work has a significant bearing on advancing CBE with research focusing on embodied carbon and LCA, advanced construction methods such as prefabrication and robotics. NRC also offers design support to industry partners to help embed new technologies and approaches into common practice. This section also presents other emerging education and training programs to build capacity and facilitate CBE practices in Canada.

6.1 Life Cycle Assessments

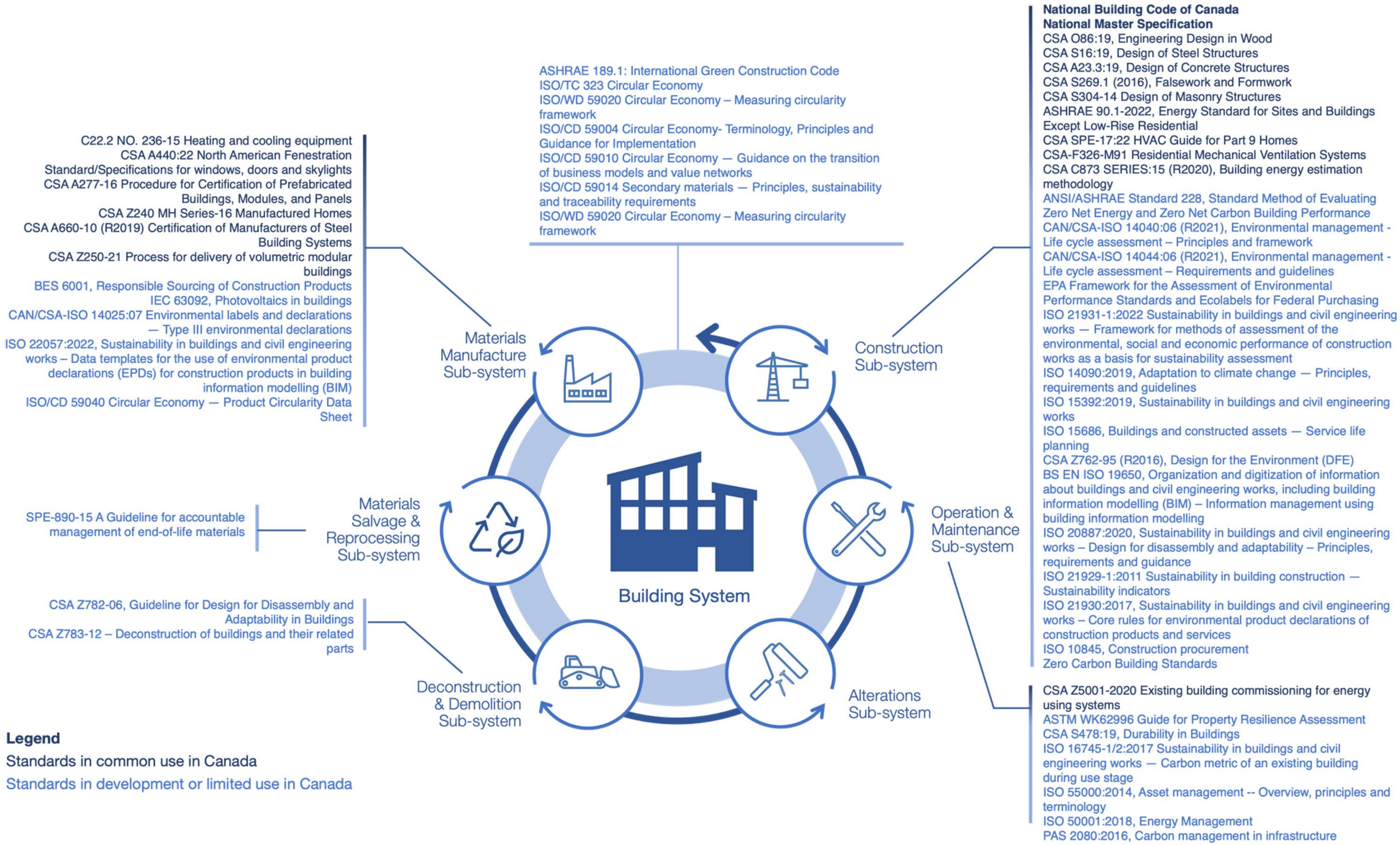
Life cycle assessments (LCA) are often produced in the design stage of a project to determine the carbon impact of constructing a new building. The use of LCA is growing quickly to support the roll-out of embodied carbon policies and there is a good deal of work currently underway at the federal level to advance its use. Led by NRC, these efforts include:

- National LCA guidelines for infrastructure [90] and whole-building LCA [91], which are building on the City of Vancouver's Embodied Carbon Guidelines
- Low-carbon assets through life cycle assessment initiative (LCA2), a national initiative that convenes industry leaders across Canada. In addition to supporting low-carbon procurement, a major accomplishment has been the creation of a centralized repository for Canadian life cycle inventory (LCI) datasets of primary construction materials [92].

For most projects, the motivation to conduct an LCA is to meet regulatory requirements. However, because the process is completed prior to construction, this offers the opportunity for the project team to investigate reuse, renovation or repurposing a building instead of demolition.

Tools to conduct LCAs do not currently use consistent material databases, resulting in varied results depending on the software platform. Data quality and integrity could be improved if the calculation of embodied carbon was uniform. A current lack of clear definitions and metrics for CBE mean that building owners and governments use embodied carbon and LCA to support policy and procurement goals. LCAs provide a somewhat more familiar concept that is supported by quantifiable measures.

Figure 3: Infographic of the standards that may be applicable to supporting CBE organized by building system and sub-system in focus, both in common use and in development / limited use in Canada



"Education and training providers across the country are adding circularity topics to existing courses and, in some cases, creating new training specifically focused on CBE."

Industry insight

"We want to be performance-based, allowing the designers and architects their full creative license to decide how to use lower embodied carbon."

"Making them look at what they're using has an impact. They think about it, and then use less. We're not being prescriptive in what the project has to do – any element they choose to reduce embodied carbon has a component of circular economy."

6.2 Education and Training

CBE is at an early stage of adoption and capacity building is needed for those involved in the construction supply chain. Education and training providers across the country are adding circularity topics to existing courses and, in some cases, creating new training specifically focused on CBE. Some examples include the following.

For industry practitioners:

- **British Columbia Institute of Technology (BCIT)** offers a nine-credit micro-credential in Applied Circular Economy, Zero Waste Buildings. There are courses on Deconstruction Management, Design for Disassembly, and Construction Material Flows [93].
- ***École de Technologie Supérieure in Montreal*** provides a summer school course to instruct participants in methods for applying circular economy strategies for a territory, organization or sector, or in the context of developing a new product or service [94].
- **North Island College in BC** offers a Building Deconstruction and Salvage course that includes practical training for deconstruction and material recovery [95].

For the business community:

- **Ivey Business School** recently began offering a Circular Leadership Program that focuses on developing circular business innovations that are technically feasible, economically viable and ecologically impactful. This program is not specific to the built environment but is part of a growing conversation on circularity [96].
- **BCIT** offers an introductory course on the circular economy in general, and an Advanced Certificate in Sustainable Business, which includes a course on the circular economy that requires development of a circular business strategy [97].

For suppliers:

- **The Cement Association of Canada** discusses sustainable construction on its website and points out its durability, adaptability, reusability and recyclability. The association educates members on low-carbon cement and supplementary materials, admixtures and capturing carbon dioxide. It aims to increase awareness and adoption of methods to make cement and concrete more sustainable [98].

Industry insight

"There is really at this stage, still very low understanding of what circular buildings are really about. When we talk about circular buildings, we are very much concerned with how we use resources effectively and, of course, carbon is related to that discussion."

7 International Best Practice Policies, Codes and Programs

The UN Sustainable Development Goals of Sustainable Cities and Communities (#11) and Responsible Consumption and Production (#12) prioritize durability, extended use, waste diversion and recycling of goods and materials [99]. Countries around the world, most notably in Europe, are looking to circular practices to grow their economies, manage resources, increase employment, and build a more sustainable future, and are incorporating these methods into construction standards.

There are many barriers to the adoption of these strategies. A lack of awareness and hesitance to adopt circular processes result from the lack of regulations, fragmented supply chains and high upfront investment costs [100] [101]. While government strategies have been developed, specific regulations and standards have not been broadly implemented. Low prices for virgin materials and labour shortages diminish or negate the value proposition for circularity in some areas.

This section presents a brief review of key initiatives that represent leading CBE practices around the world. Additional examples are provided in Appendix A.

7.1 Global Frameworks

7.1.1 Circular Built Environment Playbook

The World Green Building Council published a CBE Playbook Report in May 2023 that explains why moving to a circular built environment is important, and provides definitions that must become standardized globally for countries to work toward this common interest [102]. The playbook looks at the various stages of the built environment, from resource extraction, through design, construction, operation, retrofit, deconstruction, reuse and recycling. It also takes a look at the roles of government, business and citizens in enabling the changes necessary for a CBE transition.

7.1.2 Circularity Gap Reports

Circle Economy has published reports on the global circularity gap since 2018 [103] [104]. Its most recent report indicates that rising material extraction has reduced the rate that materials are recirculating in the global supply chains from 9.1% in 2018 to 7.2% in 2023. In other words, the proportion of waste materials that are being sent to landfills is going up. The built environment is one of four systems identified as key to reversing this decline. A framework was developed with three core elements that reference physical flows and document the enabling elements that can encourage a circular transition [105].

7.1.3 A Framework for Circular Buildings - Indicators for Possible Inclusion into BREEAM[3]

The BREEAM New Construction and BREEAM Refurbishment and Fit-Out are UK-based international green building rating systems used in over 74 countries [106]. The definitions used in these frameworks are aligned with the transition agenda for circular construction in The Netherlands [107]. The frameworks consider the performance characteristics of a building at its completion and are designed to capture actions taken during the design and construction phases.

7.1.4 Platform for Accelerating a Circular Economy (PACE)

PACE is a public-private collaboration platform for global leaders and their organizations created by the World Economic Forum in 2018 to accelerate the transition to a circular economy [108]. PACE provides metrics for governments and businesses, along with guidance for setting appropriate targets. The analysis

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determined that the three most impactful potential actions to reduce emissions for material use in buildings are to reduce the amount of floor area per person (in higher income populations), promote material efficient design, and improve recycling rates and technologies for construction materials [109].

7.1.5 UN Circularity Concepts in Wood Construction

The UN Economic Commission for Europe's Committee on Forests and the Forest Industry has developed a model based on the Ellen MacArthur Foundation's circular economy (CE) "butterfly" diagram. This model shows the life cycle of products coming from working forests and flowing to construction uses, through cascading value retention processes in the technical cycle until the end of their built life, and then into the biological cycle at the end of its useful life as part of energy recovery [110] [111].

The model takes a more inclusive view on a circular economy compared to other approaches and considers the energy recovery and the carbon absorption by forests. This is relevant for circularity in the forest sector, because wood materials can be subject to cascading use, with bioenergy at the end of life and the emissions coming back to forests to initiate a new cycle. This report raises the question of where system boundaries should be established to best capture the impacts and benefits of specific construction materials.

7.1.6 Sendai Framework

The Sendai Framework for Disaster Risk Reduction 2015–2030, to which Canada is a signatory, outlines targets and priorities for action to prevent new, and reduce existing, disaster risks [112]. The framework is an important tool for defining and investing in durability and resilience strategies in buildings and infrastructure [112]. This could be extended to consider the durability and circularity of buildings and their constituent parts to enhance disaster preparedness for effective response, and to "Build Back Better" in recovery, rehabilitation and reconstruction.

7.2 European Frameworks and Initiatives

The European Union (EU) has been leading the transition to a circular economy over many years. The overarching frameworks, strategies, policies, incentive programs, collaborative networks, marketplaces, software tools and technical support presented below are leading examples of the wide range of initiatives currently underway. Many member states are aligning their domestic and local actions with these measures.

7.2.1 Circular Cities Declaration

The Circular Cities Declaration is a commitment to transition to the circular economy from over 70 local and regional administrations around Europe [113]. The declaration provides a centre for collaboration to share experiences, challenges and successes, and emphasize the role that local and regional governments play in creating a circular economy.

7.2.2 European Green Deal and New European Bauhaus

The European Green Deal contributes to the new growth strategy for Europe [114]. With a focus on renovation, energy performance, material recovery and waste diversion, renewable energy, and protocols for quality assurance of secondary products, it encompasses a wide range of activities to combat linear consumption. The New European Bauhaus works with the European Green Deal, where innovative projects are shared to build awareness about the value of material reuse and sustainable design [115] [116] [117].

7.2.3 Circular Investment Readiness Network

The Circular Investment Readiness Network has been set up to help circular economy projects in the European Union overcome challenges in securing investment [118]. The scheme offers project teams the opportunity to collaborate with thought leaders, industry experts, companies and change-makers across Europe and Horizon Europe-associated countries.

7.2.4 New Circular Economy Action Plan

The New Circular Economy Action Plan sets out a strategy for a sustainable built environment, updates to the Construction Product Regulation, and a suite of revised material recovery targets all within EU legislation for construction and demolition waste [119] [120]. Actions identified in the plan include addressing the sustainability performance of construction, including the potential introduction of recycled content requirements for certain construction products, promoting measures to enhance the durability and adaptability of buildings in line with the circular economy principles, and developing digital logbooks for buildings. The plan introduces the concept of “levels” to:

- Integrate life cycle assessment into public procurement and the EU sustainable finance framework,
- Explore the appropriateness of setting carbon reduction targets and the potential for carbon storage [121], and
- Promote initiatives to reduce soil sealing, rehabilitate abandoned or contaminated brownfields and increase the safe, sustainable and circular use of excavated soils.

7.2.5 EU Environmental Product Declaration Standards

European standards EN 15804 and EN 15978 address the sustainability of construction products and materials, and the assessment of environmental performance of a completed building, respectively. Standard EN 15804 aims to make the information on EPDs consistent and comparable by harmonizing the format. It requires reporting on material extraction and manufacturing life cycle stages. Standard EN 15978 applies to all life cycle stages and specifies the methodology and other environmental information used to conduct an LCA. These standards work together to ensure LCAs are conducted in a transparent and uniform manner. Challenges still exist, however, due to a lack of data, data uncertainty, multiple product category rules, data format of EPDs, and varying methodologies for performing LCAs [122].

7.2.6 EU Construction Product Regulation

The EU Construction Product Regulation defines the technical performance for marketing and labelling construction products [120]. The CE Mark allows a manufacturer to self-declare compliance with the conditions set out within the Regulation. Basic Requirement No. 7, Sustainable use of natural resources, states that projects must be designed, built and demolished in a sustainable way, ensure material and building reuse or recyclability after demolition, support project durability and use environmentally sustainable materials.

Two further important provisions are set out in the Regulation:

- Item (25) says that the performance declaration should include information on the content of hazardous substances in the product. However, there is no current agreement on the testing methods for many of these substances. The Regulation does, however, establish basic compliance with the substances listed under the Registration, Evaluation, Authorisation and Restriction of Chemicals [120].
- Item (56) stipulates that EPDs should be used when there is an assessment of the sustainable use of resources, as well as the impact of construction work on the environment [120].

As part of the declaration of performance when applying for a CE mark, manufacturers must submit evidence of the sustainable use of natural resources, low environmental impact and energy efficiency from a life cycle perspective. Standards are not available for all construction products.

7.2.7 EU Building Value: Pathway to Circular Construction Finance

The Building Value Pathway is a European Commission initiative that is oriented towards construction financing and provides tools to unlock the potential of circular construction business models [123]. The research shows that circular construction increases the residual value of elements, products and materials. It therefore makes more sense to look at the value of building layers, instead of the value of a whole building [135].

> "City Loops is an EU-funded scheme that coordinates the actions of seven small- to medium-size cities to become more circular."

7.2.8 CityLoops

City Loops is an EU-funded scheme that coordinates the actions of seven small- to medium-size cities to become more circular. They are Apeldoorn (The Netherlands), Bodø (Norway), Høje-Taastrup (Denmark), Mikkeli (Finland), Porto (Portugal), Roskilde (Denmark) and Seville (Spain) [124].

The program supports investments in developing and testing a series of processes and tools to tackle biowaste and construction and demolition waste. Circular procurement is incorporated into the City Loops program through a questionnaire that invites buyers to rethink development options. The City Loops Handbook provides a comprehensive guide for local and regional governments on promoting circular construction [125].

The City of Bodø in Norway is engaging with City Loops as a demonstration of circularity in the relocation of an airport and construction of a new part of the city. The demolition is using technology to identify materials for reuse or recycling potential, creating a materials passport and marketplace. Interested parties are involved in the vision for future development, as well as to share sustainability information. Construction of the new airport and city is planned to similarly incorporate technology to highlight circular practices and engage the community. Project development assistance is available for circular economy projects from DEFINITE-CCRI and Circular Invest [126] [127]. Selected projects receive tailor-made services free of charge to become investment-ready and increase their chances for success.

7.2.9 EU Big Buyers for Climate and Environment

The Big Buyers initiative brings together local and regional governments, central purchasing bodies and other public agencies across the EU to maximize public market power and orient the demand for targeted innovative and sustainable products and services [128]. One of the working groups, for example, cooperates on zero-emission construction sites to aggregate demand and accelerate the transition, which will enable infrastructure that can result in lower prices. Twenty public administrations participate, with a combined procurement value of €14 billion annually.

7.2.10 European Union Framework for Digital Building Logbooks

The European Union Framework for Digital Building Logbooks is not an established standard but may be an important precursor. Given that building-related data (e.g., physical characteristics, environmental performance information and real estate transactions) continue to be scarce or unreliable in terms of quality, this framework represents the EU's first attempt to define and standardize the concept of a digital logbook as a common repository for all relevant building data. The objective is to facilitate transparency, trust, informed decision-making and information sharing within the construction sector and among building owners and occupants, financial institutions and public authorities [129].

7.2.11 Materials and Product Passports

A digital product passport is an expandable digital framework to share product data more effectively. There is a growing number of passport developers, management sites and exchanges, though they are predominately in Europe. Example passports include:

- Building Circularity Passport®, EPEA / Drees & Sommer ((DE/NL)
- City Loops H2020 project (DK, ES, FI, NL, NO, PT)
- Madaster: The cadastre of material (NL)
- Opalis (FR, BE, NL)
- ToxNot (USA)
- Salvoweb (UK)
- BAMB 2020 (EU)
- Re-sign app (IT)
- restado (AT, CH, DE)
- Concular (AT, CH, DE)
- DECORUM: DEmolition and COnstruction Recycling Unified Management (IT)

7.2.12 EU Green Public Procurement Criteria for Office Buildings

Green Public Procurement (GPP) is a voluntary instrument for the design, construction and operation of office buildings. A web-based tool (CIRCABC) allows groups to collaborate across large distances. The website provides information and details on the reasons for selecting GPP criteria for office buildings, along with guidance on how to effectively integrate these criteria into the procurement process [130]. Criteria categories include selection criteria, technical specifications, award criteria and contract performance. For each set of criteria, there is a choice between these two ambition levels.

1. Core criteria allow for easy application of GPP, focusing on the key area(s) of environmental performance and keeping administrative costs to a minimum.
2. Comprehensive criteria consider higher levels of environmental performance for those who want to go further in supporting environmental and innovation goals.

7.2.13 Reversible Building Checklist

Buildings As Material Banks (BAMB) in the EU has developed a checklist that serves as a qualitative support tool for reversible building design and can be used from design through the remaining phases of the project [131] [132]. It addresses "spatial reversibility," which aims to extend the life of the building by facilitating changes in future use and function, and "technical reversibility," which aims to dismantle and reuse elements, components and materials.

7.2.14 EU Construction and Demolition Waste Protocol

The EU Construction and Demolition Waste (CDW) Protocol addresses some barriers to the recycling and reuse of construction waste, such as the quality assurance of secondary products, by encompassing objectives [133] such as improved waste identification, source separation and collection, improved waste logistics, better waste processing, quality management and aligned policies and frameworks. The goal is to address concerns regarding the quality of recycled materials and the potential health risks for workers using them. Several individual countries have expanded these to develop their own strategies.

7.2.15 EU End-of-Waste Criteria

End-of-waste criteria describe when waste becomes a product or a secondary raw material. This is important for manufacturers to be able to incorporate "waste" materials into production processes. According to the EU Waste Framework Directive, certain specified materials cease to be waste when they are recovered, including through recycling, and when the following specific criteria are met.

- The substance or object is commonly used for specific purposes.
- There is an existing market or demand for the substance or object.
- The use is lawful, i.e., the substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products.
- The use will not lead to overall adverse environmental or human health impacts [134].

The European Commission Waste Framework Directive is preparing a set of end-of-waste criteria for high priority waste streams such as iron, steel and aluminum scrap [135]. The next waste streams to be addressed include copper scrap, recovered paper, glass cullet, plastics and biodegradable waste/compost. There are no such criteria for "end of waste" in Canada.

7.3 National Actions: Spotlight on The Netherlands and the United States

Fourteen countries have been identified as working on an array of frameworks, regulations, standards and other initiatives to advance CBE. They are Austria, China, Chile, Denmark, Finland, France, Germany, Italy, Slovenia, Spain, Switzerland, The Netherlands, the United Kingdom and the United States. Some are further along than others. Of these, The Netherlands is the furthest ahead given that their circularity measure is higher than any other country at 29.7% [136]. Actions underway in the United States are also included due to its geographic proximity and close economic ties. The work of the other countries is presented in Appendix A.

7.3.1 The Netherlands

The Dutch have a goal of being completely circular by 2050 [137]. To achieve this target, policies are being put in place to ensure production processes use raw materials efficiently, so that less is needed. When new raw materials are required, they endeavour to use sustainably produced renewable and widely available raw materials (e.g., from plants, trees and food waste) to reduce dependence on fossil fuel resources. Investments are also being made to develop new production methods and design new products to be circular.

The Netherlands has implemented an integrated policy-driven approach to construction waste minimization and management. Starting with a landfill ban on construction and demolition waste, the Chain-Oriented Waste Policy program considers the material chain as a whole, including all the stages in the life cycle of a product or material – from raw material extraction, production and use to waste and potential recycling. The chain approach identifies the stages in the material chain where the greatest environmental benefit can be found most efficiently and then sets out the necessary actions for realizing this benefit. Care is taken to avoid the potential for an environmental benefit in one stage to cause a higher environmental impact in another stage [138].

In addition to policies and regulations on landfill and incineration, there are also standards for building materials and how they should be handled at end of life. Comingled wastes are separated at government-certified material sorting plants, and landfills accept waste only from certified operators, who sort and certify loads. Other elements of the policy are as follows:

- Economic instruments to reduce waste volumes and to steer the waste to the preferred treatment include a municipal waste tax paid by citizens and among the highest landfill taxes in the EU.
- Planning at the national level which starts with concessions for collection and treatment, a pro-market approach and integral national waste planning.
- Education to create awareness and enhance participation in the various collection schemes. The focus in construction is on source separation of recyclables by providing collection bins on site.
- Extended producer responsibility (EPR) programs that are paid by consumers, producers and importers.
- Notification and registration of waste haulage – amalgamating the various systems to one integral registration and notification process.

In addition to the landfill ban on CRD waste, control and enforcement is also aided by "flow control" measures, starting with an export ban for CRD waste. Construction waste is highly mobile, and controls are needed to prevent waste from being shipped from locations with high disposal costs and stringent regulations to neighbouring locations that may be laxer. The Dutch borders with neighbouring countries are all closed to CRD waste transports.

Building material reuse and recycling in The Netherlands is estimated to be as high as 90%. Asphalt, concrete and mixed granulates are used in road building, and almost all fly ash produced in the country is used in concrete. There are limits to the amount of material that can be left on-site and mixed with soil after demolition. There are also regulations that stipulate what materials can be reused (e.g., recycled aggregate in place of gravel in concrete). Other measures in effect in The Netherlands at the regional and local level illustrate how the Dutch policy development process has taken a cross-cutting, multi-tier approach.

- The Dutch Environmental Performance of Buildings method takes a life cycle approach to prioritizing sustainability, aiming to halve virgin material consumption by 2030. The approach minimizes a building's impacts across the entire life cycle. The methodology helps users to tackle the issue that as buildings become more energy efficient, the climate impact of the materials they contain increases as a share of the buildings' total life cycle impact.
- The Building Circularity Index (BCI) is a software application that consists of two key performance indicators (KPIs) – material use and detachability at the material, product and element levels – to arrive at an overall circularity score. Key features and functions include materials passports, baseline circularity measurement of building and design, and a database of circular products and materials [139].
- Werflink is a construction equipment and materials sharing platform [140]. Users can post or request available equipment, materials and services for a given location. It is meant to increase collaboration and circularity for neighbouring companies and reduce costs.
- The Concrete Awareness Label (Beton Bewust) is a quality certification for concrete production that has achieved a 6% reduction in carbon emissions since 2012, and a 28% increase in the use of secondary materials from 2014 to 2015 [141]. The program accounts for a producer's circularity status, energy consumption, concrete binding agent use, raw material use, production fuel consumption, and the average amount of carbon emitted per m3 of product [141]. The initiative also aims to raise awareness that the circularity of a product starts from its design.
- Circular Friesland is an organization that brings together business and government [142]. They analyze raw material consumption and material flows within Friesland and promote circular practices by defining steps that can be taken to change habits and improve sustainability.
- The City of Amsterdam follows seven principles of a circular economy. They are closed loop systems, reduced emissions, value generation, modular and flexible design, innovative business models, region-oriented reverse logistics, and natural systems upgradation [143].

7.3.2 United States

There are CBE-related actions at all levels across the US. Nationally, the Buy Clean initiative promotes the use of low-carbon construction materials in US federal procurement and federally funded projects [144]. The program aims to prioritize construction materials with significant embodied carbon concerns, enhance transparency in embodied emissions by encouraging the use of environmental product declarations (EPDs), provide incentives and technical assistance to help domestic manufacturers to better report and reduce embodied emissions, and initiate pilot programs to increase federal procurement of cleaner construction materials and gain insights into how they perform. Other national initiatives include:

- The International Green Construction Code (IgCC)/ ASHRAE 189) is a model code offering sustainability guidelines for the entire construction project and its site, covering design, construction, operations and beyond [145]. It establishes baseline green requirements for both new and existing buildings and aligns with voluntary rating systems like LEED. In the context of CBE, the IgCC provides measures to conserve materials, including requirements for at least 55% of construction materials to be recycled, recyclable, bio-based or indigenous, and to divert at least 50% of construction waste from landfill.

- USA EPA Comprehensive Procurement Guideline (CPG) Program promotes the use of recovered materials by designating a recommended percentage of recovered content for eight categories of specific products [146]. The program provides a supplier directory with details of percentage recovered content for products in those categories. The program works with member cities to assess their path to circular procurement implementation and define specific activities.
- EPA Methodology for Evaluating Beneficial Uses of Industrial Non-Hazardous Secondary Materials and the Beneficial Use Compendium identify construction and demolition waste as a significant source of secondary materials. The methodology assesses whether the proposed beneficial use poses adverse impacts to human health and the environment comparable to or lower than those from a similar product. Additionally, it helps determine if the impacts are at or below pertinent health-based and regulatory benchmarks [147].
- The EPA Recycled Content (ReCon) Tool helps companies and individuals quickly estimate embodied carbon based on varying degrees of post-consumer recycled content [148]. Results from the ReCon Tool are meant to help establish voluntary reporting initiatives.
- Build Reuse serves to advance the recovery, reuse and recycling of building materials in the United States [149]. It has also organized a national approach to deconstruction and building reuse though initiatives such as deconstruction training, a registry of deconstruction trainers, and resources such as template specification language for deconstruction. Build Reuse also offers a materials assessment service that supports the federal tax deduction (and state tax where applicable) for donations of used building materials to non-profits [150].

At the state level, the California Green Building Standards Code (CALGreen) is the first US building code to require the majority of construction projects and most demolition activities to recycle or salvage a minimum of 65% of non-hazardous construction and demolition waste (CDW) [151]. Proof of recycling or reuse is required to receive an occupancy permit and waste management companies must provide appropriate documentation. Local jurisdictions may have more stringent requirements which override this limit, such as in the City of San José, which requires 75% diversion [152]. Leading efforts at the county and city scale include:

- The Marin County Low Carbon Concrete Code is applicable to all construction in the California county [153]. Two pathways are provided to comply with the requirements – reducing cement levels or replacing lower carbon-emitting cementitious materials in concrete designs.
- The City of Portland Green Building Policy has an 85% waste diversion goal that stipulates reuse and recycling as priorities for city-owned buildings. [154] Single stream recycling is required for metal, unpainted scrap drywall, wood, cardboard, land-clearing debris, and inert materials where project sites have sufficient space. Preservation or relocation, followed by full deconstruction, are encouraged where possible for city projects.

8 Gap Analysis

CBE adoption in Canada is at a nascent stage. While policy development at the civic level has resulted in disparate actions with policy discrepancies between regions, there is action underway at both the federal and provincial levels. There are plans to incorporate measures that support a circular economy, specifically related to retrofits and embodied carbon, into building code and NMCS. The NRC's recently launched decarbonization platform is also a potentially powerful enabler of change [89].

This section presents market/economic, technical and governance barriers and challenges, comparing the Canadian context with leading CBE jurisdictions internationally. Information came from interviewees

"Terminology for circularity is not consistent across Canada. This can result in a misunderstanding of the effort required and the benefits gained from keeping materials at their highest value or, worse, greenwashing."

and roundtable participants, and from an analysis of standards in common use and under development in Canada.

Where appropriate, potential solutions, enablers or international examples are proposed in section 9.

8.1 Standards

8.1.1 Definitions

Terminology for circularity is not consistent across Canada. This can result in a misunderstanding of the effort required and the benefits gained from keeping materials at their highest value or, worse, greenwashing. Standardized definitions are needed to provide alignment in perceptions. Then, further education and outreach is needed to inform Canadians as to the value of circularity. Policymakers have identified the need for standard language that is consistent across jurisdictions so policies and programs can align properly. The ISO/TC 323 Circular Economy Technical Committee is working on terminology, principles, frameworks and management system standards that, although not construction specific, will be an important start. Once agreed, consistent definitions can then be inserted into existing standards, which will be important for future building code and NMS updates.

Included in this would be definitions for reuse, downcycling, upcycling, recycling, retrofit, renovation, refurbishment, renewal, restoration, revitalization and resiliency. It would define, for example, if chipping of wood waste for fuel or crushing of concrete for fill is considered recycling or should be renamed to downcycling. Definitions that are broadly available throughout many standards and that can be referenced by policymakers will help ensure these terms are received with their original intent.

Definitions that go further, such as standards for prefabricated or modular components or their connections, provide consistency for secondary use and increase understanding of what can and cannot be incorporated to support reuse and recycling.

Standards are needed to clearly define when circular strategies should be considered in the building's life cycle. For example, the Circle Economy's Framework for Circular Buildings addresses the performance characteristics of a building at its completion [107]. However, it may be necessary to develop different standards for different life stages, for example, during design, operation and at end of life. Voluntary programs like LEED did an important job of establishing definitions and methodologies for green buildings when the concepts were new. However, there is no such comprehensive methodology that designers and builders can use to evaluate the circularity of their project.

There are several organizations and jurisdictions that have started to report GHG emissions and other environmental performance indicators. Frameworks and tools such as GRESB (The Netherlands), Energy Star Portfolio Manager and the Task Force on Climate-Related Financial Disclosures (TCFD) are being used, but collaborative guidance for industry is limited. Reporting processes through disclosure can be standardized.

In the National Building Code, there is ambiguity with respect to the definition of "alterations" (e.g., what is a "major" versus "minor" alteration) and the degree of work necessary on the unaltered portion of the building to meet current code. Lack of standards may be at the root of many of these issues, starting with the variety of terms associated with alterations to existing buildings. Standards are needed to define the types and varying degrees of alteration, as many terms are used interchangeably (addition, conversion, expansion, refurbishment, renovation, retrofit, etc.)

There are also standardization gaps in Canada's building codes related to safety management of an existing building during a renovation process, the use of salvaged materials, and how to allow flexibility to encourage alterations to existing buildings.

The review of standards in common use found that there was a lack of definitions and descriptions of circular and low-carbon building materials (inclusive of equipment, fittings, and fixtures). In particular, clear definitions of scope and terminology are required related to testing, evaluation and qualification of products and materials, and these need to be extended to include reclaimed materials. The following definitions were identified as needing standardization – reuse, recycling, upcycling and downcycling, and reverse logistics.

8.1.1.1 Reuse

The best cases for circularity are when materials are reused in their original application, ideally in redesigned buildings at or close to their existing location. "Adaptive reuse" refers to the process of reusing part of, or the entire, existing building for a purpose other than for which it was originally designed (e.g., building conversions).

8.1.1.2 Recycling

Recycling is a catch-all term that may be interpreted to include reuse and downcycling. A definition of recycling in the context of plastics is currently in development as "the reclamation of materials in such a manner that they can be used to displace the primary or raw materials they were produced from" [155]. This is a strong starting point for validating a definition for other building materials [156].

Industry insight

Steel and drywall (gypsum) are excellent examples of materials that are being recycled in the built environment. In some countries, concrete aggregates can include up to 10% recycled materials and there is currently an interest in a similar policy in Canada.

8.1.1.3 Upcycling and Downcycling

Upcycling involves the transformation of materials into higher value products. Examples of this could be plastic bottles being turned into fabrics, seating or carpets, or furniture being made from scrap wood.

Downcycling refers to the process of recycling and refabricating products into new items of lesser quality. For many materials, all recycling is downcycling to some extent, given that many recyclable materials slowly break down with each cycle.

8.1.1.4 Reverse Logistics

Reverse logistics involves a return of products from end users, and moving products from construction projects, deconstruction sites and material recovery facilities back into the value chain. To make reverse logistics effective, the materials need to undergo a series of steps, including collection, identification, sorting, processing, grading and testing, before being either directly reused or remanufactured into new products. In Canada, current waste haulers and recyclers are in a favorable position to foster secondary markets and provide increased support for reverse logistics, provided the market demand for recovered materials expands.

8.1.2 New Standards

The review of standards in common use and standards in development or limited use identified significant CBE gaps at all key stages of a building's life cycle. These stages are design, construction, procurement, construction supply chain, secondary materials and materials marketplaces (Table 4).

Industry insight

"When I'm talking about wood waste, and that it goes to fuel, I honestly don't know if it's better, if it's going to be chopped up because it's not good enough to use for buildings. Is it better for it to go to landscape? Or is it better to go to fuel? Some just analysis about what the highest and best use really is for some of these materials, I think would be valuable."

8.1.3 Existing Standards

The review of standards that currently support building codes and regulations, and inform the design, construction and operation of buildings, demonstrated that many lack the technical or functional details to execute CBE strategies effectively. In particular:

- CAN/CSA S478:19, Durability in buildings excludes mechanical, electrical and plumbing (MEP) and does not provide guidance on how to use LCA to assess the environmental and carbon benefits of extending the life of buildings.
- Most standards do not mention CBE principles, and the standards that are being developed to address CE are not construction specific.
- Most standards do not include technical design strategies to accommodate future disassembly and deconstruction.
- Existing standards do not cover the material-specific, in-service life-cycle considerations for material or elements (e.g., maintenance), nor provide information on recovery or end of use. There is also no consideration of the life cycle impacts of the prefabricated products.
- Existing standards do not provide direction on design strategies that can reduce the use of ecologically harmful chemicals such as fire retardants, treatments and preservatives.
- There are no end-of-waste standards or criteria, or standards referenced for the salvage and reuse of materials.
- Standards generally do not mention the use of digital tools or building information modelling (BIM), and do not connect into the suite of BIM standards such as ISO 19650, *Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling.*
- Standards do not discuss durability or reference durability standards. Standards do not refer to service life planning or offer information on service life expectations and performance.
- Design standards do not address specifics related to renovations and retrofits. For example, in seismic zones, there are challenges retrofitting unreinforced masonry units without losing floor space.
- Standards related to prefabricated products do not consider life-cycle impacts and could do more to enhance decarbonization of existing modular construction standards through performance-based standards or provisions. Standards are also needed to specify connections for prefabricated components for ease of adaptation and repair.
- Standards relating to energy efficiency and thermal comfort need to ensure the appropriate climate data is referenced (e.g., 2050, not 2020).
- Standards related to appliances and equipment do not discuss the service life of the product, nor provide information on the recovery or end-of-life processes. There are no standards for plug-and-play systems and prefabricated service pods (e.g., for HVAC), such as how they should work, characteristics of universal or inter-connectable systems, etc.
- Standards related to HVAC equipment do not discuss the need for ongoing regular testing and

recommissioning to ensure there is no refrigerant loss. Also, they do not address the GHG impacts of refrigerants or the phase-out of R-134A and R-410A in HVAC equipment, for lower GWP refrigerants (A2Ls are the leading contenders but need special handling).

- Many standards are focused on larger buildings. Energy efficient HVAC standards are needed for smaller buildings to address approaches to retrofit, salvage or recycling of HVAC elements. A commissioning standard for existing part 9 buildings that includes energy and associated operational carbon requirements (notably for passive house buildings) is needed.
- Energy efficiency standards (such as ASHRAE Standard 90.1-2022—*Energy Standard for Sites and Buildings Except Low-Rise Residential Buildings [18])* are focused on operational energy analysis and do not consider embodied impacts and trade-offs, equipment service life, etc. Further, as embodied carbon becomes a design consideration, energy efficiency standards may need to be updated to reference methodologies by which to calculate and analyze the trade-offs between operational and embodied energy and emissions. Energy and emissions modeling procedures need to be aligned with data quality, digital design and construction standards.
- Standards relating to deconstruction and disassembly provide insufficient technical/functional information for practitioners. For example, it is not clear which project life stage the standard is applicable to, or when is the best time for building owners to take action. Technical guidance is needed for strategies such as the use of reversible connections, specifying sufficiently durable products that can withstand disassembly (e.g., appropriate grades of framing lumber). Checklists and templates would be useful.

Table 4: CBE gaps identified from a review of standards in common use, and standards in development or limited use

Design
▪ Retrofit design guidance and technical standards on embodied carbon savings ▪ Definitions and technical standard(s) related to "deep" energy efficiency retrofits and how to incorporate salvaged materials ▪ Building use standards for future adaptability (reconfiguration of the interior spaces), covering offices, classrooms, multi-family housing and hospital wards, etc. ▪ Reversible design standards with design guides and templates for planning that incorporate functional and spatial modularity and systems thinking ▪ Alignment of the National Master Specification with CBE standards to support the reuse of existing materials ▪ Standards on circular strategies for whole building updates with terminology for building alterations, including renovation, retrofit, renewal, refurbishment, restoration and revitalization ▪ Guidance on the application of salvaged and recycled products and materials in the design and construction of new buildings ▪ Seismic design requirements that incorporate protection of the life of the building for use after an event ▪ Application of CBE principles in the context of disaster management and recovery for the building industry
New Construction
▪ Technical guidance, templates and checklists for implementing zero waste renovation on site, including addressing potential safety issues, definitions of waste and reporting methods ▪ Standardized metrics for CBE activities such as product quality, durability and ease of disassembly for repair ▪ Guidance on how to prepare a pre-demolition audit when a building reaches end of life

Valuation and Appraisal
▪ Standardized methodologies for valuing circular buildings, products and materials, including financial modelling, quantifying ecosystem services, and life cycle costing of environmental impacts
Procurement and Supply Chain
▪ Standards related to responsible sourcing and traceability of supply chain materials, and for assessing the level of circularity and sustainability of supply chain ▪ Standards on allocation of GHG spending for activities that have future emission reduction or other environmental impacts ▪ Standards relating to product as a service (PaaS) to describe the roles, responsibilities and expectations of the supplier and customer
Secondary Materials and Materials Marketplaces
▪ Guidance for developing and operating material marketplaces, including establishing metrics for quantifying environmental impact reductions due to marketplace transactions ▪ Specifications for composition, quality and quantity of manufacturing by-products ▪ Standards that define salvaged materials and elements, describe the salvaging processes including safety considerations, provide metrics and guidelines or specifications for product reuse, and set out testing and evaluation methodologies for material re-use ▪ End-ofWaste criteria for construction materials

8.2 Issues with Data, Metrics and Indicators

8.2.1 Technical Data

There is a lack of data related to material use, waste generation and diversion in Canada. Further, where metrics exist, there is a lack of alignment with the NBC, especially related to energy efficiency, carbon and waste. Consistent measurement and reporting of waste going to landfill is essential to monitor waste reduction and diversion progress [157].

Many municipalities, provinces, territories, recycling councils, waste management associations, non-governmental organizations (NGOs) and private businesses in Canada have been measuring waste going to Canadian landfills, but the measurement approach has been inconsistent. Data is variable between provinces for certain material categories (e.g., building material, plastics, paper) and there is notable variation in some categories (e.g., plastics) within certain provinces. Consistent reporting at the national level will allow for the scope of the issue to be fully understood and addressed. Standards are needed for the collection and reporting of construction industry KPIs and key CBE activities, such as:

- Waste generation and diversion rates for new construction, renovations and demolition
- Key construction waste streams and material flows (e.g., wood, drywall, asphalt, concrete, scrap metals, etc.)

There are also challenges related to data quality, notably around LCA, as well as for salvaged material characteristics and constituents, and existing building information.

8.2.2 Cost Data

There is a lack of benchmark cost information for building renovations and retrofits. There are several large quantity surveying firms that publish benchmark new construction cost data for a range of building types for major urban centres across Canada. However, these reports do not extend to retrofits, renovations or conversions. There is also a lack of life cycle costing data for owners to use to plan ongoing renovations and renewal projects.

8.2.3 Metrics and Indicators

There are several indicators for CBE. However, there is a lack of overall consistency and most CE indicators are not construction specific. Those that exist are mostly oriented towards organizational circularity, such as ISO/TC 323. Indicators are needed at the project scale and at the sector level. For example, it is important to understand the overall circularity rate for the building sector, that is, the portion of the economy's material needs that are supplied by recycled or recovered materials. This is something the EU is already doing using materials flow analysis [158]. The United Nations Environment Programme (UNEP) International Resource Panel (IRP) differentiates the various ways in which the term "resource efficiency" is used and sets out all the relevant definitions. These definitions are consistent with the definitions used in the OECD Policy Guidance on Resource Efficiency [159].

8.3 Governance Gaps and Challenges

8.3.1 Retrofit Codes and Policies

There are several initiatives under way to update the National Building Code (NBC) that include defining alterations, operating and embodied carbon requirements, and digitization of the code. However, this process could be expanded to specifically consider building renovations as a whole, the use of salvaged materials, standardized and unified testing, and verification processes. Beyond well-established energy efficiency programs and sustainability programs such as BOMA BEST and LEED O&M, there are few policies that promote renovations and retrofits.

8.3.2 Application of the NBC for Existing Buildings

Although the NBC applies to the alteration, change of use and demolition of existing buildings, there are no specifications that describe "major" and "minor" alterations. There is concern that applying too much emphasis on bringing existing buildings up to code during an alteration project may tip the decision away from renovation towards demolition. In addition, calculation of embodied carbon and waste generated during renovations is not always required.

The NBC does not describe who is responsible for assessing whether designs, technologies or materials conform to the code or how those with this responsibility might carry it out. This responsibility is usually established by the governing legislation of the adopting provinces and territories. However, the procedure is different for each jurisdiction, and some are more involved than others.

8.3.3 National Waste Management Framework

There is no national strategy or policy framework for construction waste management in Canada. Examples of existing frameworks are the EU Waste Framework Directive described in Appendix A and the Dutch Chain Oriented Waste Policy.

8.3.4 Embodied Carbon Policies and Regulations

Life cycle carbon is not currently regulated in Canada. Regulations that aim to reduce carbon emissions from building operations do not set a cap on embodied emissions. Therefore, the additional materials required to meet the operational goals may negate the benefits and add to the upfront carbon "burden."

Further, embodied carbon policies, where they exist, do not consider end of life. While ISO-defined LCA methodology can be used to evaluate Reuse, Recovery and Recycling Potential (Scope D), this is normally beyond the typical system boundary for LCA (e.g., in embodied carbon policies) [160].

Requiring LCAs to expand to consider embodied carbon for energy retrofits and for demolition or deconstruction, as well as the emissions from transportation of construction materials and waste, clarifies how much carbon can be diverted from landfill and increases awareness. This, along with standards and regulations, are tools that may encourage the use of reclaimed materials to limit embodied carbon. In this way, reuse of materials can be embedded into existing low-carbon campaigns.

8.3.5 Intergovernmental Collaboration

There is a lack of alignment between provinces, and between local governments, in terms of commitment to, and the pace of adoption of, CBE. Municipalities have tremendous potential to advance CBE. They are usually directly involved with the waste management service providers and may even act as the waste management authorities themselves. Transitioning to a circular economy requires collaboration across government ministries and all levels of government. A common challenge is the lack of integration or alignment among different policies, programs or strategies [161].

8.3.6 Cross-Disciplinary Governance

Governance is needed to create synergies between the various fields of expertise involved in CBE, including business, technical, legal and financial perspectives.

8.3.7 Regional Waste Management Policies

Currently, waste management regulations, data collection and tracking procedures are locally specific, which works against the national and international construction supply chain. Templates for construction waste management usually come from LEED or local waste management utilities, but there is generally no unified best practice. Each region/utility has a different set of recycling/diversion requirements and measures waste diversion differently.

Some municipalities have deconstruction requirements to recycle a percentage of material for certain types of properties. Transfer stations operated by private companies provide receipts for recycled materials that are deposited there. There is concern that because these transfer stations are not audited, receipts are not given out properly and some receipts may be given for materials that are not recycled. Auditing these stations would close the loop on the policy to ensure it is enforced.

Some municipalities have considered raising landfill rates to increase recycling activity. For municipalities close to the US border, this can result in waste being exported to the northern US states where landfill rates may be less expensive. However, requirements to retain waste within Canada may conflict with trade agreements.

Industry insight

"You have a lot of private facilities, basically private transfer stations, that are writing whatever you want on the receipt, and that's the problem. There needs to be enforcement on them. They need to be audited... I believe that the City of San Francisco and San Mateo County, who have very similar policies...have taken that step to regulate the actual transfer stations because of this exact problem."

A national standard would provide consistency between municipalities and bylaws. Enforcement activities would be required to maintain consistency and change behaviour. In particular, policy guidance is needed for:

- Measuring waste and operationalizing waste reduction for waste processors, municipalities and builders
- Performing waste audits

8.3.8 Definitions and Methodologies with International Standards

Recognizing that construction operates within a global supply chain, the development of definitions, technical descriptions and guidance on sustainable materials management for the Canadian context needs to be coordinated with EU/OECD activities.

8.4 Technical Issues

8.4.1 Durability and Resilience

Durability and resilience are key to circularity at all of the life stages of a building but have yet to be commonly included in design discussions. For new materials, industry practitioners seek clarification on environmental impacts by using environmental product declarations (EPDs). However, the information available on EPDs varies and is often formatted differently. Material producers can help their customers make informed choices by providing EPDs. Formatting of the information could become standardized for ease of comparison. EPRs could help materials manufacturers reuse materials or incorporate recycled materials into new products.

Industry insight

"More emphasis needs to be placed on building maintenance and operations to extend the life of buildings and to ensure materials are reusable at end of life – an asset management standard."

8.4.2 Non-Standard Products and Materials

There is resistance to specifying reused materials in building projects because of the lack of research into long-term performance. When a product cannot be qualified using a code-referenced standard, or when the use of the product is outside the scope of the building code, compliance must be demonstrated via an "alternative solution," which usually requires submission of technical evidence to the authority having jurisdiction (AHJ). The alternative solution path is so onerous that, for example, dimensional lumber used for framing in its first life may only be used for non-structural applications in its second life.

Responsibility for determining conformity of non-standard products with building code requirements, and how it might be carried out, is usually set out in the governing legislation of the adopting provinces and territories. There are several means available to help ensure that materials, appliances, systems and equipment meet the requirements of the code, ranging from on-site inspection to the use of certification services provided by accredited third-party organizations. Test reports or mill certificates provided by manufacturers or suppliers can also assist in the acceptance of products [162]. Engineering reports may be required for more complex products. However, the procedure is different for each jurisdiction, and some are more involved than others.

Industry insight

"As soon as you go alternative compliance, that means it's up to the building inspector to approve or not approve, which means it's quite often cost prohibitive, resource prohibitive for those small companies."

Industry insight

Participants in interviews and roundtables stressed that federally supported academic research on how materials can be reused is necessary to encourage wider adoption of salvaged materials. Current European research does not meet the needs of Canadian professionals. Specifically, participants would like to know how reused materials differ from new ones and what risks, if any, may be incurred from using them. Policies to certify circular approaches in materials and processing should also include guidance and technical procedures that instruct on approved methods. Standards based on this research would also define what can be reused in structural and non-structural ways.

8.4.3 Testing and Standardization of Connections

Structural connections in buildings are currently selected to meet code requirements and optimized for cost and speed of construction. Reversible connections can be chosen to simplify renovation or adaptation and improve the circular potential of the materials. However, this will likely impact cost and schedule and is not current practice. Currently, there is inconsistent documentation as to the strength and durability of reversible connections and there is no standard approach to achieving them. Design for deconstruction of tall buildings will likely require new fastening methods. Modular construction would benefit from standards that include electrical and plumbing connections between panels and other building components.

8.5 Market Barriers and Challenges

Construction projects are often faced with challenges in schedule and cost. Supply chain fluctuations and availability of materials, wait times for permitting, availability of trades or labor, and the impact of extreme weather provide a steady stream of uncertainty that can be challenging to manage.

Once technical and regulatory barriers are overcome, normalizing circularity into contracts, standards and available materials will transform it into a matter of choice of sources, where cost, quality and availability are similar.

8.5.1 Collaborative Project Delivery

Collaboration between businesses is required to achieve a circular economy so that waste from one process becomes input for the next. Communication is required to identify where the channels exist or can be created for that material flow. Collaborative strategies such as lean planning methods and integrated project delivery are starting to be used to encourage project teams to work together early to eliminate waste.

Industry insight

Collaboration on project delivery will reduce waste by identifying efficiencies at an early stage and limiting waste generated from rework. Methods such as integrated project delivery (IPD) have been implemented on construction projects to take advantage of these efficiencies. Increased use of this approach, perhaps beginning with government construction projects, can demonstrate how the early engagement of contractors and trades who are aligned with the goals of circular buildings increases adoption and encourages innovation.

8.5.2 Procurement Policies

Procurement policies for governments and institutions can help designers and contractors become more familiar with how to create a circular built environment. Contracts must remain consistent in their policies around materials procured. One interviewee noted that environmental requirements for steel are much higher, and emissions are much lower, in North America than in other parts of the world, which drives up the price locally [163]. Circularity of processes and GHGs resulting from production and transportation of materials should be evaluated consistently between sources.

8.5.3 Permitting

At the local and regional level, requirements for parking, unit sizes, setbacks, and open space can be impossible to achieve with an existing structure. Interviewees noted that accelerating the permitting process might be one incentive for circularity. If a project could demonstrate reuse of materials or design for disassembly or another method of incorporating circularity, they would get priority for permitting.

8.5.4 Asset Management Standards

International asset management standards exist for general, non-construction specific assets (ISO 55000:2014, *Asset Management – Overview, Principles and Terminology* [85]) and for those identified through building information management (BIM) workflows (ISO19650, *Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM)* [164]). Missing from Canadian standards are those specific to asset management in the built environment, whether BIM is available or not. The development of standards for operations and maintenance to extend the life of assets and improve building resiliency are needed. These would refer to standards for waste management for replacement parts and standards for retrofits to include circular practices.

8.5.5 Lack of Market Incentives

Market incentives for deconstruction are limited in Canada. One interviewee argued that if taxes are raised on raw materials and lowered on labour, the reverse might be the case. This scenario is dependent on the available labour force, but if taking buildings apart is less expensive and reused materials are less expensive than new ones, owners would find it more economical to disassemble and reuse.

Designing buildings for circularity comes at a cost premium in the short term. Low-carbon materials, LCA analysis and reporting, building components that have been designed for disassembly, and certification of reused materials all add to the upfront cost. These investments may have a long-term return if the operational energy is low, or the materials are reused at the end-of-life of a building.

While architects and engineers can provide options for circularity and identify costs and risks, it is ultimately the owners who must be convinced to take on those upfront costs. There are currently limited economic incentives for owners to take on those risks to mitigate the future costs and impact on the environment.

Industry insight

"Long-term owners will benefit the most from design for disassembly. They benefit from repair and maintenance, as well as end of life."

8.5.6 Waste Disposal Fees

In many Canadian jurisdictions, garbage disposal fees are below the original cost of the product [165] and do not account for the full costs associated with landfilling. Adjusting waste management service prices to reflect their full cost, and standardizing fee structures across jurisdictions, would incentivize the building industry to choose products with fewer materials or materials that are easier to recycle or compost. This, in turn, would motivate producers to design and manufacture goods that generate less waste.

8.5.7 Transportation Costs to Recycle

In some areas of Canada, recycling transfer stations for materials are located far from project sites. Transportation of materials to reprocessing facilities can be more expensive than landfill fees. Material salvage and repossessing infrastructure needs to be established more widely to take in used materials and facilitate their movement to a location where others looking for those materials can find them. It is a logistical problem that would require feeder nodes for multiple materials and would be difficult to make cost effective in the current market.

Industry insight

On Prince Edward Island, the federal government has waste diversion targets for its projects. However, with few projects requiring recycling facilities, the closest one requires the material to be shipped on a barge or trucked off the island. Those extra shipping costs can be prohibitive for smaller projects, resulting in more being sent to landfill.

8.6 Focus on Performance-Based Outcomes

Many participants in the study stated that standards should focus on outcomes and goals rather than being prescriptive. Expectations might include durability, carbon intensity of materials, or connection methods for ease of disassembly or adaptation.

Some roundtable participants suggested applying a standard “circularity index” to new and existing buildings. The index would incorporate the expected lifespan of the building, how useful the existing materials would be in a new structure, how easy the components could be taken apart, and if they could be reused or upcycled to maintain value. It could add value to existing buildings that have potential for secondary uses and could aid in making design choices for materials and methods, while maintaining freedom for creativity and innovation. Additionally, standardizing collaborative project delivery could stimulate creativity and create a safe space for innovation.

Standardizing tools such as material tracking, BIM and building logbooks could help mitigate the risk and complexity associated with disassembly, reuse and recycling.

9 Recommendations

Reinforcing and expanding the circular built environment (CBE) in Canada will require many different independent agents to collaborate toward a common goal. Government policies and regulations, codes, standards and market mechanisms, all backed by research targeted to address the issues that will have the greatest impact, can all help to address CBE. Metrics should be implemented with defined timelines to ensure actions are not delayed. Manageable steps with shorter timelines will facilitate the behaviour change necessary to implement a new way of thinking about, and working with, the built environment.

A summary of the actions that can be taken by key industry groups to advance CBE is provided in Table 5. This summary also includes some "big moves" that a coalition of all members of the construction industry will need in order to move forward collectively. The actions are then discussed further below.

9.1 Define a Common Language

The most prominent recommendation identified from interviews and roundtable workshops was that the language of a CBE needs to be defined, standardized and brought into mainstream activities. Common terms such as recycling and renovating mean different things to different audiences. Standard language should be added in the NMS that relates to deconstruction, disassembly, salvaged materials (and how to incorporate them into new projects) and circular strategies.

Some sample definitions include:

- Adaptive reuse: The process of reusing part of, or the entire, existing building for a purpose other than for which it was originally designed.
- Recycling: A catch-all term that may be interpreted to include reuse and downcycling.
- Upcycling: The transformation of materials into higher value products.
- Downcycling: The process of recycling and refabricating products into new items of lesser quality.
- Reverse logistics: The return of products from end users, moving them from construction projects, deconstruction sites, and material recovery facilitiesExisting standards must be updated to include language about circularity. Ultimately, reuse and recycling should be incorporated wherever possible. Generic statements on the need to consider all stages of the material's life cycle could be added to design standards for specific structural types. The National Research Council (NRC) is working to update the National Model Codes and National Master Construction Specification to include low-carbon solutions, prioritizing performance-based solutions. These efforts can be expanded to accommodate building renovations and the use of salvaged materials. Publicizing the embodied carbon footprint of structural materials used in federal projects per the National Policy on Green Procurement will encourage carbon reduction and provide example language and methodology for other projects.

9.2 Embrace Data-Driven Activities

While disclosure of operational emissions is becoming a requirement for large buildings in Canadian cities, disclosure of embodied emissions is not. These cities can take the next step through LCA requirements for large buildings, by including deconstruction and demolition stages. With increased data on the embodied carbon generated by the built environment, better information can inform incentives or regulations incorporating circular methods to best fit each region.

Research participants identified inconsistent availability and formatting of data in EPDs an issue when collecting embodied carbon data for LCAs. They added the software tools that produce LCAs use different sources of information. For this data to be valuable, it must become more consistent.

While diversion of reusable or recyclable materials from landfill is the goal, many communities face infrastructure challenges due to lack of available storage or transfer stations for those materials. Others also lack available landfill space and have the additional obstacle of transportation requirements to relocate materials. If provinces develop policies and regulations to limit construction and demolition waste from being sent to landfill, they must remove the obstacles that these communities face to ensure their success.

Figure 4: Collaboration of systems to support CBE

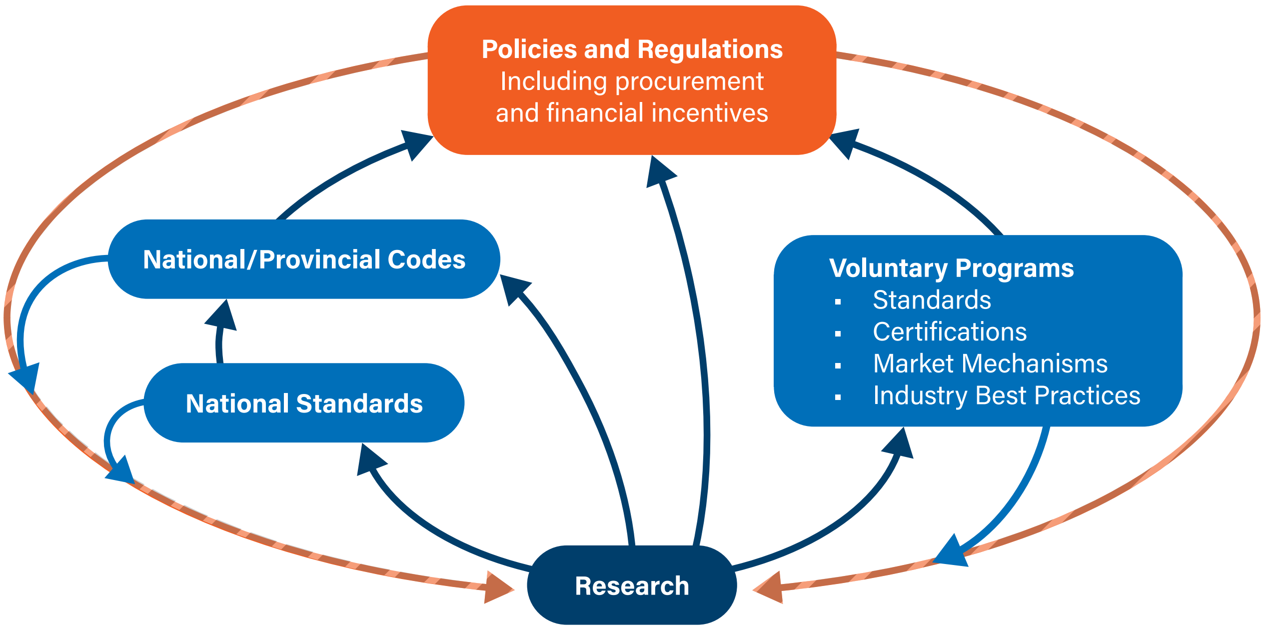

Table 5: Summary of actions that can be taken by industry groups to advance CBE in Canada

CBE Big Moves: Collaborative Actions by All Members of the Construction Sector
▪ Create a national waste management framework with aligned metrics, definitions and targets across regions and provinces ▪ Entrench embodied carbon requirements and references into all codes and policies ▪ Incorporate CBE criteria and how to use reclaimed materials into design standards for key structural materials referenced in the NBC (steel, concrete, wood, masonry) ▪ Simplify certification of salvaged materials for re-use (not down-cycling) ▪ Create a pan-national network of markets for reused materials along with increased disposal fees ▪ Commit to a national BIM mandate to facilitate project data management and reporting ▪ Extend net zero policy roadmaps to cover waste/resource efficiency and other benefits circular practices may offer

<table>
<tr><th colspan="3">CBE Big Moves: Collaborative Actions by All Members of the Construction Sector</th></tr>
<tr><th>Federal, Provincial and Municipal Policymakers</th><th>Standards Development Organizations</th><th>Industry</th></tr>
<tr>
<td>

Speed up or reduce cost of permitting for projects that implement circularity
Audit recycling centres to verify materials and require delivery to audited centres for waste diversion credit
Create a database of project information
Create a market for secondary materials along with increased fees for disposal of reusable materials
As more single family homes are demolished, ensure materials do not go to landfill
Work material consumption topics into net-zero policy development
Create infrastructure to store and catalogue salvaged materials
Showcase success stories with case studies
Develop a transparent building performance rating system and disclosure "Circularity Index"
Consider a “Renovation First” act along the lines of Wood First for public projects
Establish embodied carbon requirements for all building types and set targets to net-zero carbon
Implement a model national retrofit code
Include recycled aggregate up to a percentage for certain types of concrete
Create coalition of government, industry, property owners and researchers

</td>
<td>

Prioritize updates to those standards that are referenced in the building codes
Add generic statements about CBE to design standards for specific structural types (e.g., wood, concrete, steel)
Define CBE terminology
Define circularity
Use language that indicates the intention is not to exclude circularity
Stay informed on major complementary efforts, such as updating the NMS, roll-out of retrofit codes, etc.
Simplify certification of lumber or concrete for structural reuse
Bring CBE experts into standards technical committees
Develop standards on the strength and durability of reversible connections and an approach to achieving them

</td>
<td>

Increase use of technology, BIM and virtual construction management to facilitate data management, track materials and data-flow diagram (DfD) methods, and improve circular decision-making
Work with digital and green building advocacy groups to create a program that promotes the adoption of digital building logbooks
Focus on adoption by large property owners, with a plan for owners with fewer properties
Develop standard RFP language for specifying CBE strategies such as design for deconstruction/ disassembly in procurement
Work with voluntary green building program providers to incorporate circularity measures and reporting into their programs for existing buildings

</td>
</tr>
</table>

Speed of permitting has been cited as a possible incentive. For example, for single family homes built before 1950, proof of deconstruction combined with diversion of 75% of non-hazardous materials provides early release of deconstruction permits and discounts on disposal of remaining waste [62]. These types of policies can motivate people to consider deconstruction and expand the conversation about CBE.

9.3 Focus on Renovations and Resilience

Many of the buildings that will exist in 2050 already exist today. Maintaining those buildings to increase durability and extend asset usefulness will keep their materials from ending up in landfills. Maintenance can range from replacement of equipment or materials to improve performance, to change of appearance in order to improve leasing capabilities.

Industry insight

Durability is key to circularity at all life stages of a building but has yet to figure into many design discussions. By maintaining our existing buildings, we extend their useful life and slow down the flow to landfill. There are educational components at all stages of circularity that must be addressed.

Operational emissions reductions have been a priority for many property owners who are focused on reducing both their energy costs and emissions. When items such as windows, cladding, insulation or HVAC systems are replaced, a great deal of extra material can be generated, and care must be taken to repurpose or recycle that material where possible.

The NBC applies to renovations but is often only applied to the design and construction of new buildings. However, AHJs have requested that guidance specifically applying to retrofits be created. The Joint Task Group on Alterations to Existing Buildings (AEB) has recommended that these guidelines be incorporated into the National Model Codes for the 2020–2025 code cycle and not a standalone document [20]. Though some believe the City of Vancouver's Part 11–Existing Buildings is unwieldy to implement, it contains definitions and pathways that provide important pointers for future policy-making to retain and upgrade existing buildings.

As these guidelines are developed, adding specific language to include circular construction methods and prefabricated components can reduce barriers of alternate compliance pathways. This language should apply to new construction as well as renovations and retrofits.

9.4 Develop a CBE Framework and Activities

The international solutions discussed in this report provide examples for Canada to develop its own framework for the CBE. Cities within Canada have already taken policy and regulatory steps in that direction. This framework can draw on these ideas and be customized to address Canada's unique challenges and regulatory environment. It should provide clear actions and examples.

Efforts to coalesce CBE in Canada are ramping up. A coalition of government, industry, property owners and researchers should be established to identify, review, implement and communicate best practices, common language, and policy or regulation proposals. The coalition would assess regulatory, market and policy issues that limit implementation of CBE, and stay informed on the workflows, deliverables and timeframes for major complementary efforts, such as updating the NMCS and roll-out of retrofit codes. It would advise on if or when it might be necessary to develop BIM standards for working with existing buildings, and work together to break down barriers.

This coalition could create a circularity indicator, a measurement tool to identify circular buildings, activities, policies and communities, and state what is working and worthy of high marks. New buildings and retrofits could use standard metrics to measure key efficiencies. Buildings that use salvaged or low-carbon materials, or otherwise performed well, could receive recognition, as could organizations that streamlined capabilities for their communities to donate, store or acquire materials for reuse.

Data can be organized at the national level or through this coalition to better identify locations where opportunities are low, or costs are prohibitive, to properly reuse or recycle waste. New programs could then be developed to support circular practices in those areas. Guidelines for local governments could be published to create consistency in policies.

Second-hand goods marketplaces must be better established before they are commonly accessed as part of the normal supply chain. Government programs to establish them, and material contributions from deconstruction on government projects, could provide needed momentum. Reuse of materials in government projects should also be encouraged, either with the materials existing on-site before deconstruction, or through purchase of products in an established second-hand marketplace.

Government should encourage more collaborative projects and create the contract forms that work with them. Engaging more participants in the process early on can help identify solutions for more circular practices and reduce waste-generating changes as new teams are brought on board.

9.5 Educate Participants

Education and capacity building can be expanded across the construction supply chain. Materials manufacturers, property owners, designers, engineers and other industry practitioners each have a role to play in the CBE. Organizations who develop standards for materials can offer training on circularity principles as they are added to new and existing standards. This training should include the reasons for adopting circular practices, standard definitions and terminology, and examples and templates for implementation. Reframing the conversation by defining what is valued in the built environment, including healthy buildings, efficient use of resources and limiting contribution to climate change, will help adjust behaviour through awareness and example.

Cities can reference the resources provided by the Canadian Circular Cities and Regions Initiative [166], which provides webinars, workshops, networking and guidance for communities as they begin to incorporate circular practices.

Resources should be offered in multiple formats to best reach a wide audience. The opportunity exists to address how buildings are designed, constructed, operated and deconstructed to bring circular efforts for the built environment into the mainstream.

10 Conclusion

Prioritizing a circular built environment will be key to reducing embodied emissions as Canada works with other nations to reduce the carbon impact of buildings.

Canada can contribute to this change by tackling the issue from multiple angles. Through standards, building codes, regulations, market incentives and awareness, many of the obstacles can be overcome.

The development of standards for CBE will require extensive cross-committee coordination. Engineering solutions, standards and policies must work together because they complement one another and will be required simultaneously in order to succeed. However, there are some actions that can be taken to address gaps in standards, build awareness and develop a collaborative platform to help share best practices. Some actions have been implemented on a local level in Canada, and the results and lessons learned will aid in expansion of those programs and adoption in broader regions. Some of the gaps that have been identified will take time and effort to be effectively implemented.

Industry insight

"The visibility of existing standards is totally a problem. Like the durability standard, I don't think anybody used that until LEED made it a credit then, because it was referenced in the credit, it got some exposure. The other circularity-related standards, like design for deconstruction, just need to be more visible, so that people know that those resources are there."

A first step is to set a solid foundation for conversations about circularity by defining the terminology, inserting that terminology into standards, codes and regulations, and providing examples for how it can be implemented, such as language for contracts and design guidance. Canada can develop a coalition of professionals to define what it values for the environment and the economy, to help establish a framework to implement more circular practices. This coalition can advise on methods to acquire more data around the materials we use and how they are disposed of to better guide new practices. Data such as those provided by EPDs, LCAs and from building energy use is especially valuable. It not only helps designers understand how their decisions impact GHGs but, aggregated to the industry level, it can show where progress is being made and where further work is needed.

Strengthening the second-hand goods marketplace will create an economic incentive for materials to be kept out of landfills. While better auditing of disposal will help enforce current regulations around recycling requirements, resources needed for auditing may be better spent establishing that marketplace.

Celebrating successes in circularity as much as possible, and advertising who is doing well and rewarding them, can go a long way. Participants in this study suggested the creation of a Circularity Index to identify buildings, owners, policies and activities that perform well and are helping to achieve the goals of a CBE.

Increasing awareness and educating professionals in the construction and real estate industries is also vital to achieving these goals. Circular principles must be well understood and celebrated to encourage action. Incorporating these principles into the net-zero conversation will increase awareness and remind us that we cannot simply trade operational carbon emissions for embodied carbon emissions.

Industry insight

"If the design community has a framework, it will help position the industry" and achieve goals faster. "Setting some kind of a standard puts everybody under the same umbrella that I think is very helpful."

There are many tools to aid in the implementation of circular practices, including the use of virtual construction management systems and BIM to track materials and their data, DfD methods, and collaborative project delivery methods that require contracts be approached differently. Permitting incentives can play a role in providing momentum to get started more quickly. Adding embodied carbon data from retrofits to tools such as GRESB will enable them to make more circular decisions about material choice and encourage activities to extend the life of their buildings. Choices made by those owners and investors – and the practices they support – can lead the way for owners with fewer properties to have more economical options to choose circularity.

The CBE is within reach but requires commitment to become a reality. Including guidance and technical solutions in standards will help ease the transition and change the way designers and builders think about materials. Research into the reuse of materials for structural purposes will help provide confidence to the designers and engineers who can specify them.

Appendix A

National Actions: Expanded Global Review

1. Austria

The City of Vienna has committed to the transition to a circular city and reframed local policies accordingly. DoTank Circular City Wien 2020-2030 (DTCC30) is a key project of the City of Vienna's 2030 economic strategy, with a focus on sustainability and resource conservation [167]. The long-term goal of the program is to establish the concept of recycling in the built environment – from planning, production and use or reuse, to processing for recycling and the market for secondary raw materials.

The timing of policy interventions is important. For example, to optimize the potential for deconstruction, policies need to encourage designers to consider future disassembly at the beginning of the design process. By 2030, circular planning and construction for maximum resource conservation will be standard for new builds and renovations. By 2040, the city will require the reusability of at least 70% of the components, products and materials from demolished buildings and major conversions. The overall goal is for Vienna to reduce its consumption-based material footprint per capita by 30% by 2030, and by 50% by 2050. To get started, the city has set the following operational goals:

- Anchoring the topic of a "circular city" in the mindset of Vienna, its civic activities and its interactions with influential organizations
- Recognition of the built environment as a store of materials and that construction projects are long-lasting
- Creating the foundations for material transparency, i.e., which materials are used when, where and how in the built environment.
- Collecting and presenting the business case and economic advantages of a recyclable built environment

2. China

China has established green building development goals to be met by 2025 for reducing the environmental impact of buildings (Table 4) [168]. China's circular economy policies are focused on improving resource efficiency and decoupling economic growth from the use of resources [169]. The activities to achieve this efficiency are similar to European ones. They include reuse and recycling, design for disassembly, design for durability, design for energy efficiency, and design for flexibility.

Table 6: China's national green building development goals [168]

Indicator	2025 Goal
Total consumption of secondary energy for building operations (billion tons of standard coal)	11.5
Proportion of new residential buildings with improved energy efficiency levels in the urban–rural area	30%
Proportion of new public buildings with improved energy efficiency levels in urban–rural area	20%

Indicator	2025 Goal
Area of energy efficiency retrofitting of existing buildings (billion square meters)	0.35
Area of construction of ultra-low and nearly-zero energy buildings (billion square meters)	0.05
Proportion of prefabricated buildings to new urban buildings	30%
The new installed capacity of solar photovoltaic in buildings (billion kWh)	0.05
Area of application of new geothermal energy building (billion square meters)	0.1
Replacement rate of renewable energy in urban buildings	8%
Proportion of electricity consumption in building energy consumption	55%

3. Chile

Chile developed a Circular Economy Roadmap to 2040 using a collaborative process that considered inputs from a variety of stakeholders across sectors. It established seven goals to be achieved by 2030 [170].

While these goals are not specific to the construction sector, they demonstrate the commitment of Chile to the circular economy. A set of actions accompany these goals and among them are some with a construction focus.

- Promote the use of interactive platforms for the development of secondary materials markets, which help to create links between companies that generate potentially valuable waste and those that could use them.
- Take advantage of the latest technologies to establish effective and timely links, starting with flows of high priority waste streams, specifically construction and agriculture.
- Prepare a technical standard with specifications and minimum requirements for building demolitions under a circular economy approach (addressed with Chilean standard prNCh3727 *Gestión de residuos - Consideraciones para el manejo racional de residuos de demolición y auditorías de pre-demolición*)
- Develop technical standards to facilitate the reuse of construction materials such as recycled aggregates.
- Incorporate circularity requirements and criteria into public infrastructure and social housing projects, (e.g., requirement to incorporate certain amounts of secondary materials) [171].

In addition, the roadmap sets out a series of actions to be taken to transform the culture to adopt more circular practices, including communication, education, awareness, certifications, labeling, and data collection and monitoring. The roadmap also includes product labeling requirements to allow users to better evaluate the useful life of products before purchasing them. This, in turn, leads producers and distributors to increase product quality and durability, and facilitate their repair.

Table 7: Goals of Chile's Circular Economy Roadmap [170]

Indicator	2030 Goal	2040 Goal
Generation of green jobs	100,000 new jobs	180,000 new jobs
Generation of municipal solid waste per capita	Decrease of 10%	Decrease of 25%
Total waste generation per GDP	Decrease of 15%	Decrease of 30%
Material productivity	Increase of 30%	Increase of 60%
General recycling rate	Increase to 40%	Increase of 60%
Recycling rate of municipal solid waste	Increase to 30%	Increase to 65%
Recovery of sites affected by illegal dumping	Recover of 50%	Recover of 90%

4. Denmark

In the Danish Government's Action Plan for a Circular Economy, a sustainable built environment is identified with a focus on all phases of a building's life cycle. The government has committed to:

- Update the building regulations with elements from the voluntary sustainability policies and programs
- Introduce increasing limit values for climate footprint from buildings
- Develop the existing Danish LCA and life cycle costing (LCC) tools for buildings into design-tools
- Introduce requirements for standardized demolition plans
- Establish national limit values for problematic substances in recycled concrete and brick
- Create unambiguous rules and better traceability for construction and demolition waste [172]

5. Finland

Finland published its first roadmap to a circular economy in 2016, with an expected €2 to €3 billion in added economic value by 2030, and significant environmental and social benefits. Resource efficiency, public procurement and new funding models are defined as key targets to make Finland a global leader in the circular economy. Five areas of focus are defined to achieve its goals:

1. Sustainable food systems
2. Forest-based loops
3. Technical loops
4. Transport and logistics
5. Common action

One of the principles of the technical loops is to lengthen the product life cycle and return materials to the loop. By minimizing the need for raw materials, maximizing lifespan and reusing materials, combined with increased use of secondary materials, Finland plans to increase its competitiveness.

For example, Helsinki has a lot of vacant office space that cannot be converted to residential use because of planning restrictions. Even if only a third of this space were converted by 2030, it could generate approximately €255 million in rental income a year. Denmark's national economy could also save close to €700 million from not having to build new housing [173].

Since 2016, Finland has continued to refine its targets and created a new plan The Critical Move: Finland's Road Map to the Circular Economy 2.0 [174]. It has also developed a guide for other nations to refer to in developing their own strategies [175]. In the new plan, four strategic cross-sectoral goals are defined:

1. Renew the foundations of competitiveness and vitality
2. Transfer to low-carbon energy
3. Regard natural resources as scarcities
4. Everyday decisions work as a driving force for change

6. France

France introduced regulations called RE2020, which addresses operational and embodied carbon emissions for housing projects and office buildings. To reduce embodied emissions, designers must produce an LCA and use manufacturers' EPD information to declare embodied carbon of the materials as part of a building permit application. The INIES[4] database contains almost 4,000 EPDs for construction products available in France. The regulation establishes a base threshold for carbon intensity, which is reduced every three years from 2022 to 2031 [176] [122].

7. Germany

Germany's Circular Economy Act (*Kreislaufwirtschaftsgesetz*) promotes conservation of natural resources and improved waste management through reuse and recycling [177]. Through aggressive recycling efforts and a ban on putting biodegradable and organic waste into landfills, Germany has become a leader in recycling with a municipal recycling rate of 71.1% in 2021 [178]. The waste management system also relies on incineration to limit the use of landfills, with the energy recovered contributing to electricity generation. Other CBE related efforts include the following.

- DGNB Certification is an advanced sustainable building certification system for the planning and assessment of buildings, interiors and districts [179]. DGNB has many measures that contribute to CBE. The DGNB toolbox includes life cycle assessment, and assistance with selecting construction products with regard to their composition and origin, as well as the ease of recovery and recycling [180].
- The BMWK has set up a funding program to help with the roll-out of industrial prefabrication solutions for building renovations [181]. Financial assistance is available in three areas – funding to conduct feasibility studies, support for pilot projects, and grants to build production facilities.

4 The French national reference database for environmental and health data on construction products and equipment

8. Italy

Reference Practices in Italy are a collection of published best practices that remain valid for a period of no more than five years, at which point they are either transformed into a regulatory document or withdrawn. Reference Practice UNI/PdR 75: 2020 *Selective deconstruction—Methodology for selective deconstruction and waste recovery from a circular economy perspective* includes the following aspects [182]:

- Supports the planning and realization of buildings designed for disassembly for the recovery of materials and components
- Defines methods for waste management to overcome challenges of current construction waste tracking systems
- Considers both existing buildings that are to be refurbished or demolished, and new construction
- For demolition, it includes a pre-demolition audit and a database of materials
- For new construction, it includes design and a list of materials

9. Slovenia

Slovenia bases its Circular Economy Roadmap on a three-sided "Circular Triangle" [183]. It unites the Circular Economy (business models), Circular Change (government policies) and Circular Culture (citizens) as three interdependent elements that are at the core of systemic change.

They have set a goal to increase material productivity from 1.79 purchasing power parity (PPP)/kg in 2015, to 3.5 PPP/kg in 2030 to reduce dependence on raw material imports. They have identified an opportunity with public procurement to apply circular methods to stimulate the economy and the circular transition with pilot projects. Each side of the triangle must consider the other two and the interdependence of circular transition. The three sides of the triangle are as follows:

- "Circular Economy" is focused on businesses, with actions to transition that include design factors, transitioning from products to services, identifying waste products that can be raw materials for other businesses, and converting waste energy to an input.
- "Circular Change" reflects government policy and interdependence between sectors and identifies financial, awareness and support policies that reflect the values of the circular economy.
- "Circular Culture" identifies that citizens' choices play a vital role. Sharing goods and transitioning towards products as a service requires choices in everyday activities.

The Slovenian government is participating in the Deep Demonstrations of Circular, Regenerative Economies to transform systems across sectors [184]. It defines interventions to enable transformation as:

- Enhancing capacity building in systems innovation and circularity thinking
- Developing a Policy Lab to enable policy experimentation
- Supporting research and academic institutions in the transition to a circular economy
- Developing a funding strategy and investment plan

In construction, they are exploring the use of wood for taller buildings and buildings as material banks, along with policies that consider circularity as part of procurement.

10. Spain

Spain has launched the Spanish Strategy for the Circular Economy (España Circular 2030), which focuses on maintaining the value of products and reducing waste. Construction is one of six sectors identified in the strategy because, while it contributed 6.5% of Spanish GDP in 2018, it consumed 40% of resources, generated 40% of waste, and emitted 35% of greenhouse gases [185]. The target is to realize an overall 15% reduction in waste generation and a 40% reduction in natural resource consumption by 2030, compared to 2010 levels. The strategy defines a series of three-year plans that define a roadmap to meet the target.

11. Switzerland

Switzerland has one of the longest and most successful track records for carbon-based building standards, which are proving to deliver measurably low-carbon buildings. The MINERGIE® energy and carbon rating standard not only sets out detailed criteria for "in-use" performance for heating, hot water, ventilation and air conditioning [186], it also includes a life-cycle-based regulatory framework and practical infrastructure to calculate and regulate embodied energy associated with building operations, materials and construction practices. This consists of a coordinated suite as follows:

- Standards, guidelines and targets (SIA 2040 Energy Efficiency Path, SIA 2032 Embodied Energy of Buildings, the Minergie-ECO building rating standard, 2000-Watt Society, etc.) which establish a framework for the following two impact categories:
  - Global warming potential measured in kg CO_2-eq/m^2/year
  - Non-renewable primary energy measured in kWh/m^2/year
- Software and tools (Therm, Lesosai, etc.)
- Datasets and lifecycle inventories (Ecoinvent)

MINERGIE also requires that any additional costs of achieving the standard must not exceed 10% of the building costs over a comparable code-compliant building.

The impetus for a holistic energy/GHG impact-based policy has been the adoption of the 2000-Watt Society vision, which aims to achieve a balance between industrialized and developing countries, making it possible for all nations to achieve a good standard of living. The goal of the 2000-Watt Society is to achieve a sustained primary energy use of 2,000 watts per person, and annual emissions of no more than one tonne of CO_2 equivalent per person by 2050. Under the 2000-Watt Society, a building's energy and carbon footprint includes the materials and processes associated with construction, retrofits, maintenance and operation, as well as deconstruction at the end of its life [187].

12. United Kingdom

- The **UK Building Safety Act** was created to oversee the safety and performance of all buildings, with a special focus on high-rise buildings [135]. It promotes competence and organizational capability within the sector, including for building officials and tradespeople. As part of this new regulation, the UK has created a National Regulator for Construction Products, which is primarily responsible for making sure all construction products on the UK market are safe for their intended use [136]. The act requires residential building owners to register their buildings and to provide a description of what the building is made of to demonstrate compliance with the safety standards. The outcome will be a significant new dataset on the composition and condition of building structures, which will be an important basis for further policy development aimed at extending the lives of existing buildings.

- The **UK Green Building Council** published the **"Circular Economy How-to Guide: Reusing products and materials in built assets."** There have been relatively few practical and accessible guides published for designers and builders on CBE. This document sets out in straight-forward language the steps to creating a product and material inventory to support reuse within an existing project. It also explains how to reuse products and materials from another project, and how to send products and materials offsite for reuse on another project [188].
- **BRE Design for Deconstruction (DfD)** Methodology was developed to evaluate the design for deconstruction (DfD) potential of buildings. The methodology helps designers determine where there might be potential to maximize deconstruction opportunities, and thereby gauge the "deconstructability" of their designs. [189]. The methodology results in an overall score that is aggregated from evaluations for materials and component choices, types of connections used, the accessibility of components and connections, the deconstruction process, and the level of project information relating to deconstruction [189].
- The **ReSOLVE Framework**, developed by The Ellen MacArthur Foundation in partnership with Arup, has set out six actions that can be applied to the built environment as a way to guide the transition to a circular economy. They are Regenerate, Share, Optimize, Loop, Virtualize and Exchange [190].
- **Material Circularity Indicator (MCI)** is a tool to evaluate materials for their potential to be reused or recycled during the design phase of a building project. Developed by the Ellen MacArthur Foundation, the MCI helps companies to identify and extract additional circular value from their products and materials, while mitigating potential risks from material price volatility and material supply [191].
- The **Whole life carbon assessment (WLCA)** for the built environment is a standard developed by the Royal Institution of Chartered Surveyors (RICS) based on the European standard EN 15978 Sustainability of construction works. Assessment of environmental performance of buildings [192]. It sets out the technical methodology for assessing carbon emissions for each of the standard modules commonly used in life cycle assessment – from extraction of raw materials and manufacturing, construction and operation to recovery and disposal at end of life. It specifies timing of when assessments should be made, what is involved and guidance for quantifying carbon.
- **Contaminated Land: Applications in Real Environments (CL:AIRE)** is a UK-based not-for-profit charged with sustainable land reuse [193]. CL:AIRE has a register, along with map of materials donors, receivers and treatment facilities, that supports a nationally developed code of practice (including End of Waste criteria) that deals with soil stripping during construction, what to do with soils that are to be removed, and how to determine potential reuse applications [194].
- **UK Product Platform Rulebook** is a comprehensive package for construction projects, involving components, processes, knowledge and relationships. The Rulebook is an open-access guide that can support stakeholders in enhancing capabilities for product platform development. Product platforms offer a streamlined approach for managing project commonality and variability. The goal is to combine manufacturing efficiency with customization for client needs. The UK government aims to create a new construction manufacturing market using product platforms, providing a steady demand for industry investment and stable employment. Of significance to CBE is the potential for product platforms to create resilient supply chains that are decoupled from the project design, allowing scope for repetition, thereby leveraging the efficiency of manufacturing. This will dramatically reduce errors and waste. However, the adoption of platforms in North America is still limited.

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