

# CIRCULAR ECONOMY & THE BUILT ENVIRONMENT SECTOR IN CANADA

FINAL REPORT

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In Partnership with:



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## Glossary & Acronyms

**Adaptive reuse** - Rather than demolishing functionally obsolete buildings, adaptive reuse encourages the retention and repurposing of building components -such as the structural elements - for the new structure.

**Building Information Modelling (BIM)** - is an open-source digital 3D modelling tool that communicates information relating to all phases of an asset's life cycle. It can be used by designers, contractors and building operators to plan, design, construct, and manage buildings and infrastructure.

**Built environment** - comprises the man-made elements of our surroundings such as buildings as well as infrastructure including transportation, telecommunications, energy, water, and waste systems.

**Building flexibility** - Flexibility and accessibility allow for spaces to be adapted to the needs of a building's occupants, prevent demolition and contribute to preserve materials and reduce waste.

**Circular economy** - aims to keep materials, components, products and assets at their highest utility and value at all times. In contrast to the 'take, make, use, dispose' linear model of production and consumption, material goods are designed and produced to be more durable, and to be repaired, refurbished, disassembled and reused in perpetuity - thereby minimising resource use, eliminating waste and reducing pollution.

**Circular inputs** – Use of renewable energy, bio-based, or potentially completely recyclable materials.

**Closed loop cycles** - are those in which nearly all materials remain within the system, and are recovered and used by other organisms or processes rather than being lost as waste.

**CRD waste** – Construction, renovation, and demolition waste

**Design for Disassembly and Adaptability (DfD /A)** - Designing for disassembly is an eco-design strategy that extends the useful life cycle of buildings and their components by enabling the building to be more easily upgraded, maintained and modified. End of life disassembly enables the collection and reuse of building materials and components.

**Materials passports** - provide information on the value of materials and products, their reusable or toxic content and the ease with which they can be disassembled. Information is collected in a database to facilitate the recovery, recycling and/or re-use of materials.

**Offsite Modular Construction (OMC)** - Offsite Modular Construction (OMC) is a subset of lean manufacturing that allows both mass customization and process standardization, thus reducing material waste and build time compared to traditional onsite construction techniques.

**Product use extension** – Prolongation of product (or asset) use through repair, reprocessing, upgrading, and resale.

**Product as a service** – Offer of a product (or asset) use with retention of the product at the producer to increase resource productivity (e.g., leasing models).

**Sharing platforms** – Increased usage rates of assets through collaborative models for sharing, access, and/or ownership.

**Resource recovery** – recovery of usable resources or energy from waste or by-products at end of life.

**Reverse logistics** - is a closed loop approach that uses remanufacturing, refurbishment, repair, reuse or recycling to recover and process materials and products after the point of consumption.

|  |           |
|--|-----------|
| <b>1. Executive Summary</b>  | <b>1</b>  |
| <b>2. Introduction &amp; Background</b>                                  | <b>6</b>  |
| <b>2. Circular Economy &amp; the Built Environment</b>                   | <b>8</b>  |
| What is the Circular Economy?  | 8         |
| Circularity Applied to the Built Environment                             | 9         |
| Global Market Trends in Circular Built Environment                       | 11        |
| <b>3. Circular Built Environment: The Canadian Context</b>               | <b>14</b> |
| Circular Building Design   | 15        |
| Circular Building Materials & Manufacturing                              | 17        |
| Construction   | 21        |
| Building Use & Operations  | 23        |
| Deconstruction & Resource Recovery                                       | 24        |
| Reverse Logistics  | 26        |
| The Enabling Ecosystem   | 26        |
| <b>4. Deep Dive on Design for Disassembly &amp; Adaptability</b>         | <b>32</b> |
| Design for Disassembly and Adaptability in Canada                        | 36        |
| Assessment of the ISO Standard for DfD/A                                 | 38        |
| Benefits and Opportunities for DfD/A Practices in Canada                 | 45        |
| <b>5. Key Barriers &amp; Enablers for the Circular Built Environment</b> | <b>47</b> |
| Barriers   | 47        |
| Enablers   | 48        |
| <b>6. Accelerating the Circular Built Environment in Canada</b>          | <b>52</b> |
| Summary of Recommendations   | 52        |
| <b>Appendix A: List of Organizations Consulted</b>                       | <b>54</b> |
| <b>Appendix B: Case Studies</b>  | <b>55</b> |

## 1. Executive Summary

In Canada, construction is one of the most important economic sectors, generating \$141 billion in GDP in 2020. Simultaneously, Canada’s construction sector generates one-third of total solid waste in Canada (equal to more than 4 million tonnes of waste per year). Much of the value from these waste materials and resources are currently being lost from Canada's economy at end of life.

### Circular Economy & the Built Environment

The circular economy has come to the forefront as a solution for moving away from today's linear 'take-make-waste' economy. Applying circular economy principles to Canada’s construction and real estate sector could generate multiple benefits, including reducing waste and greenhouse gas (GHG) emissions; improving the resiliency of supply chains; creating a new economic, investment, and employment opportunities; enhancing natural ecosystems and urban green spaces; and providing greater equity and related social benefits.

Circular strategies and approaches applied to the built environment (as shown in **Table ES1**) promote renewable inputs, help keep materials and resources in use for as long as possible, and support resource recovery at end of life in order to recapture the value of the materials that is currently being lost.

**Table ES1: Circular economy strategies, approaches, and best practices for the built environment and construction sector.**

| Strategies                               | Approaches           | Best practices  |
|--|----------------------|---|
| Circular Inputs & Resource Recovery      | Circular inputs      | <ul style="list-style-type: none"> <li>Renewable energy for powering and heating buildings</li> <li>Renewable materials (e.g., mass timber)</li> <li>Recycled content in products (e.g., concrete)</li> </ul> |
|  | Eco-design           | <ul style="list-style-type: none"> <li>Design for disassembly and adaptability (DfD/A)</li> <li>Design for durability</li> </ul>  |
|  | Process optimization | <ul style="list-style-type: none"> <li>Building Information Modelling (BIM)</li> <li>Modular construction</li> <li>Just-in-time construction</li> </ul>   |
|  | Resource recovery    | <ul style="list-style-type: none"> <li>Deconstruction</li> <li>Material recovery</li> <li>Reverse logistics</li> </ul>  |
| Sharing Platforms & Product As a Service | Sharing economy      | <ul style="list-style-type: none"> <li>Labour sharing</li> <li>Asset sharing</li> </ul>   |
|  | Leasing models       | <ul style="list-style-type: none"> <li>Asset leasing models</li> <li>Equipment renting</li> </ul>   |

| Strategies                                      | Approaches             | Best practices  |
|---|------------------------|---|
| Extending Product Life / Product Use Extensions | Maintenance and repair | <ul style="list-style-type: none"> <li>Proactive maintenance (asset management)</li> <li>Secondary product markets</li> </ul> |
|   | Refurbishing           | <ul style="list-style-type: none"> <li>Flexible building cores (adaptability)</li> <li>Adaptive reuse</li> </ul>              |

Source: Adapted by the Delphi Group from Circular Economy Global Sector Best Practices Series on Construction, Smart Prosperity Institute (February 2021)

## Circularity in Canada's Built Environment Sector

Applying circular building practices in Canada is not new. Construction and demolition waste management efforts, life cycle analysis (LCA) approaches, and material and process innovation practices and policies (including policies that support wood-first approaches) have been adopted by industry and/or governments in many provinces. These efforts have been leading to greater material circulation and lower GHG emissions in the built environment sector.

That said, the built environment in Canada remains one of the largest consumers of raw materials and energy and is also the largest contributor to the waste stream by weight. Efforts to date have largely focused on waste diversion and, to some degree, resource recovery. Very little has been focused on more upstream circular strategies, such as circular inputs and product as a service.

There are a range of stakeholder groups that touch the built environment at various points in the building life cycle that are beginning to drive more circular practices, albeit to varying degrees of adoption. These key stakeholder groups include:

- Architects, designers, and engineers
- Product and equipment manufacturers and suppliers (including modular construction firms)
- Builders and trades
- Property owners, developers, and managers
- Deconstruction firms
- Waste haulers and recyclers

In Canada, circular economy practices and business models are being applied by the leaders in these key stakeholder groups across the various stages of a building's life cycle, as summarized in **Table ES2**. Broader actors, including governments and regulators (at all levels), educational institutions, research agencies and academic thinktanks, industry associations and non-profits, and standards bodies, are important catalysts and supporters of the circular built environment in Canada and make up the enabling ecosystem.

**Table ES2: Current state of circular economy in Canada’s built environment sector, by building life cycle stage.**

| Circular Building Life Cycle Stage          | Current State  |
|---|--|
| Circular Building Design                    | Fundamental to the circular built environment is the need to design well from the beginning, eliminating waste, harmful chemicals, and pollution, while allowing for flexible building use, adaptive reuse, long-term durability, and optimized material recovery. Leading Canadian design and architecture firms are incorporating circularity principles into their projects with the future in mind.  |
| Circular Building Materials & Manufacturing | Canadian industry players have been stepping up in recent years with respect to material innovation and circular manufacturing practices, including off-site and modular construction. Renewable products (such as mass timber) and other innovative materials and products with recycled content (such as asphalt, concrete, steel, carpets, plastics, window frames, and other products) support lower-carbon, circular construction.  |
| Construction                                | The construction phase of a circular building’s life cycle is largely focused on waste prevention onsite, diversion from landfill, and resource management. Leading firms in Canada are focused on onsite waste diversion and management practices during the construction and renovation stages of a building.  |
| Building Use & Operations                   | Enabling circular building use and operations requires embracing several circular principles and strategies, including design for durability, design for adaptability, adaptive reuse, as well as extending a building or infrastructure asset’s life cycle and usage through regular maintenance, renovation, and repair to ensure they can withstand the test of time. Building owners and property managers in Canada are beginning to develop innovative leasing approaches and models that enable more flexible use of real estate but opportunities to go further exist. |
| Deconstruction & Resource Recovery          | Deconstruction is an emerging trend in Canada as firms shift away from the traditional demolition of buildings to recover valuable materials and resources from buildings at end of life and look at secondary markets for these materials, with a handful of industry leaders at the forefront. Currently, the market demand for recovered resources varies depending on the geographic location in Canada and the material type, although in general remains relatively low.   |
| Reverse Logistics                           | Managing the return and recovery of products and materials from businesses, deconstruction sites, and material recovery facilities back into the value chain through reverse logistics is a key tenet of the circular economy that enables products materials to be recycled, sorted, processed, reused, and remanufactured. Existing waste haulers and recyclers in Canada are well-positioned to enable secondary markets and support more reverse logistics should market demand for recovered materials grow.  |

## Deep Dive on Design for Disassembly & Adaptability

Although DfD/A guidelines were developed by CSA Group in Canada starting back in 2002 and have formed the precursor for the ISO Standard released in 2020, there has been minimal adoption of this practice in Canada over the last two decades, with the exception of a handful of projects.

While theoretical awareness exists with Canada's design community, the actual adoption and demand from building owners and developers remain low. Recent growth in offsite and modular construction in Alberta, B.C., Quebec, and Ontario, as well as green roof deployment in locations such as Vancouver and Toronto that include simple layers to reduce contamination of fusion of materials, has required DfD/A thinking.

However, the industry has yet to respond in terms of developing construction best practices, investing in material and component innovation, or supportive policy and educational / training resources at a broad scale given the current lack of demand from industry.

## Key Barriers & Enablers for the Circular Built Environment

There are multiple structural and systemic barriers that must be addressed to improve the business case for investing in circular strategies in Canada's construction, real estate, and built environment sector, including:

- Cost challenges of transition to a more circular built environment versus the linear status quo
- Lack of awareness / information and standardized definitions
- Fragmentation across construction industries and sectors
- Misaligned policies, incentives, and market signals
- Infrastructure gaps and supply chain issues

Key enablers that can support the circular built environment transition in Canada include:

- Embracing circularity in the design stage
- Education and awareness building
- Supporting cross-sector collaboration
- Developing supportive policy, incentives, regulation, standards, procurement practices
- Supporting business model, process, supply chain, and technology innovation

## Accelerating the Circular Built Environment in Canada

There is a significant economic opportunity for Canada to rethink how buildings are designed, managed, maintained, as well as how construction materials and resources can be more effectively recovered and brought back into the supply chain at end of life to eliminate waste in all of its forms. This, in turn, has the potential to provide additional economic, social, and environment benefits (including GHG emission reductions) – as well as support economic recovery efforts in Canada. Recommendations for advancing circularity in Canada's built environment sector are summarized in **Figure ES1** below.



|  |  |
|--|--|
| <b>Embrace Circularity in Design Stage</b> | <ul style="list-style-type: none"> <li>• Use certification programs to incentivize circular design best practices (e.g., DfD/A, durability, deconstruction) through a point accreditation system (E.g., LEED)</li> </ul>   |
| <b>Education and Awareness</b>             | <ul style="list-style-type: none"> <li>• Demonstrate the business case for the circular built environment through case studies, resource toolkits for industry, and knowledge sharing</li> </ul>   |
| <b>Cross Sector Collaboration</b>          | <ul style="list-style-type: none"> <li>• Enhance relationships between building suppliers and architects to increase shared responsibilities over material use</li> </ul>  |
| <b>Support Innovation</b>                  | <ul style="list-style-type: none"> <li>• Support adoption of digital innovation in areas of BIM, building as material banks, and material passports</li> <li>• Develop an innovation fund and grants to support circular business models and building products and materials.</li> </ul> |
| <b>Government Processes</b>                | <ul style="list-style-type: none"> <li>• Develop long-term policies that encourage the scaling of circular solutions, including through procurement practices, to drive the market demand.</li> <li>• Transition to more performance-based practices and standards</li> </ul>            |

**Figure ES1: Recommendations for accelerating circularity in Canada’s construction and real estate sector.**

## 2. Introduction & Background

More than 100 billion tons (U.S.) of raw materials globally are transformed into new products every year. At the same time, only 8.6% of the planet's materials and resources used for these products are cycled back into the economy at the end of their use.<sup>1</sup> Two-thirds of these materials end up dispersed into the environment as unrecoverable 'waste' or pollution – garbage into landfills, plastics into the oceans, carbon dioxide (the 'waste' by-product from burning fossil fuels) into the atmosphere. This linear 'take-make-waste' economy – where resources are extracted, turned into something of use, and then discarded – puts significant pressure on the Earth's ecosystems and exacerbates social inequalities as a result. It also presents enormous lost economic opportunities from failing to recapture the value of these material resources.

The circular economy model allows the full value from these currently 'lost' materials and resources to be maximized throughout their lifetimes by restructuring business models and supply chains, as well as recapturing these materials and resources at end of use. Fundamentally, however, the circular economy is about designing out the concept of waste from products and services altogether.

In Canada, construction is one of the most important economic sectors, generating \$141 billion in GDP in 2020. Simultaneously, Canada's construction sector generates one-third of total solid waste in Canada (equal to more than 4 million tonnes of waste per year).<sup>2</sup> Much of the value from these waste materials and resources are currently being lost from Canada's economy at end of life.

Applying circular economy principles to Canada's construction and real estate sector could generate multiple benefits, including reducing waste and greenhouse gas (GHG) emissions; improving the resiliency of supply chains; creating a new economic, investment, and employment opportunities; enhancing natural ecosystems and urban green spaces; and providing greater equity and related social benefits.

As other industries in Canada and globally, such as plastics, look to the circular economy model to address the waste and pollution crisis while promoting long-term sustainability and economic resiliency, the construction sector can look to do the same.

### About this Study

To better understand the current and potential future opportunities and challenges related to advancing a more circular built environment in Canada, this study provides an initial assessment of the current state of the circular built environment landscape and market readiness in Canada in line with global trends and circular economy principles and practices.

This study, carried out by The Delphi Group in collaboration with Scius Advisory, was completed in March 2021 on behalf of Forestry Innovation Investment Ltd. (FII) in British Columbia and Natural Resources Canada (NRCan) as the co-sponsors for the research.

<sup>1</sup> See: <https://www.circularity-gap.world/2020>

<sup>2</sup> Zahra S H Teshnizi, *Opportunities and Regulatory Barrier for the Reuse of Salvaged Dimensional Lumber from Pre-1940s Houses*.

The work identifies a broad range of current efforts across Canada and undertakes a deeper dive on design for disassembly and adaptability (DfD/A) best practices, including an analysis of the ISO Standard 20887:2020 (i.e., design for disassembly and adaptability) in line with current Canadian industry practice and market readiness.

Research for the study also included fifteen key informant interviews from across Canada, building on two dozen stakeholder interviews undertaken over the previous six months by Delphi on the topic of circularity in Canada's built environment sector. These Interviews helped identify the current state of the market in Canada, existing barriers and enablers, and supply chain gaps.

This report brings together the insights from the research, summarized in the following sections:

1. **Section 2: Circular Economy and the Built Environment** – provides an initial high-level overview of the circular economy in the context of the built environment.
2. **Section 3: Circular Built Environment in the Canadian Context Economy** – provides a summary of circular strategies being applied across a building's life cycle, including circular building design, building material innovation and manufacturing, construction, building use and operations, and deconstruction and resource recovery. It also includes a high-level overview of the enabling ecosystem landscape in Canada.
3. **Section 4: Deep Dive on Design for Disassembly and Adaptability** – provides more in-depth discussion on DfD/A, including an analysis of the ISO Standard 20887:2020 and CSA Group's Guideline CSAZ782-06 as they relate to circular design and construction principles and best practice approaches.
4. **Section 5: Key Barriers and Enablers** – provides an overview of some of the key barriers, challenges, and enablers for a more circular built environment in Canada.
5. **Section 6: Accelerating the Circular Built Environment in Canada** – provides a set of recommendations and considerations for future research and efforts to improve the business case for the circular built environment in Canada.

An appendix also includes three case studies showcasing Canadian examples of circular economy strategies being applied within the built environment sector.

Outputs from this study are intended to support future research, discussions, and engagement efforts, including plans to host a broader stakeholder workshop on advancing the circular built environment in Canada in late May 2021, future activities within the Circular Economy Solutions Series Built Environment Track, and inform programming related to the *World Circular Economy Forum*, being co-hosted by the Government of Canada and the Finnish Innovation Fund Sitra in September 2021.

## 2. Circular Economy & the Built Environment

In an unprecedented response to the COVID-19 crisis, trillions in economic stimulus are being unveiled worldwide. In the next stage of their recovery plans, governments will have to decide where recovery investment will be allocated. As an instrument to decouple economic growth from resource use and environmental impact, the circular economy opens up the way for a resilient recovery and the next wave of economic prosperity. By fostering innovation and competitiveness, reducing resource dependency and environmental impact, and creating new jobs, the circular economy presents a promising way forward.

The pandemic has laid bare the entrenched shortcomings of the built environment sector, underscoring the prevalence of low-quality buildings, issues around the affordability of decent housing, and the lack of flexibility and adaptability of our current real estate and building stock in Canada. These issues, coupled with the growing concern around the industry's highly wasteful and resource-intensive nature, present a strong impetus for the sector's transformation.<sup>3</sup>

### What is the Circular Economy?

The circular economy has come to the forefront as a solution for moving away from today's linear 'take-make-waste' society, addressing growing environmental and social challenges and risks. The circular economy model aims to:

- (1) Design out waste and pollution through upstream interventions;
- (2) Keep products and materials in use at the highest value possible throughout their lifetimes; and
- (3) Regenerate natural systems.

It provides opportunities to go further in terms of greenhouse gas (GHG) emission reductions by rethinking how resources are used throughout their lifetime and recaptured at end of life, how products can be designed for durability and repairability, and how new services and technologies are leveraged to maximize the usage of assets and 'dematerialize' the need for certain products.

The circular economy model presents new economic and employment opportunities while simultaneously creating more resilient communities, businesses, and supply chains, improving competitiveness and affordability, spurring innovation, and attracting new investment that can support economic recovery.

<sup>3</sup> Ellen MacArthur Foundation, '10 Circular Investment Opportunities for a Low-Carbon and Prosperous Recovery' <<https://delphigroup.sharepoint.com/sites/Projects/Shared Documents/Active Projects/Forest Innovation Investment DfDA/Research/Desktop Research/Secondary Reports/EMF The-Built-Environment.pdf?CT=1616950014854&OR=ItemsView>> [accessed 28 March 2021].

## Circularity Applied to the Built Environment

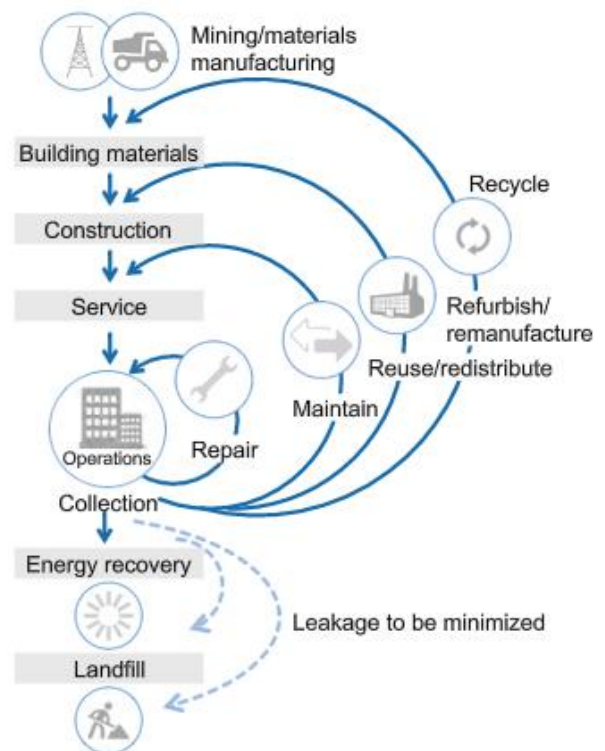
Circular economy principles can be applied to the built environment sector, including construction and real estate value chains, to address current waste issues, recapture lost value, and to realize new economic, social, and environmental benefits. Waste (or lost value) within the construction and built environment sector can be considered across four realms:

- **Wasted resources** (i.e., the use of materials and energy that cannot be continually regenerated);
- **Wasted or underutilized assets** (e.g., buildings that sit empty);
- **Wasted life cycles** (i.e., the premature end of use of buildings given lack of repair, maintenance and/or reuse and adaptability); and
- **Wasted embedded value** (i.e., materials, components, and energy from buildings not recovered at the time of disposal or demolition through deconstruction and material recovery).

Applying circular economy strategies to the construction value chain (as illustrated in Figure 1) through innovative design, maintenance, adaptive reuse, refurbishment, repair, recovery, and recycling, can help to recapture some of this value.

There are five well-established circular business strategies (which take a life cycle approach to consider products and services) that look to capture the full value of resources and eliminate the concept of 'waste'. These are:

1. **Circular Inputs** – Use of renewable energy, bio-based products, or potentially completely recyclable materials.
2. **Product as a Service** – Offer of a product (or asset) use with retention of the product at the producer to increase resource productivity (e.g., leasing models).
3. **Sharing Platforms** – Increased usage rates of assets through collaborative models for sharing, access, and/or ownership.
4. **Product / Asset Use Extension** – Prolongation of product or asset use through repair, maintenance, upgrading, and resale.
5. **Resource Recovery** – Recovery of usable resources or energy from waste or by-products at end of life.



Source: Ellen MacArthur Foundation; World Economic Forum; The Boston Consulting Group

Figure 1: Circular economy in the construction value chain.

The built environment has broad opportunities for increasing circularity (see Table 1). Circular built environment practices can be used to inform strategies, practices, and business models that help keep materials and resources in use for as long as possible and recover their value at end of life. The opportunities span the entirety of both the supply chain and building life cycle, from buildings and material design, to a building’s operations and maintenance, and the end-of-life treatment of buildings and infrastructure.

**Table 1: Circular economy strategies, approaches, and best practices for the built environment and construction sector.**

| Strategies                                      | Approaches              | Best practices  |
|---|-------------------------|---|
| Circular Inputs & Resource Recovery             | Circular Inputs         | <ul style="list-style-type: none"> <li>• Renewable energy for powering and heating buildings</li> <li>• Renewable materials (e.g., mass timber)</li> <li>• Recycled content in products (e.g., concrete)</li> </ul> |
|   | Eco-design              | <ul style="list-style-type: none"> <li>• Design for disassembly and adaptability (DfD/A)</li> <li>• Design for durability</li> </ul>  |
|   | Process optimization    | <ul style="list-style-type: none"> <li>• Building Information Modelling (BIM)</li> <li>• Modular construction</li> <li>• Just-in-time construction</li> </ul>   |
|   | Responsible consumption | <ul style="list-style-type: none"> <li>• Deconstruction</li> <li>• Material recovery</li> <li>• Reverse logistics</li> </ul>  |
| Sharing Platforms & Product As a Service        | Sharing economy         | <ul style="list-style-type: none"> <li>• Labour sharing</li> <li>• Asset sharing</li> </ul>   |
|   | Leasing models          | <ul style="list-style-type: none"> <li>• Asset leasing models</li> <li>• Equipment renting</li> </ul>   |
| Extending Product Life / Product Use Extensions | Maintenance and repair  | <ul style="list-style-type: none"> <li>• Proactive maintenance (asset management)</li> <li>• Secondary product markets</li> </ul>   |
|   | Refurbishing            | <ul style="list-style-type: none"> <li>• Flexible building cores (adaptability)</li> <li>• Adaptive reuse</li> </ul>  |

Source: Adapted by the Delphi Group from Circular Economy Global Sector Best Practices Series on Construction, Smart Prosperity Institute (February 2021)<sup>4</sup>

<sup>4</sup> See: [https://institute.smartprosperity.ca/sites/default/files/Construction\\_Best%20Practices.pdf](https://institute.smartprosperity.ca/sites/default/files/Construction_Best%20Practices.pdf)

## Global Market Trends in Circular Built Environment

The most considerable environmental impact from the built environment sector comes as a result of lost resources and materials. The greatest impact associated with the construction sector is the ongoing need for virgin resource extraction. The significant amount of energy and resources required to produce new building materials—extraction, transportation, and manufacturing—also include GHG emissions associated with each stage of making new building materials.

According to a 2012 U.N. Global Compact and Accenture report<sup>5</sup> approximately half of all extracted raw resources are used to make construction materials with up to 40% of urban solid waste is construction and demolition waste<sup>6</sup> and 11% of global energy related GHG emissions can be attributed to the construction industry.<sup>7</sup> By 2025, it is expected that 2.2 billion tonnes of construction waste will be generated around the world; nearly double the amount of waste in 2018.<sup>8</sup>

The World Economic Forum and Boston Consulting Group note that the construction industry is shaped by two key megatrends that transcend the industry:

- First, 30% of GHG emissions globally are attributable to buildings, with governments having committed to addressing these emissions through net zero building and low-carbon retrofit pathways over the coming decades.
- Second, rapid urbanization is increasing global demand for resources and materials, as well as for affordable housing and infrastructure, placing pressures on the construction industry and its supply chain.

These trends necessitate a rapid transition to more sustainable business practices across the entire sector and will require innovation at new scales within a sector that has historically been a slow adopter of innovation. The circular economy can provide economically feasible, resource and GHG efficient solutions for addressing many of the challenges faced by the construction and real estate sectors, including as it relates to climate action, innovation, and broader sustainability.

Over the last two decades, green building practices have come to the forefront, with standards and certifications that provide a framework for sustainable practices in design, construction, and building management. Part of this has included a focus on reducing building waste, as well as adaptive reuse, including an increasing focus on end-of-life treatment for materials. This is beginning to drive considerations for alternative business models that integrate design for disassembly and adaptability thinking, modular construction, durability, and deconstruction.

<sup>5</sup> 'Options for Waste Reduction and Diversion - Construction Canada' <<https://www.constructioncanada.net/options-for-waste-reduction-and-diversion/>> [accessed 26 March 2021].

<sup>6</sup> *MAKING BUILDINGS WITH NEW TECHNIQUES THAT ELIMINATE WASTE AND SUPPORT MATERIAL CYCLES CIRCULAR ECONOMY IN CITIES* <[www.ellenmacarthurfoundation.org/our-work/activities/circular-economy-in-cities](http://www.ellenmacarthurfoundation.org/our-work/activities/circular-economy-in-cities)> [accessed 29 March 2021].

<sup>7</sup> *MAKING BUILDINGS WITH NEW TECHNIQUES THAT ELIMINATE WASTE AND SUPPORT MATERIAL CYCLES CIRCULAR ECONOMY IN CITIES*.

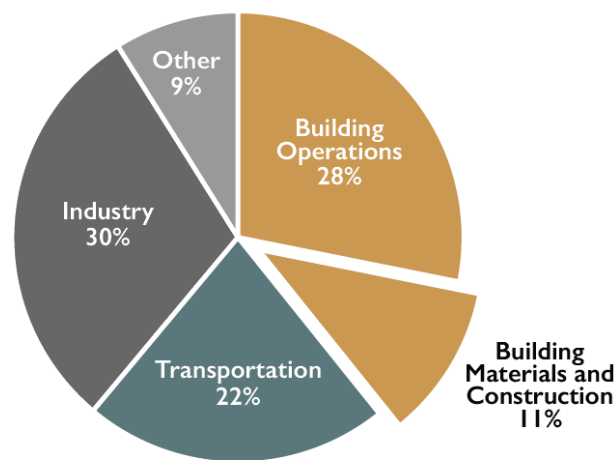
<sup>8</sup> Ellen Macarthur Foundation.

The use of mass timber as a sustainable building material has grown dramatically in Europe and Canada. Mass timber can effectively sequester carbon when the full life cycle of wood is optimized. Across the globe, more research is taking place to better understand the carbon sequestration potential of mass timber and other materials. In addition, the life cycle and embodied carbon of products such as mass timber and its production is a work in progress, as well as developing a better understanding for how long wood remains in use.<sup>9</sup> In short, sustainable forestry management is a growing field coupled with an optimized mass timber life cycle in the building sector which poses unique opportunities for the circular built environment.

The growing trends in digital and disruptive technologies are also enabling the circular economy in the built environment through improved productivity, efficiency, process improvements, and enhanced collaboration. Construction technology (or ‘contech’) refers to the collection of innovative tools used during the construction phase of a project – including machinery, modifications, and software – that enable greater productivity, reduce material waste, and result in higher-performance buildings.<sup>10</sup> Examples include building information modeling (BIM) software, virtual reality (VR), drone technologies, and new digital tools that improve material flow tracking.

Addressing climate change through building energy use has also become a critical focus for many, with a more recent extension to include the embodied carbon contained within products and materials by taking a life cycle accounting approach to measuring GHG emissions. Currently, buildings are mainly viewed as contributing to climate change via operational emissions. However, as considerations for consumption-based GHG emissions and life cycle accounting grow, embodied carbon impacts become more important (i.e., to include accounting for the total GHG emission impacts of a building).

Jurisdictions are starting to adopt regulations to address the embodied carbon within buildings and this is resulting in a greater focus on the impacts of materials over their life cycle.<sup>11</sup> Annually, embodied carbon is responsible for 11% of global GHG emissions and 28% of global building sector emissions (see Figure 2).<sup>12</sup> It is estimated that embodied carbon will be responsible for almost half of total new construction emissions between now and 2050.<sup>13</sup> By the year 2050, accounting for all the new construction in that 30-year span, embodied carbon emissions and operational carbon emissions will be roughly equivalent.



Source: © 2018 2030, Inc. / Architecture 2030. All Rights Reserved. Data Sources: UN Environment Global Status Report 2017; EIA International Energy Outlook 2017

Figure 2: Global GHG emissions by sector.

<sup>9</sup> ‘As Mass Timber Takes Off, How Green Is This New Building Material?’ - Yale E360’ <<https://e360.yale.edu/features/as-mass-timber-takes-off-how-green-is-this-new-building-material>> [accessed 8 April 2021].

<sup>10</sup> Industry Whitepaper, ‘The Contech Ecosystem in Metro Vancouver’, July, 2020, 1–8.

<sup>11</sup> Zizzo Strategy Inc, Brantwood Consulting, and prepared for Forestry Innovation Investment Ltd, *Report: Embodied Carbon of Buildings and Infrastructure: International Policy Review*, 2017.

<sup>12</sup> See: <https://architecture2030.org/new-buildings-embodied/>

<sup>13</sup> ‘New Buildings: Embodied Carbon – Architecture 2030’ <<https://architecture2030.org/new-buildings-embodied/>> [accessed 8 April 2021].



The focus on embodied carbon, in turn, is driving the demand for lower-carbon and renewable materials as circular inputs into the buildings and infrastructure, with products such as mass timber and those with increasing amounts of recycled content (e.g., concrete, windows, carpets, etc.) becoming favourable from a climate change perspective. This emerging focus on the upstream components of the building life cycle is presenting new opportunities for the sector using a circular economy lens.

Europe has been embracing circular economy as a model for improving economic competitiveness and resource efficiency while also realizing the environmental and GHG benefits. The EU's Circular Economy Action Plan was adopted in March 2020 as part of the European Green Deal and includes a focus on construction and the built environment.<sup>14</sup>

The value of the materials in buildings is also increasingly being recognized through projects in Europe such as the Building as Material Banks (BAMB) program<sup>15</sup> and the concept of material passports, as well as through online marketplaces for trading and selling reclaimed materials. BAMB and its material passport initiative is designed to track and save materials used in the building process, linked to a digital document that chronicles the precise materials used in a particular building. The material passport additionally notes which materials used are best positioned for recovery and reuse, by highlighting which areas of the building are most valuable for construction purposes through the notation of their quality and maintenance.

While the Canada Green Building Council has identified circular economy as an emerging trend for the built environment sector for the coming decade, it also recognizes that “success will depend on industry innovation and the ability to accept and overcome political trade-offs and broader societal challenges, including behaviour change”.<sup>16</sup>

<sup>14</sup> See: <https://ec.europa.eu/environment/circular-economy/>

<sup>15</sup> See: <https://www.bamb2020.eu/>

<sup>16</sup> See page 81: [https://www.cagbc.org/cagbcdocs/advocacy/CaGBC\\_CanadasGreenBuildingEngine\\_EN.pdf](https://www.cagbc.org/cagbcdocs/advocacy/CaGBC_CanadasGreenBuildingEngine_EN.pdf)

### 3. Circular Built Environment: The Canadian Context

The built environment in Canada is one of the largest consumers of raw materials and energy and is also the largest contributor to the waste stream by weight. In Canada, 3.4 million tonnes of construction materials are sent to landfill annually representing an estimated 1.8 million tonnes of embodied carbon.<sup>4</sup>

Research shows that greater material circulation could significantly lower GHG emissions in the construction sector. For example, a report published by the National Zero Waste Council suggests that 1.3 million tonnes of embodied carbon could be avoided per annum if all buildings renovated or demolished in Canada were disassembled and reused.<sup>17</sup>

It is important to note that applying circular building practices in Canada is not new. Construction and demolition waste management efforts, life cycle analysis (LCA) approaches, and material and process innovation practices and policies (including policies that support wood-first approaches) have been adopted by industry and governments in many provinces. These efforts have been leading to greater material circulation and lower GHG emissions in the built environment sector. That being said, over the last several decades, efforts have largely focused on waste diversion and, to some degree, resource recovery. Very little has been focused on more upstream circular strategies, such as circular inputs and product as a service.

In the early 2000s, organizations such as the Canada Green Building Council, the CSA Group, and others were convening stakeholders and working on various related initiatives, including linking efforts to green building standards and certification programs such as Leadership in Energy and Environmental Design (LEED). In fact, since 1995, the CSA Group has developed three standards or guidelines that are highly-relevant to circular economy practices in Canada's built environment sector. These are:

1. **CSA S478:19 Durability in Buildings**<sup>18</sup> - Released in 1995 and was updated in 2019 (and referenced in LEED Canada for Durable Building Credit).
2. **Z782-06 Guideline for Design for Disassembly and Adaptability in Buildings**<sup>19</sup> – Was released in 2006.
3. **Z783-12 (R2016) Deconstruction of buildings and their related parts**<sup>20</sup> – Released in 2012 and updated in 2016.

It is fair to say that the market potential for circular economy solutions in Canada is large, and awareness and interest are growing with industry, governments, academia, and other key stakeholder groups. There are a range of stakeholder groups that touch the built environment at various points in the building life cycle (as illustrated in Figure 3) that are beginning to drive more circular practices, albeit to varying degrees of adoption.

<sup>17</sup> See: <http://www.nzwc.ca/Documents/NZWC-WastePreventionReport.pdf>

<sup>18</sup> See: <https://www.csagroup.org/store/product/CSA%20S478%3A19/>

<sup>19</sup> See: <https://www.csagroup.org/store/product/2702528/>

<sup>20</sup> See: <https://www.csagroup.org/store/product/2703337/>

These key stakeholder groups include:

- Architects, designers, and engineers
- Product and equipment manufacturers and suppliers (including modular construction firms)
- Builders and trades
- Property owners, developers, and managers
- Deconstruction firms
- Waste haulers and recyclers

Broader actors, including governments and regulators (at all levels), educational institutions, research agencies and academic think-tanks, industry associations and non-profits, financial institutions, and standards bodies, are important catalysts and supporters of the circular built environment in Canada and make up the *enabling ecosystem*.

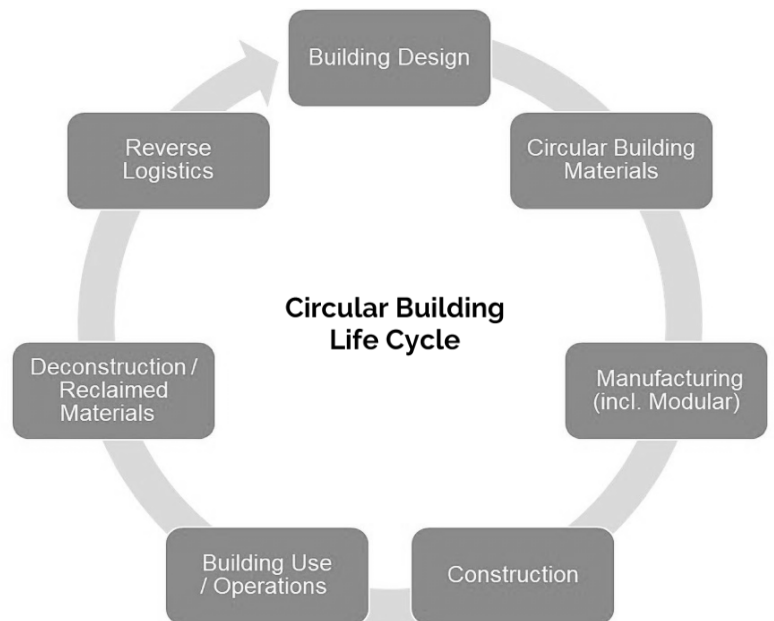


Figure 3: The circular building life cycle.

There are many relevant examples of circular built environment / construction initiatives and businesses in action. Across Canada, the provinces of British Columbia, Quebec, and Ontario are hubs for circular built environment initiatives and increasing levels of related innovation. Many industry leaders are focusing on the design challenge of embedding circular practices at the beginning of the building's life cycle process. However, given the fragmented nature of the construction sector, there are significant system barriers and existing inertia that must be overcome.

The following sub-sections profile examples of the current state of circular built environment practices and initiatives across Canada, using the circular building life cycle (depicted in Figure 3) as a framework for discussion purposes.

## Circular Building Design

Fundamental to the circular built environment is the need to design well from the beginning, with the concept of eliminating waste, as well as allow for flexible use, adaptive reuse, long-term durability, and optimized material recovery. Many Canadian design and architecture firms are incorporating circularity principles into their projects with the future in mind.

The Royal Architectural Institute of Canada, a leading voice in the built environment, notes the increased emphasis in the sector to design holistically, eliminate waste, and support the rapid transition to circular economy. Designing for whole-life-cycle value, by approaching projects as value-adding investments in regenerative

economies, is emerging as best practice in the leading architecture and design community – although a broad adoption of this philosophy is not yet wide-spread.<sup>21</sup>

The new mindset dramatically changes the practice of architecture and the craft of design, most especially by requiring professionals in the field to rethink the way buildings are put together so that the materials can be disassembled and reused, maintaining both their resource and carbon value. It also places a larger emphasis on the entire life cycle of building and site materials, setting the stage for the building industry to move from a waste-management model to a circular economy model.

Below is a short-list of Canadian leaders as examples:

- **Perkins+Will** is recognized for its commitment to sustainability with a recent pledge to deliver net zero interiors by 2030, putting circular design firmly at its heart.
- **DIRTT** is using advanced, digital technologies such as virtual reality (VR) software to optimize its projects and allow for maximum flexibility and sustainability as part of its lean interior design pre-fabrication process (see sidebar).
- **BNKC** Architecture and Urban Design has developed Canada's tallest timber office building at eight storeys, located at 77 Wade Avenue in Toronto.<sup>22</sup> The firm's design exceeded the current building code in Ontario, and, as such, it was able to work with the City of Toronto to have the project approved through the City's Alternative Solutions Process (ASP).

### CASE STUDY: DIRTT's Circular Design for Interiors

**DIRTT** (Doing It Right This Time) is a publicly-traded OEM (TSX: DRTT) with manufacturing facilities in Kelowna, B.C., Phoenix, Arizona, Savannah, Georgia, and Calgary, Alberta, where their Corporate Headquarters are co-located. Their core product offerings are structural interiors intended for commercial, institutional, and business customers conducting new builds and/or renovations: their products provide designers, architects, office tenants / lease-holders, and other construction industry actors with a wealth of design and material options, all completely customized for every project.

DIRTT's core value proposition is based on what can be saved in terms of materials, costs, and time during a construction or renovation project. Prefabricated custom components arriving on-site in a 'ready to install' state can prevent a myriad of complications and costs common during construction. These include, but are not limited to, mistakes in measurements or cuttings resulting in 'start-overs' or the need for new/replace materials and site congestion. Scheduling overlaps where multiple tradespeople wind up working 'over top' of each other, thereby decreasing efficiency and increasing costs, clients who are surprised by or dissatisfied with how things look (thereby triggering new 'start-overs' and re-designs) and so on.

To address costly on-site complications, DIRTT products are carefully designed, planned, and manufactured to spec: they do not hold 'ready made' inventory. DIRTT's proprietary ICE planning software generates VR models of customers' spaces, overlaid with various DIRTT products and materials within the VR model. This allows customers or their designers (i.e., interior designers) to test various configurations, colours, textures, and structures before anything gets manufactured. Once the overall aesthetic and design have been approved, the ICE platform immediately triggers JIT work orders to fulfil the project needs at the exact specifications used in the VR model. **See Appendix B for full case study.**



<sup>21</sup> 'Designing for the Future | Royal Architectural Institute of Canada' <<https://raic.org/raic/designing-future>> [accessed 29 March 2021].

<sup>22</sup> See: <https://www.bnkc.ca/project-spotlight/77-wade-avenue/>

- **Arup** is a global firm that is active in Canada with more than 20 building projects. Arup aims to translate the principles of a circular economy into the everyday built environment practices. By designing-in flexibility from the start, Arup seeks to ensure better returns on investment for building owners.
- **HDR** is transitioning the building design practice from static to dynamic, and from fixed to flexible. By pursuing hybrid mass timber structures with steel lateral braces instead of the typical steel and concrete structure, HDR is addressing embodied carbon and enhanced the interior environment.
- **Henriquez Partners Architects** is designing a 21-storey rental tower, exploring two possible mass timber hybrid systems: a post and platform system and a post, beam, and panel system.
- **GSky Living Green Walls**, based in Vancouver, B.C., is a global provider of living walls, vertical gardens, and green walls tailored to fit both interior and exterior green wall designs – aligning with the regenerative nature of circular economy principles.

## Circular Building Materials & Manufacturing

Canadian industry players have been stepping up in recent years with respect to material innovation and circular manufacturing practices. Renewable products (such as mass timber) and other innovative materials and products with recycled content (such as asphalt, concrete, steel, carpets, window frames, and other products) support lower-carbon, circular construction.

The importance of embodied carbon has been enabled by rigorous quantitative modelling that tracks carbon emissions across the full life of materials and products, using life cycle assessment (LCA). In recent years, the Canadian building industry has adopted LCA as the globally accepted method for evaluating and communicating environmental impacts and applied these methods to the study of materials, products, and assemblies.

A life cycle assessment is a methodology used to measure the impact that a product or process has on the environment, from the beginning of the process (raw material extraction) to the end of the process (disposal). These assessments can be used to analyze anything from building materials to furniture. LCAs are used to measure both material and energy inputs and outputs, evaluate the effects of those inputs and outputs and formulate the data into useful information for understanding the outcome of a particular product or process on the air (i.e. ozone depletion), land (i.e. waste) or water (i.e. pollution).<sup>23</sup>

Gestimat is a LCA tool developed in Quebec. It is used for estimating GHG emissions linked to the manufacture of structural materials, which makes it possible to compare different building scenarios in a Quebec context. The modeling of scenarios can be done using the estimation of the quantities of materials according to typical buildings or by entering quantities of materials specific to a given project. Gestimat also allows the various provincial ministries and organizations to share the data from their GHG analyses with the Ministry of Forests, Wildlife and Parks of Quebec (MFFP).<sup>24</sup>

Another important consideration for circular products and materials are Environmental Product Declarations (EPDs). EPDs are third-party verified documents that incorporate LCA and other environmental considerations (e.g., chemical compounds such as VOCs), written in conformance with international standards, and act as

<sup>23</sup> 'Life Cycle Assessment (LCA)' <<https://greenbuildingcanada.ca/green-building-guide/life-cycle-assessment-lca/>> [accessed 8 April 2021].

<sup>24</sup> 'About Us' <<https://gestimat.ca/about-us>> [accessed 8 April 2021].

labels on products and materials to help identify their environmental impact. In Canada, LCA, EPDs, and the Gestimat tool are being used by early adopters such as government bodies and private sector companies that support the government with their infrastructure builds.

To reduce the impacts from buildings on the environment, including GHG emissions, building components are being designed to sequester more carbon over their life cycle than they emit. This means: zero energy use operational design; the incorporation of renewable carbon storing materials such as mass timber and cellulosic fiber insulation; site carbon sequestration elements such as green roofs and soil building algae farming; and carbon sequestering concrete.

Building with wood products such as mass timber can reduce the overall carbon footprint in several ways:

- First, wood is a renewable resource. Growing a tree is a low-impact production method (i.e., it uses photosynthesis rather than a plethora of machines).
- Second, trees are grown in abundance all over Canada and do not require importation, reducing the amount of energy expended on shipping.
- Third, harvesting trees allows forests to become more efficient at carbon sequestration. When a tree is harvested, it stores carbon. When another tree is planted in its place, it will also store carbon, making that plot of land's carbon sequestration indefinite.
- Fourth, timber's durability allows it to be disassembled and then reassembled into other buildings and furnishings, sequestering carbon for longer so long as it stays out of the landfill.<sup>25</sup>
- Lastly, assuming wood waste can be diverted from landfills, it can continue to sequester carbon and be turned into various, valuable bio-based products, such as biochar. Biochar can be used to replace coal, as well as for agricultural fertilizer.<sup>26</sup>

Canada is a major wood-producing country, with governments and industry making the link between the economic vitality of the forests sector and renewable bio-based products. Historically, Canada has been an exporter of conventional lumber products. However, over the last decade, there has been a holistic and strategic approach from all levels of government and industry, including investments in research and development (R&D), by industry and governments to enable Canadian companies to become leaders in engineered and value-added wood products and technologies (e.g., cross-laminated timber), as well as related building design and engineering. Canada also has growing expertise in building prefabrication and modular construction, as well as related components and processes.<sup>27</sup>

B.C. and Quebec are leaders in the mass timber construction movement in Canada. In Ontario, the market for mass timber is well-positioned for growth, with building code changes in 2015 enabling 6-storey wood buildings. Ontario's access to wood resources and its proximity to Eastern U.S. states puts the province in a strategic

<sup>25</sup> 'Is Mass Timber Really Sustainable?' <<https://www.archpaper.com/2017/11/timber-construction-sustainable/>> [accessed 8 April 2021].

<sup>26</sup> 'Home | BC Biocarbon' <<https://www.bcbiocarbon.com/>> [accessed 8 April 2021].

<sup>27</sup> Canada Green Building Council/The Delphi Group, *GREEN BUILDING IN CANADA Assessing the Market Impacts & Opportunities, 2020* <[www.cagbc.org](http://www.cagbc.org)> [accessed 10 March 2021].

position for export. The Canadian dollar also makes mass timber products more affordable in the United States, giving Canadian manufacturers a comparative advantage.

Offsite and Modular Construction (OMC) is a subset of lean manufacturing that allows both mass customization and process standardization, thus reducing material waste and build time compared to traditional onsite construction techniques. The demand for prefabrication and modular construction is growing in Canada due to its cost savings and shorter lead times for building. It also allows for energy and process improvement that increase overall performance requirements for emerging net zero energy buildings and related codes – performance that is difficult to meet through onsite construction. Below is a short-list of Canadian leaders in mass timber manufacturing and OMC as examples:

- **Element5** is an Ontario-based leader in prefabricated mass timber construction. In 2020, Element Five completed the construction of the Oakville fire station in Ontario.<sup>28</sup> The building used prefabricated components such as cross-laminated insulated panels (CLIPs). CLIPs are a customizable building envelope solution that reduces material use and construction time, and increases site safety and project sustainability.



Source: <https://elementfive.co/project/oakville-fire-station-8/>

- **Structurlam**, based in British Columbia, was the first manufacturer of cross-laminated timber (CLT) in North America, and is the first Canadian manufacturer of CLT to be certified to the SFI 2015-2021 Chain-of-Custody Standard. Structurlam blends the expertise of wood science with the ingenuity of European fabrication to produce mass timber products, including CLT.

- **Kalesnikoff**, based in British Columbia, have an integrated business model similar to companies in Europe. They are able to saw their own stock for CLT and glulam, maximizing lumber yield and profit while minimizing waste.

- **Nordic Structures** is a leading example of a company that has embraced modular structures that can adapt to the changing demographics in a community and allow for adaptive reuse (a key circular strategy). Its modular mass timber structures provide turnkey solutions that allow building owners, such as school boards, to adjust over time to meet their needs. As communities change and population demographics shift, their modular classrooms are helping administrators contend with student surpluses and provide much-needed space during school renovation and construction projects. Once the



Source: <https://www.nordic.ca/en/projects/mass-timber-modules-classrooms>

<sup>28</sup> See: <https://elementfive.co/project/oakville-fire-station-8/>

community population ages, the school boards can relocate these modular classrooms to neighbourhoods that need them.

- **3HD Panels** is a prefabricated wall panel supplier based in Alberta. Their prefabricated wall panels are manufactured in a 18,000 square ft. facility using laser technology to ensure consistent quality and fit. The panels are then delivered to the construction site as a complete package, reducing waste, construction delays, which allowing project to be built faster and more efficiently.
- **BuiltPrefab** designs, manufactures, and installs premium prefab modular buildings. This company actively uses cross laminated timber.<sup>29</sup>
- **Intelligent City** offers a turnkey solution to multi-family housing through the convergence of mass timber, automated manufacturing, and proprietary parametric software. Using mass timber in a turnkey, automated production process, Intelligent City has developed a fast, de-risked, and cost-efficient process for the design and delivery of urban housing projects called Platforms for Life.

**Cardinal Prototype house** is a prototype for a prefabricated mass timber home intended to help meet the housing needs of First Nations communities. Cardinal – along with a skilled team of construction professionals – designed, prefabricated and assembled the first Cardinal House, a prototype that was completed in October 2020 for the Elsipogtog First Nation in New Brunswick.

The 1,100-sq.ft. two-storey, three-bedroom/two-bathroom Cardinal House is a high-performance, mold-resistant mass timber design. Manufactured off-site to exacting standards in a controlled indoor environment, then shipped on a single truck and assembled by a small crew in just a few days, Cardinal House is an affordable solution that uses modern materials and methods to successfully address many of the key issues contributing to the housing crisis.



Beyond mass timber and engineered wood products, products and materials with reclaimed and circular inputs, such as recycled content, are helping reduce GHG emissions and divert waste from landfill, as well as saving builders disposal or tipping fees. Products such as recycled concrete can also reduce transportation costs because concrete can often be recycled in areas near the demolition or construction site. It is commonly used as a base for roads, parking lots, and driveways, as well as recycled stone, backfill material, and shoulder stone.<sup>30</sup>

<sup>29</sup> See: <https://builtprefab.com/the-product/>

<sup>30</sup> 'The 411 on Recycled Concrete: Uses, Benefits, and How To | Ozinga' <<https://ozinga.com/blog/the-411-on-recycled-concrete-uses-benefits-and-how-to/>> [accessed 25 March 2021].



Researchers at UBC Okanagan's School of Engineering conducted side-by-side comparisons of recycled and conventional concrete within two common applications—a building foundation and a municipal sidewalk. They found that the recycled concrete had comparable strength and durability after five years of being in service.<sup>31</sup>

The integration of recycled plastics is another example of circular building materials being manufactured in Canada today. Recycled plastics can be blended with virgin plastic to reduce costs and improve environmental benefits, without sacrificing performance. Recycled plastics are used to make polymeric timbers for use in everything from picnic tables to decking and fences. In addition, recycled plastic feedstock from beverage containers are being spun into fiber for the production of carpet in building interiors.

Below is a short-list of Canadian leaders in recycled content construction materials as examples.

- **Lafarge** is a leader in recycled product manufacturing and has employed a successful recycled asphalt program (RAP) delivered in partnership with the National Zero Waste Council and the City of Richmond.<sup>32</sup> Lafarge is also a leader in recycled concrete and has found that it can perform better than conventional concrete in many cases.
- **CRH Cement** turns site waste into cement by producing and processing cement-based materials such as construction shale as raw material feed; petcoke utilization; recovery of waste oils/solvents; and CRH Slag Cement.
- **CarbonCure** is a unique company dedicated to make concrete a climate solution and reduce embodied carbon in the built environment by 500 megatonnes annually. They have developed three products that reduce GHG emissions; CarbonCure for Ready Mix, CarbonCure for Precast, CarbonCure Masonry.
- **Viking Recycling** is a recycling and environmental services company, which specializes in diverting heavy, durable materials from landfills.<sup>33</sup> Based in Ontario, the company specialize in carpet recycling and have recently released a unique line of carpets and fibres.
- **Full Circle Plastics** works with local businesses and municipalities to source recycled plastic from around Alberta and neighbouring provinces and manufacture it into recycled plastic lumber. Plastic lumber has a large variety of uses from nailer board, fence posts, and bollard posts, to furniture and garden boxes.
- **Dinoflex** makes flooring out of old rubber tires and have been early pioneers of recycled construction materials used as soft matting in playgrounds and in other applications.

## Construction

The construction phase of a circular building's life cycle is largely focused on waste prevention onsite, diversion from landfill, and resource management. Key activities include waste minimization, as well as material recycling (i.e., collection, sorting / separation, processing, and transportation). This sub-section on construction focuses on onsite waste diversion and management practices during the construction and renovation stages of a

<sup>31</sup> 'New UBCO Research Suggests Recycled Concrete Could Be a Sustainable Way to Keep Rubble out of Landfills' <<https://news.ok.ubc.ca/2020/11/30/new-ubco-research-suggests-recycled-concrete-could-be-a-sustainable-way-to-keep-rubble-out-of-landfills/>> [accessed 18 March 2021].

<sup>32</sup> See: <https://canada.constructconnect.com/joc/news/projects/2020/12/richmond-paves-way-for-recycled-asphalt>

<sup>33</sup> See: <https://www.vikingrecycling.ca/about-us>

building. Waste prevention as a topic is covered in the circular design and building materials sections whereas, waste diversion is expanded on in the deconstruction and resource recovery sections of this report.

With landfill space at a premium, onsite waste diversion and management is a critical issue for local and regional governments, as well as for industry. Leading Canadian construction firms have developed robust onsite waste management plans and processes are to effectively optimize source separation, material reuse, and recyclability options.

In some provinces and jurisdictions, major real estate developments are expected to more effectively divert and manage construction waste, with a shifting focus of waste as a resource. As one example, Waterfront Toronto is actively looking to revitalize and transform 800 hectares (2,000 acres) of brownfield lands on the waterfront into sustainable, mixed-use communities and dynamic public spaces. Throughout the major development, Waterfront Toronto has set a 50% waste diversion target.

Below is a short-list of Canadian leaders in onsite construction resource and material management as examples:

- **EllisDon** has an environmental policy that takes advantage of local reduction, salvaging, and recycling opportunities by creating a projection—a site-specific waste reduction work plan meeting federal, provincial, and local regulations and taking into consideration green building rating systems. The company’s sub-contractors, suppliers, and service providers are also expected to assist with the preparation of the waste projection, keep track and report out against the metrics, and follow the waste reduction plan during construction.
- **Ledcor** is a multi-faceted construction company that offers specialized services in project and construction management. Ledcor is a frequent user of recycled crushed concrete in many of its building construction projects and has been pursuing deconstruction as a practice. Ledcor also a leader in design and adaptive reuse having developed the largest LEED® Platinum Adaptive Re-use project in North America in 2011.<sup>34</sup>
- **Pomerleau** is a leader in lean construction, a project management method used at many of Pomerleau's construction sites in Quebec that is designed to maximize added value through the minimization of all wastes (materials, time, etc.).
- **Naikoon Contracting Ltd.** has developed expertise in digital project delivery and prefabricated mass timber systems. Utilizing building information modelling (BIM), Naikoon executes a “virtual build” prior to starting work on site to minimize errors and waste while speeding up erection and weather protection of its building projects.

Beyond waste minimization and recovery, sharing platforms are an additional circular strategy being applied during the construction and renovation phase of the building life cycle, with organizations offering shared equipment and tools as an example – although many are primarily focused on the residential do-it-yourself (DIY) sector. One example is the Toronto Tool Library, one of 40 tool libraries that have been founded across

<sup>34</sup> See: <https://www.ledcor.com/our-projects/building/commercial/green-exchange>

North America since 2012, which provides its members with various tools and equipment for home maintenance, remodelling, carpentry, plumbing, and electrical work.<sup>35</sup>

## Building Use & Operations

The use and operations stage of the building and infrastructure asset life cycle is of critical importance to advancing a more circular built environment in Canada. Enabling this phase requires embracing several circular principles and strategies, including design for durability, design for adaptability, adaptive reuse, as well as extending a building or infrastructure asset's life cycle and usage through regular maintenance, renovation, and repair to ensure they can withstand the test of time. Buildings and infrastructure must also be able to withstand growing pressures exerted from environmental factors such as climate change and extreme weather events.

As referenced earlier, the CSA Group has developed a standard for design for durability (S478:19), which was referenced in the LEED Canada for Durable Building credit (although it was not adopted for LEED v4). Renovations and repurposing buildings can increase the performance of a building over the entire life cycle.

The CSA Group has also developed its guideline for design for disassembly and adaptability (covered in more detail in the next section). To date, design for adaptability considerations in Canada have not been broadly adopted, partly because of a disconnect between the interests of property developers and building owners often not extending the typical lifetime of a building.

However, across Canada, shifting demographics are requiring buildings to be more flexible as communities and their needs change. The concept of flexible spaces also builds on the trend of co-working spaces to unlock the potential of underutilized space in buildings while balancing the risks normally associated with shorter tenures.

Most recently, the impact of the COVID-19 pandemic in Canada is resulting in structural shifts in the demand for commercial office space, as well as retail and warehousing real estate, with more people working from home and many shifting to ecommerce platforms to do their shopping. The City of London, England, for example, has witnessed increased demand for flexible commercial office space, in some instances by 114%, in towns on the outskirts of the city centre, also termed “second-tier” cities. An Arcadis survey found that while offices will remain important for fostering collaborative work, their sizes will likely decrease and need to become more flexible.<sup>36</sup> As a result, upgradable buildings that are adaptable to meet changing building functions is becoming an emerging priority for building architects and designers in Canada.

Building owners and property managers are also beginning to develop innovative leasing approaches and models that enable more flexible use of real estate (retail, commercial, and mixed-use properties as examples). Façade leasing is another innovative model that looks at leasing the building envelope components and maintains them over time through long-term service contracts (i.e., product as a service circular strategy) in order to improve energy, cost savings, and GHG emissions performance, as well as an opportunity to recover and repurpose the materials at end of life.

<sup>35</sup> See: <https://www.torontotoollibrary.com/about-us>

<sup>36</sup> Federation of Canadian Municipalities, 'Urban Project Framing Report: City-Building, Intensification and COVID-19', 2020 <<https://data.fcm.ca/documents/up/urban-project-report-city-building-intensification-COVID-19.pdf>> [accessed 8 April 2021].

GI Quo Vadis is a leader in construction practices and building property management, is one example of a company that is working to redevelop a building as a technological showcase. Based in Montreal, Quebec, Quo Vadis has repurposed a historical textile industrial facility originally built in 1908 to a dynamic business centre, the Dompark Complex.<sup>37</sup> The building is employing a façade leasing model that has been instrumental at improving the buildings energy performance and reducing its environmental impact.

## Deconstruction & Resource Recovery

Deconstruction is an emerging trend in Canada as builders shift away from the traditional demolition of buildings, to recover materials from landfill and look at secondary markets for these materials and resources. Deconstruction is also a major job generator, with potentially three to five times the employment created than through traditional demolition.<sup>38</sup>

Construction waste such a wood, cement, concrete, and steel can be separated and reused for future applications. Currently, however, the market demand for recovered materials and resources varies depending on the geographic location in Canada and the material type.

Key drivers behind the movement toward deconstruction and resource recovery in Canada include supply chain and material pricing volatility. While extracting metal for recycling has long been economical, with lumber prices at a three-year high in Canada, there is growing interest in salvaging structural timber. Procurement and lifecycle assessment (LCA) initiatives are also drivers of growth in resource recovery and secondary material utilization in Canada.

In addition, building codes and bylaws across Canada are starting to consider diversion and recycling targets to drive the uptake of more deconstruction over

<sup>37</sup> See: <https://giquovadis.com/portfolio/complex-dompark/>

<sup>38</sup> *The National Zero Waste Council, an Initiative of Metro Vancouver, Is a Leadership Initiative Bringing Together Governments, Businesses and Non-Government Organizations to Advance Waste Prevention in Canada ACKNOWLEDGEMENTS*  
<<https://www.oregon.gov/deq/mm/Documents/mmFramework2020.pdf>> [accessed 26 March 2021].

## CASE STUDY: UNBUILDERS DECONSTRUCTION



Vancouver-based **Unbuilders** Deconstruction ‘unbuilds’ homes and buildings by hand. They operate with solid business models based on circular material flows which benefits them, their extended supply chain, and the environment in general.

As a material wholesaler, Unbuilders supplies artists, designers, and other value-adding actors such as Wood Shop, Life Space, and Western Reclaimed Timber with source material allowing them (among others) to operate viable businesses using reclaimed materials. Unbuilders supplies their sister company Naturally Crafted with high-value materials and items, which sell directly to consumers thereby realizing retail-level profit margins while providing consumers with highly sought-after ‘character’ materials and forms. Moreover, at clients’ requests, reclaimed structural timber is donated to Habitat for Humanity (a registered charity) resulting in client tax receipts potentially into the thousands of dollars. Hence, Unbuilders provides value along several supply chain nodes.

Unbuilder’s main challenge is scalability: it is a labour-primary business requiring skilled and semi-skilled workers for every project. More projects = more labourers: there are very few ‘economies of scale’ to be had so all projects carry high labour costs. Both the wholesale and retail markets for reclaimed materials are relatively small compared to new material markets, and, although this allows for higher per-item price points, it means the total volumes are low. However, as reclaimed materials become more sought after by both structural and interior designers due to their ‘character’ and distinctiveness, these markets, however small, will continue to thrive. **See Appendix B for full case study.**

wasteful demolition practices. Metro Vancouver regional government, for example, charges disproportionately higher tipping fees on unsorted CRD waste at its material recovery facilities, thereby incentivising diversion and alternative disposal/reuse models for materials with embedded value. The City of Toronto's Green Standard encourages higher diversion rates based on its Tiered model (see more details in the following 'Enabling Ecosystem' sub-section).

The City of Vancouver has been out in front, however, having introduced a Green Demolition Bylaw back in 2014 that requires 75% of materials from homes built before 1950 one- and two-family homes to be recycled. Pre-1910 and heritage-registered one- and two-family homes require deconstruction.<sup>39</sup> This cohort of homes in this age range represents approximately 70% of all home demolitions in the Greater Vancouver region. The Bylaw is expected to result in diversion of up to 18,000 tons of wood and building material from landfills annually and is both a strong signal to move the construction and demolition sectors towards sustainable innovation, and an enabler of circular business models such as **Unbuilders** (see sidebar). The City of Vancouver has also linked its municipal permitting at the building's end of life (traditional demolition) phase to support resource recovery. This policy can trickle into other circular strategy areas (e.g., adaptive reuse for product use extensions).

Below is a short-list of Canadian leaders in deconstruction and resource recovery as examples. Metro Vancouver has published a useful construction and demolition waste reduction and recycling toolkit that includes a number of additional case studies on resource recovery and deconstruction.<sup>40</sup>

- **Sea to Sky Removal**, a certified B Corporation, hand separates all recyclables from construction sites to maximize diversion, as well as recovers any reusable items.
- **3RMCDQ** is a consortium of companies and stakeholders from all regions of Quebec. They have in common to promote the development of the recovery, recycling, reuse, and reclamation of products. The companies share collection, transport, sorting, recovery, conditioning, recovery, recycling, and reuse of construction products.
- **Nouvel Horizon Saint-Laurent G.P. (NHSL)** is the leading firm responsible for the deconstruction of the Samuel De Champlain bridge, one of the largest and busiest bridges in North America.
- **Priestly Demolition** is one of the most versatile and innovative demolition companies in Canada. Priestly Demolition is recognized for recovering and salvaging assets, including wood beams, steel structures, and plant equipment from demolition project for reuse. They also have custom concrete crushing services that they can recycle and repurpose.
- **Enwave Energy** is a waste hauler and recycler, as well as a waste-to-energy facility operator. Enwave supports PEI by providing their primary method of dealing with CRD waste. PEI uses Enwaves' W2E. on waste wood as a primary fuel, saving cost and CO2 in hauling, 90% landfill diversion.

<sup>39</sup> See: <https://vancouver.ca/home-property-development/demolition-permit.aspx>

<sup>40</sup> See: <http://www.metrovancouver.org/services/solid-waste/SolidWastePublications/DLCToolkit.pdf>

## Reverse Logistics

There are business opportunities to ensuring materials and resources are diverted from landfill and brought back into the supply chain through 'reverse logistics'. Reverse logistics is the process of moving goods from their typical final destination for the purpose of capturing value or proper disposal. It is a crucial part of the circular value chain and one of the main differentiators between a traditional value chain and a circular one.

Reverse logistics is the process that enables the circular loop and associated mini loops to be closed. Managing the return and recovery of products and materials from businesses, deconstruction sites, and material recovery facilities back into the value chain is a key tenet of the circular economy that enables products materials to be recycled, reused, and remanufactured.

Existing waste haulers and recyclers in Canada (firms such as Waste Management, GFL, and others) are well-positioned to enable secondary markets and support more reverse logistics should market demand for recovered materials grow.

## The Enabling Ecosystem

Advancing a circular built environment in Canada will require more than just a coordinated approach amongst the direct supply chain stakeholders across the building and infrastructure asset life cycle. It will only succeed through collaboration with the broader ecosystem, in particular governments and regulators at all levels, educational institutions, research agencies and academic think-tanks, industry associations, labour unions, non-profits, standards bodies, and financial institutions.

Enabling ecosystem actors foster cross-industry and sector-wide collaboration, as well as provide platforms for sharing and exchanging information, knowledge, and best practice. Engagement with local actors, training, education, and ongoing engagement between the building's life have all helped to drive development in the circular economy in Canada. Opportunities to learn from, and share, experiences can accelerate the industry transition.

## Government & Regulators

Policy direction and regulatory measures from leading cities and regional governments in Canada, as well as incentives, have been responsible for driving change on the ground across the built environment sector in order to enable the circular agenda.

At the federal level, the 2020 National Building Code includes provisions for mass timber construction up to 12 storeys. The Government of Canada has also launched its Greening Government Strategy that includes considerations for procurement and real property.<sup>41</sup> All new construction and major retrofits prioritize low-carbon and climate resiliency. A building life cycle cost-benefit analysis is used to inform building decisions. The federal government through Natural Resources Canada (NRCan) has been promoting circular materials and innovation, including through its Green Construction through Wood program which encourages the greater use of wood

<sup>41</sup> See: <https://www.canada.ca/en/treasury-board-secretariat/services/innovation/greening-government/strategy.html>

in construction projects and supports Canada's transition to a low-carbon economy.<sup>42</sup> In addition, the National Resource Council (NRC) is creating a life cycle inventory database for Canada, referred to as LCI2 (to be launched in 2023), along with guidance documents for how LCA should be conducted in Canada.

Provincial governments have been important for supporting circularity in the built environment, including through extended producer responsibility (EPR) measures, bans on certain products from landfill, and for various wood first policy initiatives. The provinces have also been collaborating with Environment and Climate Change Canada through the Canadian Council for Ministers of the Environment (CCME), having published a guide in 2019 for identifying, evaluating, and selecting policies for influencing CRD waste management, including considerations for circular economy principles.<sup>43</sup>

In 2009, the B.C. Government amended its building code to allow six-story (mid-rise), wood-frame residential construction. In the twelve years since Wood First was introduced in B.C., the use of wood in building construction has grown rapidly, particularly in the multi-storey residential market and in institutional and recreational buildings. More recently, B.C. launched its Office of Mass Timber Implementation (OMTI) within the Ministry of Jobs, Economic Recovery, and Innovation, to lead the expansion and use of mass timber in B.C. buildings.

In Quebec, la Charte du Bois du Québec's (the Quebec Wood Charter) objective is to increase wood use in the building sector and to decrease GHG emissions associated with this sector. The Charter also aims for developing wood products with high-value added. The Charter is administered by the Ministère des Forêts, de la Faune et des Parcs.<sup>44</sup>

At the local government level, examples of leaders in Canada include:

- The **City of Vancouver**'s Zero Waste 2040 Strategy has a circular economy lens applied and includes construction waste as a key focus area, supported by its Green Demolition Bylaw described earlier in this report.<sup>45</sup>
- The **City of Victoria** recently launched its Zero Waste Victoria strategy that has Construction and the Built Environment as one of five key pillars. Short-term actions include a focus on demolition material salvage.<sup>46</sup>
- The **City of Toronto** has been largely focused to date on home renovation waste and bans on some materials.<sup>47</sup> However, the Toronto Green Standard includes targets for CRD material diversion, including 75% for Tier 2 and 90% diversion for Tier 3, which has been encouraging salvage and reuse locally. Its version 4 has also been taking into consideration embodied carbon.<sup>48</sup>

<sup>42</sup> See: <https://www.nrcan.gc.ca/science-data/funding-partnerships/funding-opportunities/forest-sector-funding-programs/green-construction-through-wood-gcwood-program/20046>

<sup>43</sup> See: <https://www.ccme.ca/en/res/crdguidance-secured.pdf>

<sup>44</sup> *Promoting Sustainable Building Materials and the Implications on the Use of Wood in Buildings A Review of Leading Public Policies in Europe and North America.*

<sup>45</sup> See: <https://vancouver.ca/green-vancouver/zero-waste-priorities-and-background.aspx>

<sup>46</sup> See: <https://www.victoria.ca/EN/main/residents/climate-change/waste-reduction.html>

<sup>47</sup> See pages 50-51: <https://www.toronto.ca/wp-content/uploads/2017/10/9803-Final-Long-Term-Waste-Management-Strategy.pdf>

<sup>48</sup> See: <https://www.toronto.ca/city-government/planning-development/official-plan-guidelines/toronto-green-standard/toronto-green-standard-overview/>

- The **City of Montreal** is currently developing a Circular Economy roadmap with CRD waste as a key focus. The roadmap is not yet released in the public domain.
- **Lunenburg County** became the first jurisdiction in Nova Scotia to create a waste management system that required waste to be source separated into 3 distinct streams. They opened the first centralized commercial scale composting facility in North America. Lunenburg's system was influential in determining how the province's municipal solid waste should be managed, focusing on maximizing the recovery of materials from waste.<sup>49</sup>

The City of Vancouver's economic development agency, the Vancouver Economic Commission, has also been championing various circular economy initiatives as it relates to the built environment, including a study on the business case for deconstruction and its economic potential, in partnership with BCIT and Unbuilders.<sup>50</sup>

### Post-Secondary Education, Training & Research Institutions

Post-secondary education and research institutions across Canada have been actively involved in both applied research and relevant training. Below are just a few leading examples from across Canada:

- **BC Institute of Technology (BICT)**'s School of Construction and the Environment is supporting circular practices in construction through its programs, as well as leading work on embodied carbon and consumption-based GHG emissions and material flows through its Centre for Ecocities.
- **The Wood Innovation Research Laboratory (WIRL)** at the **University of North British Columbia (UNBC)** is a state-of-the-art wood science and engineering research facility in Prince George that provides students, faculty members, and researchers from UNBC's Master of Engineering in Integrated Wood Design program with the ability to build and test large-scale integrated wood structures using engineered wood products such as Cross-Laminated Timber, Glued Laminated Timber, and Laminated Veneer Lumber.<sup>51</sup>
- **University of Toronto's Mass Timber Institute** aims to position Canada as a global leader in sustainable mass timber research, education, development, and export by leveraging relationships between educators, researchers, industry, and Indigenous groups across Canada and internationally.
- **CIERC Center at École de technologie supérieure (ÉTS)** is establishing a living lab for circular construction and deconstruction, a first of its kind in Quebec. The living lab will include stakeholders from across the value chain (i.e., manufacturers, distributors, architects, builders, and researchers) with a focus on DfD/A, low-carbon materials innovation, modular construction, and deconstruction.
- The **Canadian Industrial Research Chair on Eco-responsible Wood Construction (CIRCERB)** at **Laval University** is a multidisciplinary and integrated academic platform, partnered to an industry consortium, whose efforts cover the entire construction value creation network, in order to develop eco-responsible solutions, using wood-based materials to reduce the ecological footprint of buildings.<sup>52</sup>

<sup>49</sup> *Waste Management Practices: Literature Review*, 2011.

<sup>50</sup> See: <https://www.vancouvereconomic.com/research/the-business-case-for-deconstruction/>

<sup>51</sup> See: <https://www2.unbc.ca/engineering/wood-innovation-research-laboratory>

<sup>52</sup> See: <https://circeb.chaire.ulaval.ca/a-propos/eng/>



- **Universite de Montreal** has an architecture school doing applied research on circularity in the built environment.

## Industry Associations & Not-for-Profits

Industry associations and non-profits play an important role in supporting collaboration and awareness building for the circular built environment in Canada. Below are a few leading examples from across Canada:

- **National Zero Waste Council** has several initiatives that support the circular built environment, including a core focus on deconstruction over demolition, efforts to improve the business case for recycled asphalt, and a CRD Working Group which is focused on assessing the opportunities to enhance waste prevention and promoting circular economy principles within the construction and built environment sector.<sup>53</sup> The CRD Working Group is made up of industry professionals and government representatives across Canada.
- **Canadian Construction Association (CCA)** helps to lead industry on adopting best practices. The CCA is the host of Canadian Design-Build Institute and the Lean Construction Institute of Canada.
- **Canadian Home Builders' Association (CHBA)**, represents the residential construction industry with committees and councils in the home renovation space, net zero energy, modular construction and the urban council.
- **Royal Architectural Institute of Canada (RAIC)** is a not-for-profit, national organization that has represented architects and architecture for over 100 years. RAIC promote excellence in the built environment and to advocate for responsible architecture and circular design practices.
- **Canada Green Building Council (CaGBC)** has been working since 2002 to advance green building and sustainable community development practices in Canada. The CaGBC is the Canadian license holder for the LEED Green Building Rating System and supports the WELL Building Standard in Canada.
- **Building Owners & Managers Association (BOMA)** represents the Canadian commercial real estate industry and supports the sector in various ways, including the connectivity between industry leadership and the built environment.
- **Smart Prosperity Institute** has been conducting research on the circular economy as applied to various industrial sectors, including construction.
- The **Carbon Leadership Forum** has founded the embodied carbon network which is advancing a stream of work in North America that aligns with circular materials and practices.
- **FPIinnovations** is a private not-for-profit organization that specializes in the creation of solutions in support of the Canadian forest sector's global competitiveness. Efforts include research on forest bioproducts, LCA, environmental EPDs, as well as construction materials and process innovation. etc. Also interested in buildings and novel bioproducts such as biofuels and biochemicals.

<sup>53</sup> See: <http://www.nzwc.ca/focus-areas/construction/what-we-are-doing/Pages/default.aspx>

- **CIRAIG** is the International Reference Center for Life Cycle of Products, Services, and Systems (CIRAIG) and is the leading research group and center of expertise on sustainability and life cycle analysis (LCA) thinking in Canada.<sup>54</sup> It is also one of the largest internationally.
- **Athena Sustainable Materials Institute** is a non-profit research collaborative bringing life cycle assessment to the construction sector. Life cycle assessment (LCA) is the science behind environmental foot-printing.<sup>55</sup> The Athena Institute works with sustainability leaders in product manufacturing, building design, construction, and green labelling programs to enable smaller footprints in the production and consumption of construction materials.

## Collaborative Platforms

System enablers such as product as a service and sharing platforms help keep resources in the system for longer. These include both traditional services associated with manufacturing, such as construction, repair, or maintenance services, as well as entirely new types of services, often enabled by digital innovation, such as co-access mechanisms or models focused on selling a service related to a product—e.g., leasing or repair services—rather than the product itself. Furthermore, in a circular economy, the emphasis is placed upstream to design out inefficiencies and waste throughout product value chains and life cycles. This involves an increasing use of services—a trend that the post-COVID-19 recovery may help accelerate.<sup>56</sup>

Many of the sharing platforms leverage social networks, which has the effect of increasing transparency and consumers' ability to advocate for responsible products, business practices, and affordability. Tool and equipment sharing, leasing, and renting are becoming more common. Tool libraries such as the Toronto Tool Library referenced earlier, are enabling people access to items they would not otherwise have access to, enabling project affordability.<sup>57</sup>

Additional examples of some of these platforms designed to support the built environment and construction sector in Canada include:

- **Ontario Materials Marketplace** is a material sharing platform that was developed by the Council of the Great Lakes Region.<sup>58</sup>
- **BizBiz Share** is a resource and online materials marketplace that includes a new focus on the construction sector.<sup>59</sup>

<sup>54</sup> See: <https://ciraig.org/>

<sup>55</sup> See: <http://www.athenasmi.org/>

<sup>56</sup> Saara Tamminen and others, *Trading Services for a Circular Economy Ministry for Foreign Affairs of Finland*, 2020 <[www.sitra.fi/en](http://www.sitra.fi/en)> [accessed 23 March 2021].

<sup>57</sup> Margherita Finamore, *Circular Economy in the Built Environment*.

<sup>58</sup> See: <https://ontario.materialsmarketplace.org/?locale=en>

<sup>59</sup> See: <https://bizbizshare.com/>

### Case Study: Industrial Symbiosis at Valoris Eco-Industrial Park

The Valoris Eco-Industrial Park exemplifies the Industrial Symbiosis model where materials formerly considered waste have found new uses cases, new value, and new opportunities. The Eco-Industrial Park has created fertile conditions for business innovation, research and development, and collaboration between agencies and related industries.

In 1998, GSI Environmental opened a facility at Valoris to provide services for integrated management of biomass, and in 2005 the ELS and participating MRCs began operating a sorting and conditioning bioreactor test centre with GSI. This spawned the opening of a Regional Ecocentre at the ELS to further enhance materials sorting, prioritization, and recovery. From 2013 to today, all of Sherbrook's and HSF's MSW has been taken to Valoris, providing a stable stream of recoverable materials for industrial inputs.

Valoris is a contracted waste hauler with a fleet of trucks servicing the Sherbrook and surrounding municipalities. Hence, part of the business model is for-profit waste removal and management service at various levels: from curbside residential pick-up to CRD waste from contractors and developers and everything in between. On the recovery/disposal end, several companies have been working on technologies, processes, and services to not only recover materials but create new use cases and value-added products.

Biomass created from feedstocks of wood (CRD and household), as well as and forestry waste, dominates the 'types' of technologies in play at Valoris. This is a sector of considerable importance and focuses in Quebec, with various ministries, industry associations, and funding agencies all supporting and developing the sector. The Quebec Ministry of Economy and Innovation, the Centre of Excellence for the Valorization of Residual Materials, and the Centre of Excellence in Clean Technologies are all direct participants in Valoris, helping to create an ecosystem of support, funding, technology transfer, and R&D to keep advancing the sector. **See Appendix B for full case study.**



## 4. Deep Dive on Design for Disassembly & Adaptability

Design for Disassembly and Adaptability (DfD/A) supports circularity in the built environment by promoting innovative design practices aimed at lengthening the lifespan of a building. It applies a systems-thinking approach whereby the project team must consider the full life cycle of the building and its materials.<sup>60</sup> As such, DfD/A is all about "planning with the end in mind".

**Design for Disassembly and Adaptability (DfD/A) can be defined as the process of designing structures such that they can be disassembled into component parts to be repurposed for future activities.**

The primary benefit of DfD/A is that it allows for individual components of buildings to be more easily reused when the buildings are dismantled, as an alternative to demolition and landfilling, with the potential to reduce construction related waste streams. To be successful, DfD/A relies on minimizing and standardizing parts and fasteners, where possible, and avoiding glues and adhesives, which create irreversible connections.<sup>61</sup>


DfD/A fits broadly into the 9R circular economy waste hierarchy illustrated in Figure 4 as follows:

- **Refuse** – utilizing products that can be resold or repurposed at their component's end of life.
- **Rethink** – using product-as-a-service a service model for design elements rather than purchasing assets.
- **Reduce** - designing buildings with the least amount of materials and resources, supported by lean manufacturing and modular construction processes.
- **Reuse** – avoids irreversible connections and finishes enabling reuse of component parts.
- **Repair / Maintenance** – provides opportunities for component swap out, facilitating easier maintenance and repair.
- **Refurbishment/Remanufacturing** – increase access to components to facilitate refurbishment and remanufacturing of components.
- **Repurpose** – consider post-component uses of materials used for the building and its components, including cycling them into secondary markets.
- **Recycle** – choosing materials that can be recycled at the end of component life should other preferable options not be economically viable.
- **Energy Recovery** – isolates components for conversion to energy at the end of life, if necessary.

<sup>60</sup> [https://www.ellenmacarthurfoundation.org/assets/downloads/news/EMF\\_Engineering-the-Circular-Economy\\_300913.pdf](https://www.ellenmacarthurfoundation.org/assets/downloads/news/EMF_Engineering-the-Circular-Economy_300913.pdf)

<sup>61</sup> See World Business Council for Sustainable Development (WBCSD). 2018. Design for disassembly/deconstruction.

<https://www.ceguide.org/Strategies-and-examples/Design/Design-for-disassembly-deconstruction#:~:text=Design%20principle%20that%20calls%20for,and%20materials%20can%20be%20deconstructed.&text=It%20can%20also%20help%20ensure,whole%20components%20to%20be%20reused.>

|   |  | STRATEGIES                                     |  |
|---|--|--|--|
|   |  | Code   | Description  |
|  | Smarter product use and manufacture      | R0 Refuse                                      | Make product redundant by abandoning its function or by offering the same function with a radically different product. |
|   |  | R1 Rethink                                     | Make product use more intensive (e.g., by sharing product).  |
|   |  | R2 Reduce                                      | Increase efficiency in product manufacture or use by consuming fewer natural resources and materials.                  |
|   | Extend lifespan of product and its parts | R3 Reuse                                       | Reuse by another consumer of discarded product which is still in good condition and fulfills its original function.    |
|   |  | R4 Repair                                      | Repair and maintenance of defective product so it can be used with its original function.                              |
|   |  | R5 Refurbish                                   | Restore an old product and bring it up to date.  |
|   | Useful application of materials          | R6 Remanufacture                               | Use parts of discarded product in a new product with the same function.  |
|   |  | R7 Repurpose                                   | Use discarded product or its parts in a new product with a different function.   |
|   |  | R8 Recycle                                     | Process materials to obtain the same (high grade) or lower (low grade) quality.  |
| R9 Recover  |  | Incineration of material with energy recovery. |  |

Source: Ellen MacArthur Foundation (adapted from Circular Economy: Measuring innovation in product chains).<sup>62</sup>

Figure 4: 9R Circular Economy Hierarchy

Construction companies around the world are leveraging advances in digital technologies and new approaches to improve productivity and reduce waste. These new approaches not only help companies save money by doing more with less but also establish the foundation for developing a circular construction economy. Emerging practices and approaches to support circularity in construction include:

- **Product-as-a-Service and Product Use Extension strategies**<sup>63</sup> - Product-as-a-Service is when a product is used by one or many customers by means of lease or pay-for-use arrangement. Product Use Extension strategies extend the life cycle of a product by repairing, upgrading and reselling.
- **Offsite and Modular Construction**<sup>64</sup> - Standardized, modular components are produced in offsite production facilities. The controlled, high-tech process environment ensures process efficiency and product quality.

<sup>62</sup> See: [https://www.ellenmacarthurfoundation.org/assets/galleries/CEinaction\\_Activity06-nine-Rs-6R3\\_from-graham-081217.pdf](https://www.ellenmacarthurfoundation.org/assets/galleries/CEinaction_Activity06-nine-Rs-6R3_from-graham-081217.pdf)

<sup>63</sup> UKGBC. 2019. Circular Economy Guidance for Construction Clients. <https://www.ukgbc.org/wp-content/uploads/2019/04/Circular-Economy-Report.pdf>

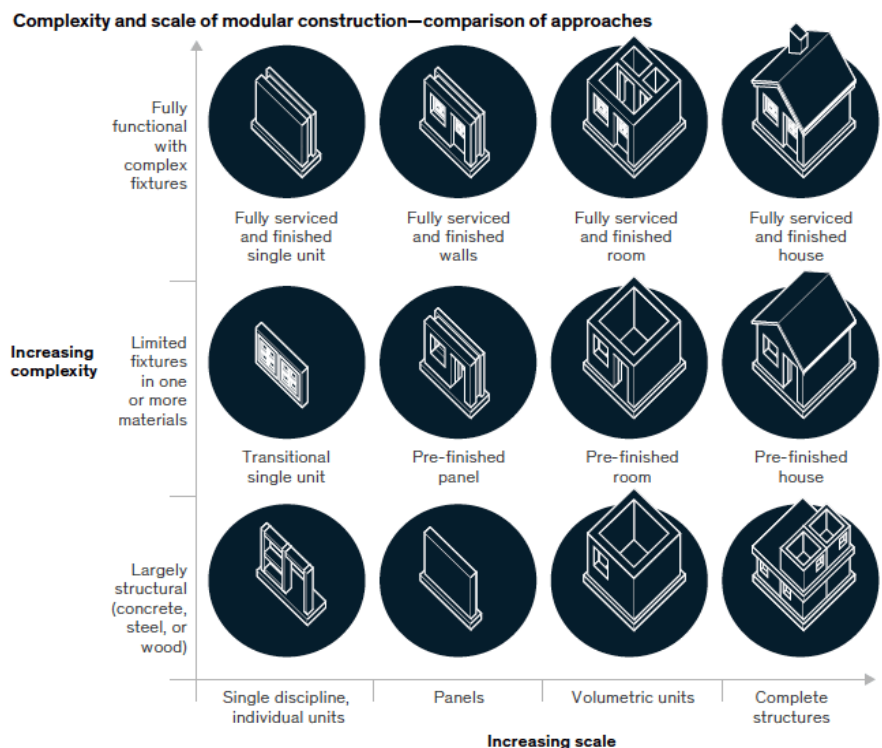
<sup>64</sup> Webster, Colin. 2013. Engineering Circular Economy. [https://www.ellenmacarthurfoundation.org/assets/downloads/news/EMF\\_Engineering-the-Circular-Economy\\_300913.pdf](https://www.ellenmacarthurfoundation.org/assets/downloads/news/EMF_Engineering-the-Circular-Economy_300913.pdf)

- **Materials Passports**<sup>65</sup> is a document consisting of all the materials that are included in a product or construction. It consists of a set of data describing defined characteristics of materials in products, which give them value for recovery, recycling and reuse.
- **Standardization**<sup>66</sup> is the process of establishing uniformity across manufacturing materials and processes. Potential benefits of standardization include lower production and procurement costs through economies of scale, easier and less expensive repair and replacement, and faster and more efficient processes.

Wood products (and designing with wood) are well suited for DfD/A, Wood products can be altered to standardized or modularized forms supporting the DfD/A process. Wood also lends itself to a broad area of reversible fasteners and can be finished with sustainable products facilitating reuse at the end of building or component life. Relatively little energy is needed for the manufacture and processing of wood construction materials compared to alternatives such as concrete and steel. Typically, wood-based products use mainly biomass residues for processing energy and have lower climate impacts than alternatives.

Tall timber structures also have the potential to contribute to a circular construction sector. They can be very durable and resilient, even in seismic zones. Tall timber structures comprise highly engineered prefabricated systems that can be assembled with mechanical fastenings. Indeed, there are now connection systems available that allow timber buildings to be "re-set" for reuse after an earthquake instead of demolishing.

Considering the end-of-life for wood products, the value proposition for



Source: <https://www.bdcnetwork.com/modular-construction-can-deliver-projects-50-faster>

**Figure 5: Modular construction covers a broad set of approaches and can deliver projects 50% faster.**

<sup>65</sup> See Circular Economy Global Sector Best Practices Series on Construction, Smart Prosperity Institute (February 2021)

<sup>66</sup> See Grau, David and Fernanda Cruz Rios. 2020. Circular Economy in the Built Environment: Designing, Deconstructing, and Leasing Reusable Products. Reference Module in Materials Science and Materials Engineering 5: 338-343. Available at <https://www.sciencedirect.com/science/article/pii/B9780128035818114948>

deconstruction and salvage is improving, although the demand for salvaged materials remains a barrier to broader scalability at present.

Finally, as a last resort, energy recovery from clean post-use wood is viewed as an increasingly important source of renewable energy. However, wood product use at the end of life varies broadly. For example, 70% of French wood is used for raw materials in wood processing, compared to 90% for energy in Sweden.<sup>67</sup>



Source: [https://commons.wikimedia.org/wiki/File:The\\_Landing\\_Vancouver.jpg](https://commons.wikimedia.org/wiki/File:The_Landing_Vancouver.jpg)

Vancouver's oldest tall timber structure is the Kelly Douglas building (now known as The Landing). Standing at 8 storeys (1 storey partially below grade), it was built in 1905. It started life as a warehouse and wholesale grocery outlet. It was refurbished in 1988 and now has offices on the upper floors with two storeys of retail and a pub at street level.

<sup>67</sup> See Dodoo, Amrbose, Leif Gustavsson and Roger Sathre. 2014. Chapter 11 - Recycling of Lumber. Handbook of Recycling. Available at <https://www.sciencedirect.com/science/article/pii/B9780123964595000118>

## Design for Disassembly and Adaptability in Canada

Although DfD/A guidelines were developed by CSA Group in Canada starting back in 2002 and have formed the precursor for the ISO Standard released in 2020, there has been minimal adoption of this practice in Canada over the last two decades except for a handful of projects.<sup>68</sup> Examples include:

- **Mountain Equipment Co-op Stores** (multiple locations) - Mountain Equipment Coop (MEC) has four buildings across Canada that showcase circular building practices and building material stewardship, with the flagship Ottawa building is recognized for a model for DfD/A in Canada since its original construction more than 20-years ago (see sidebar).
- **C.K. Choi Building** – Based in Vancouver, B.C., this award-winning building was designed in 1996 by Matsu-zaki Wright Architects Inc. and is home to the University of British Columbia's Institute for Asian Studies. It is recognized for extensive material salvage and reuse, in addition to applying principles of DfD/A.
- **DIRTT** - Headquartered in Calgary, Alberta, since 2005, DIRTT has been applying DfD and reuse strategies for its prefabricated building interiors.
- **3XN** – Danish architecture firm 3XN is an international leader on DfD/A and has projects in Toronto, including the T3 Bayside complex that is part of the Waterfront Toronto development.<sup>69</sup>

Additional examples include retail stores, supermarkets, aircraft hangars, and federal government buildings (including Department of National Defence and Public Services Canada).

Active players beyond the architectural and design community in Canada that have been supporting DfD/A as a practice include CMHC that has published information on the topic, and post-secondary institutions that have developed short (2-day) training programs and materials.

While theoretical awareness exists with Canada's design community, the actual adoption and demand from building owners and developers remain low. The industry has yet to respond in terms of developing construction best practices, investing in material and component innovation, or supportive policy and educational / training resources.

Recent growth in offsite and modular construction in Alberta, B.C., Quebec, and Ontario, as well as green roof deployment in locations such as Vancouver and Toronto that include simple layers to reduce contamination of fusion of materials, has required DfD/A thinking. This is because offsite and modular construction requires the ability to assemble and disassemble projects – including multiple layers, components, and subcomponents – while also allowing for flexibility.

Given some limitations around the use of precast concrete and steel, the adoption of mass timber and bylaws in Canada that favour wood construction are also well aligned to enable more DfD/A projects in the coming years. Further, the move away from many mechanical connections in buildings, as well as the adoption of

<sup>68</sup> Estimates by experts provide through key informant interviews for this project suggest approximately 20-25 buildings in Canada have effectively applied DfD/A principles.

<sup>69</sup> See: <https://3xn.com/project/t3-bayside>



digital technologies in design processes (such as BIM) in Canada, is further enabling adaptive reuse and flexible building design concepts to be brought forward.

Deconstruction initiatives are mainly driven by local waste management policies and rely on proprietary BIM tools to support their framework. Canada lacks universal BIM standards, so there are significant hurdles to overcome before DfD/A becomes common practice.

### Corporate Leadership in DfD/A: Case Study on MEC

Mountain Equipment Coop (MEC) has four buildings across Canada that showcase circular building practices and building material stewardship. The first two are the Ottawa and Winnipeg buildings, both of which were built to C2000 standards at the time. C2000 was the predecessor of LEED and other building performance metrics, the buildings being classed the 1<sup>st</sup> and 2<sup>nd</sup> ever C2000 certified in Canada.

The **Ottawa building** is recognized for a model for DfD/A. The original 40-year old building was carefully dismantled with the intention of reusing as much material as possible, utilizing the disassembly-friendly original construction components. As a result, roughly 75% of those materials were re-incorporated into the new building, including 50% of the timber, and the majority of the steel building frame. Key participants in this project were Derek Badger, who went on to author "The Residential Deconstruction Manual" for the CHMC, and Linda Chapman Architecture.

An important aspect of this project was the preservation of heritage features of the building, a 60's era two-storey grocery store with curbside character contributing to the area's heritage and aesthetic. Critics of the project implicated MEC as adding to the 'gentrification' of the area, preserving heritage elements that much more important. **See Appendix B for full case study.**



Source: <https://www.mec.ca/en/explore/green-buildings>

## Assessment of the ISO Standard for DfD/A

The ISO Standard 20887:2020(E) "*Sustainability in buildings and civil engineering works — Design for disassembly and adaptability*" (the 'ISO Standard') provides an overview of design for disassembly and adaptability (DfD/A) principles for integration into the built environment design process (ISO 2020). DfD is defined as an:

*"approach to the design of a product or constructed asset that facilitates disassembly at the end of its useful life, in such a way that enables components and parts to be reused, recycled, recovered for energy or in some other way, diverted from the waste stream (ISO 2020)."*

For ISO, DfD/A exists within the circular economy paradigm, which is defined as an "economy that is restorative and regenerative by design, and which aims to keep products, components, and materials at their highest utility and value at all times (ISO 2020)." The ISO Standard outlines necessary conditions for implementing DfD/A and adaptability but does not outline specific performance requirements. Of note, the ISO Standard does not suggest overbuilding to meet future uncertainty regarding use cases. Rather, the ISO Standard focuses on a design process integrating future use cases to retain the value of material components and avoid waste generation.

A circular economy within the built environment is currently an emerging opportunity within the Canadian market. Consideration of international best practices is important for shaping these principles' future integration into Canada's construction industry and supply chain. This analysis of the ISO standard has two objectives:

1. Synthesizing and analyzing the principles outlined within the ISO standard; and,
2. Providing recommendations on how the Canadian Government and industry stakeholders can integrate DfD/A principles from the ISO Standard into the built environment.

## Decision-making Considerations for DfD/A

Decision-making is the origin point for integrating DfD/A and adaptability into the built environment. As such, the largest burden for implementation falls on designers, building owners and developers, and the state and non-state regulatory processes governing their decisions. The ISO Standard suggests a collaborative process between clients and designers (ISO 2020). Collaborative approaches are apparent in a variety of case studies. Within this collaborative process, functional specifications should be challenged with respect to how they stand the test of time and change (ISO 2020). Integrating these processes is likely to be discretionary and unlikely to be enforceable through any tangible mechanism. Therefore, in implementation, design thinking could provide an effective tool in the design process to enhance collaboration between clients and designers. The ISO Standard provides a list of considerations for clients and designers to consider when preparing a brief (ISO 2020).

The purpose of integrating DfD/A into the design is to allow for the built environment to adapt to changing requirements and use cases.<sup>70</sup> As such, the ISO Standard proposes five levels of analysis for DfD/A and adaptability in the design, construction, and material information process:

<sup>70</sup> It is important to note certain components of the built environment are not suitable for DfD are technology reliant and can be expected to reach obsolescence.

- **Systems** – adaptable construction works that can change to suit changing requirements.
- **Elements** – major structural parts of construction works, and modularized elements and panelized elements, fitting common dimensional standards.
- **Components or Assembly** – non-structural combinations of subcomponents or different systems designed to allow for upgrading, repair, or replacement.
- **Subcomponents** – smaller pieces of a component.
- **Materials** – most basic form of an input which may be considered feedstock in a recycling process.

When undertaking analysis on each level, the ISO Standard recommends consideration of the principles included in Table 1 below. These principles, expanded upon below, can form the basis of benchmarking and thresholds for owners/operators to evaluate potential designs and set markers for designers to achieve. While this is a discretionary activity, further implementation could lead to categorical requirements in the procurement process or relevant building code for these structures, thus regulating its incorporation.

During the design stage, a variety of strategies can be undertaken to further circularity in the built environment. According to the ISO Standard, the first priorities to consider are:

- Current and potential functional requirements;
- Service life requirements;
- Regulatory requirements;
- Policy requirements; and,
- Other requirements.

To consider these requirements within a DfD/A paradigm, the consideration of potential trade-offs and undertake scenario planning that includes life cycle costing and assessment (ISO 2020). Designers can conduct these analyses with respect to the overall design, systems, elements, components, subcomponents, and material options (ISO 2020). The ISO Standard (2020) recommends the following characteristics of a built structure and its environment be considered in the design process:

- Physical context (location);
- Cultural context;
- Owner type;
- Use type(s);
- Typologies;
- Available construction technologies;
- Construction materials;
- Size;
- Design life;
- Performance goals;
- Climate change;
- Schedule; and,
- Service environment.

These criteria may not be applicable for all cases but can form the basis of specific design parameters that can be analyzed with respect to integrating DfD and adaptability. The production of guidance documents and business cases for DfD and adaptability may aid in generating heuristics for decision-makers when designing built environment structures. Alternatively, these considerations may facilitate a new value chain activity focused on assessing the implications of design. For this alternative to be viable, mandates may be required to spur demand for this type of analysis.

Durability is closely linked with adaptability, and DfD/A is providing an important lens in the decision-making process. Durability refers to the ability of a constructed asset or any of its components to perform its required functions over a specified period of time without unforeseen maintenance or repairs (ISO 2020). Integrating durability allows for the maximum use-case value of a product (or asset in the case of buildings) to be realized, thus reducing waste (ISO 2020).

### Principles for DfD/A in Design, Construction, Materials, and Use

The full life cycle of the built environment and its materials must be considered to optimize the disassembly of a building. Table 2 provides a summary of principles for this integration. These principles can be applied at each stage of the built environment value chain, and each have quantitative or qualitative outcome-based measurement opportunities. Within each of these principles, a subset of the characteristics of the built environment (listed above) can be considering when conducting trade-off and scenario-based analysis.

As demonstrated above, there is a multitude of avenues to incorporate DfD and adaptability, as defined by the ISO Standard, into the Canadian built environment. However, to integrate DfD and adaptability, a variety of other circular economy strategies and initiatives should be viewed as necessary conditions, including asset (building) use / life cycle extensions, modular construction, the use of BIM, and product-as-a-service models. Specific to DfD/A recommendations for integration into the Canadian context, the focus should be on design thinking, capacity building, and establishing secondary markets.

- First, design thinking can be integrated into the project planning and material design stage to develop products and designs more aligned with consumer needs.
- Second, capacity building can increase the awareness and availability of DfD/A products and services within the market by creating demand.
- Third, customer demand for recovered materials and related secondary markets will enhance the business case for DfD/A by allowing owners to realize value on materials at the end of the constructed asset's life.
- Fourth, opportunities for referencing DfD/A guidelines and standards in the National Model Building Code, provincial building codes, and/or local bylaws should be explored as a pathway to drive greater awareness and adoption.

In summary, the ISO Standard principles can be effectively integrated into the Canadian built environment along with complimentary circular economy initiatives. Both public and private actors have a role to play in their integration, but regulatory and industry association pressure can be viewed as catalysts in pursuing these principles.

**Table 2: Principles for DfD/A and recommendations for integration into the Canadian context.**

| Principle  | ISO Standard Definition   | Measurement <sup>a</sup>   | Supporting Circular Economy Principles   | Recommendations for Integration  |
|--|---|--|--|--|
| <b>Adaptability</b>                              |   |  |  |  |
| <b>Versatility</b>                               | Ability to accommodate different functions with minor system changes.   | Percentage change of usable space that has multiple uses at defined time intervals without changing major built features.      | <ul style="list-style-type: none"> <li>• Modular construction</li> <li>• Design Thinking</li> <li>• Asset (Building) Use Extension</li> </ul>                            | <ul style="list-style-type: none"> <li>• Utilize Design Thinking to design spaces with potential users</li> <li>• Collaboration between client and designer</li> </ul> |
| <b>Convertibility</b>                            | Ability to accommodate substantial changes in user needs by making modifications.   | Percentage of usable space that has been designed to be converted easily into multiple uses.                                   | <ul style="list-style-type: none"> <li>• Modular construction</li> <li>• Design Thinking</li> <li>• Asset (Building) Use Extension</li> </ul>                            | <ul style="list-style-type: none"> <li>• Utilize Design Thinking to design spaces with potential users</li> <li>• Collaboration between client and designer</li> </ul> |
| <b>Expandability</b>                             | Ability of a design or the characteristic system to accommodate a substantial change that supports or facilitates the addition of new space, features, capabilities and capacities. | Additional floor space possible without major alterations to the structural system.  | <ul style="list-style-type: none"> <li>• Modular construction</li> <li>• Design Thinking</li> <li>• Standardization</li> <li>• Asset (Building) Use Extension</li> </ul> | <ul style="list-style-type: none"> <li>• Increase modularization and DfD components</li> <li>• Collaboration between client and designer</li> </ul>                    |
| <b>Design for Disassembly</b>                    |   |  |  |  |
| <b>Ease of access to components and services</b> | Design which allows for easy access to materials, components and/or connectors of an assembly, particularly those with the shortest life cycle.                                     | Graded scale based on level of exposure for connections.   | <ul style="list-style-type: none"> <li>• Modular construction</li> <li>• Product-as-a-service model</li> </ul>   | <ul style="list-style-type: none"> <li>• Increase capacity of designers and client knowledge of DfD</li> <li>• Incorporate into relevant building codes</li> </ul>     |
| <b>Independence</b>                              | Allowance for parts, components, modules and systems to be removed or upgraded without affecting performance of connected or adjacent systems.                                      | <ul style="list-style-type: none"> <li>• Graded scale based on consideration of assembly techniques and modularity.</li> </ul> | <ul style="list-style-type: none"> <li>• Modular construction</li> <li>• Product-as-a-service model</li> </ul>   | <ul style="list-style-type: none"> <li>• Integrate a 6S's approach rather than the three-layer approach outlined in the ISO Standard</li> </ul>                        |

| Principle   | ISO Standard Definition  | Measurement <sup>a</sup>  | Supporting Circular Economy Principles   | Recommendations for Integration   |
|---|--|---|--|---|
|   |  | <ul style="list-style-type: none"> <li>Binary consideration of reversibility for connections</li> </ul>   | <ul style="list-style-type: none"> <li>Asset (Building) Use Extension</li> </ul>   |   |
| <b>Avoidance of unnecessary treatments and finishes</b> | Avoiding the use of finishes that do not serve a specific non-aesthetic purpose.   | Binary consideration of if a finish inhibits recyclability or reuse.  | <ul style="list-style-type: none"> <li>Building Information Modelling (BIM) System</li> </ul>                                      | <ul style="list-style-type: none"> <li>Utilize BIM such that economic consequences of finishings on end-of-life value are apparent</li> <li>Provide differentiating labels for relevant materials</li> </ul>      |
| <b>Supporting reuse business models <sup>b</sup></b>    | Supporting secondary materials markets to facilitate the circularity of built environment materials.   | <ul style="list-style-type: none"> <li>Material recovery percentages (weight or volume)</li> <li>Practicality of recyclability or reuse</li> <li>Binary assessment of refurbishability or remanufacturability.</li> </ul> | <ul style="list-style-type: none"> <li>Product-as-a-service models</li> <li>Asset (Building) Use Extension</li> <li>BIM</li> </ul> | <ul style="list-style-type: none"> <li>Utilize BIM to provide data on secondary materials market</li> <li>Design components for circularity</li> <li>Increase awareness of secondary materials markets</li> </ul> |
| <b>Simplicity</b>                                       | Assembly or system that is designed to be straightforward, easy to understand and meets performance requirements with the least amount of customization. | <ul style="list-style-type: none"> <li>Parts per components or element</li> <li>Ranges on dimensions/sizes of similar components</li> </ul>   | <ul style="list-style-type: none"> <li>BIM</li> </ul>  | <ul style="list-style-type: none"> <li>Integrate a 6S's approach rather than the three-layer approach outlined in the ISO Standard</li> </ul>   |
| <b>Standardization</b>                                  | Use of common components, products or processes to satisfy a multitude of requirements.  | Percentage of build (cost, volume or mass) for materials considering dimensions, components, connections, modularity and interoperability.  | <ul style="list-style-type: none"> <li>BIM</li> </ul>  | <ul style="list-style-type: none"> <li>Increase awareness of standardization benefits</li> </ul>  |
| <b>Safety of disassembly</b>                            | Consideration of a safe plan for disassembly at the onset of design to ensure effectiveness.   | Checklist based on measurement criteria above and durability (component service life as a percentage of asset life).  | <ul style="list-style-type: none"> <li>Resource Recovery</li> </ul>  | As this integrates the above principles, all previously referenced recommendations are applicable.  |

Note(s):

- a) Additional measures considered to be less practical for implementation are available in the ISO Standard.
- b) Includes supporting reuse, refurbishment, remanufacturing and recycling.

Source(s): ISO 2020

To implement these principles and associated recommendations, key stakeholders along the supply chain beyond architects and designers must be engaged, including suppliers, construction, owners/operators, and those undertaking decommissioning. Each stakeholder along the supply chain, along with broader stakeholders, such as government and industry associations, have broader responsibilities, including facilitating 'best' economic and environmental opportunities and education and capacity building.

Product and component suppliers influence the integration of DfD/A through the principles identified above. The ISO Standard notes the importance of evaluating product characteristics and composition to define sector specific improvement strategies (ISO 2020). "DfD should enable the selection, collection, recycling / reprocessing, and reuse of construction materials, products, components and systems," contributing to the circular economy (ISO 2020). In doing so, the designer can enable the secondary market by providing supply.

Most decisions related to DfD/A are made during the design stage. Therefore, the construction stage's primary role is to carry out these decisions (ISO 2020). As such, effective knowledge transfer between design and construction teams is pivotal to the success of DfD/A. Collaboration during the design and construction processes should be assumed as integral to the successful implementation of DfD/A. It can be enhanced through IPD processes and using tools such as BIM. Therefore, building knowledge of and capacity within the construction industry should be viewed as a key success factor for implementing DfD/A. This can facilitate the construction team identifying feasible alternatives and updating design parameters (ISO 2020). Finally, the construction team should ensure relevant documentation and modelling are handed over to owners and operators of the constructed asset, and support training is provided, if necessary (ISO 2020).

During the use stage, owners and operators have three primary responsibilities:

- Updating and transferring documentation and information models;
- Complying with maintenance requirements to optimize durability; and,
- Avoiding applying unnecessary finishes and treatments (ISO 2020).

The purpose of these responsibilities is to ensure disassembly properties of the constructed assets are not compromised (ISO 2020). Within the use stage, refurbishment may be possible. During a refurbishment, the principles defined above should be maintained to ensure the viability of DfD during the decommissioning stage for the construction works (ISO 2020).

At the outset of the decommissioning stage, DfD approaches developed, maintained, and retained throughout the constructed works' life should be transferred to the decommissioning party (ISO 2020). Possession of this knowledge will aid the decommissioning party in successful disassembly. During the design process, decommissioning should be considered through scenario planning reflective of different deconstruction techniques ranging from full disassembly to full demolition (ISO 2020). Scenario planning should consider maximizing socio-economic and environmental outcomes with respect to the characteristics considered in the design process (ISO 2020). This type of analysis will accomplish two primary objectives: facilitating life cycle analysis and providing a plan to those responsible for decommissioning. First, to conduct a life cycle analysis during the design stage, end-of-life must be considered. Second, by considering decommissioning in the design stage, planning for deconstruction should be available for the responsible party at the appropriate time.

## Documenting DfD/A

Documentation is an important component of integrating DfD/A and adaptability into the design process. The purpose would be to provide information to future users and those conducting disassembly to make informed choices with respect to the materials available and their quality for future use. Collecting this data will also aid in quantitatively enhancing the business case for DfD/A. The ISO Standard (2020) recommends the following information should be collected:

### Design details

- Disassembly methods, material composition, recovery methods, and adaptable design features available through specific disassembly drawings, sequences and methods of construction, including component size, strength, and material composition.

### Material constituents and manufacturers

- Traceable products and materials to the specific manufacturer or supplier with appropriate contact details.
- Labelled material constituents with their engineering properties and potential hazardous properties.

### Connection detailing

- Detailed design documents (shop drawings) covering connection type, connector, size, material, required tools, and handling space.
- Non-standard connections should have a step-by-step assembly and disassembly guidance with required tools retained on site.

Data should be updated when repairs and maintenance are undertaken or if new information be made available (ISO 2020).

Considering the above, the ISO Standard is recommending two primary activities occur: a collection of detailed design drawings and a material information registry. Retaining design details can occur through two principal methods: mandate or precedent. The mandate would require the collection of this information through regulatory action. Precedent is a soft power mechanism through which documentation becomes a norm within the industry, thus becoming repeatable. Its implementation relies on establishing this norm through convincing key stakeholders of the value. Material information aligns with the introduction of a BIM system to track material information. Both of these strategies enable the transfer of knowledge to the next party responsible for handling the specific built environment component.

To facilitate ease of transfer, data should be digitized into a BIM system and made available in standardized formats (ISO 2020).

Examples of potential solutions identified by ISO (2020) include bar coding, Q.R. coding, RFID tags, or computer chips. These solutions enable the production of standardized data sets while minimizing labour associated with increased data collection. Implementation of this process can be considered very feasible given global trends towards digitization and data across the broader economy. Adoption is likely to occur organically or be the implementation strategy most utilized should a BIM system be mandated. For the purposes of data transfer, a checklist could be adopted covering key documentation categories (ISO 2020).



## Comparison Between CSA Guidelines and ISO Standard

The Canadian Standards Association (CSA) has a *Guideline for Design for Disassembly and Adaptability in Buildings (Z782-0)* ("the CSA Guideline") covering similar material to the ISO Standard. The CSA Guideline was developed between 2002 and 2007 in cooperation with the federal government, CSA, industry, and academia. The aim of the CSA Guideline was to provide guidance on the conceptual framework, concepts, and principles for the design of buildings following disassembly and adaptability principles.<sup>71</sup>

Differences between the CSA Guideline and the ISO Standard are predominantly cosmetic. This is to be expected given the ISO Standard was developed, at least partially, based on the CSA Guideline. As such, the principles in both are similar.

The ISO Standard has fewer principles as it consolidates some secondary market focused principles into a singular category. The CSA Guideline and ISO Standard also utilize the same levels of analysis, which are defined above (CSA 2012; ISO 2020). The ISO Standard also provides more detail on design stage considerations for DfD/A, including defining the characteristics of the built environment which should be analyzed.

A key distinction is the CSA Guideline was more pessimistic on end-of-life economic opportunity than the ISO Standard. Annex B of the ISO Standard provides a guide for developing end of life scenarios, which goes beyond the guidance provided in the CSA Guideline (CSA 2012; ISO 2020). Therefore, it is recommended government adopts the ISO Standard given it builds upon the initial CSA work, the similarity between the two, and the expanded information available in the ISO Standard.

## Benefits and Opportunities for DfD/A Practices in Canada

The circular economy is both applicable to the built environment and aligns with global trends towards sustainability and growing demand. When it comes to implementation, circular economy has a variety of benefits for both public and private stakeholders. However, challenges remain for implementation, including both tangible and intangible value chain constraints. While challenges are present, this creates opportunities for policy makers and the private sector to capitalize on opportunities for enhancing circular economy in the built environment.

As DfD/A practices have not yet been widely adopted in Canada, many benefits are speculative. These include both theoretical estimates of potential gains from DfD/A, and speculative unrealized gains. While arguments for DfD/A are often based on strong evidence and are integral in generating a case for broader adoption, realized benefits are more appropriate for demonstrating the merits of a DfD/A approach.

Case studies that promote the benefits of DfD/A focus on the material efficiency for private sector actors and reduced externalities, targeted towards public sector readers. Other benefits of DfD/A are not as apparent within the literature. If these benefits are described, they are often done so qualitatively. Some examples of tangible benefits from integrating DfD/A and other circular economy initiatives are summarized in Table 3. To enhance the case for DfD/A and other circular economy initiatives, proponents developing case studies should focus on creating holistic and quantifiable descriptions of a project's benefits.

<sup>71</sup> See [https://www.astm.org/DIGITAL\\_LIBRARY/STP/PAGES/STP47525S.htm](https://www.astm.org/DIGITAL_LIBRARY/STP/PAGES/STP47525S.htm)

**Table 3: Summary of benefits from DfD/A approaches for public and private sector stakeholders.**

| Benefit                                 | Evidence   |
|---|--|
| <b>Private Sector</b>                   |  |
| <b>Material Efficiency</b>              | <ol style="list-style-type: none"> <li>1. Riverdale Village Apartments (1997) salvaged 76% of materials which were resold at 5%-50% of retail costs</li> <li>2. SEGRO relocated a warehouse building generating a 25% cost saving and a 6% reduction in lifetime carbon footprint</li> <li>3. Virgin management achieved cost savings through using existing materials such as glazing, doors, partition layouts and flooring</li> <li>4. EPA notes deconstruction was 5% more effective than demolition<sup>72</sup></li> </ol> |
| <b>Reduced Construction Time</b>        | <ol style="list-style-type: none"> <li>5. Derwent London's Angel Building in Islington London was overclad and fully let within 13 months.</li> </ol>  |
| <b>Incorporates Flexibility</b>         | <ol style="list-style-type: none"> <li>6. MEC Ottawa (2000) was able to add 9,000 sqft due to modular and DfD principles</li> <li>7. Marie Short / Glenn Murcutt House incorporates flexibility through modularity and DfD allowing for varied layouts and use</li> </ol>  |
| <b>Increased Utilization</b>            | <ol style="list-style-type: none"> <li>8. Place Ladywell incorporates DfD and exceeds space standards by 10%</li> </ol>  |
| <b>Public Sector</b>                    |  |
| <b>Employment</b>                       | <ol style="list-style-type: none"> <li>9. Limited case studies but consensus in the literature (and logically supported) that increase labour is required for deconstruction/disassembly than demolition</li> </ol>  |
| <b>Less 'On-site' Construction Time</b> | <ol style="list-style-type: none"> <li>10. The NZWC identifies modular construction, a supporting circular concept for DfD, can decrease on-site construction time by 50% while reducing costs and defects.</li> </ol>   |
| <b>Reduced Externalities</b>            | <ol style="list-style-type: none"> <li>11. Recovery rates between 50%-90% considering recycled and reused materials</li> <li>12. Resources Row in Denmark uses materials from abandoned homes generating a 70% carbon saving</li> <li>13. Woodward Avenue Environmental Laboratory reduced landfilling by 90% while also using local and recycled sources generating further downstream environmental savings</li> </ol>   |

Source(s): Aggregated from various sources noted in footnote 73

<sup>72</sup> See <https://www.sciencedirect.com/science/article/pii/S1877705815021402>

<sup>73</sup> See <https://www.sciencedirect.com/science/article/pii/S1877705815021402> and Grau and Rios 2020, Balodis 2017; UKGBC 2019

## 5. Key Barriers & Enablers for the Circular Built Environment

### Barriers

There are multiple structural and systemic barriers that must be addressed to improve the business case for investing in circular strategies in Canada's construction, real estate, and built environment sector. The barriers are described below.

- **Cost challenges of transition to a more circular built environment versus the linear status quo.** The current linear system does not assess the real costs of consumption (they are currently externalities borne by society). Many developers, the design community, and construction firms do not maintain responsibility for their buildings and related materials at end of life and are, therefore, not incentivized to consider their environmental impact. Furthermore, the extraction and use of virgin materials / resources is often subsidized and/or cost less than secondary, recycled materials. The benefits of minimizing waste during construction and operations do not necessarily accrue to those paying the costs, creating disincentives to change. For example, builders' factor into their tender price the waste that will be generated during construction, and frequently they allow for waste if it means speeding up the schedule (particularly common with drywall).
- **Lack of awareness / information and standardized definitions.** There is a broad lack of awareness and understanding of the circular economy as it relates to the built environment and its opportunities and benefits for communities and the private sector. Where awareness and understanding exist, the focus remains largely on waste management and recycling rather than harnessing the full value through design, material and process innovation, and new circular strategies such as leasing models. Furthermore, the lack of standardized definitions, information, and data (such as on material flows) creates challenges for local, regional, and cross-border collaboration.
- **Fragmentation across construction industries and sectors.** The industry and its ecosystem are often fragmented and operates in silos (and frequently at odds with each other) across the value chain (often based on service or function within the buildings life cycle), which creates barriers for the collaboration and systems approach required to advance circularity.
- **Misaligned policies, incentives, and market signals.** Current policy, legal, and regulatory frameworks, as well as incentives for circular building design and development, are not well-aligned with circular economy principles at present. Inconsistent policy and regulatory frameworks between jurisdictions create challenges for business and investment risk. Cities also lack jurisdictional control over much of the construction waste stream, creating additional challenges to regulating change. Access to capital to commercialize and scale up circular economy solutions is often lacking. Furthermore, there are often conflicting market signals, with the interests of short-term investors misaligned with the long-term investment required for the circular economy transition (i.e., investors are often not concerned with the full life cycle of a building or what happens at end-of-life).
- **Infrastructure gaps and supply chain issues.** The construction supply chain is complex and differs by geographic region, creating structural barriers to the changes required for circularity. Ensuring material and feedstock quality, reliability, and affordability within circular supply chains is a challenge for innovation and investment and can also create legal and intellectual property issues. The market for recycled materials is often regional, creating challenges for cross-border material flow and jurisdictional control – existing trade frameworks and policies can create further issues. Furthermore, the market demand in Canada for

reclaimed materials is limited at present, which limits the investment in new infrastructure and activities such as material marketplaces and reverse logistics.

## Enablers

A number of key enablers that can support the circular built environment transition in Canada are outlined below.

1. **Embracing Circularity in the Design Stage:** The most significant opportunity, for increasing circularity is at the design stage for both materials and whole structures. As planning for circularity is a radical departure from traditional practice, systems thinking for circularity is an essential approach that requires industry collaboration. Systems thinking for circularity can be applied broadly to both product and service applications.<sup>74</sup> By incorporating systems thinking for circularity into value chains, companies and other key stakeholders can innovate and create solutions focused on displacing linear solutions.
2. **Education and Awareness:** To unlock the circular economy, stakeholders throughout the value chain require more education and awareness to shift from prevailing mindsets and business-as-usual approaches. Designers and developers must consider the whole life cycle of an asset, from how it will perform throughout its service life, to how it can be taken apart and its component parts recovered and reintegrated into the supply chain. Similarly, operators of buildings and infrastructure must understand how approaches in leasing can support more flexible and adaptive use and reuse.
3. **Cross-sector Collaboration:** Collaboration across the value chain is essential to implementing circular economy initiatives. Given the structural change to value chains associated with integrating circularity, it is important for stakeholders to understand the needs and constraints of other value chain actors to design viable and effective solutions. Changing conditions also introduce risk into the building process. Collaborating with other value chain actors can distribute the financial risk across a broader array of stakeholders to reduce potential risk to any single party.
4. **Supportive Policy, Incentives, Procurement, and Regulation:** While the private sector can play an important role in enhancing circular economy in the built environment, government can also drive the transition through policy and regulatory approaches, incentives, and fiscal measures, as well as through public and industry procurement. Governments can introduce regulation on materials management, construction practices, and asset management to support circular economy objectives. Incentives and fiscal policies available to governments include increased landfill fees, taxes on virgin materials, grants that support innovation and new business model adoption, and undertaking capacity building programs to support re-skilling labour.
5. **Business Model, Process, Supply Chain, and Technology Innovation.** Innovation in all of its applications (business model, process, supply chain, technological, social) is a key driver for the circular economy – which is no different for the built environment and construction sector. Innovation can address cost issues and improve productivity, while technology and digital solutions can support better information sharing and tracking of resource and material flows.

The primary challenges and enablers to advancing a more circular built environment are summarized in Table 4.

<sup>74</sup> See <https://hbr.org/2018/09/why-design-thinking-works>

**Table 4: Summary of challenges and enablers to the circular built environment transition in Canada.**

| Barriers                                   | Description   | Enablers   |
|--|---|--|
| <b>Cost to transition</b>                  | <ul style="list-style-type: none"> <li>• Circular products and materials may cost more than virgin materials, increasing short-term costs.</li> <li>• The environmental and financial benefits of circular building practices (including DfD/A) are often not recognized during the design and construction phases of the building, thus they are not prioritized.</li> <li>• Circular building designs may be more expensive than traditional projects due to lack of experience in, and the structure of, the supply chain and the pricing of 'risk' around unfamiliar processes.</li> <li>• Lack of economic incentives for reuse and recycling.</li> </ul>  | <ul style="list-style-type: none"> <li>• Measuring building costs in terms of saved material costs, energy costs, water costs, saved spatial resources, reduced accountable externalities.</li> <li>• Establishing economies of scale through market demand to bring down costs of recycled materials and/or applying disincentives (e.g., taxes) on virgin materials.</li> <li>• Incentives (e.g., tax, subsidies, grants) to support circular design, adaptive reuse, building material reuse, including through public procurement, to drive demand.</li> </ul>   |
| <b>Lack of awareness and understanding</b> | <ul style="list-style-type: none"> <li>• Lack of market awareness for circular buildings practices.</li> <li>• Consumers may perceive recycled, reused, or refurbished goods as inferior.</li> <li>• Lack of certainty regarding the ability to realize the value of materials at end-of-life during recovery phase due to lack of market for secondary and recovered materials.</li> <li>• Limited government enforcement of CRD waste and little information on the amount of CRD waste generated or diverted.</li> <li>• The lack of data at the provincial level for tracking diverted CRD materials and resources.</li> <li>• Lack of case studies and information showcasing the ROI for circular practices and business models.</li> </ul> | <ul style="list-style-type: none"> <li>• Utilizing supporting and complementary circular economy practices such as material passports and BIM to support information sharing and collaboration.</li> <li>• Supporting broader education, adoption and use to increase familiarity across the construction value chain.</li> <li>• Empowering trusted third-party organizations to develop knowledge dissemination, training, and capacity building programs to increase awareness of circular practices in the mainstream construction sector.</li> <li>• Enhancing marketing efforts to show the benefits of circular building practices to increase understanding and drive demand (e.g., case studies, guides and toolkits, etc.).</li> </ul> |

| Barriers  | Description   | Enablers  |
|---|---|---|
| <b>Fragmentation across construction industries and sectors</b> | <ul style="list-style-type: none"> <li>• Lack of ‘systems-thinking’ being applied to building projects and across the construction value chain.</li> <li>• Contracts may focus risk on a singular stakeholder limiting the likelihood of adoption.</li> <li>• Lack of a well-established ecosystem for the recovery and reuse of materials.</li> <li>• Lack of demand for used building materials/ components.</li> <li>• Competing interest between various segments of the construction value chain.</li> </ul>               | <ul style="list-style-type: none"> <li>• Developing industry consortiums and/or empowering neutral third-party to support coordination, convening and education the built environment supply chain on circular building practices.</li> <li>• Developing new collaboration and co-creation processes to enhance sharing platforms and expand the market for product as a service models.</li> <li>• Involving suppliers at a very early stage in the design phase to support circularity in building design.</li> <li>• Leveraging technology and digital tools to enhance collaboration and transparency of material flows and optimize circular designs and waste streams.</li> <li>• Regulating transparency around waste diversion data to improve information flow across jurisdictions and key stakeholder groups.</li> </ul>                         |
| <b>Misaligned policies, incentives, and market signals</b>      | <ul style="list-style-type: none"> <li>• Entrenched business practices and assumptions create uncertainty and perceived risk.</li> <li>• Lack of demand downstream for recovered materials driving upstream demand (disconnect between end of life and upstream).</li> <li>• No building codes or regulations requiring consideration for the end-of-life value retention of building materials and resources.</li> <li>• Lack of circular building practices that are linked green building standards such as LEED.</li> </ul> | <ul style="list-style-type: none"> <li>• Provincial building standards that include alternative pathways for innovative projects.</li> <li>• Aligning and harmonizing policy and regulatory landscapes in Canada to support circular economy business models and innovation in the built environment sector.</li> <li>• Referencing ISO and other standards in building code and bylaws, as well as in green building certification programs, to support market uptake and awareness.</li> <li>• Exploring the application of building material passports to enable material reuse and resource recovery planning.</li> <li>• Promoting flexible building use, including developing zoning bylaw updates to accommodate adaptive reuse.</li> <li>• Developing a Canadian standard for LCA (the ISO standard does not provide specific guidance).</li> </ul> |

| Barriers   | Description   | Enablers   |
|--|---|--|
| <p><b>Infrastructure gaps and supply chain issues.</b></p> | <ul style="list-style-type: none"> <li>• Lack of reverse logistics and related infrastructure for collecting, sorting, and processing CRD diverted materials and resources.</li> <li>• Quality and quantity issues present risks for reclaimed and recycled materials.</li> </ul> | <ul style="list-style-type: none"> <li>• Investing in material sorting facilities and online material marketplaces.</li> <li>• Auditing and developing inventories of salvaged materials in all the public projects and a percentage of salvaging (with green jobs training) to secure the availability of salvaged materials in the market and support the development of deconstruction industry.</li> </ul> |

Source(s): Aggregated from various sources noted in footnote 75

<sup>75</sup> Challenges were identified in Grau, David and Fernanda Cruz Rios. 2020. Circular Economy in the Built Environment: Designing, Deconstructing, and Leasing Reusable Products. Reference Module in Materials Science and Materials Engineering 5: 338-343. Available at <https://www.sciencedirect.com/science/article/pii/B9780128035818114948> and UKGBC. 2019. Circular Economy Guidance for Construction Clients. <https://www.ukgbc.org/wp-content/uploads/2019/04/Circular-Economy-Report.pdf>, <http://www.nzwc.ca/about/waste-prevention/Pages/default.aspx>

## 6. Accelerating the Circular Built Environment in Canada

There is a significant economic opportunity for Canada to rethink how buildings are designed, managed, maintained, as well as how construction materials and resources can be more effectively recovered and brought back into the supply chain at end of life to eliminate waste in all of its forms (described in Section 3 of this report). This, in turn, has the potential to provide additional economic, social, and environment benefits (including GHG emission reductions).

Several underlying enablers have been identified that can help address the barriers outlined above – which must be considered as part of an interconnected system for maximum benefit and returns. Creating a collaborative industry culture focused on disseminating knowledge and information across the value chain and between parties engaged in the building process will increase overall confidence in the viability of these circular strategies, methods, and practices.

### Summary of Recommendations

The recommendations described below summarize key considerations for advancing circularity in Canada's built environment sector.

#### Embracing Circularity in the Design Stage:

- Since a significant opportunity for increasing circularity exists at the design stage for both materials and whole structures, there is a need to develop targeted training and education for architects and engineers on designing for circularity.
- Certification programs, such as LEED, can consider expanding their point systems to incentivize circular design best practices (e.g., DfD/A, durability, deconstruction).

#### Education and Awareness:

- Demonstrate the business case for the circular built environment through case studies, resource toolkits for industry, and knowledge sharing.
- Integrate circular principles into post-secondary education and trades training programs in Canada. Government, post-secondary institutions, professional associations, and training program administrators can play leadership roles by developing and supporting programs that train building professionals in circular design and construction principles and practices.

#### Cross-sector Collaboration:

- Enhance relationships between building suppliers and architects to increase shared responsibilities over material use, increase demand for secondary materials, and circular building designs by breaking down silos in the sector.
- Support Integrated Design Processes and Integrated Project Management approaches with circular built environment principles.
- Advance industrial symbiosis models to support secondary materials.



**Supportive Policy, Incentives, Procurement, and Regulation:**

- Enhance CRD sector diversion through expanded EPR and landfill bans.
- Harmonize regulatory approaches to drive circular practices in the built environment sector, including local government bylaws to drive more deconstruction practices in Canada.
- Embed standards for disassembly, adaptability, durability, and deconstruction into building code and local bylaws.
- Develop long-term policies that encourage the scaling of circular solutions, including through procurement practices, to drive the market demand for recovered and recycled materials and resources. The public sector can support circular procurement through its own building initiatives and practices (e.g., to drive demand for products such as mass timber and recycled concrete).
- Transition to more performance-based practices and standards that encourage building flexibility and adaptive reuse approaches.
- Undertake audits and develop inventories of salvaged materials in public and private-sector building projects in support of the deconstruction industry and secondary material markets.

**Business Model, Process, Supply Chain, and Technology Innovation**

- Support the adoption of digital innovation in areas such as BIM, building as material banks, and material passports to improve information and decision-making.
- Develop an innovation fund to support circular business models, as well as supply chain and technology innovation, focused on addressing circular economy challenges in the built environment sector.
- Develop grants to support R&D and innovation into low-carbon and circular building products and materials. (e.g., better understand the GHG emission impact of the life cycle of construction products and materials and how to minimize the embodied carbon and optimize the carbon sequestration potential through cascading resource considerations)

## Appendix A: List of Organizations Consulted

| ORGANIZATION                                    | SECTOR                                     |
|---|--|
| City of Toronto                                 | Local Government                           |
| CSA Group (Construction & Infrastructure Group) | Non-profit Organization                    |
| Ecole Technologie Superieure                    | Academic Institution                       |
| Element5  | Material Supplier, Manufacturer & Designer |
| Forestry Innovation Investment                  | B.C. Crown Corporation                     |
| HDR   | Architecture & Engineering Firm            |
| Ivanhoe Cambridge                               | Property Management Firm & Developer       |
| Lafarge Canada                                  | Material Supplier & Manufacturer           |
| National Zero Waste Council                     | Non-profit Organization                    |
| Nordic  | Material Supplier & Manufacturer           |
| National Research Council                       | Federal Government Agency                  |
| Natural Resources Canada                        | Federal Government Department              |
| Perkins+Will                                    | Architecture & Engineering Firm            |
| Vince Catalli                                   | Architect                                  |

## Appendix B: Case Studies

### Corporate Leaders in the Circular Built Environment: Case Study on Mountain Equipment Co-op (MEC)

MEC has four buildings across Canada that showcase circular building practices and building material stewardship. The first two are the Ottawa and Winnipeg buildings, both of which were built to C2000 standards at the time. C2000 was the predecessor of LEED and other building performance metrics, the buildings being classed the 1<sup>st</sup> and 2<sup>nd</sup> ever C2000 certified in Canada.

The **Ottawa building** is recognized for a model for DfD. The original 40-year-old building was carefully dismantled with the intention of reusing as much material as possible, utilizing the disassembly-friendly original construction components. As a result, roughly 75% of those materials were re-incorporated into the new building, including 50% of the timber, and the majority of the steel building frame. Key participants in this project were Derek Badger, who went on to author "The Residential Deconstruction Manual" for the CHMC, and Linda Chapman Architecture.

An important aspect of this project was the preservation of heritage features of the building, a 60's era two-storey grocery store with curbside character contributing to the area's heritage and aesthetic. Critics of the project implicated MEC as adding to the 'gentrification' of the area, preserving heritage elements that much more important.

The **Winnipeg building** saw a similar deconstruction/rebuilding cycle as the Ottawa store, except the Winnipeg project had three existing structures on the site. Using deconstruction and 'unbuilding' techniques, 96% of the original materials by weight were re-incorporated into the new building, including the reuse of the building's steel and timber frames and rubble from brick and limestone from the old buildings used as aggregate in the new floor. Completed in 2002, this was the second C2000 certified building in Canada, and all the new additions (interior sections, partitions, wall segments, etc.) were installed with bolts and screws to allow for easy disassembly at the end of the building's life as well as quick and easy reconfiguration of the store itself should it change ownership or business models.

The other two buildings of significance are the MEC Corporate Headquarters on Great Northern Way, and a new 'flagship' retail store in Olympic Village, both in Vancouver, BC. These were brand-new builds over sites that were previously vacant or had structures un-suitable for reuse. **The H.Q. building** is recognized for being a wood-first building. When it was completed in 2013, it was one of the largest mass timber buildings in Canada. The project utilized prefabricated modular NLT floor sections, advanced mass timber framing and support systems, as well as building envelope and operations technologies making it 70% more efficient than the average building. It attained LEED Platinum certification and won several design and architectural awards in 2015 and beyond. The **retail shop in Olympic Village** was designed to have maximum adaptability with most of the interior partitions, safety features (i.e., railings, mezzanine sub walls), and other interior structures being specifically designed for disassembly and reconfiguration.

MEC has incorporated circular building practices and had indicated their preference for wood as the primary building material because of its myriad of uses at the end of its life" and the interior subcomponents are attached with screws, bolts, and saddles/frames making them extremely easy to detach and reconfigure. Their building practices demonstrate downstream consideration of future material flows and use cases. MEC embraces several circular practices including reuse, repair, and repurposing.

## Prefab Manufacturing: Case Study Profile on DIRTT

DIRTT (Doing It Right This Time) is a publicly traded OEM (TSX: DRTT) with manufacturing facilities in Kelowna, BC, Phoenix, AZ, Savannah, GA, and Calgary, AB, where their Corporate Headquarters are co-located. Their core product offerings are structural interiors intended for commercial, institutional, and business customers conducting new builds and/or renovations: their products provide designers, architects, office tenants/leaseholders, and other construction industry actors with a wealth of design and material options, all completely customized for every project.

DIRTT's core value proposition is based on what can be saved in terms of materials, costs, and time during a construction or renovation project. Prefabricated custom components arriving onsite in a 'ready to install' state can prevent a myriad of complications and costs common during construction. These include, but are not limited to, mistakes in measurements or cuttings resulting in 'start-overs' or the need for new/replacement materials and site congestion. Scheduling overlaps where multiple tradespeople wind up working 'over top' of each other, thereby decreasing efficiency and increasing costs, clients who are surprised by or dissatisfied with how things look (thereby triggering new 'start-overs' and re-designs) and so on.

To address costly onsite complications, DIRTT products are carefully designed, planned, and manufactured to spec: they do not hold 'ready made' inventory. DIRTT's proprietary ICE planning software generates V.R. models of customers' spaces, overlaid with various DIRTT products and materials within the V.R. model. This allows customers or their designers (i.e., interior designers) to test various configurations, colours, textures, and structures before anything gets manufactured. Once the overall aesthetic and design have been approved, the ICE platform immediately triggers JIT work orders to fulfil the project needs at the exact specifications used in the V.R. model.

DIRTT uses both the JIT and a 'distributed' manufacturing model. The ICE platform calculates the most environmentally and economically efficient manufacturing origin(s) and distributes orders accordingly. Hence, a project in Ontario may receive components manufactured in Savannah, GA, Calgary, AB, or both, depending on where ICE has determined the fastest route with the least amount of fuel and time. Due to DIRTT's ultra product standardization, the manufacturing origin has no bearing for onsite assembly and installation.

DIRTT's custom modules can be manufactured with a large amount of embedded tech: flooring panels with fibre optics for high-speed LANs, pre-wired and structurally fortified wall systems for T.V. mounts, power distribution with re-configurable outlets, and so on. Due to 100% customization, the options are nearly endless. Full wall modules always come with nearly invisible but highly convenient access panels in case of interior equipment failures (i.e., plumbing).

DIRTT's corporate policy is very focused on sustainable materials, procurement, and processes. Wall systems have sound-baffling insulation made from recycled denim (determined to be superior to fibreglass for its baffling qualities as well as being inert, whereas fibreglass is not). The wood used in DIRTT's products comes from FSC-certified suppliers, and blended products (i.e., MDF) are made with low/no VOC composites and a high proportion of post-industrial recycled content.

One of the key features of DIRTT's products is the design for easy installation and disassembly. Their products are intended for rapid, unintrusive installation and are mostly 'surface mounted' onto walls, beams, and other existing infrastructure. According to their website, average office tenancies are 5 years, which means the same office space may see 4 – 5 "flips" over a 20-year life span. In traditional models, incoming tenants negotiate with owners for specific configurations of offices, workspaces, board rooms, etc. Then owners undertake the renovation process to meet the desired configurations, typically recovering the costs through high lease rates.

The model where incoming tenants (particularly in brand-new buildings) purchase and install customized DIRTT systems has a higher-than-usual up-front cost but will generally yield low or below-average lease rates, which can provide significant saving over the years. Furthermore, when it comes time to exit the lease, DIRTT products can be quickly and easily uninstalled with virtually no destruction of either the office space/building itself or the DIRTT products, resulting in drastically lower 'exit costs' than having to renovate the space back to its original state. It goes without saying that this model prevents an extraordinary amount of construction, renovation, and remodelling costs in direct dollars and materials.

DIRTT is one of the few Canadian manufacturers of prefabricated structural components that provide LCAs and EPDs on their products. They have also completed several Health Product Declaration (HPDs) to further their transparency on environmental performance. Their products adhere to LEED, WELL, and Living Building standards, as well as other GBRS metrics. Naturally, their products meet all the building, fire, and engineering codes; however, since most applications are interior only and not 'load bearing' are not subject to as much technical rigour as other renovators might face.

The main challenge for DIRTT is the steep up-front cost and technical/professional barriers to access their products. They do not simply sell products to an end user doing a DIY installation; they are not very 'consumer' focussed whatsoever. The complex VR-based designing cycle, JIT and D.M. models, and overall sophistication of the product requires the expertise of professional designers, accredited installers, and coordinated delivery logistics providers, adding substantially to the total cost

The 100% customized nature of their products makes them extremely difficult to repurpose except in rare cases where existing infrastructure perfectly matches former infrastructure (i.e., moving up/down floor(s) in the same building with the same level of development on each floor). However, DIRTT designers and installers routinely re-visit customer spaces to reconfigure, upscale, or repurpose their products so they can be modified onsite for new occupants or a change in the existing occupant's needs.

### **Industrial Symbiosis: Case Study Valoris Eco-Industrial Park**

The Valoris Eco-Industrial Park exemplifies the Industrial Symbiosis model where materials formerly considered waste have found new uses cases, new value, and new opportunities. The Eco-Industrial Park has created fertile conditions for business innovation, research and development, and collaboration between agencies and related industries.

Since 2010, the City of Sherbrooke and MRC Haut-Saint-Francois have been collaborating on the development of Valoris with a shared mission to address waste management issues in the region. In 2009, Quebec introduced strict new waste management regulations that prompted Valoris to change the original site from a Sanitary Landfill Site (SLS) to an Engineered Landfill Site (ELS), which enabled leachate water treatment and other run-off residues. The SLS was decommissioned. The ELS began accepting household, industrial, commercial, and institutional waste and CRD waste from the surrounding regions.

In 1998, GSI Environmental opened a facility at Valoris to provide services for integrated management of biomass, and in 2005 the ELS and participating MRCs began operating a sorting and conditioning bioreactor test centre with GSI. This spawned the opening of a Regional Ecocentre at the ELS to further enhance materials sorting, prioritization, and recovery. From 2013 to today, all of Sherbrooke's and HSF's MSW has been taken to Valoris, providing a stable stream of recoverable materials for industrial inputs.

Valoris is a contracted waste hauler with a fleet of trucks servicing the Sherbrooke and surrounding municipalities. Hence, part of the business model is for-profit waste removal and management service at various levels: from curbside residential pick-up to CRD waste from contractors and developers and everything in between. On the recovery/disposal end, several companies have been working on technologies, processes, and services to not only recover materials but create new use cases and value-added products.

Biomass created from feedstocks of wood (CRD and household), as well as and forestry waste, dominates the 'types' of technologies in play at Valoris. This is a sector of considerable importance and focus on Quebec, with various ministries, industry associations, and funding agencies all supporting and developing the sector. The Quebec Ministry of Economy and Innovation, the Centre of Excellence for the Valorization of Residual Materials, and the Centre of Excellence in Clean Technologies are all direct participants in Valoris, helping to create an ecosystem of support, funding, technology transfer, and R&D to keep advancing the sector.

Valoris is also supported by the University of Sherbrooke and the Centre for Local Development (translated from French). The former has generated hundreds of research papers, feasibility studies, and applied technology on Circular Economy principles drawing real-world examples and use cases from Valoris. The latter serves as an industry' liaison', helping to match companies with inputs/outputs suited for Industrial Symbiosis and generally facilitate business development and matchmaking.

A key challenge of Valoris is the relatively small markets they serve. Located roughly 180km from Montreal, Sherbrooke and surrounding municipalities are a fraction of the market size of Metro Montreal, meaning the potential for scaling-up of Valoris is limited at best, impossible at worst. One of the biggest economic barriers in developing viable biomass-based businesses is simply the cost of hauling large amounts of feedstocks. In general, if feedstocks require extensive management (collection, long-haul transportation, depositing), they become unviable due to the high cost of management versus what realistic downstream prices can be charged for finished or second-generation products. Additionally, some of the larger I.S. associations, working groups, and collaboration platforms are in larger markets such as Quebec City and Montreal.

The Province of Quebec "Residual Materials Management Policy 7.7" indicates the intention to develop more stringent regulations around CRD waste disposal, including phasing-in gradually higher tipping fees at MTFs. Revenues from these fees will be used to open and operate more regional sorting stations and develop more markets and technologies for residual materials. All this bodes well for Valoris.