ADVANCING CIRCULAR ECONOMY STRATEGIES FOR EXISTING BUILDINGS IN CANADA

A GUIDE FOR CANADA'S COMMERCIAL REAL ESTATE SECTOR

OCTOBER 2023

CIRCULAR ECONOMY LEADERSHIP CANADA

Circular Economy Leadership Canada (CELC) was launched in 2018 as a network of corporate leaders, non-profit think tanks, and academic researchers. An initiative of The Natural Step Canada (a national non-profit charity), CELC consists of more than 60 partner organizations and is working to connect Canada's circular economy community, as well as serving as a bridge to similar networks around the world. We provide thought leadership, technical expertise, and collaborative platforms for accelerating systems change and the transition to a low carbon, circular economy in Canada.

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Organizations consulted: Carbon Leadership Forum Toronto**,** City of Vancouver, Concert Properties, Core Two, DIRTT, HOK**,** JLL**,** Natural Resources Extension Program (NREP)**,** QuadReal, RDH Building Science, Reimagine Architects, The Salient Group, Schmidt Hammer Lassen Architects, University of British Columbia.

Cover: Le Phénix: Lemay's zero carbon revitalization of an industrial property in Montreal. *Photo credit: Adrien Williams*.

Contents

1. ABOUT THIS GUIDE

This Guide was developed by Scius Advisory, in collaboration with Circular Economy Leadership Canada (CELC) and a number of partners from industry and government. It was informed by research and consultation with a number of leading real estate owners, designers, and builders from across Canada and around the world, drawing from the two technical reports published by CSA Group with respect to opportunities for applying circular strategies to existing buildings (see featured reports on page 4).

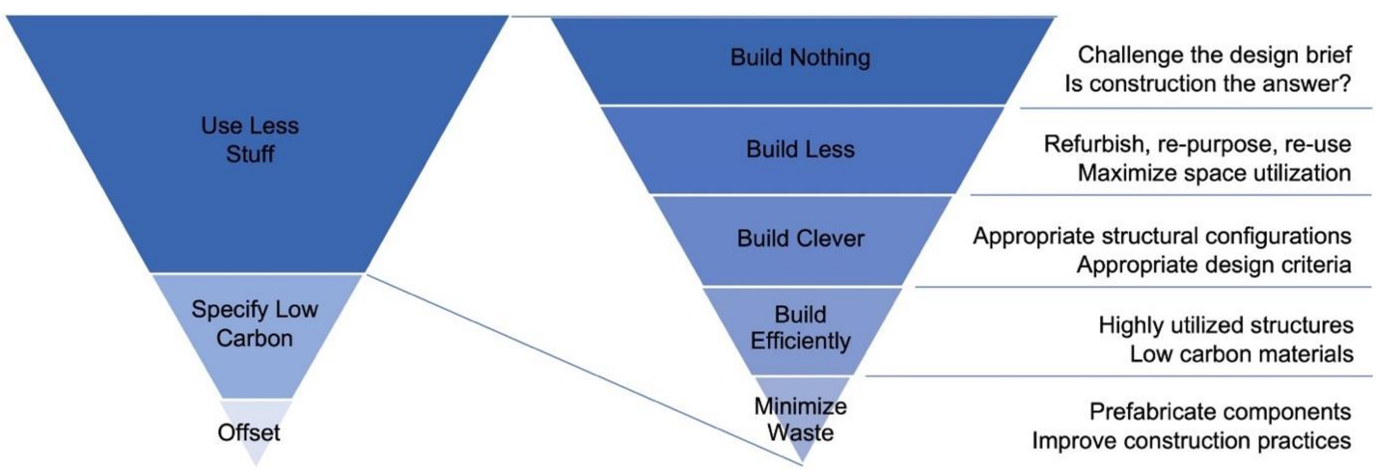
This Guide is designed for industry and organized inline with circular economy strategies that can be applied by Canada's commercial real estate sector, including concepts and practices such net zero design[1] (see Figure 1), design for flexible and adaptable use, durability, zero waste construction, innovative leasing, and deconstruction.

It presents current methods and examples (i.e., case studies) of these strategies and practices being applied within the Canadian and global commercial office market, highlighting actions that building owners, developers, property / asset managers, designers, and builders can implement. It also offers a selection of tools and resources to help get started, including important considerations when deciding whether to demolish and build new, or explore creative strategies that extend the life of existing buildings (and preserve their embodied carbon in the process).

The commercial real estate sector represents a large portion of buildings in Canada and is served by professional companies with well-established practices and well-understood market dynamics. While the changing nature of work brought about by demographic shifts, technology proliferation, and the recent COVID-19 pandemic, coupled with environmental policy and investor priorities, makes this Guide particularly relevant to office buildings, many, if not all, of the circular strategies described are applicable to other building types.

Figure 1: Hierarchy of Net Zero Design As set out by the Institution of Structural Engineers based on PAS 2080:2016 Carbon Management in Infrastructure.

Reproduced with permission from Institution of Structural Engineers



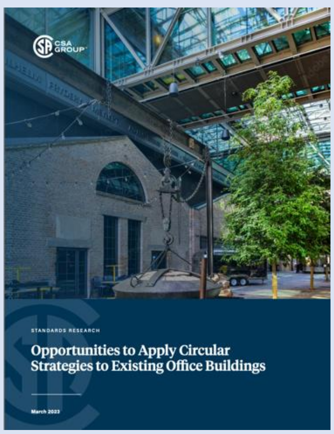
Opportunities to Apply Circular Strategies to Existing Office Buildings

The Canadian Standards Association (CSA) Group has published two technical studies that serve as companion documents to this Guide, focused on extending the lives of existing office buildings and examine:

- Design interventions that could optimize an existing building for ongoing operations while improving the potential for future renovations.
- Ways to minimize waste generated from maintenance and renovation activities and, ultimately, end of life.
- Construction material flows and incorporation of salvaged materials into projects.
- The greenhouse gas (GHG) and embodied carbon benefits of extending the life of existing buildings through renovation and upcycling.

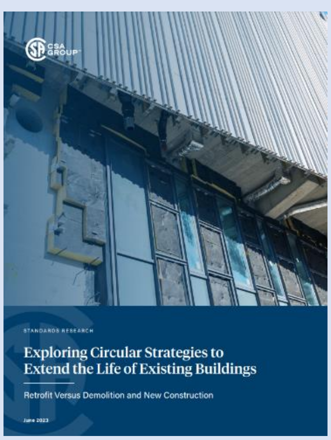
Available at: https://www.csagroup.org/standards/areas-of-focus/construction-infrastructure/standards-for-circularity-in-construction/

CSA Group Technical Reports:



- **Opportunities to Apply Circular Strategies to Existing Office Buildings**

  (March 2023)



- **Embodied Carbon Benefits of Extending the Life of Existing Office Buildings: Retrofit versus demolition and new construction**

  (June 2023)

2. INTRODUCTION

The construction sector is an important part of Canada's economy. It generates nearly 7% of the country's gross domestic product (GDP) and employs approximately 7.5% of the workforce. However, buildings are environmentally impactful and a major contributor to greenhouse gas (GHG) emissions.

According to the United Nations, buildings and construction comprised 37% of global energy-related carbon dioxide (CO_2) emissions, of which non-residential direct and indirect emissions made up 10%[2]. Worldwide, the building industry is the largest consumer of raw materials and other resources, representing about one-third of global material consumption. It is also wasteful, with an estimated 40% of solid waste in urban waste streams coming from construction and demolition processes. Reducing waste is not enough to change this and, although new buildings can be built extremely "green" and energy-efficient, it can still take anywhere from 10 to 80 years to make up the negative impacts of a new construction project due to the role of embodied carbon stored within building materials[3].

Traditional construction is largely organized around linear processes. Raw materials and resources are extracted, manufactured, used for a time, and then usually disposed of at the end of their designed lives. In Canada, less than 20% of construction and demolition waste is diverted from landfill[4].

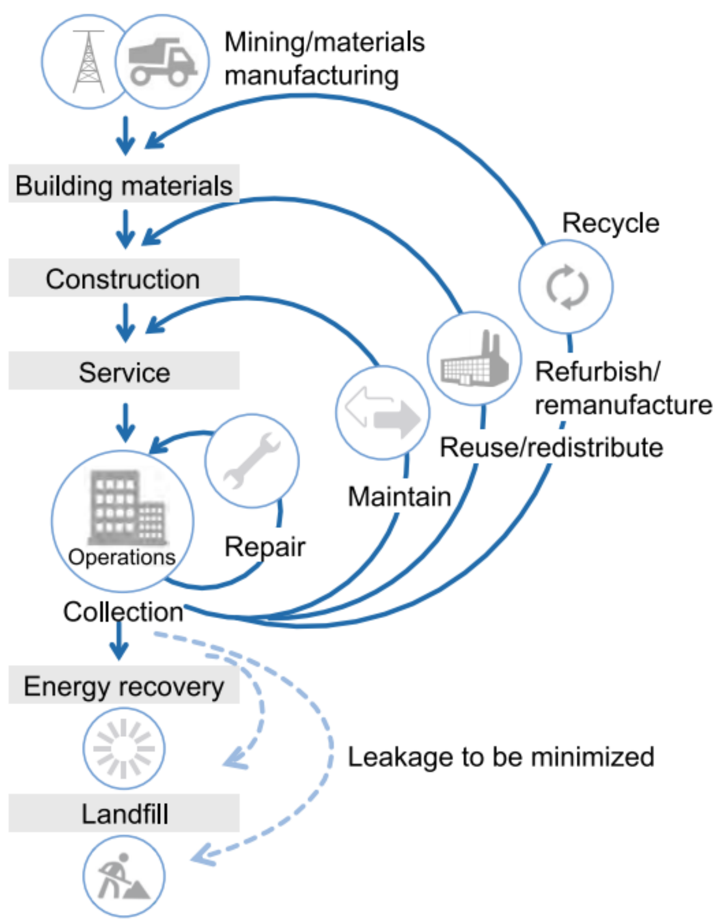
A growing body of research[5] indicates that circular economy practices can yield substantial GHG emission reductions by supporting a shift away from current linear "take-make-waste" value chains to ones that utilize resources more efficiently, increasing the value retention of resources already in the economy and cycling back those resources that have reached their end of first life (see Figure 2).

There are also economic benefits to construction businesses in the form of improved efficiency and reduced exposure to labour and material price volatility, as well as to society through the creation of green jobs and more resilient communities.

In a circular economy, growth and consumption is redefined. Components are specifically designed so that they can be re-used or refurbished. This protects the planet's resources and reduces environmental impact. The circular economy model eliminates waste from the equation by creating products that are "made to be made again".

Figure 2: Circular strategies for the built environment.

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



The Ellen MacArthur Foundation defines a circular economy by three principles:

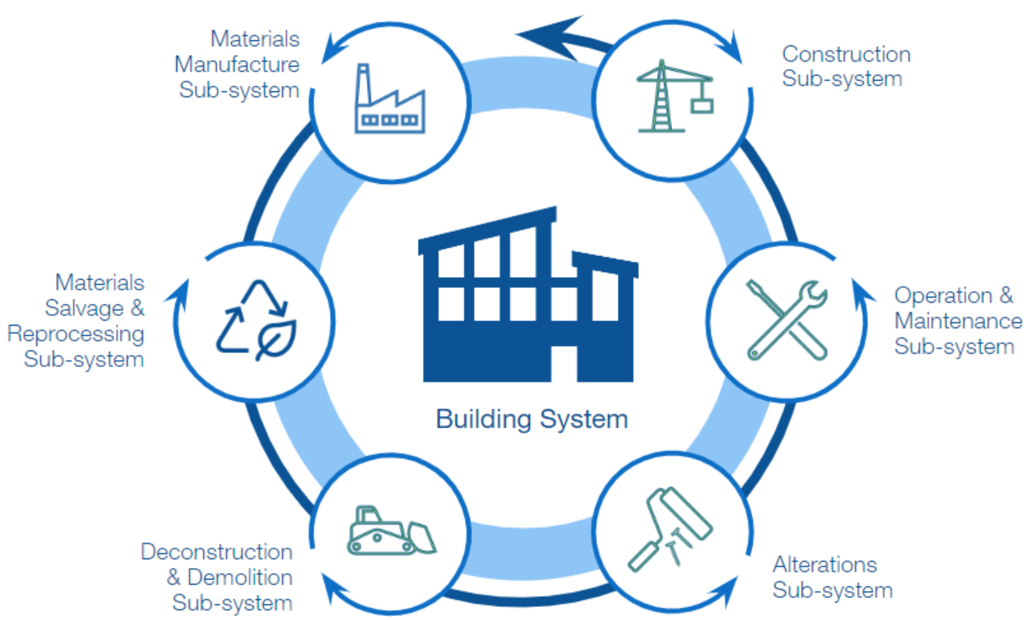
- Design out waste and pollution;
- Keep products and materials in use; and
- Regenerate natural systems.

Circular strategies can be applied across a building life cycle, inline with taking a systems of focus approach (see Figure 3). Applying circular building practices in Canada is not new. Industry and governments in many provinces have adopted construction and demolition waste-management efforts, life cycle assessment (LCA) approaches, and material and process innovation practices and policies. According to a 2021 survey by BOMA Canada[6], the following circular economy strategies are currently being implemented in buildings:

While efforts have led to greater material circulation and lower GHG emissions in the built environment sector, much more needs to be done to bring construction's ecological footprint[7] back in line with the earth's biocapacity to provide natural resources, the construction industry needs to reduce its demand for virgin materials and instead start to use what is already above ground (preferably locally above ground).

Figure 3: Circular strategies can be applied across the building system and life cycle.

Image Source: ISO/CD 59004 Systems of Focus



Circular Best Practices Case Study: Venlo City Hall (The Netherlands)

Implementing comprehensive circular strategies requires leadership at the policy and practical levels. To this end, the region of Venlo in The Netherlands, has committed to having the entire city and region function on the basis of Cradle-to-Cradle principles. Cradle-to-Cradle (C2C) is about seeing waste (garbage) as an eternal resource and doing the right thing from the beginning[8]. It is about making community and product development function in the same way as a healthy ecological system where all resources are used effectively, and in a cyclical way (as opposed to the current linear “take-make-waste” system). C2C methodology builds on the concept that “waste = food”, meaning that what is considered waste can become food in a new product cycle.

In practical terms, C2C requires products to be designed in such a way to ensure that all materials can be classified into either “biological” or “technological” cyclical systems. Biological materials naturally biodegrade and can be returned to the ecological system (e.g., natural fibres, bio plastics, etc.) and technological materials (such as metals, oil-based plastics and chemicals) are valuable materials that can be recycled or reused producing the same or better quality in closed systems, so long as they are not mixed.

Completed in 2016, the new 13,500m^2 (145,000sf) Venlo City Hall in The Netherlands[9] was designed from the outset to respond to four C2C themes: enhance air and climate quality, integrate renewable energy, enhance water quality, and define materials and their intended pathways. All of these themes are examples of circular practices. For example, products and materials were selected based on criteria such as their end-of-life residues serve as raw materials for new products, they are appropriate for either a biological or technological cycle, they offer added social or environmental values to the owner, and/or they are C2C certified. Compared to a traditional “base case” design, the project required an additional investment of €3.4 million to achieve the C2C goals. However, after a service life of 40 years, this investment would bring a return of €16.9 million (ROI of 11.5%).

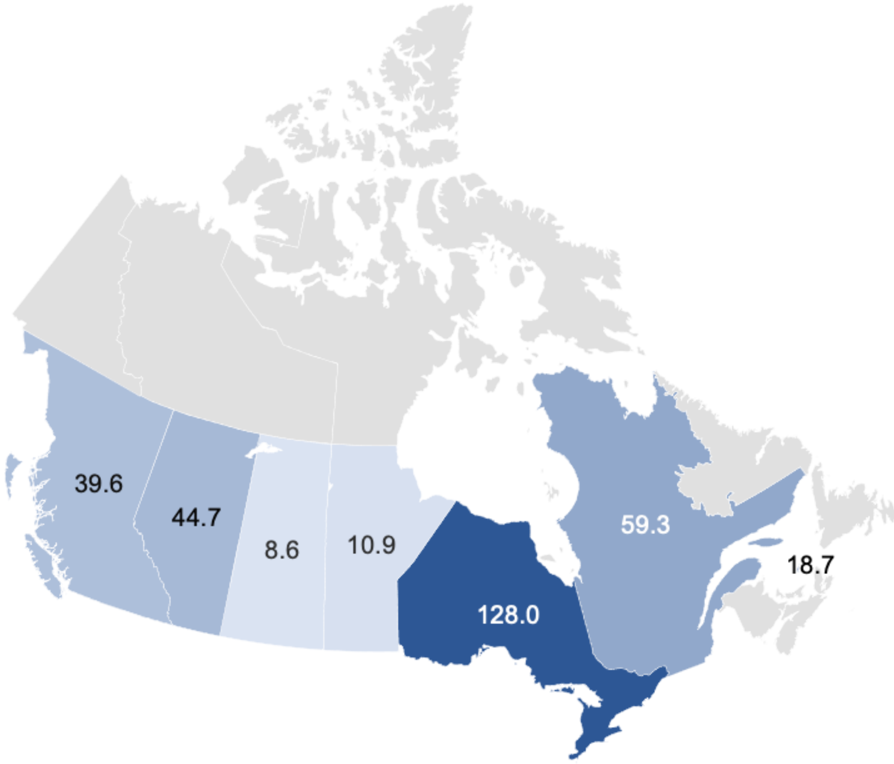
Figure: Venlo City Hall, The Netherlands. Photo credits: Ronald Tileman.

3. COMMERCIAL OFFICE MARKET IN CANADA

According to Natural Resources Canada (NRCan), there are over 482,000 commercial and public buildings in Canada, representing about 309.8 million square meters (3.3 billion square feet) of office floor area. This space includes activities related to finance and insurance; real estate and rental and leasing; professional, scientific, and technical services; public administration; and others. It captures both publicly and privately owned office buildings but does not include medical offices (Figure 3).

Figure 3: Distribution of office space in Canada by province (million m^2) in 2019.

Source: Natural Resources Canada



Office buildings are most likely to be threatened with demolition when they are no longer economically viable. The intrinsic characteristics that impact profitability include vacancy rates, operational costs, location, age, quality of fit and finish, and physical properties (such as size, floor layout, and construction type).

Office buildings in Canada are differentiated according to “Class A”, “Class B”, and “Class C”, with Class A being the most prestigious and commanding the highest rents. As of Q2 2022, Class A was the largest category by floor area and Class B the largest in terms of number of buildings.

In many markets, Class A buildings can be divided into sub-categories such as AAA, AA, and A. These buildings have the highest level of fit and finish, and may include a wide range of amenities such as underground parking, concierge services, retail, gyms, day cares, and more.

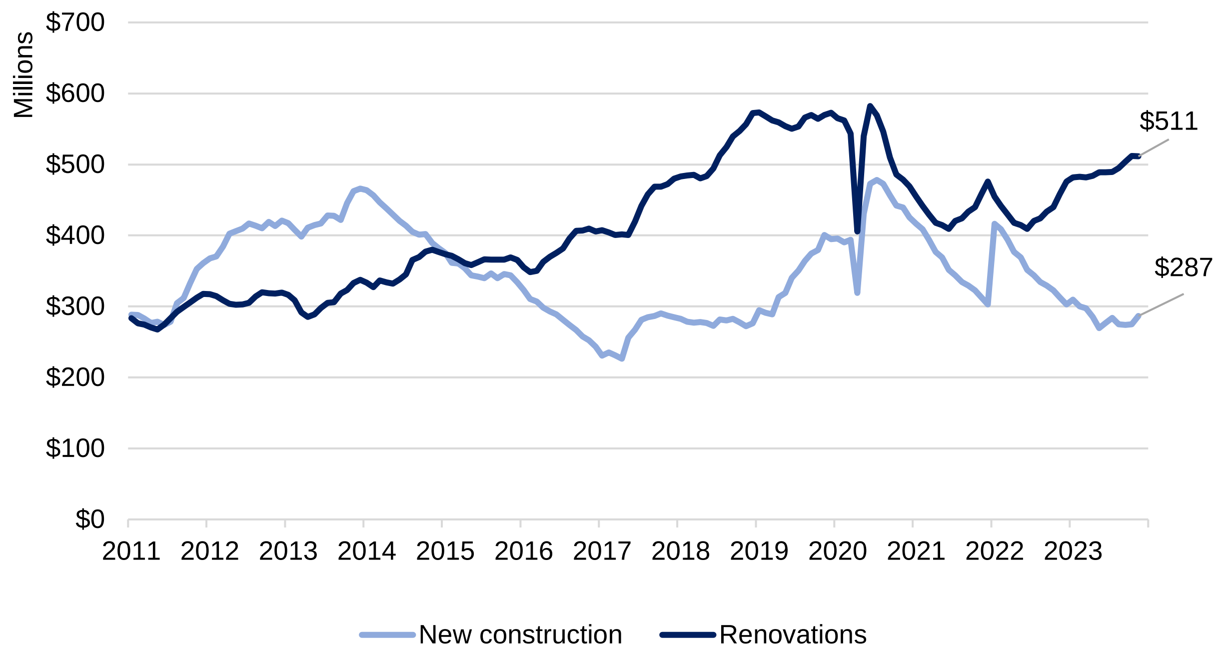
By comparison, Class B buildings tend to be slightly older and less well-appointed; however, they are nonetheless well maintained with good quality systems and fair to good finishes. They may be targeted by investors planning renovations to restore them to Class A.

Class C is the lowest grade for useable office buildings. Class C properties are older with less impressive architecture, limited infrastructure, and dated or obsolete technology. They may be located on less desirable streets or in older (non-heritage) sections of the city. They attract tenants requiring affordable, functional space, but may also have higher than average vacancy rates for their market. Class C buildings are most likely to need extensive renovations. Some buildings may be difficult to lease and therefore be targeted for demolition.

Canada's commercial office sector is a major generator of construction activity. In 2021, over $4.2 billion was spent on new office construction projects, and a further $5.2 billion on office renovations (Figure 4). As office tenants returned after the pandemic, many building owners have taken the opportunity to upgrade their properties. Nationally, renovations have comprised the largest portion of investment in office construction since 2015 and although the pandemic dampened all construction activity, renovation spending is now back to 2018 levels, whereas investment in new office buildings continues to decrease.

Figure 4: Monthly investment in office building construction in Canada ($ millions), 2011-2023.

Source: Statistics Canada. Table 34-10-0175-01 Investment in Building Construction

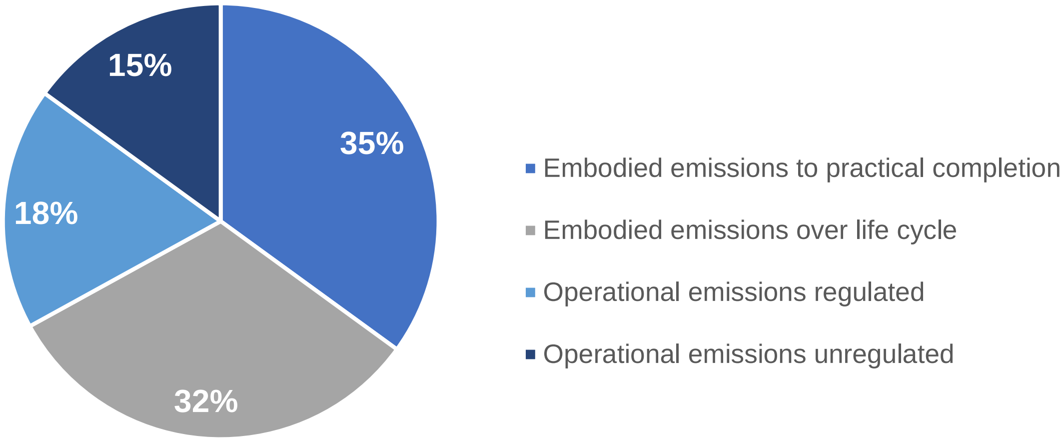


Office buildings are environmentally impactful. The operation of office buildings in Canada is responsible for 10.6 mega tonnes (Mt) of GHG emissions annually (2020 data from NRCAN, excluding emissions from electricity). The GHG emissions from office buildings constitute about 12% of the total GHG emissions from buildings in Canada. The carbon intensity of office building operations varies by province, with the most intensive being found in Alberta (60.43 kg CO_2e/m^2/year) and the least intensive are in Quebec (20.24 kg CO_2e/m^2/year).

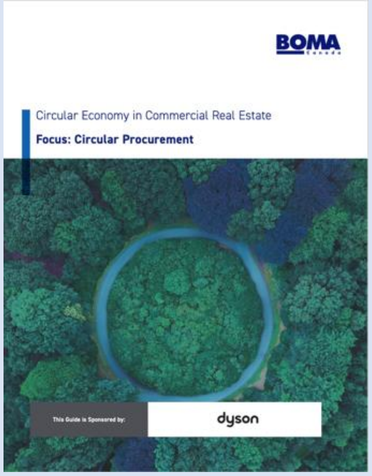
The construction, renovation and demolition of office buildings also generates GHG emissions from the extraction, manufacture, and transportation of construction materials, as well as the disposal of waste at the end of a building's life. Globally, the construction and operation of non-residential buildings comprises about 10% of energy-related direct and indirect GHG emissions. For office buildings, the embodied carbon impacts generated over the building's life cycle can be more than twice as much as the operational impacts. 35% of these embodied impacts are generated at during construction[10] (Figure 5).

Figure 5 Environmental impacts of a speculative office building with a Class A fit-out.

Source: RIBA Sustainable Outcomes Guide assuming building location in central London, UK



BOMA Canada (2021): Circular Economy Guide for Commercial Real Estate



Applying circular economy principles to management and operational practices provides building managers a process where goods and services can be purchased systemically and purposefully to incorporate closed energy and material loops within value and supply chains, to reduce waste and other environmental impacts.

The *BOMA Canada Circular Economy Guide* introduces the circular economy to commercial real estate professionals to help them begin their journey towards adopting circular practices in their assets.

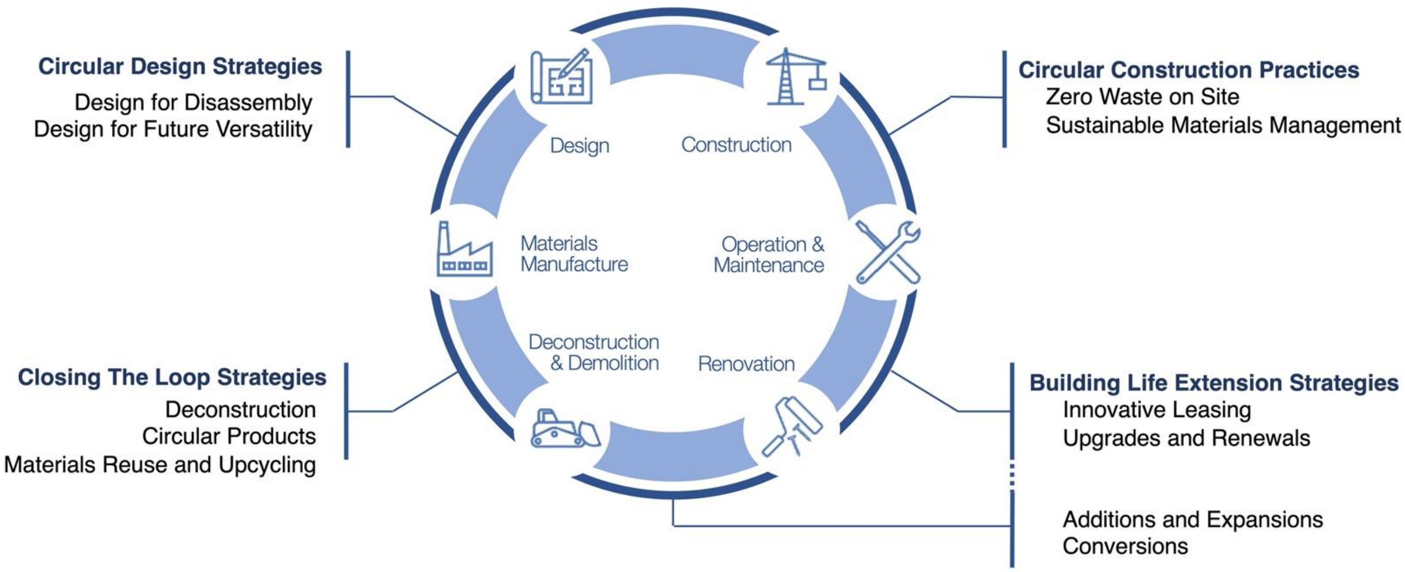
It sets out core definitions and concepts to support a deeper understanding of circular economy as it relates to management of commercial real estate. After providing an overview of the opportunities that exist across many areas of building operations, the guide explores circular procurement in more detail as a topic that holds the potential for immediate impact on building operations and its impact on environment.

Available at: https://bomacanada.ca/2021-circular-economy-guide

4. CIRCULAR STRATEGIES FOR OFFICE BUILDINGS

"Circular strategies" applied to existing office buildings means rethinking the design, construction, usage patterns and operational processes, and end of life activities so that products, as well as entire structures, have a regenerative life cycle (see Figure 6). In other words, they can be repeatedly repaired, reused, recycled, or transformed. Interventions can be applied at any point in a building's life cycle and can be championed by the developer, owner, designer, builder, or tenant. Some product manufacturers are fostering circular solutions in their own businesses which serves as an encouragement to other project team members. This Chapter provides more detail on each of the circular strategies as it relates to office buildings.

Figure 6: Summary of circular strategies for office buildings.



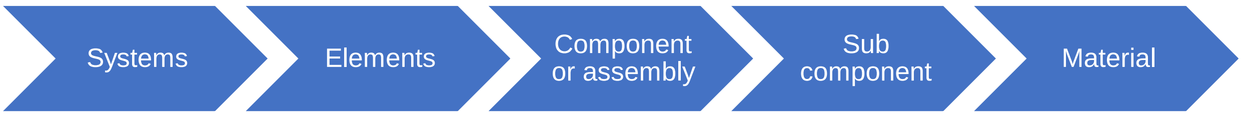
4.1. CIRCULAR DESIGN STRATEGIES

Circular design can support building life extension strategies and practices. It can involve extending the life of a building in its current form, expanding the form with new construction to create additional space, or a completely new structure that incorporates strategies that provide flexibility, adaptability, and ease of reuse as the building ages. Building owners are increasingly adapting their corporate values to incorporate sustainability measures and seeking design teams who can explore these options and provide both visualizations and financial expectations. Owners who are mindful of their carbon impact have requested a life cycle analysis early in the design process to aid in decision making. Architects and engineers are often the proponents of the options to limit embodied carbon through retention of the original structure and have developed creative ways to seamlessly incorporate the old and the new.

Buildings are being reimagined as new spaces that have interiors that can be reconfigured to suit the changing requirements of tenants or with components that can more easily be swapped out in the future as new or more efficient components become desirable. Cultural shifts to prioritize high-quality long-lasting components that are better maintained and reduce waste will influence changes in the materials used in design.

4.1.1. Design for Disassembly

"Circular thinking" during the planning stages of a building upgrade, addition, or conversion, involves incorporating features and components that allow for the building's materials, systems, and assemblies to be reclaimed for other purposes and their value retained at end of life. The challenge with disassembling modern buildings is that, starting in the 1970s, builders tended to use materials that have not held their value. Construction also used more glue, spray foam sealant, caulking, and other chemical applications, which can make it harder to dismantle and separate materials.



The following disassembly strategies can be applied to any level of the building design:

- **Exposed and/or reversible connections** allow for easier disassembly and reduces the potential for the product or material being damaged in the process. The objective is, where possible, to remove a component in a way that it, and the connectors, can be used again. Planning for future disassembly means prioritizing easy-to-access, "dry-assembly" solutions such as mechanical fastenings and "snap-fit" systems as opposed to adhesive, prevents the materials from becoming contaminated and impacting the potential for re-use.
- **Independence** involves designing the building in "layers" that stand separately for easy removal when they need to be replaced. This approach considers the fact that building products and materials have different life spans and, whether it is for maintenance or at end-of-life, building products need to be removable without impacting other components around them.
- **Inherent finishes** help to preserve substrate materials for recycling or reuse by avoiding contamination with applications such as grouts, paint, stains, and other coatings that are difficult to remove. In many cases, there are interior or exterior materials that have suitable finishes in their "natural state" such as timber, stone, concrete, some metals, etc.
- **Recyclability:** Selection of materials that have a high recyclable content (such as metals, gypsum, etc.) reduces the chance that they will end up in a landfill. This approach can reduce costs, protecting companies against the volatile prices associated with raw materials and providing more security of supply. Currently, when it comes to demolition, the majority of building components are reduced to lower grade materials with lower values. Selecting materials that can be recycled in their existing form will extend their life by many years.
- **Re-manufacturability** considers the potential for a product or material, after it has been removed from the building, to be taken back by the original manufacturer or acquired by another reprocessing company, to be refurbished or made into a new product of similar value. Re-manufacturability may rely on the product being removed or handled in a specific manner and may have certain requirements as to the level of material contamination.
- **Reusability:** some products and materials may offer economic value through re-use as opposed to recycling. The rationale for selecting reusable products at the design stage relies on the product being able to retain its value and function. In other words, it can be reused in its original form without repair beyond normal maintenance to achieve the benefits of disassembly.
- **Simplicity:** Simple forms need fewer parts and therefore, require a simpler disassembly. Fasteners that require standard tools allow for simple and fast disassembly. Traditional techniques such as Japanese joinery connections that are made entirely without the use of metal fasteners or adhesives are also being revived.

"It's essentially a way of looking at cities and buildings as material stores for the future."

- ***Circular economy specialist***

Design for Disassembly (DfD) allows for ease of reuse or recycling of materials to reclaim value of those items at the end of their current use. This methodology is usually not cost prohibitive and allows for long-term costs to be minimized. It requires consideration of the full building life cycle costs during design, not the short-term payoff.

In fact, if operational costs and end-of-life costs for buildings were incorporated into construction cost considerations, circular designs might be more widely considered.

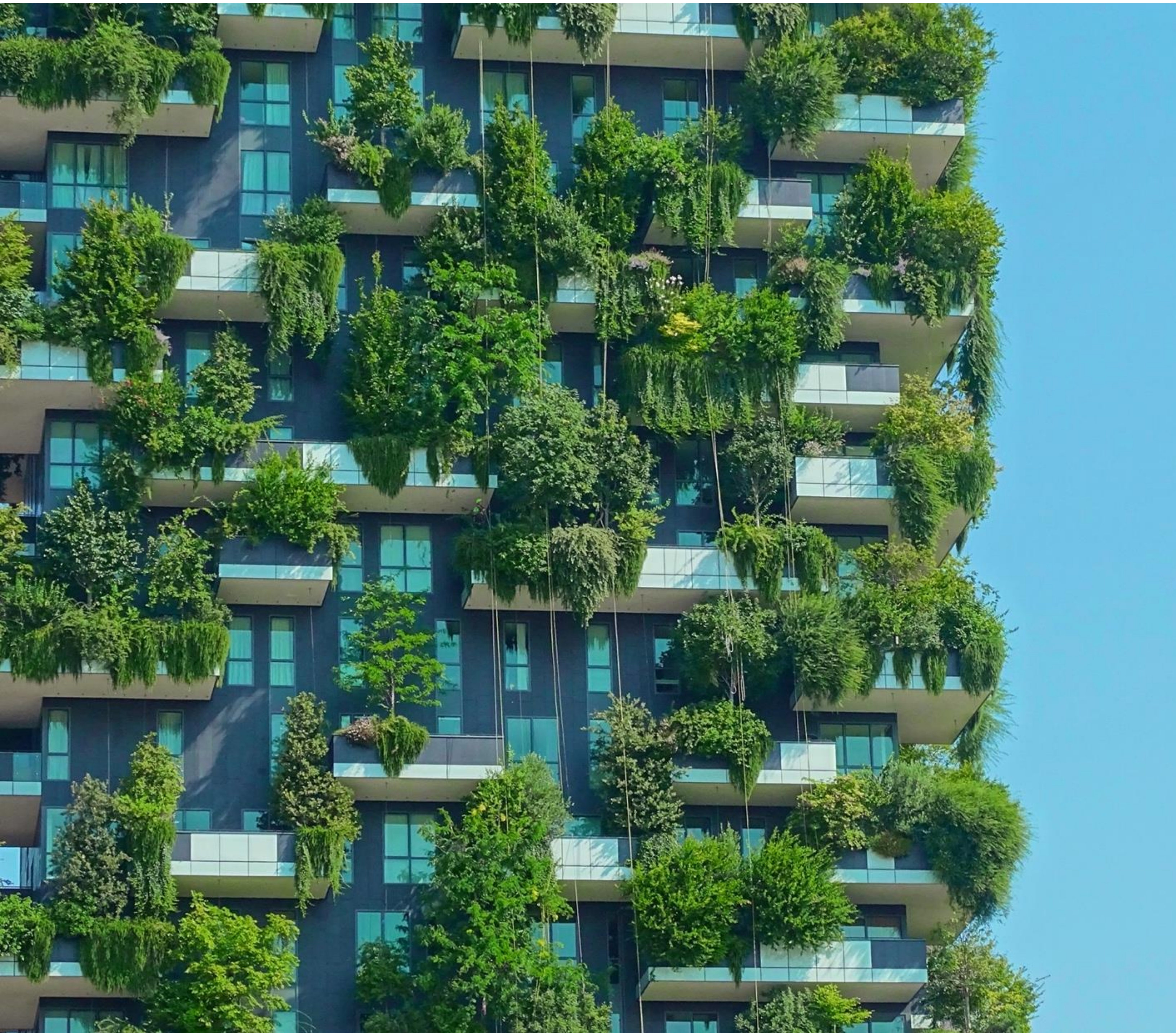


Figure 7: The BRE "Office of the Future" was designed to be deconstructed. Photo credit: BRE

BRE Office Design for Deconstruction Methodology Case Study

The BRE Office Design for Deconstruction (DfD) Assessment Case Study[11] presents a methodology to assess the deconstruction potential of new build properties. The three-storey 1,300m^2 concrete office case study building in Garston, Hertfordshire, England, was completed in 1996. It was built as the first "Energy Efficient Office of the Future" to showcase state-of-the-art solutions for sustainability and efficiency. The building represented a major advance in the design of low energy buildings. It is still a leader today. It was designed to demonstrate techniques which can be used in future low energy and environmentally friendly offices. The building specifications are summarized in

Table 1 (next page).

Of note from the circularity perspective, 96% of the material from demolition of the redundant workshops on site was recycled during construction. It was the first UK use of recycled aggregate for the concrete structure. Other recycled materials included brickwork, screeds, made from recycled power station gypsum and wood block floors that were repurposed from County Hall in London.

Using this building as an example, BRE developed a methodology to evaluate the DfD potential of buildings to inform the design process of where there is potential to maximise deconstruction opportunities, thereby help project teams to establish metrics by which to gauge the "deconstructability" of their designs. The methodology sets out a series of parameters to arrive at an overall score that is aggregated from evaluations for materials and component choices, types of connections used, the accessibility of components and connections, the deconstruction process, and the level of project information relating to deconstruction.

The BRE office case study scored 72% overall for its DfD potential (Figure 8). Elements which had greater potential for DfD are the services which run along the raised access floors or ceiling voids making them accessible, the roof and the upper floor. The connections criteria (91%) and the optimisation of the deconstruction process (74%) scored the highest and reuse and recycling potential the lowest (64%).

Figure 8: Overall results for key elements of the BRE case study building using the BRE Office Deconstruction Assessment Methodology

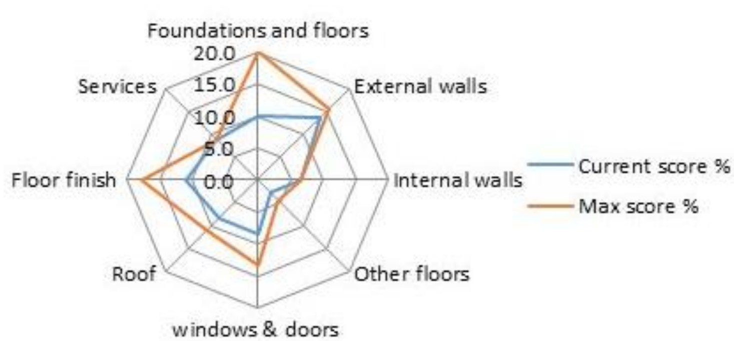


Table 1: BRE Case Study Building Specification. Data source: BRE

Element	Description
Foundation	Concrete strip foundation
Ground floor	In-situ concrete slab, rigid PIR insulation, screed
Upper floor	Prefabricated raised access concrete floor, carpet tiles
External & internal walls	Main external wall – 100mm reclaimed brickwork with Portland cement), 100mm insulation, 150mm dense block work, dense plaster Timber framed insulated, internally timber panelled, external ply for aluminium flashing Internal wall – Timber framed stud partitions, plaster board Stack – Rendered, Precast concrete wall and glass bricks
Roof	Main office block roof – Aluminium, breather membrane, 200mm insulation, vapour check barrier, timber decking on Glulam beams, or steel frame, plaster board Flat roof areas – Aluminium, 200mm insulation, 150mm concrete, plaster Aluminium eaves welded to steel channel sections Aluminium coping, gutter, flashing
Windows & doors	Aluminium/timber composite frame, Double glazed low E argon filled glass Aluminium/timber composite frame full glazed doors, solid timber doors Shading – Glazed louvres fixed using aluminium brackets attached to vertical metal frames
Floor finishes	Carpet tiles, ceramic tiles, hardwood tongue and groove flooring
Cladding	Cedar cladding
Sanitary ware	Ceramic dual flush WC; sink with low flow taps; wet room with ceramic tiling, steel bath
Services	Ground source heat pump, gas fired condensing boilers and photovoltaic panels Heating flow and return: running below raised floor to serve office radiators, above ceiling in ground floor toilet areas
Fixtures and Fittings	Fitted chipboard kitchen units including cabinets Steel staircase and balustrading Prefabricated aluminium gutter, bolted to isobar system Aluminium flashing, metal eaves welded to steel C sections

Most of the components could be dismantled using non-specialised equipment, as mechanical fixings are commonly used. Key issues identified were:

- The use of lime mortar rather than cement mortar for the reclaimed brick external wall would enable future reuse.
- It is preferable to fix the hardwood parquet flooring using nails or other mechanical fixings rather than glue, which could limit the reuse potential.
- Consideration of materials that have a potential recycling route (if reuse is not appropriate). Products that are difficult to recycle currently include the OSB boards, mineral wool insulation, and breather and vapour control.
- Precast concrete products, e.g., the raised floor panels, can be reused, however it is likely that information would be required with regard to their service life, structural integrity and load capacity etc. It could also be difficult to find another suitable application, without having to alter the dimensions of the panels.
- Accessibility of building services was considered during the design which resulted in them score highly for disassembly potential at the end of life.

4.1.2. Design for Future Versatility

Circular strategies can be applied to a building upgrade program of work so that, going forward, the building can continue to accept future renovations affordably and with minimal disruption. Versatility is an important characteristic in contemporary office building design because the nature of office work is continually evolving. Versatility can be measured by the percentage of floor space or building footprint that has multiple uses on a daily, weekly, monthly basis without requiring changes to the main features of the space. Long term versatility means that the building can weather changes in market conditions and remain economically viable without threat of demolition. This can be achieved using:

- Simple open floor space with flexible planning grids: From the 1980's through to 2000's, the 1.5m (5ft) planning grid was an established office layout that coordinated the exterior glazing system with ceiling and carpet tiles, lighting, and modular partitioning. This made for easy reconfiguration of floor areas. With the move towards more open, collaborative spaces, flexibility now takes the form of clear span, column-free space and ergonomic, furniture systems that are pulled away from windows.
- Reconfigurable structures, fit-out technologies, "plug and play" systems, moveable componentized systems and "partitioning as a service".
- Low embodied carbon products, systems and solutions that can be recycled or composted, that sequester carbon or intentionally bio-degrade.
- Energy generating products (such as drain water heat recovery, built-in photovoltaics, etc.) that can contribute to the operational heating, cooling, and power needs of the building.
- Standardisation and interoperability to reduce the number of unique components and protect against "built-in obsolescence" of critical items, and/or of elements becoming unavailable.
- Solutions that support disassembly and reconfiguration.

Accurate and complete documentation of building information is critical to ensuring future versatility and for implementing circular solutions for all types of buildings. The features of the building that lend themselves to future adaptation and disassembly should be captured by means of as-built drawings and manuals and integrated into the BIM objects data and the main body of the design and specification details. Product information should include data about constituent materials, structural properties, handling instructions, and how to contact the manufacturer. It is important to ensure the data is maintained and remains up to date and accessible for the life of the building.

Case Study: Framehouse (Dragør, Denmark)

Reconfigurable structures, fit-out technologies, "plug and play" systems, moveable componentized systems and "partitioning as a service" can all contribute to future versatility for office space organization, and can even help the building accommodate a change of use. Framehouse, a 1,810m^2 (19,475sf) flexible office building in Dragør, Denmark, is a highly sustainable workspace located in an industrial business area 12 kilometres south of central Copenhagen. The two-storey structure is an innovative exposed timber system that allows for mezzanines to be added or removed or reconfigured from office to meeting room depending on the needs of the tenants.

Figure 9: Framehouse. *Photo credit: Schmitt Hammer Lassen Architects*

4.2. CIRCULAR CONSTRUCTION STRATEGIES

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.

Application of circular best practices to the construction process are primarily dictated by strategies established during the design phase. By the time construction starts, the building elements, materials and components that will be removed or retained will have already been decided. Nevertheless, there are actions that the builder can take to minimize the environmental impacts of materials that are brought to site, eliminate waste generated from construction activities and make future renovations easier and less wasteful.

Circular thinking on the construction site is informed by two overarching approaches: sustainable materials management and lean project delivery. The successful application of these two philosophies will result in an efficient construction process that maximizes value to the owner and stakeholders by minimizing non value-added activities, which includes GHG emissions and waste generation.

A key enabler of circular practices in construction is the adoption of technology. Digital tools and flexible project delivery methodologies help to improve efficiency, reduce waste, and optimize the performance of assets. For example, cloud-based building information modelling (BIM) can be used to record and track materials and components through their life cycle. BIM can integrate into fabrication and assembly processes so that components can be fabricated off-site to reduce waste produced on-site.

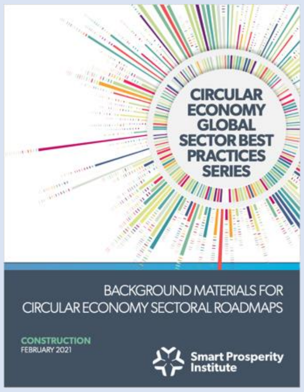
Green procurement policies and full life-cycle contracts are starting to be used to provide standardized frameworks within which circular solutions can be established. For example, stipulations can be made to eliminate primary material use. Components and materials may also be reused to construct new buildings, repurposed for use in infrastructure or transferred for use in other sectors.

"It is normal for standard specification language to state that "all materials to be new and unused". There are salvaged materials that can perform just as well as new but are rejected from the outset because of this."

- ***Architect***

Circular Economy Global Sector Best Practices Series

Background Materials for Circular Economy Sectoral Roadmaps – Construction



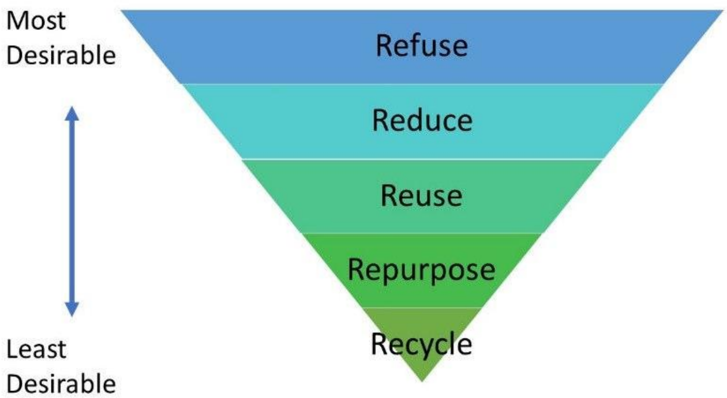
This report, published by the Smart Prosperity Institute, profiles the construction sector. It begins with an outline of the economic and environmental importance of the sector, including data on economic potential of waste resources where available. It then profiles the existing circular practices that were identified in the sector, organized according to a common framework for circular economy approaches and strategies developed in 2018 by L'Institut EDDEC in collaboration with RECYC-QUÉBEC.

Available at: https://institute.smartprosperity.ca/BestPractices

4.2.1. Zero Waste on Site

Zero Waste goals are whereby waste is eliminated and products are sold, consumed, collected and then reused, remade into new products, returned as nutrients to the environment or incorporated into global energy flows. At the heart of all waste management planning is a combination of strategies known as the Waste Hierarchy (Figure 10).

Figure 10: The circular waste management hierarchy.



Utilizing materials with high levels of recycled content and maintaining a construction waste diversion plan on the jobsite are vital. Any products that must be replaced often, such as carpet tile and furniture, should be sourced from organizations who are leaders in sustainable product attributes and who have extended producer responsibility programs in place.

Application of circular best practices to the construction process include process optimization approaches such as Lean Project Delivery (see Edith Green Wendell Wyatt Federal Building in Portland, Oregon) which leverages collaborative planning, just-in-time construction (where materials are ordered and received on an as-needed basis), and the use of prefabrication, which can reduce waste by optimizing material efficiency and minimizing waste through factory construction, eliminating on-site resizing and cut-offs. The potential of prefabrication for new buildings has already been established in Canada[12]. However, its potential is not limited to new buildings. Applied to building renovation processes, it can be part of the solution to increase the quality and rate of project completions – notable examples include plug-and-play prefabricated HVAC and building services and partitioning systems.

TRUE Zero Waste Certification Program

TRUE is a certification for zero-waste performance available through the Canada Green Building Program. It offers a whole-systems approach aimed at changing how materials flow. TRUE encourages the redesign of resource life cycles so that all products are reused. It promotes processes that consider the entire life cycle of products used within a facility to minimize waste.

Like LEED, TRUE is an assessor-based certification program for any type of facility. TRUE certification is achieved by attaining at least 31 out of 81 credit points on the TRUE scorecard and meeting seven minimum program requirements.

Website: https://true.gbci.org

Case Study: Integral's Zero Waste Office Fit Out (Calgary, Alberta)

The fit-out of Integral's Calgary office was designed to achieve LEED and Fitwel certifications while creating a landmark project and welcoming space[13]. A primary goal was that no waste would go to landfill from the project, while also diverting waste from other projects and planning to reduce the number of offcuts that lead to waste. Items had to either be recyclable or reusable. For example, a partition wall was made out of old window samples.

The project team reduced the typical interior office construction project's site waste from seven tonnes (1kg/ft2) down to zero for the 6,800sf space. Zero-waste construction has its own unique challenges and is often overlooked due to perceived cost and effort. However, the Calgary office came at no additional cost—capital was redirected from landfill and material fees to refurbishment fees.

Figure 11: Zero Waste Office Fit Out, Calgary. *Photo credit: Integral Group*

4.2.2. Sustainable Materials Management

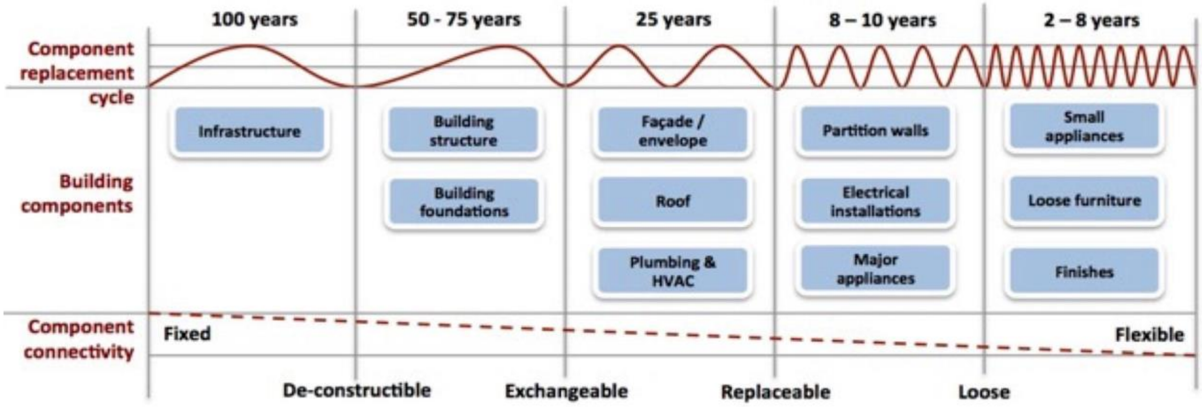
Sustainable Materials Management (SMM) can help both to improve the environment, by reducing the amount of resources that human economic activity requires as well as diminishing the associated environmental impacts, and to improve resource security and competitiveness[14].

Applied to the construction site, SMM principles look both upstream in the supply chain to inform decisions about input materials and processes - to reduce resource consumption and the environmental impacts of the resources consumed - and downstream to understand and address the installation, operation, and end of life impacts. A fundamental tenet is to accommodate the different life cycles of building products and systems so that the various elements can be maintained and replaced efficiently, thereby extending the life of the building (Figure 12 next page).

"Sustainable Materials Management is an approach to promote sustainable materials use, integrating actions targeted at reducing negative environmental impacts and preserving natural capital throughout the life-cycle of materials, taking into account economic efficiency and social equity."

- **OECD**

Figure 12: Typical life cycles of buildings and their components. *Reproduced with permission from UNECE*



Case Study on Lean Project Delivery: The Edith Green Wendell Wyatt Federal Building

The Edith Green Wendell Wyatt (EGWW) Federal Building in Portland, Oregon comprised extensive modernization of an existing 18 level government building that houses 16 different federal tenant groups[15]. Originally built in 1974, the building's mechanical, electrical, data and fire and life safety systems were out-dated and worn out. Completed in 2013, the renovation project not only had to meet stringent green building standards but also had to be completed extremely quickly in order to meet funding deadlines. Every building system was improved, including: a new energy-efficient building envelope; new highly energy-efficient mechanical, electrical, and voice/data telecommunications systems; a blast-resistant curtain wall; tenant and core upgrades; and seismic structural upgrades. As a modernization of an existing building, the additional coordination between designers and trade contractors encouraged by using Lean Project Delivery provided a significant advantage and helped address unknown field conditions before construction. EGWW is LEED Platinum certified and uses 60-65% less energy than a typical office building. A unique rainwater harvesting system was also included, which is aims to achieve greater than 65% potable water savings.

Lean Project Delivery (LPD) is a highly collaborative process that comprises the application of target value design and lean "pull planning" methods during construction[16]. In essence, Lean proposes a new production model based on minimizing losses and maximizing the value of the final product. Taking lessons from the Toyota Production System which focussed on slimming down the manufacturing process to include only the necessary steps, the Lean planning process for construction works to eliminate non-value generating activities, known as "waste". Extra hours, excess materials, additional workers are all examples of "waste" that construction projects may bear whether they are needed or not. Globally, the hidden cost of this waste is estimated to be over $1 trillion a year[17]. Given its "obsession" with eliminating all forms of waste, lean project delivery is an efficient means to deliver on circular goals.

Figure 13: Edith Green Wendell Wyatt (EGWW) Federal Building before (top) and after (bottom) a whole building renovation and energy retrofit. *Photo credit: Sera Design*

4.3. BUILDING LIFE EXTENSION STRATEGIES

4.3.1. Innovative Leasing

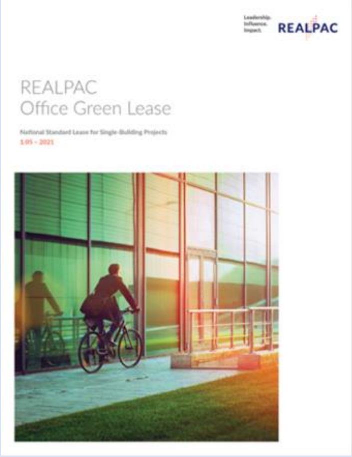
In their Green Leases report, JLL notes that with more than 7,900 companies and 555 financial institutions signed up for the UN's Race to Net Zero, real estate owners will soon have tenants and investors asking them for emissions reduction plans for their buildings[18]. "Green leases" have been developed to assist sustainability-minded landlords and tenants.

Tenants are increasingly demanding more flexibility from their office spaces. Shorter leases are one solution. Leasing of equipment and "product as a service" schemes mean that a wide range of office functionality can be decoupled from the traditional triple-net lease. Anything can be leased including IT equipment, carpeting, elevators, and solar panels. Leasing offers an effective way for companies to reduce their impact on the environment. They can ensure they receive full utility of the product without having to worry about maintenance responsibilities or disposal at the end of its useful life because it is all handled by the leasing company. Short, flexible leasing structures are eminently feasible in the Canadian market and can include concepts such as:

- "Co-working spaces" offer tenants "move-in ready" spaces with short term leases. The interior requires no custom improvements thereby eliminating waste generation from a tenant fit-out project. The tenant's company can expand and contract without a wall needing to be moved.
- "On demand space" allows tenants to rent individual components of offices – such as project spaces, meeting rooms, conference facilities, even kitchens or cafes– for days or even hours at a time. An on-demand space requires a level of service akin to a hotel, which may be a new direction for some landlords.
- "Precincts" are buildings that work together to give tenants greater options through a more comprehensive offering.

4.3.2. Upgrades and Renewals

The goal for building owners in all building upgrades and renewals is to maximize net operating income through a combination of improved lease-up rates, improved rental rates, cost savings and reduced tenant turn-over. While every property is different, office upgrades usually comprise improvements to envelope and mechanical systems and may be completed in phases and while some tenants remain in place. Building upgrades generally aim to maintain existing uses and functionality, but the challenge for many owners is to do so in the face of the changing nature of work and evolving market conditions.



REALPAC Office Green Lease (2021)

National Standard Lease for Single-Building Projects

REALPAC provides a Green Lease template for single building projects that not only contemplates a trajectory towards zero carbon operations but also climate resiliency. While the application of this Lease is intended for office projects, the sustainability elements of the lease are also transposable with appropriate modifications to other asset classes.

Available at: https://realpac.ca/product/realpac-office-green-lease-national-standard-lease-for-single-building-projects

Case Study on Upgrading Class B and C Buildings: Le Phénix (Montreal, Québec)

Making the case for upgrading suburban Class B and C buildings to reposition them as Class A, or at least to generate rents that are close to Class A is more challenging than for premium downtown properties that are sited on high value land. Class B and C buildings tend to be low to mid rise structures, with fewer amenities and located outside the downtown core.

There is a large number of Class B/C buildings in Canada. The lack of amenities associated with them and the fact that they primarily compete on price make it a very competitive market segment, and these buildings may be vulnerable to demolition when the market turns. Indeed, pressure to demolish suburban office space is not only being brought about by an increasingly competitive office market, but also from rising demand for other building uses, including manufacturing and warehousing. However, there are companies across Canada and the US that have become specialised in leveraging the opportunity and value of Class B/C buildings to create elite, retrofitted office space that commands much improved rents. The money saved from acquiring a lower-tier space can be channeled towards high-end features and adaptations.

Le Phénix in Montreal is a deep retrofit (envelope and systems) of a three-storey, 9,264 m^2 structure that was originally built in 1950 and used for industrial purposes[19]. The project was designed by Lemay – a 350-person architecture firm to be a unique work environment for their own staff. The motivation for pushing environmental goals was for staff to test out new concepts and Net positive approaches in support of the design excellence and sustainable development leadership Lemay offers its clients. The Phénix building achieved a (maximum) 3-star Fitwel rating, as well as Zero Carbon Building Standard and is LEED-Platinum certified as well as having Living Building Challenge – Petal Certification.

Figure 14: Le Phénix, Montréal. *Photo credit: Adrien Williams*

4.3.3. Conversions

Conversions and changes of use offer the possibility of retaining the inherent value of existing structures and avoiding the significant environmental impacts of demolition. Office conversions tend to occur in regions where there have been persistently high office vacancy rates combined with high or volatile construction materials costs. Convertibility can be measured by the percentage of building space that has been designed to be converted easily to multiple uses.

So far, the most common change of use is from office to residential as this offers the maximum "lift" in real estate value and fills the pressing demand for housing. This has been the case in Alberta, and both Edmonton and Calgary have seen a number of office-to-residential conversions over the past 5 years.

"We need BIM models for all existing buildings in danger of being demolished, so we know what is available".

- ***Builder***

The characteristics that make an office building a good candidate for conversion to residential include:

- Lease spans of 25 to 35 feet are perfect for smaller residential units. Allow a 600-square-foot unit to be 20 feet wide with a corridor behind.
- Floor-to-floor heights for Class C offices go as low as 11 feet, but that is much higher than the 9 feet, 6 inches, which is currently targeted for new residential developments.
- Small floor plates — around 8,000–10,000 square feet — are generally very desirable and can be easily subdivided to a good mix of residential units.
- Offices require more elevators and servicing than residential. This generally means that one of the existing elevators can be converted to a riser or garbage chute.
- Taller buildings with split elevator banks can make for an excellent mixed-use building. Splitting residential and commercial across the low rise and high-rise banks provides great flexibility.

Taking a holistic, long-term view of the role of an office building as a useful contributor to the economy, the community and the planet can result in attractive, unique, and profitable solutions. "Adaptive reuse" is a forward-looking attitude toward buildings, blocks, and even urban infrastructure that is nonetheless rooted in local urban context.

Considerations about community building are important when considering new uses for old office buildings. While residential uses can bring vitality to downtown cores, it is also necessary to provide opportunities for local employment. Converting office buildings to alternative places of work that generate similar rents requires creative thinking by both building owners and local governments. New uses that generate opportunities for employment include hotels, warehouses, manufacturing and industrial facilities, schools, retail, start-up incubators and urban farms.

4.4. “CLOSING THE LOOP” STRATEGIES

For the owners of office buildings, “circular thinking” is a helpful holistic approach to managing the risks associated with managing properties in the face of future uncertainty. There are a growing number of building owners and tenants who are not only making commitments to reducing the environmental impact but also, after the pandemic, improving the healthfulness of their properties. However, it all starts with how the property is managed and operated. Innovative leasing solutions are emerging to ensure circular strategies are understood and fostered by all stakeholders.

Existing buildings that are refurbished or decommissioned represent a vast source of future building material. However, each generation of buildings over the past century has its own materials palette and construction techniques - each varying in quantity, quality, and accessibility. Despite the fact that most modern buildings were created without consideration for re-use or recycling of their constituent materials, a large portion can be salvaged and re-made into “new” buildings. Indeed, whereas the construction industry has historically employed the harvesting of natural resources, the future will see an increase in “urban mining” whereby resources will be harvested from the existing built environment.

An important consideration when closing the loop on materials flows, is to ensure that maximum value is retained in the product – ideally, “upcycling” the product to a more valuable function. For some designers, finding economic and aesthetic merit in the combinations, recombinations and even defects that arise from upcycling building elements (e.g., the character of old timber beams, salvaged bricks, etc.) can be as important as the actual reuse itself. Enhancing or changing the value of reclaimed products is essential to offsetting the cost and time associated with deconstruction.

Managing the return and recovery of products and materials from construction projects, deconstruction sites, and material recovery facilities back into the value chain through “reverse logistics” is a key principle of the circular economy. For reverse logistics to work, materials must be collected, identified, sorted, processed, graded, and tested, then reused directly or remanufactured into new products. 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.

4.4.1. Deconstruction

CSA Z783:12 “Deconstruction of buildings and their related parts” defines deconstruction as “a process of disassembly to recover materials, components, products or systems for potential reuse or recycling”. It describes the selective dismantling or removal of materials from buildings prior to or instead of conventional demolition. It is an approach to building removal that can convert this waste stream into highest-value resources in a manner that retains their original functionality as much as possible for re-use in future buildings.

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. Noting that very few buildings have been designed to be disassembled, deconstruction approaches currently tend to be selective, focussing on materials that are high value, easy to extract or required to be removed for regulatory purposes (e.g., are the subject of landfill disposal bans). The objective is to disassemble as much of the building as possible in a way that preserves the highest and best value and utility of the materials and components. Deconstruction may be slower than demolition, but it has benefits beyond the reduction in environmental impacts. It is also quieter and reduces dust generation. Building deconstruction can be handled in several ways:

- **Manual building deconstruction** is the systematic disassembly of a structure to maximize reuse and recycling.

- **Hybrid deconstruction** describes the use of people and machines to efficiently deconstruct buildings, with the goal of maximizing reuse and recycling. It refers to the hybrid of demolition and manual deconstruction.
- **Building harvesting** is the fastest way to remove a building while still trying to divert materials from the landfill, especially focusing on reusable materials.
- **Partial deconstruction** is the removal of part of a structure without harming the remaining section(s) while still focusing on maximizing reuse and recycling.
- **Building kits** are collections of materials that have been labelled, diagrammed, and then carefully disassembled so they can be reassembled at another job site.

"Managing the return and recovery of products and materials from construction projects, deconstruction sites, and material recovery facilities back into the value chain through "reverse logistics" is a key principle of the circular economy."

- ***Manufacturer***

Hoarding for Humanity

Hoarding materials have the shortest life span resulting in a high amount of waste. Hoarding for Humanity partners with the Habitat for Humanity Canada to provide commercial owners and tenants with a well-rounded recycling program with guaranteed, sustainable accountability. Hoarding for Humanity uses an environmentally friendly approach to the hoarding process and receive donated hoarding materials from renovation and fit-out projects, for use in the homes Habitat builds.

Website: https://hoardingforhumanity.ca

Case Study on Material Salvage and Reuse: MULTI tower (Brussels, Belgium)

Figure 15: Multi project, Brussels (top) with the salvaged limestone panels (bottom left) that were reprocessed into paving slabs (bottom right). *Photo credit: Rotor Deconstruction*

Located in the historic heart of Brussels, the Multi project aims to give a second life to a 19 storey H-shaped tower on its three-storey base built in the 1960s[20]. The building offers a panoramic view of the city in a revitalised urban environment. The building features maximum flexibility for different workspaces and has achieved BREEAM Excellent certification. Reusing 89% of the existing concrete structure saved 20,000 tons of CO_2, 3,259 tons of embodied carbon and 20,000 tons less waste.

As part of the project, Rotor Deconstruction, a side-project of Brussels-based NGO Rotor that specialising in deconstruction and reconstruction took down and refurbished 82 heavy blocks of blue limestone reclaimed from the Multi project. The blocks were carefully remanufactured to produce slabs for the terrace of the new project. The upper layer with the original chiseled finishing was reused as an interior wall cladding. The project achieved the highest percentage of reused materials of any large-scale office building in Brussels.

4.4.2. Circular Products, Materials Reuse, and Upcycling

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. Circular products and materials have the following features and characteristics:

- They can be operated and maintained efficiently with little or no GHG emissions or waste
- They can be used and re-used repeatedly.
- They have a low embodied carbon footprint with low environmental impacts of raw material extraction or harvesting, manufacture, transportation and end of life.
- They are in and of themselves low carbon or sequester carbon (such as sustainably sourced wood products)

Case Study: DIRTT and APEL Extrusions Office Renovation (Oregon, USA)

DIRTT is a leading interior construction company with a long history of leadership in sustainability. Within their products and the construction projects they participate in, DIRTT has been focusing on maintaining high levels of recycled content, using paper-based products, and reusable packaging or packaging with recycled content. They are also developing local partnerships with organizations who can reuse any materials or items that would otherwise be in our recycling or waste stream, and transparency documents (environmental product declarations, ESG reporting).

In 2014, APEL Extrusions fitted out their office in Coburn, Oregon, using DIRTT’s modular office partitioning system to suit their 80-employee workforce on the first floor of their building. By 2018, the space was no longer big enough. The DIRTT modular construction system is designed for disassembly, so when APEL decided to move their offices to the second floor of the building and dedicate the main floor to their manufacturing operation, the DIRTT system could be easily reconfigured and relocated. Not only was the “kit-of-parts” design of the DIRTT system integral in the office expansion, but the data maintained in DIRTT’s proprietary software (ICE) that helped build the original space, also helped in the reconfiguration.

As a result, 98% of the DIRTT from 2014 could be reused upstairs. After finalizing a new layout, it only took three days to disassemble the offices with no drywall demolition, no mess and no disruption to APEL’s business operations. APEL was able to keep working. One week later the DIRTT assemblies were installed upstairs. With DIRTT’s adaptive reuse, APEL prevented 22,565 pounds of construction waste from going to the landfill.[21]

Figure 16: APEL Office renovation using DIRTT’s re-usable modular partitioning system. *Image credit: DIRTT*

5. KEY ENABLERS

Policies, economic measures, regulations, and voluntary programs can all be used to deter demolition and encourage circular practices in existing office buildings. They can stimulate improvements to existing buildings and send short- and long-term signals to the marketplaces so that the building industry has the confidence to invest in the requisite skills and technology. These measures can apply to the entire building, to the site the building is located on, or to specific building components (i.e., envelope; mechanical, electrical, plumbing systems; finishes; fixtures and fittings). A unique feature of policies directed to promoting a circular economy is the need to consider the entire supply chain and to take a life cycle approach (e.g., to drive recycled materials back up the 5R waste management hierarchy via the highest value markets).

5.1. EMBODIED CARBON AS CATALYST FOR CHANGE

Governments and business across Canada, and around the world, are beginning to develop policies and targets that consider the embodied carbon impacts of construction materials, products, and entire buildings. For example, in the City of Vancouver's 2023 Building By-law, new projects will be required to calculate and report embodied carbon and the 2025 update will then impose GHG emission caps.

Conducting a Life Cycle Assessment (LCA) is already required for rezoning applications in Vancouver.[22] LCA is the methodology by which quantitative analysis of the environmental impacts of a product over its entire life cycle are considered – including both operational and embodied carbon impacts. LCA is necessary for quantifying and evaluating a project's success in sustainable materials management.

According to Architecture 2030, three materials – concrete, steel, and aluminum – are responsible for 23% of total global emissions (with most of these being used in the built environment). Using LCA, designers can understand and address the design trade-offs between meeting operating versus embodied carbon goals. LCA analysis can help pinpoint environmentally impactful materials and evaluate the performance trade-offs with materials with lower embodied carbon. It allows developers and designers to balance the initial environmental cost of producing a building with its longer-term performance and, hence, assess its sustainability.

A recently published study and LCA analysis, undertaken by Mantle Developments as part of a joint project between CSA Group, CELC, and other industry partners, investigated the whole-life carbon impacts of extending the life of existing commercial office buildings in Canada through the circular strategy of retrofit as opposed to demolishing and building new, including the related embodied carbon considerations. It was found that a retrofit of these buildings led to a 26% to 70% lower whole-life carbon emissions than demolition and new construction by 2030, and 11% to 58% lower emissions by 2050. These reductions were mainly achieved by reusing the existing concrete structure when retrofitting.

Additional key takeaways from this study included:

1. Deep green retrofits achieve the same post-construction level of annual operating carbon emissions as demolition and new construction. Deep green retrofits also result in lower whole-life carbon emissions due to the savings from not rebuilding the structural system.
2. The case for retrofits is strongest in regions with green electricity, such as British Columbia, Quebec, Manitoba, and Ontario.
3. If new construction is required, it is beneficial to limit embodied carbon emissions by focusing on low embodied-carbon materials, including low-carbon concrete and steel, and bio-based materials such as wood. Accounting for biogenic carbon storage in biomass materials can also support the case for

building new timber buildings, since it can lead to similar whole-life carbon as retrofits. More analysis for calculating biogenic carbon is required.

4. Additional guidance and data are needed to link circularity and reuse principles to embodied carbon emissions and LCA benefits.

5.2. DIGITAL TECHNOLOGIES

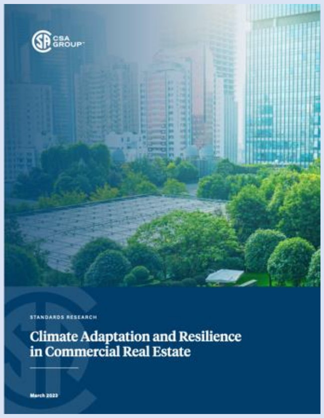
Several technologies have the potential to transform how renovations are conducted and how building information is managed. Technologies such as sensors, 3D scanning, 3D printing, the Internet of Things (IoT), drones, automated fabrication using robotics, and Building Information Modelling (BIM) all have the potential to improve the business case for working with existing buildings. Of these, BIM has already become standard in many parts of the world and is the first technology to embrace in the context of existing building projects.

BIM is a digital form of construction delivery and facility management that fosters collaboration and information exchange across the entire project team, over a building's entire service life. BIM is key to unlocking the potential of the circular economy through the efficient collection and management of data throughout the building's life cycle. Adoption of BIM will help the construction industry make significant productivity and performance gains due to its ability to document a project's assets in a single location, with real time data. 3D modelling of project data, design drawings and development of the project specifications enhances the knowledge base upon which a project is founded and therefore enables more resource efficient future uses.

However, it is still early days when it comes to using BIM in building renovations. Canadian cities are starting to invest in digital twins to document the cities' environment, functionality, and changing situations. These digital assets include 3D models of the city's terrain, buildings and infrastructure along with an energy and climate atlas which contains comprehensive building registry data, so there is diverse information on the heat sources, materials, renovation history, and protection designations of buildings.

Nevertheless, creating a 3D BIM model of a building slated for demolition can prove costly and hard to justify. This is a problem for existing older buildings that do not have a 3D model but will be less of a barrier in the future as buildings are increasingly designed and delivered with BIM. In the meantime, more simple material inventories can be done without a digital model by contracting an expert auditor to visit the site, identify materials with high reuse potential and make a plan for selective demolition.

CSA Report: Climate Adaptation and Resilience in Commercial Real Estate



Climate-related disruptions to the commercial real estate sector are projected to rise, resulting in major asset losses and significant social impacts.

Addressing climate adaptation and resilience is motivated by many factors, including business continuity, support of tenants, protection of future and current investments and long-term value, and alignment with environmental, social and governance (ESG) disclosure frameworks and evolving best practice. It is also a key consideration to advancing the circular economy.

This report by Mantle for CSA Group provides a comprehensive literature review of available resources, a gap analysis, and recommendations on how to support climate adaptation and resilience for commercial real estate. Available at: www.csagroup.org/article/research/climate-adaptation-and-resilience-in-commercial-real-estate

Digital twins for building renewal: HMRC (Liverpool, UK)

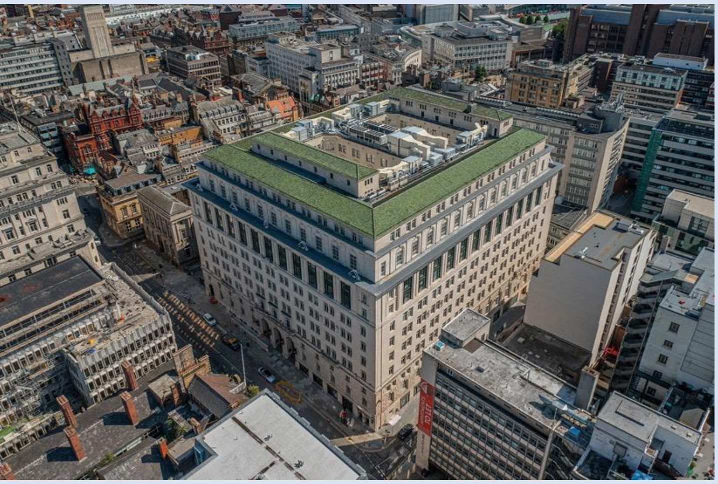


Figure 17: The use of digital tools was instrumental in the restoration and redevelopment of Liverpool's India Buildings. *Image credit: BIM Academy*

The redevelopment of His Majesty's Revenue and Customs (HMRC) offices in Liverpool involved the comprehensive use of Building Information Modelling (BIM) to restore the iconic 320,000 sq.m India Buildings which was constructed in the late 1920s[23]. BIM Academy, digital construction specialists based in Newcastle, UK, were brought on board to help manage the coordination and digital information for this large and complex office renewal project. The digital project delivery was driven by and in line with the UK Government's building information requirements whereby BIM is mandatory on government projects. The work involved developing and implementing an information management and digital strategy, creating specifications of each piece of information and data that needed to be collated and what format it needed to be in, as well as ensuring that all of the information was collected during the design and construction process.

5.3. CIRCULAR PROCUREMENT

Circular procurement can be defined as a process where goods and services are purchased systemically and purposefully to incorporate closed energy and material loops within value and supply chains, to reduce waste and other environmental impacts[24]. The real estate and construction sectors have tremendous purchasing power which can be used to shift markets and offer products and services to advance broader environmental and social goals.

Projects that plan to deploy circular solutions to address energy efficiency and/or GHG emissions reduction need to set measurable and absolute standards (in kilowatt-hours (kWh), kilograms of carbon dioxide equivalent (kg CO_2e), etc. per unit of gross floor area per year) so they can demonstrate that a return from the investment in innovation has been achieved. Incentives can then be put in place in the form of a bonus for exceeding the goal and/or a penalty for failure.

"I would like to see it mandated by government that you're not just looking at what it costs to build a building now. That as part of every application, there is an analysis of long-term costs.

Some cities require a life cycle assessment (LCA) for large buildings; but they are not asking for life-cycle costing, just embodied carbon – which is their only concern. But it is hard to make any justification unless there is a financial aspect as well."

- ***Building owner***

5.4. LIFE-CYCLE COSTING

Life-cycle cost (LCC) analysis is used to assess the total cost of facility ownership. It takes into account all costs of acquiring, owning, and disposing of a building at end of life. LCC can be a key enabler of the adoption of novel construction products and techniques. Many innovative solutions may incur higher up-front costs but once operating costs are considered, the overall investment may provide a better return. LCC can be used as an evaluation tool within competitive tendering procedures so that investments in innovation can be valued correctly and completely. To allow project teams to respond effectively, owners need to establish clear, quantifiable criteria in terms of:

- The expected magnitude and timeframe of the return on investment (ROI).
- The value given to non-financial benefits (social, environmental, occupant wellbeing, etc.).

For public building owners, the Government of Canada's Policy on Green Procurement[25] takes into account both environmental performance and costs that occur throughout the life cycle of assets and acquired services, including planning, acquisition, use and disposal. Some cost elements related to environmental factors that could be taken into account in assessing value for money include:

- Operation costs, such as energy or water consumed by the product over its life.
- Indirect costs (less energy efficient IT equipment will produce more heat causing the building's air conditioning system to work harder and increase electricity costs).
- Administrative costs, such as complying to Workplace Hazardous Materials Information System (WHMIS).
- Investing up front to save costs later, such as specifying higher levels of insulation where extra expenditure can be recovered from lower energy costs.
- Cost of disposal arrangements.

Materials "passport" system: Madaster

Madaster is an online registry for materials and products. In Madaster, data are recorded on all materials and products that are incorporated in a real estate or infrastructure object, such as buildings and bridges. Madaster allows users to create a digital twin, or digital copy, of a building or other construction object, which provides a clear overview of the materials used in it, the amount of CO_2 these materials contain and the extent to which they could be reused.

Registering every component provides insight, for example, into the degree to which an object can be dismantled, embodied carbon, or the toxicity of the materials and products used. It also enables determining whether materials and products can be reused after disassembly.

Website: https://madaster.com

5.5. SUPPORTIVE POLICIES

The application of circularity is an emerging topic for the construction sector and there are not yet many established standards in Canada by which to measure success. Where they exist, regulations and incentives vary between regions. The following are a selection of standards and policies from Canada and some examples from around the world to illustrate the range of approaches being taken to discourage demolition and support circular solutions for office buildings.

5.5.1. Standards and Technical Guidelines

- **CSA Z782-06, Guideline for Design for Disassembly and Adaptability of Buildings.** Addresses the reduction of adverse economic, environmental, and social impacts of building construction through the application of principles related to design for disassembly and adaptability (DfD/A). DfD/A can be used to identify design approaches and potential waste-reduction solutions, to develop system-specific disassembly- and adaptability-conscious details, and to adopt specific strategies for building structure or parts thereof (e.g., the envelope).

- **CSA Z782-06, Guideline for Design for Disassembly and Adaptability of Buildings.** Addresses the reduction of adverse economic, environmental, and social impacts of building construction through the application of principles related to design for disassembly and adaptability (DfD/A). DfD/A can be used to identify design approaches and potential waste-reduction solutions, to develop system-specific disassembly- and adaptability-conscious details, and to adopt specific strategies for building structure or parts thereof (e.g., the envelope).

- **CSA Z783-12, Deconstruction of buildings and their related parts.** Provide a consistent approach to deconstruction methodologies for those involved in the deconstruction of buildings, including but not limited to contractors, consultants, consumers, designers, building owners, regulators, and material supply and value chain organizations.

- **CSA S478:19, Durability in Buildings.** Durability is fundamental to ensuring a building is built to withstand the forces of nature and can be maintained to last. Durability is also a potential indicator for circular building technologies because it implies a focus on extending the lifespan of the major building elements through pro-active consideration of their maintenance and replacement cycles.

  S478 sets out minimum requirements to assist designers in creating durable buildings. It provides guidelines for planning, design, construction, and operation of buildings to meet a building's planned service life, including operations and maintenance plans that can include planned repair, renovation, reuse, replacement, or recycling of elements.

- **ISO 15686-5, Buildings and constructed assets – Service life planning – Part 5: Life cycle costing.** Describes Life Cycle Costing methodology and how comparative cost assessments are to be made over a specific time, taking into account initial capital costs and future operational costs.

5.5.2. Circular Policies in Canada

- **Downtown Calgary Development Incentive Program:** The City of Calgary is offering owners of downtown office buildings $75/square foot, up to a maximum of $10 million per property to convert to residential buildings[26]. The city has allocated $45 million to this program in the hopes of spurring on such conversions.

- **The City of Vancouver Embodied Carbon Strategy** describes how the city intends to meet its goal of achieving a 40% reduction in embodied carbon from construction by 2030 compared to 2018[27]. The goal has subsequently been adopted by the World Green Building Council (WGBC) in their Call-to-Action Report, which also set a goal of zero embodied carbon by 2050.The City already requires a LCA study for new large buildings.

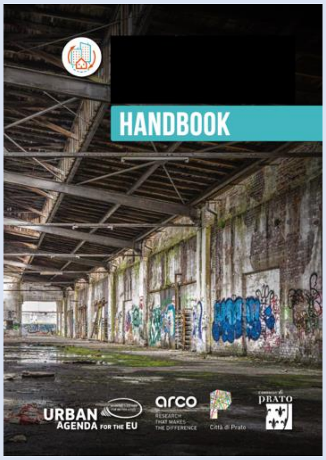
- **The City of Langford** in B.C. is the first jurisdiction in Canada to adopt a low carbon concrete policy, with a view to accelerating the deployment of technologies to decarbonize the built environment[28]. Effective June 1, 2022, all concrete supplied to City-owned or solicited projects, and private construction projects greater than 50m^3, will be required to be produced using post-industrial CO_2 mineralization technologies, or an equivalent which offers concrete with lower embodied CO_2.

- **City of Guelph** Circular Opportunity Innovation Launchpad (COIL) of assistance and financial support for projects that advance circularity[29].

- **The City of Toronto** is working toward an aspirational goal of making Toronto the first municipality in Ontario with a circular economy and is working on a series of Circular Procurement pilots[30].

- **City Policy Framework for Dramatically Reducing Embodied Carbon**: The township of Douro-Dummer in Ontario provides the first 50 applicants the opportunity to apply for a block grant for projects whose embodied carbon emissions are below a fixed target[31]. The planned program outline is to reward builders for meeting an embodied carbon limit of 75 kg$CO2_e$/m^2, measured in accordance with defined criteria and the associated Carbon Calculator, with a grant of $10,000 per house.

- **GHG Emissions Disclosure Policies:** Starting in 2024, building owners in Canada's largest cities must measure and disclose their buildings' emissions from operations. In Montreal, the disclosure process begins with buildings over 15,000 m^2, followed by buildings above 5,000 m^2 and 2,000 m^2. in 2025 and 2026, respectively[32]. After this initial "information" period, mandatory GHG performance requirements take effect, starting in 2028, when the largest buildings have to satisfy the first level of mandatory emissions reductions. The City of Vancouver reporting requirements for carbon pollution limits for commercial buildings over 100,000 sf (~9,000 m^2) will be in effect starting 2027[33].



Sustainable and Circular Re-Use of Spaces and Buildings Handbook

The Sustainable & Circular Re-Use of Spaces & Buildings Handbook offers wide review and analysis of good practices of urban re-use. It is a European document that has been designed to serve as a stimulus and an incentive for strategic planning at the urban level, especially carried out by public authorities, but also supported by the regional and the national level.

It is intended to be a useful tool to lay the foundations for an overall strategy that looks at a new model of urban re-use management following the principles of the circular economy.

Available at:

ec.europa.eu/futurium/en/system/files/ged/sustainable_circular_reuse_of_spaces_and_buildings_handbook.pdf

5.5.3. International Policy Examples

Digital building logbooks: In its study on the development of a European Union framework for digital building logbooks, the European Commission is seeking to create a common repository for all relevant building data[34]. The objective is to facilitate transparency, trust, informed decision making and information sharing within the construction sector, among building owners and occupants, financial institutions, and public authorities.

A digital building logbook is envisaged as a dynamic tool that allows a variety of data, information, and documents to be recorded, accessed, enriched, and organized under specific categories. It represents a record of major events and changes over a building's lifecycle, such as change of ownership, tenure or use, maintenance, refurbishment, and other interventions. As such, it can include administrative documents, plans, description of the land, the building and its surrounding, technical systems, traceability and characteristics of construction materials, performance data such as operational energy use, indoor environmental quality, smart building potential and lifecycle emissions, as well as links to building ratings and certificates. As a result, it also enables circularity in the built environment.

DoTank Circular City, Vienna: The City of Vienna has committed to the transition to a circular city and reframed local policies accordingly. DoTank Circular City Wien 2020-2030 (DTCC30) is a key project of the City of Vienna's 2030 economic strategy with a focus on sustainability and resource conservation[35]. The long-term goal of the program is to establish the concept of recycling in the built environment - from planning, production and use or reuse to processing for recycling and the market for secondary raw materials.

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

- Anchoring the topic of a circular city in the City of Vienna and the organizations in the sphere of influence of the City of Vienna.
- Recognition of the built environment as a store of materials, construction projects are long-lasting, designed and built so that they can be dismantled or separated.
- Create the foundations for material transparency, i.e., which materials are used when, where, and how, in the built environment.
- The business case and economic advantages of a recyclable built environment are collected and presented.

6. ADDITIONAL PROJECT EXAMPLES

6.1. CIRCULAR DESIGN EXAMPLES

Deep Green Renewal: Interface Base Camp, Atlanta, US

Completed in 2018, the 11-month Interface Base Camp project[36] involved comprehensive renewal of a 40,000sf existing 1950s-era multi-tenant office building to a LEED v4 Platinum certified headquarters and showroom for Interface, a carpet tile manufacturer with strong sustainability commitments. The project resulted in 93% of waste diverted from landfill, including 102,160 pounds of concrete and 45,420 pounds of steel, 78% of water use reduction through rainwater collection, and 50% energy use reduction compared to code-compliant buildings.

Comprehensive Envelope Retrofit: Simpson Tower, Toronto, Canada

The look of the facade is one of the biggest reasons buildings are torn down by real estate developers and owners (not the floor plates or internal structure as much). The Recladding of the Simpson Tower, Toronto led by WSP leveraged the need to refresh the look of the 1960's 33 storey building with a comprehensive energy retrofit[37]. The work was initiated when Cadillac Fairview bought the property and was spurred by the building's gradually deteriorating condition and sub-par thermal performance. The project involved a new curtainwall hung outboard of the existing precast cladding for improved energy performance and comfort level.

The cladding system reattached the cast panels (as a result of failing ties) while providing anchor points for a new glass curtain wall. Altering the modernist aesthetic of the Simpson Tower through a new high-performance glass building envelope, the re-cladding project has drastically changed the highly visible face of the 60s design. From an economic perspective, the business case was justified by saving on ongoing costs of envelope maintenance and energy.

Design for Future Adaptability: White Collar Factory, London, UK

White Collar Factory is a naturally ventilated spec-office in the UK with a focus on smart servicing, flexibility and adaptation to future uses and likely future climate long spans, flexible floor plates, operable windows, generous volumes, and robust construction[38]. The tower represents a new type of office building that takes its cue from the multi-level factory typology. The project has become a trademark for a building type that combines the efficiencies of a new build with the character of a 19th century warehouse.

Leveraging Structural Capacity: Vancouver Post Office, Vancouver, Canada

The former Vancouver Post Office was originally designed to meet structural loads that are outside the norm for conventional office buildings[39]. The huge beams and columns in Vancouver Post Office building could take the weight of full-size delivery trucks, which made the revitalization of the original building economically feasible. The former city-block sized commercial complex has been converted into a premium downtown office complex complete with the addition of two new office towers, rising to 21 and 22 storeys over the original structure.

Planning for Adaptability / Change of Use: the Platform & Innovation Centre Parkade, Calgary, Canada

The Platform & Innovation Centre Parkade, Calgary is a parkade that was built with the future potential to be reconfigured to office or residential use[40]. As urban mobility choices evolve, the long-term need for parking may change. This mixed-use building combines seven storeys of parking for visitors to Calgary's East Village and surrounding communities, and 50,000 square feet of innovation space that is home to Platform Calgary and partners. In addition to parking, Platform Parkade offers a publicly accessible sport court on its main level and outdoor event rental space on the top floor.

The building design allows for conversion of the space into commercial and/or residential uses through considerations that make it unique among parking structures—notably, flat floor slabs, increasing floor-to-ceiling heights by one and half times that of traditional parkades and the addition of a central atrium that invites natural light through the full height of the building. Integrated within the first two floors of the building, the Platform Innovation Centre showcases the uniqueness of this project and the community's dedication to a rapidly growing tech community. In this space, innovators across Alberta will have access to programming and mentors to support their ideas through immersion in a community of like-minded entrepreneurs, investors, and start-ups.

Design for Disassembly: Legacy Living Lab, Perth, Australia

Legacy Living Lab (L3) is a 251m^2 (2,700sf) two storey prefabricated commercial building that has been designed and built to demonstrate the circular economy's applicability through the disassembly and reuse of building components[41]. The project was a joint effort between a research team from Curtin University in Western Australia, who led the conceptualisation and project management, as well as supervised the construction process, and an Australian modular building company that carried out the construction and detailed engineering.

The ceiling and internal cladding were designed to be fully disassemblable, thus granting access to the insulation and the mechanical and electrical plant systems without creating any waste. Both floors of the prototype L3 are designed for adaptability. Disassemblable buildings require connections to be easily accessible. Visible connections may be unpopular features. However, concealing these, yet leaving them accessible, presents a substantial design challenge. The project demonstrates solutions to the challenge of disguising and sealing, such as by waterproofing, two types of connections are analysed: structural and non-structural. Notably, all connections in the Legacy Living Lab can be easily accessed with standard building tools, facilitating its disassembly, and fostering component reusability.

Design for Disassembly: StructureCraft Office and Plant, Abbotsford, Canada

The StructureCraft plant in Abbotsford, BC demonstrates the flexibility of mass timber in industrial buildings[42]. Completed in 2017, the facility is a model of engineering efficiency, and sets a new standard in industrial building design with wood. Prefabricated wall and roof panels were designed with a variety of mass timber and engineered wood products, including DLT, LSL, NLT, and Glulam.

StructureCraft designed the entire building as a demountable structure, providing flexibility to expand or move the facility entirely to a new location. The building was planned according to principles of design for deconstruction with the key features being reuse of existing structure in proposal, use of screwed steel connectors, and collaboration with contractor.

Design for Disassembly: Brummen Town Hall, The Netherlands

Brummen Town Hall is a municipal office building in the Netherlands that was designed to have a service life of 20 years, due to concerns over frequently shifting municipality borders[43]. Rather than construct it using cheap materials, which would be likely to end up in landfill, it incorporates a variety of high-quality reusable materials, mostly prefabricated timber components, that will be dismantled and returned to their manufacturers at the end of the building's life.

Circular Inputs: The Radiator, Portland, USA

The Radiator is a 5 storey 32,000sf all-timber office and retail building in Portland, Oregon[44]. Fabricated steel bucket-style connections were utilized for glulam beam to beam connections for future disassembly. The design also avoided using gang nail plates that are time consuming to disassemble. Completed in 2014, the project also has a strong sustainability agenda. The developer partnered with a supermarket and two other adjacent mixed-use development projects to create an "eco-district" that comprised a loop of circulating water where excess heating and cooling loads can be shared between buildings and reduce the demand on natural resources. The building also has a full photovoltaic array on the roof and vertical sunshades programmed to move with the sun.

Building Recyclability: NASA's Sustainability Base, California, USA

NASA's sustainability base was designed from the outset to be disassemblable[45]. A rigorous materials selection protocol for the 50,000sf Sustainability Base was implemented through two approaches. First, Cradle to Cradle Certified products were used when available, cost effective, and achievable through a competitive tender process. Material content considerations included recyclable/recycled materials, salvaged materials, locally available and/or rapidly renewable materials and certified wood. The main components of the design (concrete, steel, glass, aluminum) had high recycled content and were regionally available, thereby reducing transportation energy.

Efficient and Affordable Vertical Expansion: 80 M, Washington DC, US

Completed in September 2022, the 80 M office building in Washington DC comprises a three-story timber 108,000ft2 extension added on top of an existing seven-story concrete building. The primary motivation for using timber was reduction in structural requirements due to relative lightness of timber versus structural steel frame. In fact, the team selected mass timber because, compared to steel, mass timber's lighter weight enabled the client to maximize the vertical build while minimizing structural strengthening interventions to areas outside of tenant spaces, saving capital and allowing the building to remain fully operational during construction.

The speed afforded by prefabrication was also an advantage. As a renewable material, timber carries a significantly lower carbon footprint than conventional building materials, like concrete and steel. There is also a growing consumer demand for biophilic-inspired designs that take health and wellness into consideration by maximizing the occupant's connection to nature. Both highly sustainable and aesthetically appealing, the exposed mass timber design differentiates 80 M from standard Class A office buildings in the competitive Navy Yard commercial area of Washington.

Creative Conversions: Pasona Urban Farm, Tokyo, Japan

Pasona Urban Farm in Tokyo, Japan produces edible plants in a converted nine-story office building[46]. Significant renovations to the existing superstructure included adding a green facade, offices, an auditorium, cafeterias, a rooftop garden, and most importantly, indoor urban agricultural facilities. The crop space totals over 43,000 square feet with 200 species grown including fruits, vegetables, and rice. Crops are harvested, prepared, and served in the building's cafeterias. Pasona Urban Farm is the largest urban farm-to-table agricultural project ever in an office building in Japan. It should be noted that converting an existing commercial space into a vertical farm is not without challenges. Key considerations include:

- Building HVAC, electrical services and envelope need to be customized according to indoor farming requirements and practices (e.g., CO_2 control).
- All existing building materials need to be suitable for cleaning/sanitizing in case of pest/parasite infections within the farming premises.
- Vertical farms use a large amount of power for lighting, humidity, and climate control.

Creative Conversions: Strategic Group's office to residential conversions in Alberta

Alberta-based developers, Strategic Group, have become proficient at converting underperforming downtown offices into residential buildings[47]. Strategic Group estimates that it will have saved 56,000 tonnes of building materials and 17 tonnes of CO_2 emissions from the three office-to-residential conversion projects completed since 2019 plus an upcoming fourth project. Of the 28 buildings in Calgary, totalling 3 million m^2 (32 million sf), that architectural firm Gensler examined, between 10 and 12 were viable candidates for conversion.

Creative Conversions: The Westley Hotel, Calgary, Alberta

The Westley Hotel, Calgary was converted by Silver Hotels Calgary Ltd. and NORR Architects from an under-utilized downtown office building[48]. Previously the headquarters for Birchcliff Energy, the original 62,500sf building was completed in 1980. The Westley was completed at a time when hotel investments had focussed in other areas (such as the airport). Indeed, the owners' vision was to leverage the hospitality industry's "downtime" afforded by the COVID pandemic to create a vibrant space with a strong food and beverage focus that would be used as much by locals as visitors. The five-storey building with underground parking had 68,000 square feet of office space. It had been vacant for just over a year prior to Silver Hotel Group purchasing it in 2018 for between $9 million and $10 million.

The owner had been looking specifically for a property which could be converted because buying land and building a new hotel downtown was not economically viable given the high price of land and the development costs. To make the economics work, Silver would have had to build quite a large hotel, especially given that their format was fairly high-end. Given the downturn in the local economy and the pandemic, this would have been cost-prohibitive. The work involved demolishing the entire building inside including the HVAC system, the electrical system, and all interiors down to the central core. Only once the building had been gutted did the hotel design start because all the complexity and risks associated with unknown as-built conditions were removed. Interior demolition started in 2018, design commenced in 2019 and the hotel opened in 2021.

C2C Building: the Cradle-to-Cradle Fire Hall, Straubenhardt, Germany

Straubenhardt in Germany declared itself a cradle-to-cradle (C2C) community, aligning the entire town with circular economy principles. The new central fire station is its first C2C pilot project[49]. In keeping with C2C principles, the fire station was built as simply and naturally as possible, and everything is designed to remain raw, untreated, and easily recyclable. No adhesives, paints, plasters, or chemical treatments were applied. The building is a concrete glulam hybrid structure. The concrete was selected for durability in the equipment and vehicle areas and wood for the spaces occupied by people. The concrete remained unsealed. The untreated, V-shaped glulam supports were over-sized so they would resist fire by charring. The timber elements were fastened with screws, not nailed, or glued. All building technology remains visible so that it can be easily repaired or replaced when the time comes.

Adaptive Re-use: Revitalizing Class B/C buildings in the US

There are several building owners and developers that specialize in revitalizing old low-class commercial buildings in the US, such as:

- The Apollo at Rosecrans is an adaptive reuse of 5 old defense industry and aerospace industry warehouses constructed between 1970 and 1980 and has been transformed into a creative office campus in El Segundo, California.[50]
- The former Ford Factory building in LA was upgraded from a tired class B to a premium class A in 2018[51].
- The former massive Bell Labs building in Holmdel, New Jersey, has been converted to Bell Works - a self-contained, indoor Main Street with stores, a food hall, and tech company offices[52].

6.2. ZERO WASTE & CIRCULAR CONSTRUCTION EXAMPLES

Reusable systems: R128, Stuttgart, Germany

R128 is a prefabricated construction system that allows ease of joining methods for reuse of materials[53]. It was piloted on a four-storey experimental building in Germany that is produces no emissions and is self-sufficient in terms of heating energy requirement. Its design is modular. Because of its assembly by means of bolted connections and mortice-and-tenon joints, it can not only be assembled and dismantled easily but is also completely recyclable. The columns and beams were bolted together on site with the bolts screwed into threaded holes in the columns - no nuts were used. The precision of the prefabricated components eliminated any need for tolerance-compensating measures. The four-storey steel frame, which remains visible in the completed building, was fully erected in four working days.

Lessons from the automotive assembly line: Cellophane House, New York, USA

Simple forms need fewer parts and therefore, require a simpler disassembly. Fasteners that require standard tools allow for simple and fast disassembly. Cellophane House was assembled like a car, with the entire construction process broken down into integrated assemblies that were constructed off site, delivered by trailers and stacked with a crane.[54] It was built for exhibition at the Museum of Modern Art in New York City.

6.3. 'CLOSING THE LOOP' EXAMPLES

Materials Recovery and Marketplace: MDF Recovery, UK

Around 27 million tonnes of medium density fibreboard (MDF) is wasted annually worldwide, not taking into account end of life. It is a cheap material and until now there had not been an economically viable way to recover and reuse waste MDF fibres. The UK's first commercial MDF recovery plant is scheduled to open in 2023[55]. Run by MDF Recovery, it will manufacture wood fibre insulation products in the UK.

The wood fibre will be recovered from waste MDF, a material that is typically either incinerated or sent to landfill. Through a continuous process, shredded waste MDF is heated electrically in a liquid medium to break down the resin and separate the fibres. The recovered fibre is of the same high quality as virgin wood fibre and provides a feedstock to the manufacturers of MDF board, insulation products and formable packing materials.

Materials Recovery and Marketplace: TimberHub, The Netherlands

TimberHub is a Dutch company that connects manufacturers and construction companies with sawmills while managing procurement, payments, and transportation of timber materials through its digital B2B marketplace[56]. Traditionally, construction materials markets are characterized by offline and inefficient manual processes. Suppliers are hard to vet, and buyers rely on several middlemen to source their products, resulting in elevated prices and unreliable transportation without dedicated customer support. Transparency, faster availability, and shorter lead times can accelerate timber usage in construction and contribute to the reduction of embodied carbon in buildings.

Falkbuilt circular office fit-out system

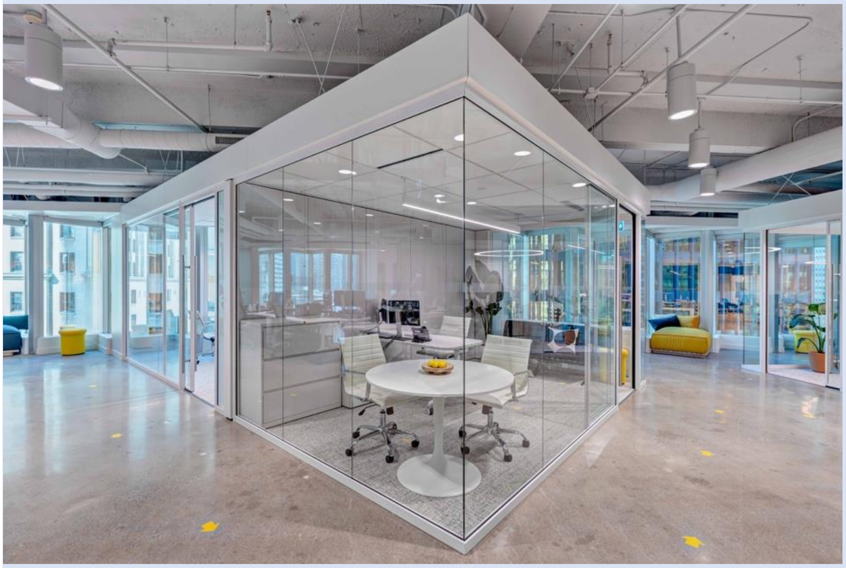


Figure 18: Falkbuilt zero waste office system. Photo credit: Falkbuilt.

Falkbuilt is a Canadian office partition company that operates a zero waste, circular business model. Not only is the product made from sustainable materials and designed for disassembly and re-use, but the manufacturing and shipping processes have been designed to dramatically cut down on carbon emissions from transportation.

For example, Falkbuilt developed a proprietary re-usable clip in which to ship glass doors which has led to an 80% reduction in packaging waste. Leftover manufacturing materials are sent to Ontario to be made into garden hoses.

https://falkbuilt.com

6.4. INNOVATIVE LEASING EXAMPLES

Dynamic Leasing: The Spinning Mills, Vejle, Denmark

The Spinning Mills in Vejle, Denmark is a 12,000 m² industrial building complex that has been modernized to allow for artists and business start-ups in the creative and cultural community to launch and grow[57]. The design by Schmitt Hammer Lassen Architects preserves the original structure and unique industrial expression but allows for tenants to draw as much or as little from the building's physical resources and services as they need. Innovative leasing arrangements allow start-ups to customize the amount of space they rent on a short-term basis and amenities are available on an "on-demand" basis.

On-demand Leasing: LendLease Project Space, Melbourne, Australia

While on-demand spaces can provide the ultimate flexibility for tenants to expand almost on a whim, another version of this model gives them the opportunity to grow or take on project partners for longer term scenarios. The Lendlease Project Space, at One Melbourne Quarter is a floor dedicated to providing flexibility; going beyond co-working to accommodate a community of companies.[58]

Within the floor, a central kitchen and common space anchors four fully fitted boutique suites, each featuring a collaboration space and private booths, a print and utility room, a series of enclosed meeting rooms and a boardroom, plus fixed benches, and workstations. The Project Space allows Lendlease to work closely with partners for the duration of a project without interrupting the lower-level workspaces or requiring partners to commit to medium-term standalone leases that may not suit the life of a project.

Co-working Partnership: Suncorp Group, Brisbane, Australia

Suncorp's new headquarters in Brisbane, Australia was designed to support its commitment to flexible working[59]. As part of the long-term lease, a key workplace requirement for Suncorp was the ability to expand and contract space over the term of the lease to meet changing business requirements.

The uniquely designed spaces and highly adaptable floors give Suncorp's people more flexibility to choose where and how to work. At the same time, some of the floor plates and settings are reconfigurable to enable a change in occupancy levels without affecting the overall office design. In addition, Suncorp specifically sought a co-working partner to share the building - on the condition that Suncorp would have a pre-agreed arrangement to access the space. This co-working partnership means Suncorp has access to additional flexible space, allowing the company to quickly adapt to changing workplace density restrictions and expand its workforce to respond to unprecedented events with little lead time. By enshrining flexible space in its lease terms, Suncorp can keep pace with future business requirements.

6.5. EXAMPLES OF DIGITAL TOOLS & TECHNOLOGY USE

Heritage Revitalization using Digital Tools: Pall Mall Court, Manchester, UK

Pall Mall Court, Manchester is a sustainability-focused upgrade of a 7,900m2 of workplace and leisure amenities that is currently underway for completion at the end of 2023[60]. Pall Mall Court is an architecturally significant 1960's office building in Manchester city centre. The original entrance poses considerable accessibility issues and was moved to the centre of the development to improve the arrival experience. The design faithfully recreates the building's Modernist cladding, while bringing the building envelope up to the standard of a modern, sustainable workplace. This included the painstaking recreation of the cladding joints, which made and tested using 3D-printed models. The building targets net zero carbon in operation, with all energy supplied to the building derived from renewable sources. Retaining the existing structure avoids a full redevelopment and saves approximately 7,900 tonnes of additional carbon emitted.

Deconstruction Technology: Urban Machine, Oakland, USA

Technology is becoming available to assist with the labour-intensive work of deconstruction. California-based Urban Machine uses an industrial robot to remove metal contaminants and damaged pieces, delivering high quality reclaimed lumber for re-use in new projects[61]. By using AI, the robot removes staples and nails from reclaimed wood to turn it into premium lumber products. This lowers the carbon footprint and solves the problem of wood waste.

7. BUSINESS CASE CONSIDERATIONS

The climate emergency is forcing market priorities to change. According to JLL, to meet global emissions standards by 2050, the rate at which commercial building stock is being repurposed needs to increase to around 5% annually (from current levels of about1.5%)[62]. Aside from pressure from tenants and regulators to reduce the footprint of the building industry, construction labour shortages, price volatility of construction materials, and advances in technology such as digital design, scanning, and prefabrication are making it easier for owners, designers, and builders to consider innovative solutions to extending the useful life of underperforming commercial building stock.

The business considerations for circularity in the built environment are becoming increasingly compelling to owners, builders and product manufacturers operating in the commercial office sector in Canada[63].

Owners and investors:

1. Reduce operating costs.
2. Engage tenants and employees.
3. Align with corporate strategy or mission.
4. Distinguish from competition.

Designers and builders:

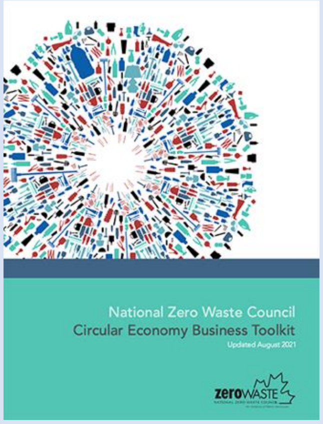
5. Mitigate risk exposure.
6. Create additional revenue from existing products and processes.

Product manufacturers:

7. Spur innovation of new products and services
8. Adapt business models and value chain relationships.

"There is no legislation prohibiting tearing down of old buildings unless they are historical or cultural landmarks. The starting point should be that you're not allowed to tear any building down, and you have to make your case about why you are going to build with new virgin materials. There's an economic value in having the competence of being able to reuse an old building structure, having the skills and being able to calculate a price for it."

- ***Architect***



Circular Economy Business Toolkit

Commissioned by the National Zero Waste Council, the Circular Economy Business Toolkit, is a how-to guide for businesses of all sizes, and sectors, to explore the opportunities of circular modes of design, production and service. It covers how to develop a circular business strategy, the steps to include circular concepts in the design process; and how to engage top stakeholders in the circular initiative.

Available at:
http://www.nzwc.ca/documents/circulareconomybusinesstoolkit.pdf

7.1. BENEFITS TO BUILDING OWNERS & INVESTORS

The successful upgrade of an existing office building can hold major benefits in improved rents, employee engagement, cost savings, space utility and overall productivity. While, upgrading these buildings can be risky with uncertainty surrounding tenant demand in the post-pandemic commercial leasing market, there is also the risk to owners of short-term thinking (i.e., doing nothing, or as little as possible) where maintenance is managed on an as-needed basis and more significant and costly interventions are deferred.

Clear long-range policy commitments have now been made regarding the decarbonization of Canada's building stock and there is a price on carbon emissions that will continue to rise to 2030 and likely through to 2050. The cost of operations is going to get more expensive, and an office building will become less attractive to tenants if decarbonization is not a core element of the asset management plan. That said, reducing embodied carbon emissions in the construction sector by maintaining existing buildings could not only address a significant portion of the carbon footprint of buildings, but it could also deliver measurable and reliable results more immediately than efforts aimed solely at reducing operating energy.

Helping Building Owners Make the Business Case for Retrofits

Carbon Risk Real Estate Monitor (CRREM)

www.crrem.eu

For office buildings to align with Canada's commitments under the Paris Climate Accord, properties across the country will need to address their carbon footprints between now and 2050. Doing nothing (or not enough) exposes properties to the risk of early economic obsolescence because they will not meet future regulatory efficiency standards or market expectations. Further, as the price on carbon increases, inefficient properties will find it hard to remain competitive (Figure 19).

CRREM is the leading global standard and initiative for operational decarbonization (of real estate assets. It is an open-source Excel-based tool to help the commercial real estate sector to calculate and clearly communicate the downside financial risks associated with poor energy performance and the quantification

TOOLS FOR OWNERS AND MANAGERS

GRESB

www.gresb.com

GRESB provides actionable and transparent environmental, social and governance (ESG) data to financial markets. GRESB Assessments capture information regarding ESG performance and sustainability best practices for real estate and infrastructure funds, companies, and assets worldwide. Building owners and managers can use GRESB to collect, validate, score, and independently benchmark building data to provide business intelligence, engagement tools, and regulatory reporting solutions for investors, asset managers, and the wider industry.

Building Resilience Index

www.resilienceindex.org

Developed by the International Finance Corporation (IFC) and funded by the Government of the Netherlands, the Australian Government, and the Rockefeller Foundation, the Building Resilience Index is an online assessment tool that provides the building sector a web-based hazard mapping and resilience assessment framework. All sector stakeholders - construction developers, banks, insurers, governments, and others - can use the Building Resilience Index to assess, improve, and disclose the resilience of their projects or portfolios.

Advanced Energy Retrofit Guide for Office Buildings

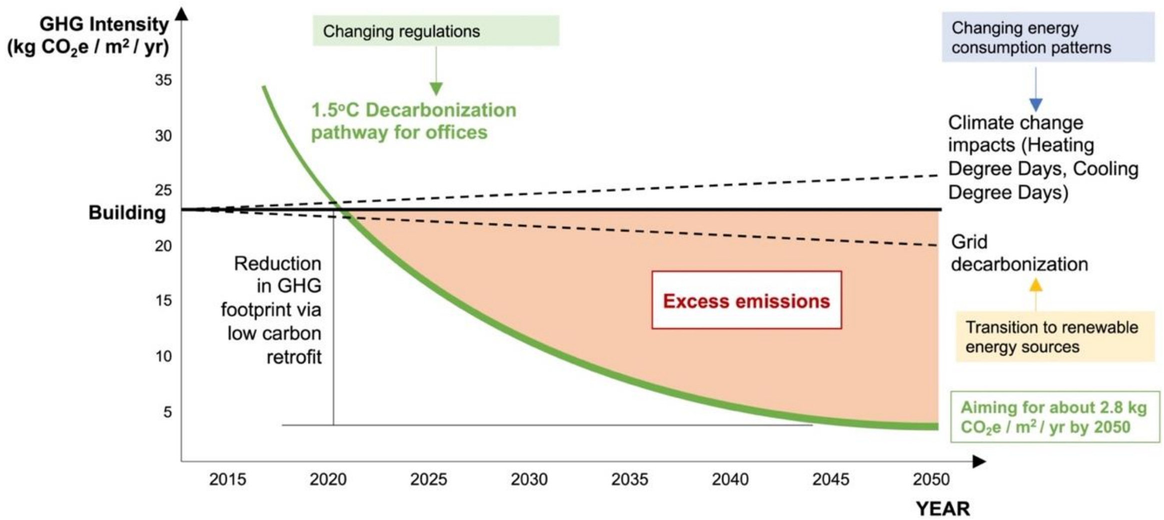
www.energy.gov/eere/buildings/advanced-energy-retrofit-guides

A series of practical guides from the US Department of Energy that cover regular and deep energy retrofit strategies for offices, retail, grocery stores and more.

of financial implications of climate change on the building stock. It aims at optimizing industry's investments in energy efficient retrofits by making risks more transparent and by unveiling opportunities for property owners and investors. The objective is to accelerate the decarbonization of the world's building stock to "2.0 °C readiness". It can also model to the Paris Climate Accord's 1.5°C Climate stretch target.

Specifically, CRREM can be used to assess 'stranding' risks whereby the cost of excess emissions puts buildings at risk of early senescence. Using regionally applicable GHG-reduction pathways that have been developed according to the Science-Based Targets Initiative, CRREM can show when assets are at risk of stranding and the economic and carbon impacts on the overall portfolio.

Figure 19: Annotated decarbonization pathway for Canadian offices to achieve the IPCC 1.5°C Climate target provided by the Carbon Risk Real Estate Monitor. *Source: www.crrem.eu*



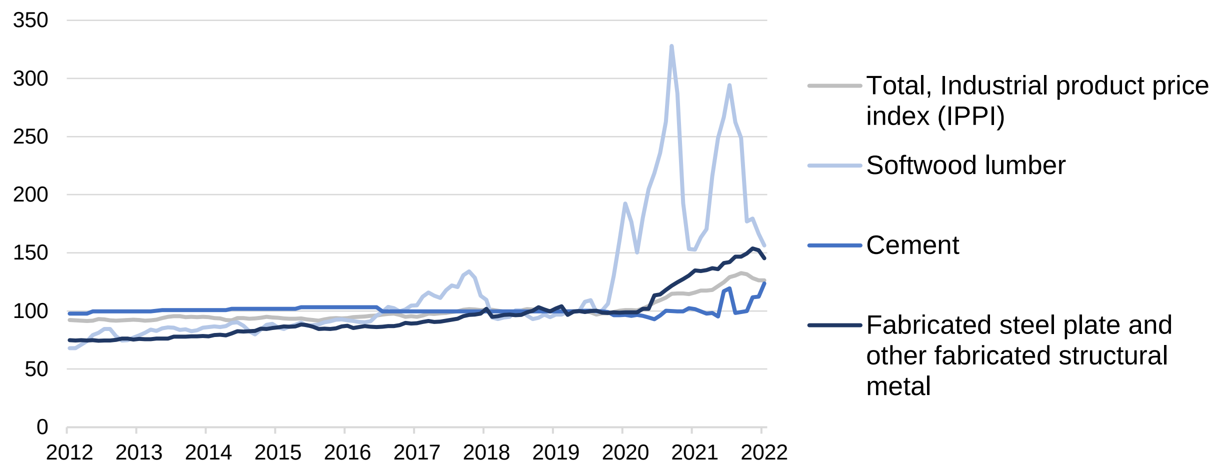
7.2. BENEFITS TO DESIGNERS & BUILDERS

The continued extraction of finite resources, demographic changes, and climate change, are putting pressure on real estate and construction businesses to provide the products and services necessary for a well-functioning real estate economy. Resource scarcity is driving up the prices of and increasing price volatility of construction materials (

Figure 20).

Renovation looks like an increasingly less risky option than demolition and building new. The application of “circular strategies” means that the design, construction, and operational processes associated with that renovation incorporate products and entire structures that can be repeatedly repaired, reused, recycled, or transformed. Further, the value of the materials that are already in a building is starting to increase. For example, the Industrial Product Price Index for steel has increased over 50% in the past two years – steel is highly recyclable. The concept of a building as a “materials bank” is being developed in Europe as a means to manage the risk associated with materials availability and cost in the future[64].

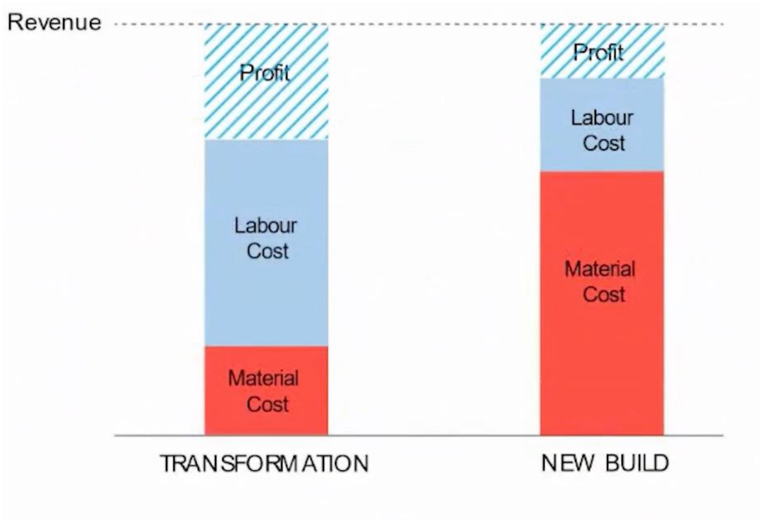
Figure 20: Industrial Product Price Index for softwood lumber, cement and fabricated steel plate and other fabricated structural metal from 2012 to 2022. Index, 202001=100. *Statistics Canada Table: 18-10-0266-01*



Transforming an existing building into a new form or to have a new function can, overall, be less expensive and less resource intensive. They typically take less time and are easier to finance, and in some cases, tenants are able to remain in the building, continuing to pay rent. However, working with existing buildings can be more labour intensive and require project teams to learn new skills. Nevertheless, experts in transforming existing buildings to commensurate functionality and performance of new ones point to the potential for greater profitability (Figure 21).

Indeed, the prevalence of powerful and affordable of digital tools for data capture, modeling and digital twinning are enabling and improving visualization of options that are streamlining project delivery. They are not only improving the technical feasibility and reducing the risks associated with as-built “unknowns”, but also providing greater visibility of return on investment and long-term savings.

Figure 21: Comparison of materials and labour cost allocations for new build versus a transformed building to commensurate quality and performance. *Source: Schmitt Hammer Lassen*



"The structure cost is 20-25% of your building, being able to reuse that helps the business case."

- ***European Architect***

7.3. BENEFITS TO PRODUCT MANUFACTURERS

The embodied carbon of construction materials accounts for 11% of global greenhouse gas (GHG) emissions[65] and, in some regions, up to 50% of the solid waste stream. Those manufacturers who can develop circular products and/or incorporate recycled content into some of their products may be able sell lower carbon products that developers are going to be asking for and builders will be looking for more in the future.

Markets whereby used construction resources can be traded are foundational to the success of a circular construction economy. There are several organizations with online marketplaces where used construction resources can be traded. These markets are foundational to the success of a circular construction economy. Examples include:

- **BizBiz Construction** (https://bizbizconstruction.com) is an initiative of Québec Circulaire and currently the largest B2B construction marketplace Canada.
- **The Ontario Materials Marketplace** (https://ontario.materialsmarketplace.org) has a construction "buy and sell" platform.
- **The Rebuild Hub** (www.habitatgv.ca/rebuildhub) has been established by Habitat for Humanity and the City of Vancouver and accepts, and re-sells used building materials.
- **Hyon** (https://hyon.ca) circulates assets for offices.

However, these markets are currently small and locally focussed but the economic and environmental benefits are potentially significant. A 2019 white paper entitled *The Case for a Resource Exchange Mechanism* (REM) from the AECOM-led MI-ROG (Major Infrastructure – Resource Optimisation Group) in the UK called for the creation of a national 'mechanism' to allow the trade of surplus materials and products across UK projects. The report notes that while there are strong environmental and social reasons for establishing a REM, the primary driver is economic - the EU could realistically reduce the total material requirements of its economy by 17% to 24%, boosting GDP and creating between 1.4 and 2.8 million jobs.

8. TOOLS & RESOURCES

8.1. ORGANIZATIONS

Zero Waste Canada - https://zerowastecanada.ca

Zero Waste Canada (ZWC) is a non-profit grassroots organization that operates nationally to bring forward policies and programs with the objective of supporting the continuous reuse of resources on the front-end and simultaneously advocating for the elimination of landfills and waste-to-energy (incineration) on the back-end. Zero Waste Canada provides a Zero Waste Certification program for organizations across all sectors to implement internationally accepted policies and practices.

Canadian Circular Cities - https://canadiancircularcities.ca

The Canadian Circular Cities and Regions Initiative (CCRI) works to build circular economy knowledge and capacity in the Canadian local government sector – offering a national webinar series on innovative approaches and providing direct support, guidance and peer-to-peer exchange to Canadian communities as they take steps to become more circular.

Canadian Construction Materials Centre (CCMC) - https://nrc.canada.ca/en/certifications-evaluations-standards/canadian-construction-materials-centre

The Canadian Construction Materials Centre is the body that evaluates innovative materials, systems or building designs with respect to the performance criteria. CCMC can help manufacturers assess compliance with Canadian building, energy and safety codes. It aims to help manufacturers get market approval and support innovation and growth in the Canadian construction industry.

Buy Social Canada - www.buysocialcanada.com

Buy Social Canada bring together purpose driven purchasers and social value suppliers to build business relationships that generate social benefits for communities across the country. Every purchase has a social, environmental, cultural and economic impact, whether intended or not. The collective effort of leveraging social value from purchasing has a powerful and positive ripple effect on local communities and helps to improve the circularity of materials flows.

Circular Procurement - https://circularprocurement.ca

CircularProcurement.ca is a first-of-its-kind Canadian resource and initiative of the Circular Innovation Council to support Canada's collective understanding of the circular economy and how purchasing advances it. Through knowledge exchange and collaboration CircularProcurement.ca showcases insights and experiences to put circular economy concepts into action. It offers a wealth of resources and a number of construction and renovation case studies.

BOMA Canada - https://bomacanada.ca

BOMA Canada represents the Canadian commercial real estate industry and facilitates national initiatives and the exchange of ideas that promote education, advocacy, recognition of excellence and networking. BOMA has actively supported the shift towards healthy, low carbon buildings and has published a number of tools and resources to help its members shift to circular practices.

Carbon Neutral Cities Alliance - https://carbonneutralcities.org

A collaboration of leading global cities working to achieve carbon neutrality in the next 10-20 years – the most aggressive GHG reduction targets undertaken anywhere by any city. The site offers research reports, tools, standards and resources related to carbon neutrality planning, implementation, impact measurement and continuous improvement.

Québec Circulaire - https://www.quebeccirculaire.org

Québec Circulaire is one of the flagship measures of the Pôle québécois de concertation sur l'économie circulaire (Quebec Centre for consultation on circular economy), a voluntary grouping of leaders from various backgrounds to accelerate the transition to circular economy in Quebec. The platform's mission is to bring together the variety of initiatives, tools and expertise that are currently dispersed and will be multiplying in the coming years.

8.2. PROGRAMS

LEED - www.cagbc.org/our-work/certification/leed

The LEED Green Building Rating System is the leading holistic green building rating system in Canada. It includes criteria for sustainable sites, energy and climate, water efficiency, materials, and occupant health. It offers programs specifically for new construction and major renovations, houses, interior design and fit-outs and for operations and maintenance. It references standards that are not yet in common use, and guidelines that could become standards in time.

LEED includes credits for embodied carbon and waste management. LEED ID&C offers a credit for conducting an integrative planning process to increase the useful life of the project space. It encourages designers to increase project space flexibility, ease of adaptive use, and recycling of building materials while considering differential durability and premature obsolescence over building design life and individual component service lives. To achieve the credit, at least 50%, by cost, of non-structural materials must have integral labels (radio frequency identification, engraving, embossing, or other permanent marking) containing information on material origin, properties, date of manufacture, in compliance with CSA Z782-06 Guideline for Design for Disassembly and Adaptability in Buildings.

Toronto Green Standard - www.toronto.ca/city-government/planning-development/official-plan-guidelines/toronto-green-standard

The Toronto Green Standard (TGS) Version 4 limits GHG emissions from newly constructed buildings, and City-owned buildings need to be net-zero. Version 4 also introduces new voluntary tracking requirements for structural and envelope components and landscaping materials and updated requirements for sustainable building materials. Future versions may include performance requirements for embodied emissions in building materials such as concrete, steel and insulation in small and large buildings.

Fitwel - www.fitwel.org

Fitwel is a building performance certification system committed to building health. Generated by expert analysis of 5,600+ academic research studies, Fitwel is implementing a vision for a healthier future where all buildings and communities are enhanced to strengthen health and well-being.

Zero Carbon Building Standards - www.cagbc.org/our-work/certification/zero-carbon-building-standard

The Canada Green Building Council's Zero Carbon Building™ (ZCB) standards recognize the importance of building emissions in reaching national climate commitments. The ZCB standards define low-carbon design and operational performance for buildings. Applicable to buildings of all types, they offer both rigour and flexibility, opening the door for all buildings to minimize their climate impact.

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