STANDARDS RESEARCH

Opportunities to Apply Circular Strategies to Existing Office Buildings

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Acronyms and Abbreviations

BIM	Building information modelling
BMS	Building Management Systems
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
CRA	Canada Revenue Agency
CRD	Construction, renovation, and demolition (waste)
DfD	Design for disassembly (or design for deconstruction)
DfD/A	Design for disassembly and adaptability
EPD	Environmental product declaration
GHG	Greenhouse gas
GJ	gigajoule
HVAC	Heating, ventilation, and air conditioning
LCA	Life cycle assessment
LCC	Life cycle costing
LEED	Leadership in Energy and Environmental Design
MDF	Medium density fibreboard
OECD	Organisation for Economic Co-operation and Development
sf	square feet

Executive Summary

In an investment landscape informed by climate-related risks, the emphasis in the commercial real estate sector on developing new buildings increasingly conflicts with achieving greenhouse gas (GHG) emission reduction targets. Even constructing the most energy-efficient building entails variable but significant upfront GHG emissions because of the resource-intensive nature of construction and the materials supply chain. Extending the life of buildings through retrofit, repair, maintenance, and adaptive reuse is a key principle of the "circular economy". The circular economy proposes an alternative to the linear system of production and consumption characterized by "take-make-use-dispose". This restorative and regenerative system minimizes resource use, waste, and emissions by narrowing (efficient resource use), slowing (temporally extended use), and closing (cycling) material loops.

This report provides guidance and best practices on extending the lives of existing office buildings by looking, in turn, at (a) the design interventions that could optimize an existing building for ongoing operations while improving the potential for future renovations; (b) the ways to minimize waste generated from maintenance and renovation activities and, ultimately, end of life; and (c) construction material flows and incorporation of salvaged materials into projects.

Many circular strategies are not new in Canada, but are undertaken on an ad hoc basis. Underutilized approaches such as embedding life cycle thinking into real estate decision-making, the use of digital technologies, and innovative leasing structures are ways for industry to get started on the journey to a circular economy for office buildings. These approaches make it easier for owners to include building reuse as an option for their office properties, stimulating demand for industry training programs and secondary materials markets – which exist, but not at sufficient scale.

This report also reviews a number of policies, financial measures, and voluntary programs in place in Canada that help to extend the lives of existing office buildings. Numerous models from other jurisdictions could be applied to the Canadian context to help fill gaps.

Standardization is necessary to ensure that the information and practices associated with products and buildings are consistently and accurately calculated and presented. Standards underpin building codes, but the standards landscape in Canada is underdeveloped when it comes to existing buildings and the circular economy. At the most elementary level, terms such as "restoration", "retrofit", "renovation", "alteration", "refurbishment", and "renewal" are all used interchangeably when, in fact, they mean different things. Research for this report uncovered gaps in local and regional policies, zoning, land use and development bylaws, and building regulations; data collection and management (for existing buildings and at the industry scale for benchmarks such as life cycle costing and life cycle assessment); building information modelling standards for existing buildings; procurement standards that promote a "renovation first" approach; documentation and certification of used materials, building adaptability information and disclosure; insurance and risk management; and industry training curricula and professional accreditation.

Applying circular economy principles to Canada's real estate and construction sectors could deliver multiple benefits, including creating new economic, investment, and employment opportunities; reducing waste and GHG emissions; enhancing natural ecosystems and urban green spaces; improving the resilience of supply chains; and providing greater equity and related social benefits. Inevitably, there are economic and environmental trade-offs and these need to be managed through the use of consensus-based analytical methods (such as life cycle costing and life cycle assessment) based on industry-accepted data.

A growing number of exemplary projects in Canada and around the world illustrate how successful renovation and adaptive reuse can maintain the functional viability of an office building while achieving economic efficiency. They offer examples for industry to build technical knowledge and for policymakers and owners to consider renovation instead of demolition for underperforming office buildings.

"Applying circular economy principles to Canada's construction and real estate sectors could reduce waste and GHG emissions; improve the resilience of supply chains and create new economic, investment, and employment opportunities."

1 Introduction

According to the UN 2021 Global Status Report for Buildings and Construction, "emissions from materials and construction processes must be urgently addressed, to ensure that the buildings being built today are optimized for low-carbon solutions across the full life cycle. This involves maximizing the refurbishment of existing buildings, evaluating each design choice using a whole life cycle approach and seeking to minimize upfront carbon impacts (e.g., Lean construction, low-carbon materials and construction processes, etc.), as well as taking steps to avoid future embodied carbon during and at the end of life (e.g., maximize the potential for renovation, future adaptation, circularity, etc.)" [1].

Globally, the construction and operation of non-residential buildings comprises about 10% of energy-related direct and indirect CO_2 emissions [1]. There are more than 482,000 commercial and public buildings in Canada; their operation is responsible for 10.6 megatonnes of greenhouse gas (GHG) emissions annually[1] [2]. Emissions from office buildings constitute about 12% of the total emissions from buildings in Canada [3].

Canada's commercial office sector is a major generator of construction activity. In 2021, more than $4.2 billion was spent on new office construction projects and a further $5.2 billion on office renovations [4]. 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.

In an investment landscape informed by climate-related risks, the emphasis in the commercial real estate sector on new buildings increasingly conflicts with achieving GHG emission reduction targets. Constructing even the most energy-efficient new building leads to significant, if variable, upfront GHG emissions because of the resource-intensive nature of construction and the materials supply chain. The Preservation Green Lab compared the environmental impacts of a new building that is 30% more efficient to the reuse of an average-performing existing building across six different building types of equivalent size and function (including offices) in four different US cities [5]. The comprehensive study found that it takes between 10 and 80 years for the new building to overcome, through energy-efficient operations, the climate change impacts of the demolition and construction processes. Indeed, renovated and reused office buildings in all four locations performed at least 10% better than new buildings across all the parameters of climate change, resource depletion, human health, and ecosystem quality.

1 2020 data excluding emissions from electricity.

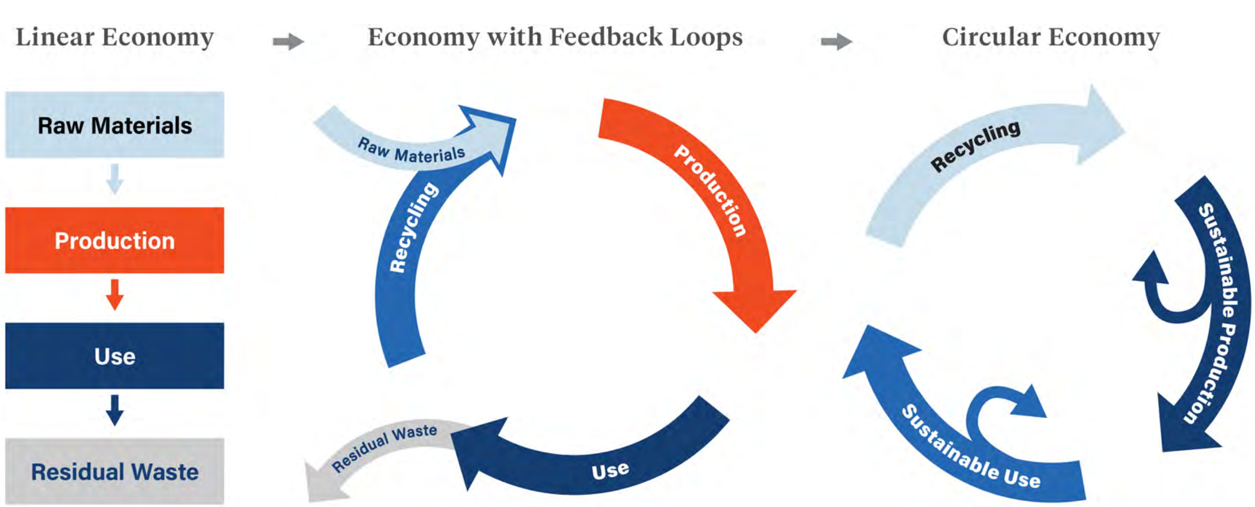
Extending the life of buildings through retrofit, repair, maintenance, renovation, and adaptive reuse is a key principle of the "circular economy". The circular economy proposes an alternative to the linear system of production and consumption characterized by "take-make-use-dispose". This restorative and regenerative system minimizes resource use, waste, and emissions by narrowing (efficient resource use), slowing (temporally extended use), and closing (cycling) material loops [6].

In the context of the built environment, the circular economy can be taken to mean "keep[ing] materials, components, products, and assets at their highest utility and value at all times. In contrast to the 'take, make, use, dispose' linear model of production and consumption, material goods are designed and produced to be more durable, and to be repaired, refurbished, disassembled, and reused in perpetuity – thereby minimising the demand for resources, eliminating waste, and reducing pollution" [7]. Figure 1 summarizes the transition from the linear economy to a circular economy.

Applying circular economy principles to Canada's construction and real estate sectors could reduce waste and GHG emissions; improve the resilience of supply chains; create new economic, investment, and employment opportunities; enhance natural ecosystems and urban green spaces; and provide greater equity and other social benefits. This is important because the building industry is the largest consumer of raw materials and other resources worldwide, representing about one-third of global material consumption. It is also wasteful (about 54% of demolition materials is landfilled) and inefficient (between 10 and 15% of materials are wasted during construction) [9]. In 2015, Canada generated approximately 1.5 million tonnes of waste from activities related to non-residential [10]. Of this, 95% was generated during the renovation and demolition stages. What's more, only 27% of construction, renovation, and demolition (CRD) waste was diverted from landfill, representing enormous lost economic opportunities from failing to recover these resources at the end of a building's life. Inevitably, there are economic and environmental trade-offs, and these need to be managed through the use of consensus-based analytical methods, such as life cycle costing (LCC) and life cycle assessment (LCA), based on industry-accepted data.

Demolition typically occurs when a building has reached the end of its economic life, either because the building no longer meets the owner's needs, the land that the building is on has a higher, better, and more profitable use than its current one (as a result of market forces or land use rezoning), or the building is no

Figure 1: The Transition from a Linear to a Circular Economy. Reproduced with permission from UNECE [8].



longer in sufficiently good physical condition. The state of a building's physical condition is determined in large part by the life cycles of all the constituent elements and components, which vary widely in the degree to which they can and need to be replaced during the life of the building [8], [11] (Figure 2). Given that demolition makes up such a significant portion of Canada's solid waste stream, strategies to extend the lives of office buildings is a logical place to start when seeking to address the impacts of buildings and the carbon embodied in their materials. The scale of the climate benefit of doing so is significant. A report published by the National Zero Waste Council suggests that 1.3 million tonnes of embodied carbon could be avoided per year if all buildings (not just offices) renovated or demolished in Canada were disassembled and reused [12].

There are interventions that owners, designers, builders, and policymakers can make at various points in the life cycle of an office building to improve its chances of remaining economically viable. Policies, financial measures, and voluntary programs can assist with creating a supportive marketplace for existing buildings and a circular economy for the built environment. While some important standards are in place and more are in development, the standardization landscape in Canada needs to evolve. Still, a growing number of exemplary projects in Canada and around the world are fostering various aspects of the circular economy in order to create new and interesting lives for existing office structures, which is encouraging. These projects illustrate how successful renovation and adaptive reuse can maintain the functional viability of an office building while achieving economic efficiency. They provide technical knowledge for industry and inspiration for policymakers and owners to consider renovation instead of demolition for underperforming office buildings.

2 Purpose

The global pandemic has redefined the "workplace" and revealed an appetite for the flexible and adaptive use of buildings. Early indications suggest a structural shift in demand for various asset classes, particularly with the office sector. Intended for building owners, the construction industry, and policymakers, this report looks in detail at opportunities to extend the lives of existing office buildings and apply circular economy principles, strategies, and practices to the Canadian office real estate market.

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

Figure 2: Typical Life Cycles of Buildings and Their Components. Reproduced with permission from UNECE [8].

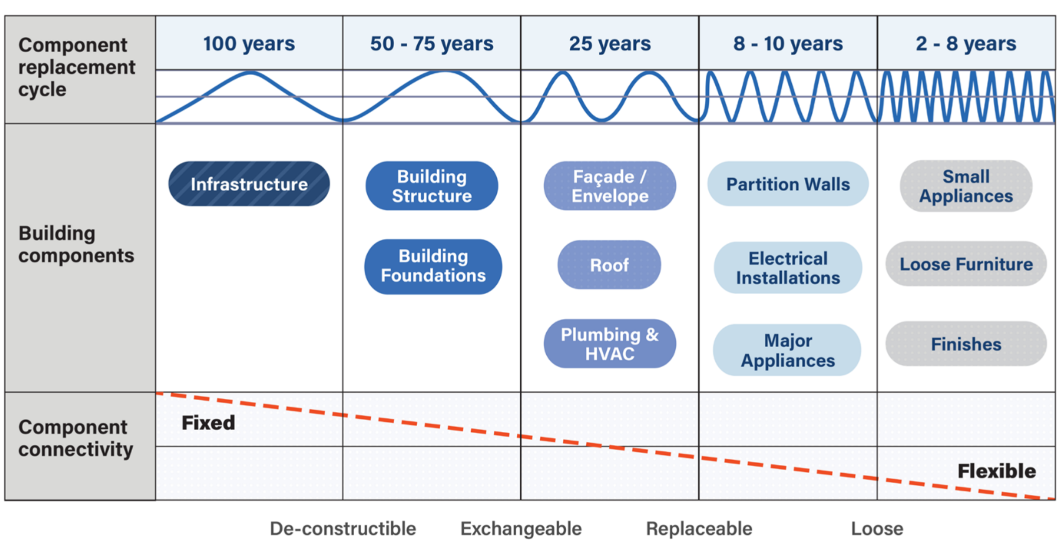
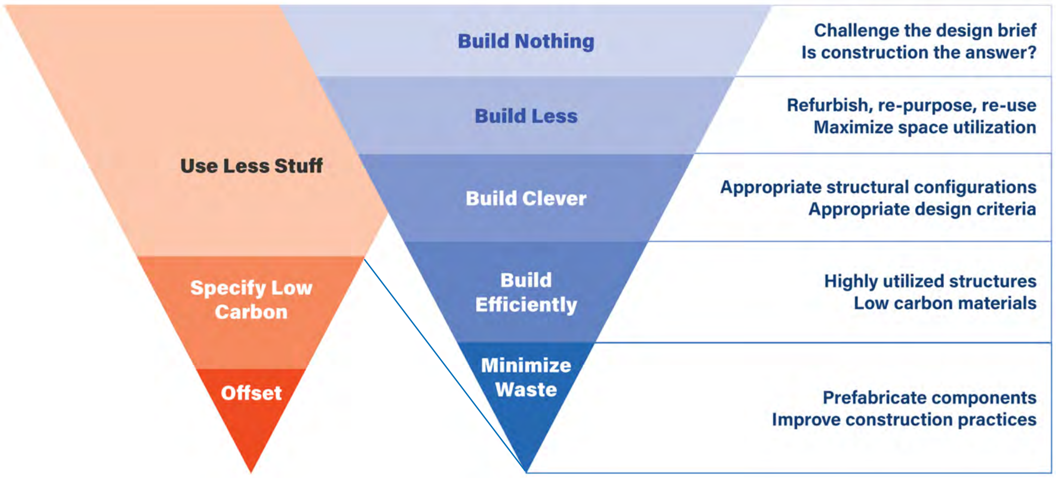


Figure 3: Hierarchy of Net Zero Design. Reproduced with permission from Institution of Structural Engineers [13].



practices and policies. These efforts have led to greater material circulation and lower GHG emissions in the built environment sector. However, the application of circular strategies is in its infancy and efforts are fragmented, at best [7].

This report is organized around the concepts of net zero design set out by the Institution of Structural Engineers [13] based on *PAS 2080:2016 Carbon Management in Infrastructure* [14] (see Section 6.5 Standards). The report identifies current methods of implementing circular practices within construction and the ways real estate practices and business models in North America – and Canada, more specifically – are shifting to accommodate climate goals while expanding business, revenue, and investment opportunities (see Figure 3). A better understanding can, in turn, help policymakers and commercial real estate and construction industry actors.

Case study projects and policies provide practical examples of strategy implementation and efficient interventions and practices that can be applied at various times during a building's life to defer demolition; and, if that is not possible, to identify the best way to keep materials out of landfill. Standards are reviewed at a high level to discern how they are applied and where opportunities for adjustment or the creation of new standards may signify a need for further research.

Achieving circular solutions builds on established best practices in the commercial real estate sector, for which ample resources exist. In particular, improving energy efficiency in office buildings is well understood.[2] The following activities are referenced insofar as they inform or are informed by circularity goals, but they are not discussed in detail:

- Energy retrofits;
- Energy audits and sustainability performance benchmarking; and
- Commissioning and retro-commissioning.

3 Research Methods and Study Organization

Data for this report were primarily gathered from publicly available online sources including corporate and academic websites and from government publications, and supplemented with information gathered through 20 targeted interviews with industry

2 In 2019, the operation of office buildings in Canada resulted in a total emission of 17.42 megatonnes of CO_2e (including electricity) [2].

Figure 4: The Circular Life Cycle of Buildings

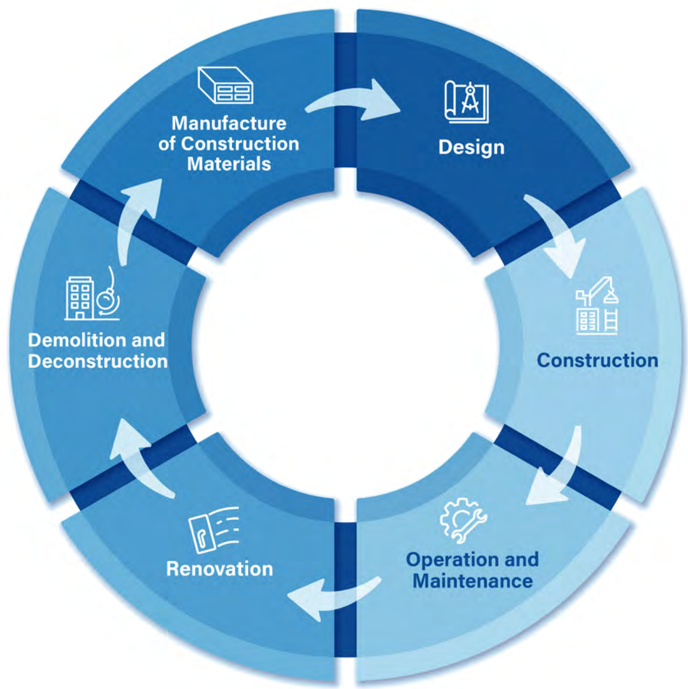
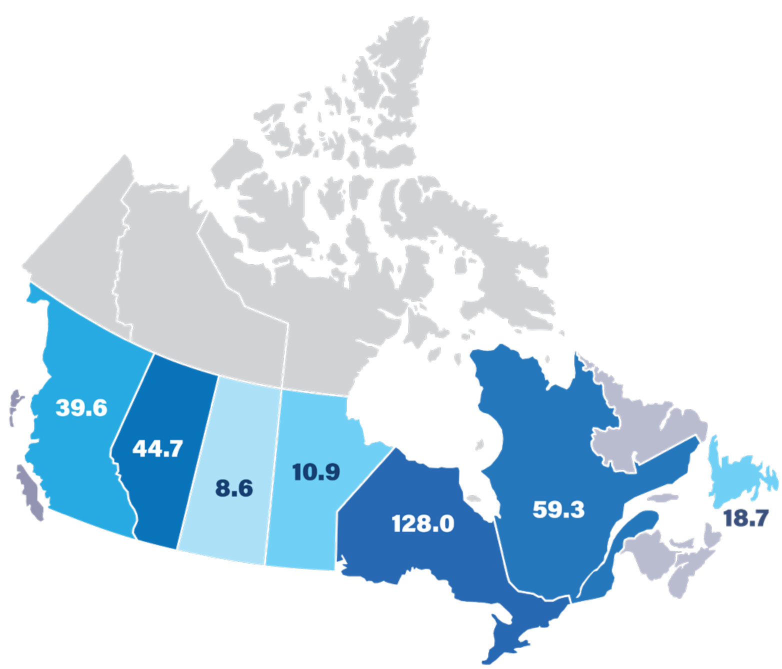


Figure 5: Distribution of Office Space in Canada by Province (million m²) in 2019. Source: Natural Resources Canada [2].



experts in Canada and around the world (Denmark, the Netherlands, the UK, and the US) conducted in the autumn of 2022. Interviewees included representatives from owners and asset managers, leasing real estate investment, architects, constructors, suppliers, and circular economy experts. The authors are grateful for the insights provided.

The report is organized to follow the circular life cycle of a building from design, through construction, to deconstruction and end of life (Figure 4).

4 Overview of the Commercial Office Market in Canada

In 2019, there was a total of 309.8 million m² (3.3 billion sf)[3] of office floor area in Canada [2]. This space included activities related to finance and insurance, real estate rental and leasing, professional, scientific and technical services, public administration, and others. This floor area includes publicly and privately owned office buildings but not medical offices (Figure 5). The largest proportion of office space on a floor area basis is found in Ontario (41%), followed by Quebec (19%) and Alberta (14%). The greatest number of buildings are in the Greater Toronto Area (2,254 buildings) and Metro Vancouver (1,033 buildings) regions [15].

Office buildings are most likely to be threatened with demolition when they are no longer economically viable. The intrinsic characteristics that affect profitability include vacancy rates; competition from newly completed projects; building quality (amenities, quality of fit and finish, etc.); operational costs (which are dictated by the efficiency and condition of the building, taxes, interest rates, etc.); physical properties such as location, age, size, floor layouts, and construction type; and ownership type. In certain areas of the country seismic concerns may also play a role in demolition decisions. The prevailing policy may also be a factor (e.g., energy efficiency requirements).

4.1 Vacancy Rates

The COVID-19 pandemic had a significant effect on office vacancy rates across Canada, but by mid-2022, vacancies in most regions had recovered to pre-pandemic levels. As of the second quarter of 2022, the national office vacancy rate was 16.2% [16]. Victoria and Vancouver enjoyed the lowest vacancy rates in Canada at 5.7% and 5.8%, respectively [15]. Even in Alberta, where the office market was additionally affected by a downturn in the oil and gas sector, net absorption improved[4] during the first half of 2022. Nevertheless, vacancies in Calgary remained the highest in the country, at 27.9%.

4.2 Competition from New Construction Projects

Some regions have recently experienced an influx of new office space, which can put pressure on older, less well-appointed properties to remain competitive. In particular, the low vacancy rates in Vancouver have triggered an unprecedented surge in new office construction. More new office space is expected to open in Vancouver in 2022 than in any other major Canadian city combined [16]. In the second quarter of 2022, there were 78 office buildings under construction in Canada, totalling just less than 1.6 million m² (17 million sf), 63% of which was pre-leased. Of these office buildings, 29 are in Vancouver and occupy just over 0.4 million m² (4.3 million sf), with a pre-leased rate of almost 60%.

4.3 Building Quality

Office buildings in Canada are differentiated according to “Class A”, “Class B”, and “Class C”, with A the most prestigious and commanding the highest rents. In many markets, Class A buildings are divided into AAA, AA, and A subcategories. Class A buildings have the highest level of fit and finish, and may include underground parking, concierge services, retail , gyms, daycares, etc., among their amenities. Class B buildings tend to be slightly older and less well-appointed, although they are well-maintained with good quality systems and fair to

3 This report uses square metre (m²) to describe surface area, with square feet in parentheses.

4 Net absorption is the sum of square feet that becomes physically occupied, minus the sum of square feet that became physically vacant, during a specific period (usually a quarter or year) [255].

good finishes. They may be targeted by investors planning renovations to restore them to Class A.

Class C is the lowest grade for usable 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 are therefore targeted for demolition [17].

As of April, May, and June 2022, Class A was the largest category by floor area and Class B the largest category in terms of number of buildings (Figure 6).

As tenants started to return to office buildings, many owners took the opportunity to upgrade their office spaces. In many regions, the main driver of absorption was with Class AAA or AA buildings in downtown cores. This "flight to quality" is putting pressure on owners of lower-class buildings located outside urban centres to invest in improvements to maintain competitiveness. Indeed, at the national level, 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, while investment in new office buildings continues to decrease (Figure 7). In 2021, the total annual investment in office building construction was $9.48 billion, of which $5.2 billion (55%) was for renovations [4].

Figure 6: Class of Office Buildings in Major Canadian Urban Centres (Except Toronto GTA) by Number of Buildings (left) and by Gross Floor Area (right) in Q2 2022 [15] [18]

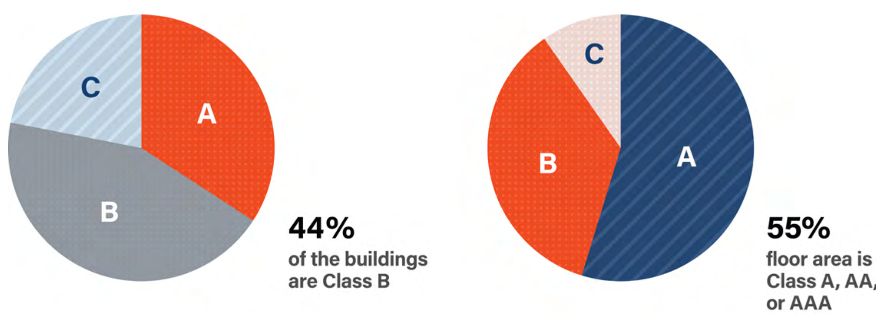


Figure 7: Monthly Investment in Office Building Construction in Canada ($ millions), 2011–2021. Source: Statistics Canada [4].

4.4 Operational Costs

In Canada, the cost of operating office buildings has a large bearing on their economic viability. These costs routinely include taxes, insurance, maintenance, utilities, landscaping, and garbage collection. Some costs are dictated by the condition of the building. Some may also be affected by changes in policy or tax regimes. Given Canada's commitment to the 2015 Paris Climate Accord, which set decarbonization targets for buildings through to 2050, the cost of energy consumption, and the cost of carbon (in the form of taxes and levies), focusing on energy efficiency improvements to protect office buildings from early obsolescence is increasingly important to building owners.

The operational energy use intensity and carbon emissions of offices varies by province as a result of climate and the carbon intensity of the grid. The average energy use intensity for office buildings in Canada is 1.4 GJ/m^2 [2]. The highest is in Saskatchewan (1.98 GJ/m^2) and lowest in the Maritimes (0.89 GJ/m^2) (Figure 8). Along with the energy efficiency of the building stock, climate has a significant impact on overall energy consumption.

The total GHG emissions for office buildings in Canada is estimated at 10.8 megatonnes of carbon dioxide emissions (CO_2e)[5] [2]. The most carbon-intensive buildings are in Alberta (60.43 kg CO_2e/m^2/year) and the least carbon-intensive are in Quebec (20.24 kg CO_2e/m2/year) (Figure 9). In addition to the energy efficiency of the building stock, the carbon intensity of the grid has a significant impact on the resulting emissions (Figure 10). As of April 2022, the federal minimum carbon tax is set at $50/tonne CO_2e and set to increase to $170 in 2030, making building upgrades particularly relevant in GHG-intensive regions.

4.5 Physical Properties

The physical properties of a building, such as location, age, size, and configuration, have a bearing on how well an office property competes in the marketplace. When it comes to location, buildings on downtown lots that are close to amenities and accessible via public transportation tend to be more desirable (and thus command higher rents) than suburban options. However, the pandemic has ushered in the hybrid office concept, a blend of in-office and remote working arrangements. This means that the physical location of the office may matter less for companies if staff are not commuting every day.

In 2021, the average age of office buildings in Canada was 13.6 years, and the average remaining service life was 56.3 years [20]. The average life span is therefore approximately 70 years, suggesting that buildings built before 1960 may be reaching the end of their service life and are more likely to be considered for demolition. Compared with other parts of the world, Canada's commercial building stock is relatively modern. By comparison, as with many European cities, 28% of the UK's office stock was built before 1940 [21].

While older buildings may be outdated in terms of fit and finish, age may not be an important factor when it comes to energy performance. New York City was one of the first jurisdictions in North America to mandate tracking of energy performance of buildings and the first to publicly report on overall performance trends [22]. A review of annual benchmarking reports shows that, on average, older buildings were outperforming their more modern counterparts [23]. This could be due to better building envelopes in older buildings (less glazing) and increased ventilation and higher energy-intense users in newer buildings.

Municipal land-use policies tend to concentrate larger buildings in central urban cores and smaller low-rise buildings in smaller communities and suburbs. The size of the building may affect carbon intensity. A 2014 study of 135 office buildings for BOMA BC found that, compared with low-rise buildings, those with more than 26 floors emit roughly 25% more GHG per square metre [24]. The reasons for this difference may be higher levels of ventilation and cooling, additional energy-using devices (e.g., elevators), and the predominately glazed and therefore lower-performance envelope.

5 2019 data excluding electricity.

Figure 8: Energy Use Intensity (GJ/m²) for Office Buildings in Canada, by Province. Source: Natural Resources Canada [2].

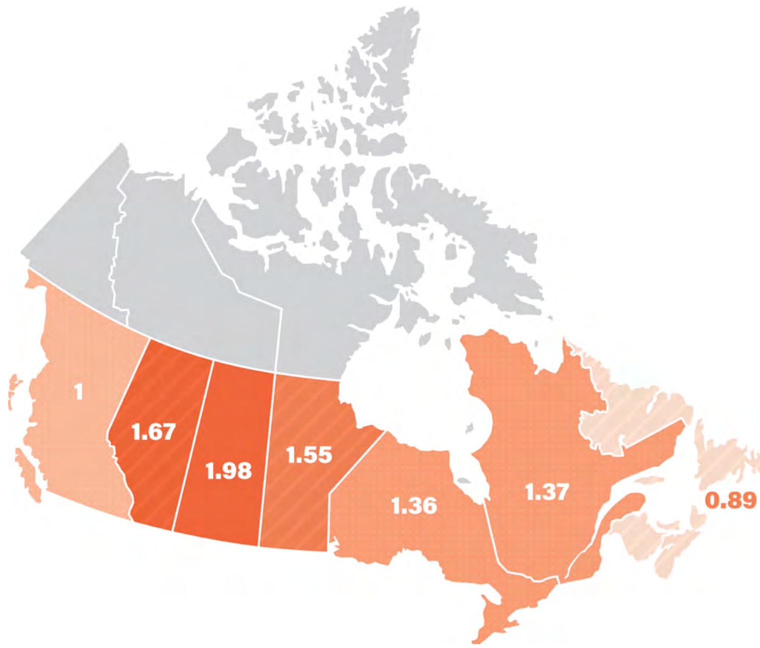


Figure 9: GHG Intensity (kg CO_2e/m^2/year) for Office Buildings in Canada Excluding Electricity, by Province. Source: Natural Resources Canada [2].

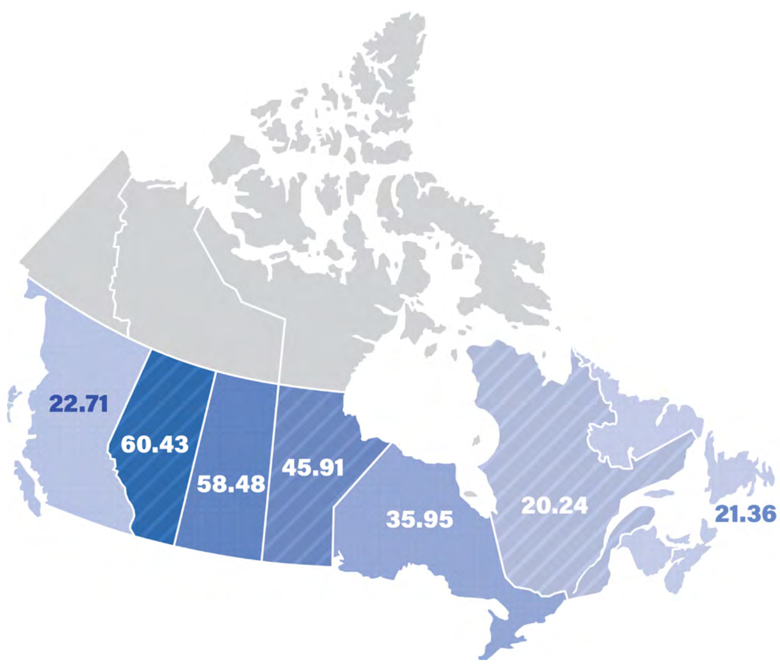
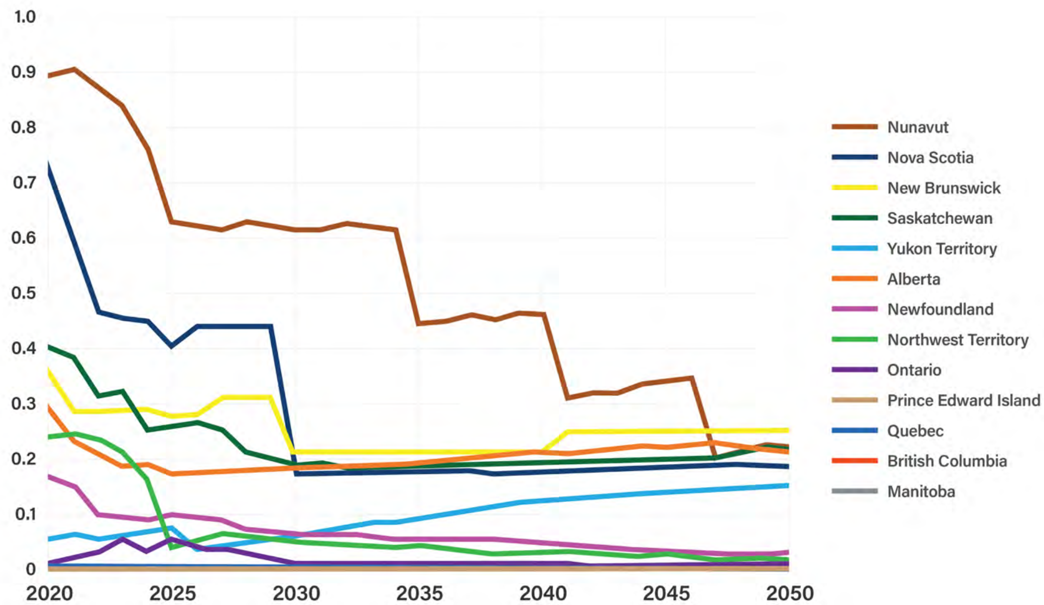


Figure 10: Forecasted Electrical Grid CO_2 Intensity by Province, 2020–2050, Without Biomass and Renewable Natural Gas (kg CO_2e/kW). Source: Environment and Climate Change Canada [19].



4.6 Ownership

The Canadian commercial real estate market has been described as fragmented [25], with the potential for attractive returns for a wide range of investors. Institutional investors, governments, businesses that own their own building, and small-scale investors are the primary groups of commercial building owners. Each group of owners may have different motivations for extending the life of their properties.

- **Institutional investors:** The commercial real estate market in Canada includes some of the largest institutional investors in the world. Investors include pension funds, private equity funds, sovereign wealth funds, real estate investment trusts, and financial institutions such as insurance companies or banks. These investors are sophisticated, retain professional asset management firms, take a long-term view, and can afford to be choosy. They tend to buy and hold premium quality (Class A) properties that offer good rental growth and capital appreciation prospects, an attractive yield, and the security of a long-term income stream while being of a suitable financial scale to make the investment worthwhile. Institutional investors have the deep pockets required to keep their buildings in top condition and weather the ups and downs of the market. They tend to be well-versed in relevant policy and regulatory trends (e.g., many have made climate commitments and provide annual environmental, social, and governance reports) and are extremely motivated in ensuring that their asset continues to perform financially.
- **Governments:** Like institutional investments, many local, provincial, and national governments have large and sophisticated real estate arms, and take a long-term view when it comes to managing real estate. While rental income may be a key factor for some properties, many governments leverage their assets, their purchasing power, and their building management practices to reinforce public policy priorities. Economic development, energy efficiency and climate action, workforce development and job creation, urban revitalization, technology development, commercialization and other such goals often come into effect in real estate investment decisions. Governments that have committed to climate action may be powerful partners in developing pilot projects that demonstrate the benefits and practicalities of fostering a circular economy for the built environment.

- **Businesses that own their own building:** Companies that choose to purchase a building for their own business needs tend to do so for reasons beyond financial returns. Owning a building offers a great deal more latitude than leasing when it comes to customizing the space. The benefits of property ownership are varied – from employee attraction, to wanting to make a statement about the business. For example, businesses in the construction industry may use their building to test concepts and demonstrate their latest ideas. Enlightened businesses may see the value of reimagining existing buildings for new and creative uses.
- **Small-scale private investors:** Small-scale private building owners and investors are more likely to operate in the Class B and Class C categories. Property investment may not be their primary line of business. High vacancy rates and market competition are the most common drivers for capital investments in their properties, but as they focus primarily on cash flow and are more sensitive to market cycles, when the property starts to underperform, they may decide to sell or redevelop. For small-scale private investors to engage with circular strategies, they need to see a compelling business case for investing in building improvements beyond the minimum to maintain functionality. As a group, they are hard to reach as very few are members of industry associations, and they may not be very sophisticated as they have not received formal training in real estate business.

Overall, the range, type, size, and configuration of office buildings in Canada is large and diverse. The data point to some potential targets for circular strategies. In terms of geographical location, the Prairie provinces have the most energy- and carbon-intensive buildings, and both Calgary and Edmonton have been struggling with high vacancy rates.

Class A buildings make up the largest category of office building by floor area in Canada. Most of the major institutional property owners are making sustained investments to maintain premium Class AAA and AA buildings while taking into account environmental goals. Many of these owners are large international organizations with significant market power. Their adopting circular strategies in their asset management plans would send an important signal to the real estate industry as a whole. By comparison, owners of older, less well-appointed, and less energy-efficient Class A buildings are having to be competitive in the post-COVID "flight to quality" and influx of new A+ properties. These owners may be interested in extending the lives of their properties as a means of re-positioning their buildings in the market.

There are more Class B and C buildings than Class A ones. The market for these lower-class buildings can be extremely competitive, as they offer the greatest potential for revitalization and adaptive reuse, and they are therefore generally the likeliest candidates for redevelopment. However, their owners – primarily small-scale private investors – may be hard to reach and without the necessary financial or organizational resources. Businesses that own their building and are purpose-driven may support the circular economy as a means of expressing their brand, attracting employees, and aligning their products and services. Progressive governments may similarly leverage investments in their buildings to communicate policy goals and stimulate market transformation. These groups could be exciting partners in developing a circular economy for the built environment in Canada.

5 Circular Strategies to Extend the Life of Existing Office Buildings

"Circular strategies" applied to existing office buildings means rethinking the design, construction, usage patterns, operational processes, and end of life from the beginning, so that products as well as entire structures have a regenerative life cycle. In other words, they can be repeatedly repaired, reused, recycled, or transformed [26]. This is a complex, multi-faceted exercise that requires a holistic approach, creative thinking, and intervention throughout the building's life cycle. The fact that modern buildings are not typically designed to be easily adapted or reconfigured has meant that, historically, it has been easy to make the business case for demolition.

““Circular strategies” applied to existing office buildings means rethinking the design, construction, usage patterns, operational processes, and end of life from the beginning, so that products as well as entire structures have a regenerative life cycle.”

Aggregated data on the reasons for demolishing office buildings in Canada are limited. A 2004 study by the Athena Sustainable Materials Institute on building durability by primary type of material used in construction involved an examination of the demolition records of 227 buildings (both residential and commercial structures) in the City of St. Paul, Minnesota, from 2000 to 2003 [27]. While the lifespans for concrete and steel structures were as long as 100 years, most of these buildings reached the end of their useful lives at between 25 and 30 years of age. Looking further into the reasons for demolition, about 60% of the structures were removed as part of area redevelopment initiatives, because the buildings no longer fit the needs of the owner or tenant, due to changing land values, or because of socially undesirable use or inability to economically bring a building up to code. Less than one-third were torn down because of physical condition and less than 7% as a result of fire damage.

However, market priorities are changing. 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.

This section provides guidance and best practices on the application of circular strategies in the commercial real estate sector, looking in turn at (a) the design interventions that can be made to optimize an existing building for ongoing operations while improving the potential for further renewals; (b) how to minimize waste generated from maintenance and renovation activities and, ultimately, end of life; and (c) how to “close the loop” when it comes to dealing with the construction material flows generated from the building and incorporating salvaged materials into projects.

Circularity in commercial office design and operation is still at an early stage of adoption in Canada. To provide a level of practicality sufficient for building owners, designers, and builders, this report illustrates each key strategy using examples of projects from Canada and around the world.

5.1 Circular Design Strategies

The durability and longevity of buildings starts with good design. Fundamental to fostering a circular built environment is the need, at the outset, to consider if a new building is needed [28]. If so, then the next step is to build for long-term value by designing well from the outset, eliminating waste and pollution, and allowing for flexible building use, adaptive reuse, long-term durability, and optimized material recovery. Leading Canadian design and architectural firms are starting to incorporate circularity principles into their projects with the future in mind [7].

However, the focus of this report is extending the lives of office buildings that are already standing. Starting with solutions to upgrade a building while retaining typical office functions within the existing envelope of the structure, this section explores opportunities for adaptive transformation that expands or physically reconfigures the structure. The building as a whole is examined, and then, where appropriate, different building components (i.e., the envelope structure; mechanical, electrical, plumbing systems; finishes; and fixtures and fittings). Finally, a selection of buildings is profiled, with examples of adaptation, reconfiguration, and even disassembly for relocation elsewhere, where the design is predicated upon planning for the future as opposed to solving a current problem of profitability and performance.

5.1.1 Upgrades and Renewals

Office building upgrades are undertaken when tenants move in and out ("tenant fit-outs") and, in the face of changing market conditions, if the building is underperforming because of its physical condition (usually due to age) or lack of the amenities necessary for the property to remain competitive. 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 turnover. While every property is different, office upgrades usually involve improvements to the envelope and mechanical systems. Upgrades may be completed in phases, while some tenants remain in place.

Buildings that lend themselves to upgrades and renewals are usually in high-value downtown locations and have the potential to generate premium rents from which to recoup the cost of construction. They tend to have a simple form and open flexible floor plans with minimal obstructions. For example, the 16-storey HSBC Place in downtown Edmonton was redesigned from the inside out to be a prominent, distinctive Class AA office tower based on the developer's calculation that yield rates would be better from the renovation than from tearing down and building anew [29]. Completed in 2020, the building was stripped down to its structure to install new efficient building systems integrated with a high-performance envelope. The building's sustainability credits include targeting LEED® Gold, WELL Building Standard® Gold, and WiredScore Platinum. There are many Class A office projects in Canada that have followed a similar path.

5.1.1.1 Tenant Fit-outs

Tenant fit-outs and retrofits of tenant spaces are key opportunities to incorporate sustainability principles and circular solutions into buildings [30]. At practically every lease turnover, the tenant must return the space to move-in conditions so that the landlord can perform renovations to the base building and the new tenant can outfit the space to suit their needs. This means that although each individual project is quite small, a tremendous amount of material routinely passes through office properties.

Prefabricated, demountable, and reusable interior systems solutions improve the environmental footprint of office fit-outs; they can also be offered as a "system as a service" model to reduce capital costs to tenants. Falkbuilt, a Canadian office partition company that operates a zero-waste, circular business model, sources its products from sustainable materials and designs them for disassembly and reuse. Their manufacturing and shipping processes have also been designed to dramatically cut down on carbon emissions from transportation [31]. During shipping, their framed glass doors are held in place using proprietary reusable clips, which has led to an 80% reduction in packaging waste. Leftover manufacturing materials are sent to Ontario to be made into garden hoses.

5.1.1.2 Circular Strategies for Whole Building Upgrades

The first step on the path towards circularity means looking beyond economics to consider environmental and social impacts. Although sustainability is important for attracting tenants, it has become increasingly vital to real estate investors [32]. Energy retrofits of office buildings are well-established practices for optimizing operational performance. Programs such as ENERGY STAR Portfolio Manager [33] provide industry-accepted methodologies and benchmarking systems. The US Department of Energy's *Advanced Energy Retrofit Guide for Office Buildings* [34] is a useful resource that covers regular and deep energy retrofit strategies. Whole building upgrades can start with energy efficiency and then leverage the project to integrate multiple improvements for multiple benefits.

A growing number of owners are committing to reducing the environmental impact of their buildings, and after the COVID-19 pandemic, improving the healthfulness of their properties as part of their corporate reporting on environmental, social, and governance goals. For example, one of Canada's largest commercial property owners, who reports on a number of environmental, social, and governance targets, has committed to eliminating GHG emissions from their portfolio by 2040 [35]. Owners are increasingly incorporating measures into their building-upgrade plans to ensure that projects are delivered sustainably. As a result, their buildings remain comfortable and safe in a changing climate (see Section 7.2.2 Climate and Natural Hazard Resilience Considerations).

One American carpet tile manufacturer that has long been recognized as a global leader in sustainability completed an 11-month project in 2018 that involved comprehensive conversion of a 3,700 m^2 (40,000 sf) 1950s-era multi-tenant office building to a LEED Platinum–certified headquarters and showroom [36]. The project:

- Diverted 93% of waste from landfill, including 46,300 kg (102,160 pounds) of concrete and 20,600 kg (45,420 pounds) of steel;
- Donated 50 items to the Lifecycle Building Center, an Atlanta, Georgia, non-profit [37];
- Reduced water use by 78% through rainwater collection;
- Reduced energy use by 50% compared with code-compliant buildings.

The rationale for the project was primarily driven by the company's commitment to sustainability and "factory as a forest" methodology [38], which looks to the local ecosystem for inspiration on achieving sustainability and productivity.

Further motivation for upgrading whole buildings is compliance with current codes and standards and future proofing against long-term policy shifts. For example, modern accessibility requirements may require reconfiguring of building entrances and circulation systems. Pall Mall Court is a sustainability-focused upgrade of a 7,900 m^2 (85,000 sf) workplace with leisure amenities currently underway for completion at the end of 2023 [39]. Pall Mall Court is a Grade II listed[6] 1960s office building in the city centre of Manchester, UK [40]. The design faithfully recreates the building's modernist cladding, while boosting energy efficiency and airtightness, bringing it up to the standard of a modern, sustainable workplace. This includes the painstaking recreation of the cladding joints, made and tested through 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 emissions.

The interior design strategy uses the original building and its distinct modernist style as a starting point, with key materials retained wherever possible, alongside a radical rethink of the workspaces and amenities. The result is a workplace with a wellness studio and gym, a cycle store, high-quality showers, and changing areas, to encourage healthy behaviours and productivity in the workforce.

5.1.1.3 Versatile Design and Planning for Future Interventions

Circular strategies can be applied to a building upgrade so that the building can continue to be renovated affordably with minimal disruption. Versatility is an important characteristic in contemporary office building design because the nature of office work is continually evolving. "Post-pandemic", "resilience", "flexibility", and "elasticity" have become watchwords associated with the design and operation of contemporary workplaces. Lease terms are getting shorter (see Section 5.4.3 Innovative Leasing Models). Whether undertaking a fit-out or a whole building upgrade, it is important to consider how the space can be designed for easy re-lease when it is eventually surrendered and how easily tenants could expand into adjacent spaces. 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:

6 See Section 6.3 Regulations on the UK's Listing system for historically and/or architecturally significant buildings.

- **Simple, open floor space with flexible planning grids.** From the 1980s through to the 2000s, the 1.5 m (5 ft) 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 work environments, flexibility now takes the form of clear span, column-free spaces and ergonomic furniture systems that are pulled away from windows.
- **Reconfigurable structures**, fit-out technologies, "plug-and-play" systems, movable componentized systems, and "partitioning as a service". Framehouse, a 1,810 m² (19,480 sf) flexible office building, is a sustainable workspace located in an industrial business area in Dragør, Denmark [41]. The two-storey exposed timber structure allows for the addition or removal of mezzanines or for reconfiguring the space from office to meeting room, depending on tenants' needs.
- **Standardization and interoperability** to reduce the number of unique components and protect against built-in obsolescence or unavailability of critical items or elements (see Section 6.5 Standards).
- **Solutions that support future reconfiguration and disassembly** (discussed further in Section 5.1.1.8 Planning for Future Disassembly). The Platform & Innovation Centre Parkade, Calgary, has been built with the potential to be reconfigured for office or residential use [42]. As urban mobility choices change, the long-term need for parking may also evolve. This mixed-use building combines seven storeys of visitor parking for Calgary's East Village and surrounding communities with 50,000 square feet of space for tech start-ups [43]. The parkade also has a publicly accessible sports court on its main level and outdoor event rental space on the top floor [44]. The building design allows for conversion into commercial or residential uses through the use of flat floor slabs, the ability to increase 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 [45].

5.1.1.4 "Up-classing" Class B and Class C Buildings

Upgrading suburban Class B and C buildings to reposition them as Class A, or to generate rents that are closer to Class A rents, may save them from demolition, but can be complicated [46]. Class B and C buildings tend to be low- to mid-rise structures located outside the downtown core. Given the large number of Class B and C buildings in Canada, their lack of associated amenities, and the fact that they primarily compete on price, this market segment is a very competitive and these buildings may be vulnerable to demolition when the market turns. Indeed, an increasingly competitive office market as well as rising demand for other building uses, including manufacturing and warehousing, is increasing the pressure to demolish suburban office buildings [47]. There are firms in the US that specialize in leveraging the opportunity and value of Class B and C buildings to create high-quality, retrofitted office space that commands higher rents. The money saved by acquiring a lower-tier space can be targeted towards high-end features and adaptations. Examples include:

- The former Ford factory in Los Angeles, California, was upgraded from a tired Class B to a premium Class A building in 2018 [48].
- The massive former Bell Labs building in Holmdel Township, New Jersey, has been converted to Bell Works, a "metroburb", that is, a self-contained, indoor "main street" with stores, a food hall, and tech company offices [49].
- The Apollo at Rosecrans is an adaptive reuse of five defence industry and aerospace industry warehouses, constructed between 1970 and 1980, and transformed into a creative office campus in El Segundo, California [50].

These examples are primarily large developments where economies of scale can help make the projects financially viable. While "up-classing" is an emerging area in Canada, the Phenix in Montréal is a deep retrofit (envelope and systems) of a more modest three-storey, 9,264 m² (99,700 sf) structure that was originally built in 1950 and used for industrial purposes [51]. An architectural firm designed the building as a unique work environment for their 350 employees [52].

The motivation for pushing environmental goals was to create a characterful workplace for testing new concepts and their energy-efficient, low-carbon-footprint ("Net Positive™") approaches in sustainable design and strategies [53].

5.1.1.5 Industrial Prefabricated Solutions for Building Renovations

Industrial prefabrication solutions have the potential to accelerate serial renovation solutions. This has been successfully demonstrated in the Dutch housing sector [54], [55]. Industrial prefabrication, or modular construction, involves the design and production of structural components or units (walls, roofs, floors, balconies, facades, kitchens, etc.) in a factory environment; these are then installed on site [56].

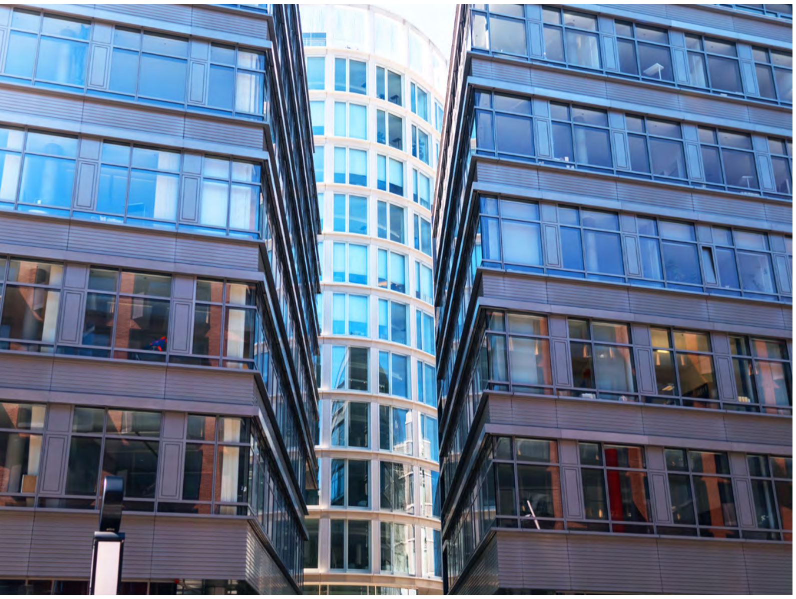
Prefabrication supports circular construction methods because it takes a "kit-of-parts" approach to the design, and therefore has the potential for future disassembly. This technique also prevents waste brought to the site [57]. Digital tools, such as building information modelling (BIM) (see Section 5.4.2 Digitalization of Design and Construction), can integrate the design model with the fabrication process, making prefabrication increasingly viable for renovations. Mechanical systems and heating, ventilation, and air-conditioning (HVAC) units, panelized walls, floors and partitions, and modular assemblies such as kitchens and bathroom "pods" can all be pre-assembled [58]. For example, White Collar Factory is a naturally ventilated "spec office"[7] in the UK that focuses on flexibility, smart servicing, adaptation to future uses, and climate resilience. It incorporates operable windows, long spans, flexible floor plates, and robust construction. The tower represents a new type of office building that takes its cue from the multi-level factory typology [59]. The project has become a template for a building type that blends the efficiencies of a new build with the character of a 19th century warehouse.

The potential of prefabrication for new buildings has been established in Canada [60]. Still, this potential is not limited to new buildings. Several external forces are driving the uptake of industrial prefabrication for renovations. These include increasingly stringent environmental standards requiring a greater focus on quality and a lack of qualified workers forcing companies to produce more with fewer factory workers. As a result, several modular interior fit-out and partitioning systems on the market allow quick and easy reconfiguration of office spaces in Canada.

In 2014, APEL Extrusions fitted out their office in Coburn, Oregon, using a modular partitioning system on the first floor of their building to suit their 80-employee workforce. By 2018, the space was no longer big enough. As the modular construction system was designed for disassembly, when the company decided to move their offices to the second floor of the building and dedicate the main floor to their manufacturing operation, the system was easily reconfigured and relocated. Not only was the system's kit-of-parts design integral to the office expansion, the data maintained in the modular partitioning company's proprietary software helped in the reconfiguration. As a result, 98% of the modular system from 2014 could be reused. 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. One week later, the partitioning assemblies were installed upstairs. With the modular partitioning system's adaptive reuse, APEL prevented 22,565 pounds (10,235 kg) of construction waste from being landfilled [61].

The successful use of prefabrication for renovations relies on process innovation, especially since most of the coordination for industrial prefabrication occurs during the planning and design stages. Further, prefabrication tends to rely on large volumes or work pipelines of standardized products: stability in supply and manufacturing is essential to improve efficiency and increase scale so that projects are cost-effective. The restoration of the Victorian Walworth Town Hall in London, UK, involved the use of a prefabricated cross-laminated timber (CLT), glued laminated timber (commonly known as glulam), and steel in the conservation context. The timber structure was prefabricated, delivered to the site, and craned into place within three weeks so that the contractor could make the building watertight and proceed with internal works [62].

7 Speculative, or "spec" buildings, are built by developers with the goal of attracting tenants during or shortly after construction.



> "As cities continue to grow and densify, increasing competition for land will exert pressure on commercial properties to generate sufficient income to remain economically viable."

Although stability of the supply chain and adequate manufacturing facilities capable of supplying necessary components efficiently are essential, they are particularly difficult to achieve at scale given the idiosyncrasies of building renovations. To this end, P2ENDURE is a European Union (EU) initiative that promotes evidence-based solutions for deep renovation that are based on prefabricated plug-and-play systems in combination with on-site robotic 3D printing and BIM [63]. The objective is to increase the scale and level of adoption through innovative combinations, processes, and supporting information and communication technology (ICT) tools. In particular, P2ENDURE aims to create the supply-chain infrastructure for large-scale commercial implementation and upscaling of prefabricated deep renovation solutions that will be applicable and replicable for the widest range of building typologies, including civic infrastructure, residential buildings, and public and historic buildings converted into housing. With 10 real projects in four geo-clusters, P2ENDURE is focused on:

- Building credible 3D-scanning and printing technology solutions in combination with prefabricated systems derived from tested results of recent EU and national research initiatives.
- Developing modular processes and systems for deep renovations through digital design, production, and installation.
- Optimizing and integrating state-of-the-art yet practical solutions.
- Completing complex deep renovations and transformations of obsolete civic and historic buildings for greater performance impacts than typical buildings.

Bundling and bulk purchasing, project aggregation, and other measures to stimulate demand can encourage manufacturers and practitioners (who might already have the capacity or potential capital costs) to pursue prefabricated solutions. While such approaches have been shown to be successful in the housing sector[8], they have yet to be demonstrated for commercial offices.

5.1.1.6 Additions, Expansions, and "Parasitic" Architecture

As cities continue to grow and densify [64], increasing competition for land will exert pressure on commercial properties to generate sufficient income to remain economically viable. This can result in the premature demolition of otherwise serviceable buildings. For example, an interviewee for this project noted that the former Canada Revenue Agency (CRA) tower at 1166 Pender Street in Vancouver was a "sole tenant" building that had the potential for a comprehensive refurbishment when CRA moved out in 2020. Indeed, the 1974-built, 12-storey, 14,000 m² (151,000 sf) Class A building provided a rare opportunity to comprehensively

8 See the example of buyer group Circulaire Bouwmaterialen in Section 5.3.2 Secondary Materials Markets.

renew the fully vacated property. Although, a proposal was put out to design teams to conduct a feasibility study, the market conditions and regulatory constraints in downtown Vancouver were such that the owners opted to demolish the existing building and replace it with a new 32-storey tower, doubling the floor space to 33,550 m^2 (361,000 sf) of state-of-the-art Class AAA office space [65].

For buildings to expand vertically and avoid demolition, the structural capacity of the base building is critical. The former Vancouver Post Office, for example, was originally designed to meet structural loads outside the norm for conventional office buildings; [9] the addition of two new office towers, rising to 21 and 22 storeys above the original structure, made the revitalization of the original building economically feasible [66].

Ideally, buildings are designed for future expansion from the outset. Vertical phasing, a common way to increase density, has been widely adopted in Asia [67]. The Bentall 5 office tower in Vancouver was the first project in Canada to implement this technique. Bentall 5 was built in two phases, with the structure designed to align with an existing underground parkade to save on excavation [68], [69], [70]. The architects designed the building so that it could expand vertically without disturbing its tenants. The phasing of the project allowed the initial 22-storey building to be leased out before the final 11 storeys were added six years later, in 2007. This meant that the builder of the Phase Two portion had to carry out construction 91 m (300 ft) above ground while the building underneath was fully operational.

Where a building was not originally designed with vertical expansion in mind, lightweight structural systems provide a solution. In particular, mass timber is an option lighter than concrete that has been used to add floors to existing office buildings in Canada and the US. For example, the 80 M Street office building in Washington, DC, has a three-storey timber extension added on top of a seven-storey concrete building [71]. The primary reason for using timber was the effect on structural requirements because of the relative lightness of timber versus concrete; the secondary reason was the speed afforded by prefabrication [72].

"Parasitic" architecture describes additional structures that attach to and use utilities from existing larger buildings [73]. Legal examples of this approach are where new structures with new uses are appended to and supported by a host building and managed under a single ownership. Such approaches are popular with start-up spaces and co-working communities where tenants can create their own space. Examples include:

- The Spinning Mills in Vejle, Denmark, is a 12,000 m^2 (130,000 sf) industrial building complex that has been modernized for artists and business start-ups in the creative and cultural community [74]. The design preserves the original structure and unique industrial expression, but allows for tenants to use only as much as they need of the building's physical resources and services.
- The Prefab Parasite was designed using a parametric digital modelling system [75]. The components of the parasitic structure include the facade, cladding, structural system, floor levels, and stairs, which are organized and handled in a single digital model. The parametric digital modelling enables the parasitic structure to adapt dynamically to the various locations it could potentially occupy.

5.1.1.7 Changes of Use and Conversions

Conversions and changes of use allow for retaining the inherent value of existing structures and avoiding the significant environmental impacts of demolition. Office conversions tend to occur wherever office vacancy rates are persistently high and construction materials costs are high or volatile.

To date, the most common change of use in Canada is from office to residential as this gives the maximum "lift" to real estate value and fills the pressing demand for housing. Both Edmonton and Calgary have seen a number of office-to-residential conversions over the past five years. Alberta-based developers, such as Strategic Group, have become proficient at converting underperforming downtown offices into residential buildings [76]. 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

9 The huge beams and columns in Vancouver Post Office building could take the weight of full-size delivery trucks.

plus an upcoming fourth project. Of the 28 buildings in Calgary, totalling 3 million m² (32 million sf), that architectural firm Gensler examined, between 10 and 12 were viable candidates for conversion [77].

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

- Structural spans of 7.6 to 10.6 m (25 to 35 ft) are perfect for smaller residential units and allow a 56 m² (600 sf) unit to be 6 m (20 ft) wide with a corridor behind.
- Floor-to-floor heights for Class C offices go as low as 3.5 m (11 ft), but that is much higher than the 2.9 m (9.5 ft), which is currently targeted for new residential developments.
- Small floor plates – about 745 to 930 m² (8,000 to 10,000 sf) – 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 towards buildings, blocks, and even urban infrastructure that is nonetheless rooted in local urban context [78].

Community building is important when considering new uses for old office buildings. While residential uses can bring vitality to downtown cores, providing opportunities for local employment is another benefit. Converting office buildings to alternative workplaces that generate rents similar to traditional offices requires creative thinking by both building owners and local governments. New uses that generate employment include hotels, warehouses, manufacturing and industrial facilities, schools, retail stores, start-up incubators and urban farms [79].

One such example is the Westley Hotel, in Calgary, which was converted from an underutilized downtown office building [80], [81]. Previously the corporate headquarters for an energy company, the original building was completed in 1980. The owner had been looking for a property to convert to avoid buying land downtown and building a new structure, which would have necessitated building a large hotel, a cost-prohibitive undertaking given the downturn in the local economy and the COVID-19 pandemic. The Westley was completed at a time when hotel investments focused on other areas (such as the airport). The owners’ vision was to leverage the “downtime” in the hospitality industry to create the newest boutique hotel in the city for use as much by locals as by visitors.

The original five-storey building with underground parking had 6,320 m² (68,000 sf) of office space and had been vacant for just over a year [82]. The entire building inside, including the HVAC system, the electrical system, and all interiors, were demolished down to the central core. Once the building had been gutted and all the complexity and risks associated with unknown as-built conditions were known, did the hotel design actually commence. Interior demolition started in 2018, design commenced in 2019 and the hotel opened in 2021 [83].

Other less common applications for converted office buildings include fulfillment centres, as centrally located offices adjacent to public transportation may be preferable to warehouses located away from major population areas, especially as same-day and even two-hour delivery become more prevalent [84]. There is also emerging interest in converting office space to urban agriculture. Pasona Urban Farm in Tokyo, Japan, produces edible plants in a converted nine-storey office building [85]. 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. With crop space of over 4,000 m² (43,000 sf), Pasona Urban Farm is the largest urban farm-to-table agricultural project to be inserted into an office building in Japan. It should be noted that converting an existing commercial space into a vertical indoor farm is not without challenges [86]. Building HVAC, electrical services, and envelope need to be customized and hygiene maintained. Vertical farms use a large amount of power for lighting, humidity, climate control (heating and cooling), and CO_2 control (which needs to be maintained at about 1,300 ppm and is difficult when customizing an HVAC system within a building renovation) [87].

5.1.1.8 Planning for Future Disassembly

"Circular thinking" during the planning stages of a building upgrade, addition, or conversion incorporates features and components that allow for future disassembly so that the building's materials, systems, and components can be reclaimed for other purposes and their value retained.

The problem with disassembling modern buildings is that, as of the 1970s, builders began to use materials that are less durable and have not held their value (e.g., plastics and particle board) [88]. Construction also used more glue, spray foam sealant, caulking, and other adhesives, which make it more difficult to take newer buildings apart by hand. Planning for future disassembly means prioritizing "dry-assembly" solutions such as mechanical fastenings and "snap-fit" systems. Traditional techniques, for example, Japanese joinery connections made entirely without the use of metal fasteners or adhesives are also being revived [89].

CSA Z782-06, *Guideline for Design for Disassembly and Adaptability in Buildings*, sets out definitions and a framework concept and principles (including a description, examples, and metrics) when designing for the future disassembly and adaptation of buildings in Canada (see Section 6.5 Standards). The disassembly measures can be applied at any level, from an individual assembly to the entire building. The measures are set out below with examples of each[10]:

- Exposed and/or reversible connections
  - Legacy Living Lab (L3) is a 251 m² (2,700 sf) two-storey prefabricated commercial building that a research team from Curtin University, Perth, Western Australia, designed and built to research the applicability of the circular economy through the disassembly and reuse of building components [90]. L3 was a joint project of the research team, who led the conceptualization and project management and supervised the construction process, and a modular building company based in Perth, Western Australia, who undertook the construction and detailed engineering.

    L3 includes a commercial area and cafe on the ground floor and an open office on the second floor. The ceiling and internal cladding can be fully deconstructed, for easy access to the insulation and the mechanical and electrical plant systems, for maintenance and at end of life, without any waste.

    The design of both floors was optimized for adaptability. Buildings that are meant to be disassembled should have easily accessible connections [91]. All L3 connections can be easily accessed with standard building tools, facilitating its disassembly and component reusability.
- Independence
  - Independent building systems are designed to stand separately to facilitate removal, adjustment, or upgrade of components. Post-tensioned timber systems, made of low-carbon materials, that improve structural performance in seismic events are being developed [92]. These systems allow for post-event adjustment so that the building can return to full functionality. By comparison, more than 60% of concrete buildings with three or more storeys in Christchurch, New Zealand, were demolished after the 2010 and 2011 earthquakes [93].
- Inherent finishes
  - oN5 is a prefabricated mass timber office in Vancouver whose structural walls, ceilings, and servicing have been left unpainted [94]. The mass timber slabs, prefabricated walls and stairs, and steel frame can be taken apart and reused.
- Recyclability
  - Materials that have a high recyclable content (e.g., metals, gypsum, etc.) are less likely to end up in a landfill (see Section 5.2.3 Zero-waste Renovations on Site). Using these materials can reduce cost and protect against the volatile prices and insecurities in supply associated with raw materials. Currently, the majority of building components from demolitions are reduced to lesser grade materials with lower market value. Selecting materials that can be recycled in their

10 It is not known if the projects identified in this section referred to or were guided by CSA Z782-06. The projects are described to illustrate the intentions of the measure.

existing form, or better, upcycled to products with enhanced value, extends their life by many years.

NASA's Sustainability Base in California, US, was designed so that it could be disassembled [95]. Cradle to Cradle®–certified products were used when available, cost-effective, and achievable through a competitive tender process. Salvaged, recyclable/recycled, locally available, and/or rapidly renewable materials as well as certified wood from sustainably managed forests were considered.

- Re-manufacturability
  - Around the world, about 27 million tonnes of medium density fibreboard (MDF) are wasted every year [96]. MDF is a cheap material and, until now, waste MDF has typically been either incinerated or landfilled because there was no economically viable way to recover and reuse waste fibres. The UK's first commercial MDF recovery plant is scheduled to open in 2023 [97]. Shredded waste MDF is heated electrically in a liquid medium to break down the resin and separate the fibres. The recovered fibre, which is of the same quality as virgin fibre, will provide feedstock to manufacturers of MDF board, insulation products, and packing materials.
- Reusability
  - Brummen Town Hall in the Netherlands was designed to have a service life of 20 years, based on frequently shifting municipality borders [98]. Rather than using cheap materials to build it, which would likely end up in a landfill, the building incorporates a variety of high-quality reusable elements – mostly prefabricated timber components – that will be dismantled and returned to their manufacturers at the end of the building's life.
  - R128 is a prefabricated, modular design, experimental construction built in Stuttgart, Germany. It produces no emissions and is self-sufficient in terms of heating. The materials, which are fully recyclable, can be reused. The columns and beams were bolted together on site, with the bolts screwed into threaded holes in the columns, that is, no nuts were used, allowing subsequent dismantling and reassembly. 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 erected in four days [99].
- Simplicity
  - Simple forms need fewer parts and are, therefore, simpler to disassemble. Fasteners that require standard tools allow for simple and fast disassembly. The five-storey Cellophane House in New York City was put together like a car, with the entire construction process broken down into integrated assemblies manufactured off site over the course of three months, delivered on trailers to the construction site, and then stacked together over 16 days using a crane [100]. A 3D BIM model was used to achieve a high level of precision, to procure materials, and to plan assembly sequencing.

5.2 Circularity in the Field

Application of circular best practices to the construction process is primarily dictated by strateges deployed during the design phase [101]. By the time construction starts, the building elements, materials, and components that will be retained and removed will have been decided on. Nevertheless, the builder can take steps 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. Leading firms in Canada are focusing on on-site waste diversion and management practices during the construction and renovation stages of a building [7].

Two overarching approaches inform circular thinking on the construction site: sustainable materials management and Lean project delivery. The successful application of these two philosophies results 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.

5.2.1 Sustainable Materials Management

The OECD defines sustainable materials management as "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" [102].

"One study of LEED multi-unit residential projects in Canada estimated that for every square metre of finished floor area, more than 100 kg of excess materials was purchased and brought to site."

Sustainable materials management principles applied to the construction site look both upstream the supply chain to inform decisions about materials and processes, reducing resource consumption and their environmental impacts, and downstream, to understand and address the installation, operation, and end-of-life impacts. Life cycle assessment (LCA) is the methodology used to quantitatively analyze the environmental aspects of a product over its entire life cycle (discussed in Section 7 Economic and Environmental Considerations and Trade-offs).

5.2.2 Lean Project Delivery

Between 10 and 15% of materials are wasted during traditional construction [9]. One study of LEED multi-unit residential projects in Canada estimated that for every square metre of finished floor area, more than 100 kg of excess materials was purchased and brought to site.[11] Implementing sustainable materials management goals on site starts with the project team identifying where inefficiencies occur during the construction process to avoid creating waste.

Lean project delivery is a collaborative process that applies "target value design" and "pull planning" methods during construction [103]. Target value design uses customer constraints as the drivers of design. Pull planning is a method of driving efficiency by having personnel, materials, information, equipment, etc., only arrive at the time and place where they are needed to maintain the production process [104]. 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 [105], which focused on streamlining the manufacturing process to include only the necessary steps, the Lean planning process for construction prioritizes only value-generating activities [106]. Productivity is defined by only doing what achieves the owner's goals for the project. Typically, contingencies are built into tasks to compensate for non-value-generating activities such as delays, waiting, changes, errors, etc. To protect themselves against such non-value-generating activities (known as "waste" in Lean), project participants build time, resource, or effort "buffers" into their scopes of work as contingencies. Extra hours, excess materials, and additional workers are examples of waste that construction projects may bear. Globally, the hidden cost of this waste is estimated to be more than US$1 trillion a year [107].

Lean methods are well-established in new construction projects in Canada and around the world. Lean blends well with the use of digital technologies and industrial prefabrication. Traditional silos of knowledge, work, and effort are broken down and reorganized for the

11 According to the Residential Construction Waste Analysis (2021) prepared for BC Housing by Light House. The sampling dataset is based on 106 multi-unit residential buildings (MURBs) from across Canada, totalling 1.96 million m² (21 million sf), from 2007 to 2019. Of these, 51 were high-rise projects that would use non-combustible construction materials and systems similar to those used in commercial buildings.

betterment of the project rather than of individual participants. The objective is to deliver significant improvements, on schedule and with dramatically reduced waste, particularly for complex, uncertain, and quick projects. This makes Lean methods applicable to renovation projects, although they are rarely used in practice.

The StepUP project [108] is developing a building renovation project guide that focuses on developing new technologies and solutions to make building renovation more attractive and affordable and to better understand the barriers to using Lean methods in renovation projects [109]. Two primary barriers identified so far include:

- All aspects related to the manufacturing, shipping, and assembly of the industrialized elements are not usually included in the process.
- Design process, monitoring, or development of new business models are not considered in the methodology.

Lean strategies are being developed during the execution of a series of pilot renovation projects, and a roadmap has been created to apply a Lean approach to industrialized renovation processes. The 10-point roadmap shows, in chronological order, the steps and actions essential to analyse and plan any renovation project using a Lean approach, with particular focus on detecting and avoiding any type of waste. At a basic level, the points are:

1. Identify the project Lean champion.
2. Define the milestones.
3. List essential activities for each partner.
4. Define a sequence of activities.
5. Define interactions and duration of each activity.
6. Look for waste.
7. Ask if it is possible to optimize the waste.
8. Reach agreement.
9. Elaborate and optimize planning.
10. Decide on dates for the essential activities.

Lean project delivery methods have yet to become mainstream in renovation projects. One success story is the extensive modernization of the Edith Green–Wendell Wyatt (EGWW) Federal Building, an 18-storey government building in Portland, Oregon, built in 1974 and housing 16 different federal tenant groups [110]. The renovation project needed to meet stringent green building standards and be completed extremely quickly in order to meet funding deadlines. Every building system was improved; added were a new energy-efficient envelope; new energy-efficient mechanical, electrical, and voice/data telecommunications systems; a blast-resistant curtain wall; tenant and core improvements; and seismic structural upgrades. Lean project methods helped with the additional coordination designers and trade contractors required to work with an existing building and address unknown pre-construction field conditions [111]. The EGWW is LEED Platinum–certified and uses 60 to 65% less energy than a typical office building.

5.2.3 Zero-waste Renovations on Site

Zero-waste goals can be applied to all types of renovation projects and, while upfront planning is critical, the primary focus is eliminating waste generated by the construction process on site. Achieving zero waste means that surplus products are sold, consumed, collected, and then reused, remade into new products, and 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 management hierarchy or the "5Rs": (a) reduce; (b) reuse, (c) recycle, (d) recover for energy, and (e) residuals management (waste to landfill). The higher levels of the hierarchy (e.g., reduce) are preferred over lower levels (e.g., residuals management).

The vast majority of CRD waste can be diverted from landfill. Construction waste management, which involves sorting and recycling waste and reporting materials waste flows, is well-established in Canada. On new construction projects, diversion rates can reach more than 90%. However, in practice only 27% of non-residential CRD waste is diverted from landfill in Canada. The volume of waste generated from renovations is more than six times that from new construction. Managing construction waste from renovations is more challenging than managing waste from new constructions because the work takes place in confined spaces, making materials storage and handling difficult.

Planning for a zero-waste site must start early to put in place solutions that avoid bringing waste to a work site. For example, some suppliers remove their packaging and pallets and take back unused materials, and "product as a service" schemes exist for formwork, scaffolding, crane mats, and other components. To help project teams plan, manage, and implement zero-waste strategies effectively and to reward exemplary performance, Zero Waste Canada is piloting a certification program that follows internationally accepted zero-waste principles and practices (see Section 6.4 Information-based and Voluntary Approaches) [112].

Goals for the fit-out of Integral's Calgary office were that no waste would go to landfill from the project, that waste from other projects would be diverted, and that the number of offcuts that lead to waste would be reduced. Items had to either be recyclable or reusable [113]. The project team reduced the typical interior office construction project's site waste from a total of 7 tonnes to zero for the 632 m^2 (6,800 sf) space [114]. Zero-waste construction is often overlooked because of perceived cost and effort. However, the Calgary office came at no additional cost – capital was redirected from landfill and material fees to refurbishment fees, and 6 to 7 tonnes of waste were diverted from landfill.

5.2.4 Deconstruction

According to CSA Z783:12 (R2021), deconstruction is "a process of disassembly to recover materials, components, products or systems for potential reuse or recycling" [115]. Despite that modern office buildings are typically not designed to be disassembled and materials may not be easy to salvage, the objective of deconstruction is to disassemble the building in a way that preserves the highest and best value and utility of the materials and components. Deconstruction may be slower than demolition, but aside from reduced environmental impacts, it is quieter and generates less dust – an important consideration if tenants are in the building.

Deconstruction is an emerging trend in Canada as the construction industry starts to recognize the value in recovering materials and resources from buildings at end of life and looks at secondary materials markets. Long-term owners are also beginning to consider the value of the materials embedded in their existing buildings as an asset they can draw on for future buildings [116]. Currently, the market demand for recovered resources varies depending on the geographical location in Canada and the material type; in general, it remains relatively low [7].

Pressure to demolish as opposed to deconstruct and salvage is driven by economics and efficiency. The disparity between the low cost of materials and the high cost of labour plays an important role in deciding whether a material is salvaged or disposed of. For example, if a new 2×4 wood stud costs only $5 [117], it is hard to justify paying a carpenter $32/hour [118] to take down, de-nail, and salvage a used one.

Creative solutions to drive deconstruction in the residential sector have started to take hold. For example, Habitat for Humanity has been working with Unbuilders to provide homeowners with a tax receipt for the value of the materials salvaged from deconstructing their home [119]. While this option is not available for commercial properties, commercial tenants can donate the hoarding used when renovating, via Hoarding for Humanity, for use in the homes Habitat builds [120].

Deconstruction must therefore be clearly articulated by the owner at the outset of a project so that the team can price the job properly, ensure they have the required expertise, and plan accordingly. Local bylaws may require certain materials to be deconstructed and recycled. Many regional waste management utilities provide a list of construction materials that can be either reused or recycled [121].

CSA Z783:12 (R2021), *Deconstruction of buildings and their related parts* provides an industry-accepted methodology for planning a deconstruction project [115]. It addresses project scope definition, procurement, suitability of materials for reuse, the deconstruction process, site issues, management, and record keeping (See Section 6.5 Standards). Underpinning this document is the fact that appropriate project documentation is very important when planning deconstruction [122]. At the end of the building's life, sufficient information should be available for the contractor to be able to take the building apart and identify the components and materials and their potential for reuse and recycling.

BRE case studies present ways to assess the deconstruction potential of new builds [123]. One such case study, of a three-storey concrete office building, consists of two parts: approximately 1,300 m^2 (14,000 sf) of offices for about 100 staff, and about 800 m^2 (8,600 sf) of seminar facilities [124]. The methodology described in the case study can be used to evaluate the design for disassembly (DfD) potential of a building according to a series of parameters, to arrive at an overall score. Taken into account are the materials and components chosen; the types of connections used; the accessibility of the components and connections; the deconstruction process; and the amount of documentation about the deconstruction.

The office deconstruction assessment case study scored 72% overall for its DfD potential. The elements that run along the raised access floors or ceiling voids, along with the roof and the upper floor, had the greatest potential for deconstruction. The connections criteria (91%) and the optimization of the deconstruction process (74%) scored the highest, and the reuse and recycling potential the lowest (64%). Most of the components could be dismantled using non-specialized equipment because mechanical fixings were commonly used. Key issues are:

- The use of lime mortar rather than cement mortar for the reclaimed brick external wall to enable future reuse.
- The use of nails or other mechanical fixings on wood flooring, rather than glue, which could limit reuse potential.
- The use of materials that can potentially be recycled, if reuse is not appropriate. Products that are difficult to recycle include oriented strand board (OSB) boards, mineral wool insulation, and air/vapour moisture (AVM) membranes.
- The reuse of precast concrete products, e.g., raised floor panels, as long as information is available regarding their service life, structural integrity, and load capacity, etc. It could also be difficult to find another suitable application without having to change the size of the panels [124].

Of note, 96% of the material from demolition of the workshops was recycled and used in the new construction project. It was the first UK use of recycled aggregate for the concrete structure. Other recycled materials included brickwork, concrete floor toppings (screeds) made from recycled power station gypsum, and wood block floors repurposed from County Hall in London.

While BRE is a research institute and the deconstruction project primarily a scientific study, there are companies commercializing deconstruction expertise. In the US, All For Reuse is an initiative to develop a network of building professionals committed to the reuse of commercial building materials [125]. In Belgium, Rotor DC, a not-for-profit side-project of Brussels-based firm Rotor, specializes in deconstruction and reconstruction, and has been promoting and facilitating the reuse of building components for at least a decade [126]. Working on between 25 and 40 buildings a year, Rotor DC's work includes unbolting building facades and extracting lighting fixtures, partitions, radiator covers, hardware, marble floors, etc., from buildings slated for demolition. While this can slow down the demolition process, many of the products command sufficient resale value that it makes economic sense.

Rotor DC is currently involved with the Multi project, which aims to give a second life to a 19-storey H-shaped office tower built in the historic heart of Brussels in the 1960s. Reusing 89% of the existing concrete structure saved approximately 20,000 tonnes of CO_2 and 3,260 tonnes of embodied carbon, and produced 20,000 tonnes less waste [127]. The building features maximum flexibility for different workspaces and has achieved BREEAM "Excellent" certification.

Rotor DC reclaimed and refurbished 82 heavy blocks of blue limestone from the Multi project [128]. The 50-year-old blocks were made into floor slabs and tile slabs for the terrace of the new project. The upper layer with the original chiselled finishing will also be reused as an interior wall cladding. The project achieved the highest percentage of reused materials of any large-scale office building in Brussels, of which 3% was sourced through Rotor DC's "urban mining" of iconic Belgian locations.

"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."

5.3 Closing the Loop – Strategies for Product and Material Reuse

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 have to 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 materials markets and support more reverse logistics should market demand for recovered materials grow [7].

An important consideration when closing the loop on materials flow is to retain the maximum value of the product, ideally upcycling it 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 [129]. Enhancing or changing the value of reclaimed products is essential to offsetting the cost and time associated with deconstruction.

Existing buildings that are refurbished or decommissioned represent a vast source of future building material. Each generation of buildings has its own materials palette and construction techniques, each varying in quantity, quality, and accessibility. Despite that most modern buildings were created without consideration for reuse or recycling of their constituent materials, a large portion can be salvaged and remade into "new" buildings. Indeed, while the construction industry has historically harvested natural resources, an increase in urban mining, harvesting resources from the existing built environment is on the increase.

This section focuses on strategies for sourcing and working with used products and materials in building renewals whereby the material flow loops are closed as much as possible.

5.3.1 Circular Input Strategies

Circular inputs involve the use of renewable energy and bio-based, or potentially completely recyclable, materials [7]. A "circular input strategy" can be developed as part of a feasibility study for a construction project whereby environmental performance goals and criteria are established for the equipment, products, and materials that will be used. LCA methodologies allow design teams to set overall carbon targets, compare options, and measure results using internationally accepted standards and processes (see Section 7 Economic and Environmental Considerations and Trade-offs).

Advances in mechanically fastened structural systems (mass timber, low-carbon precast concrete systems, etc.) allow designers to stipulate specific solutions that have low carbon footprints and are easy to maintain, disassemble, and reuse or fully recycle. For example, the Radiator is a five-storey 3,000 m^2 (32,000 sf) all-timber office and retail building in Portland, Oregon [130]. Fabricated steel bucket-style connections were used for glulam beam-to-beam connections for future disassembly. The design also avoided using gang-nail plates, which are time-consuming to disassemble.

5.3.2 Secondary Materials Markets

Markets that support trade in used construction resources are foundational to the success of a circular construction economy. A 2019 white paper entitled *The Case for a Resource Exchange Mechanism,* from the AECOM-led 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 [131]. The goals of the scheme would be to:

- Keep resources in use for as long as possible;
- Extract the maximum value from resources while these are in use;
- Recover and regenerate products and materials at the end of life; and
- Keep products, components, and materials at their highest utility and value at all times.

The paper notes that while there are strong environmental and social reasons for establishing a resource exchange mechanism, the primary driver is economic: the EU could realistically reduce the total material requirements of its economy by 17 to 24%, boosting gross domestic product, and creating between 1.4 and 2.8 million jobs [132].

The challenge for many emerging secondary materials market platforms is (a) balancing supply with demand, and (b) reliably delivering quantities of desired materials at a quality that meets industry expectations. There is generally an inverse relationship between a product's position in the 5Rs hierarchy and the potential volume of waste materials that could be utilized in making that product [133]. For example, wood makes up a large volume of waste generated in typical renovation projects. The reuse of wood heritage items is high in the 5Rs hierarchy (and commands a high dollar value per unit of material), but absorbs only a very small portion of the waste generated. At the other extreme, chipping wood is able to consume the majority of the wood waste generated, but is low in the 5Rs hierarchy (and commands a low dollar value per unit of wood).

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 business-to-business marketplace [134]. 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, unreliable transportation, and no dedicated customer support. Transparency, faster availability, and shorter lead times can accelerate timber usage in construction and help reduce embodied carbon in buildings.

Also emerging are market mechanisms that are leveraging new data management technologies to first assemble buyers and sellers, and then source and aggregate products and materials. Reseat in California does this for office furniture [135]. The buyer group Circulaire Bouwmaterialen in the Netherlands bundles the purchasing power of several housing associations to set out tenders for circular renovation solutions (for kitchen and bathroom replacements, roof repairs, etc.) [136]. Organized by the procurement expertise centre of the Dutch Ministry of Economic Affairs and Climate Policy, the aim of the program (which ended in 2021) was to bundle expertise and capacity of municipalities and larger building owners to create synergies and allow the sharing of costs and risks and the creation of performance-based tenders.

In Canada, several organizations with online materials marketplaces, for example, BizBiz Construction [137], the Ontario Materials Marketplace (construction platform) [138], and Hyon [139], circulate assets for offices. However, industry is generally unawareness of these materials marketplaces and, as a result, they are underutilized and not yet functioning at sufficient scale.

5.3.3 Working with Salvaged and Recycled Products and Materials

Construction materials left over from a renovation project or acquired from secondary materials markets can be salvaged and reused. For materials to be considered "salvaged", they should ideally retain their original form, but they may be altered, refinished, or resized, though not reprocessed. By comparison, recycled materials require reprocessing and are therefore likely to have a larger carbon footprint. Today, many construction products contain either post-industrial and/or post-consumer recycled content.

That *Metro Vancouver's Old to New – Design Guide: Salvaged Building Materials in New Construction* [140] was published 20 years ago and is still applicable today is testament to the fact that working with salvaged materials is no longer new. The guide provides case studies and a step-by-step approach for incorporating salvaged materials into a typical project. The gaps identified in the study – notably, the lack of detailed information for architects on the range, availability, and sources of salvaged and recycled materials in the region – are also still applicable. Market assessment studies have proven to be important starting points, but issues remain with performance testing and certification methodologies [141]. For example, there is no agency in Canada responsible for setting standards for secondary materials or for reclassifying used construction materials as not waste (see 6.6 Standardization Gaps). In addition, there are no standards, for example, environmental product declarations (EPDs) or product category rules, on the performance or use of salvaged materials. Building codes are also silent on the use of salvaged materials in construction projects, and designers have to either research alternative solutions or conduct testing, which add time and risk to a project.

Some jurisdictions have established policies promoting building deconstruction and DfD, and there are numerous programs in development and pilot projects. The countries that have made the most progress so far (e.g., the Netherlands) are basing their efforts on well-established construction waste-management policies and regulations [8]. For example, a former army headquarters in Utrecht, the Netherlands, was transformed into offices and a government meeting centre [142]. The Rijkskantoor de Knoop project involved partial demolition and partial new build expansion, with building materials reused. The space between the Knoop Barracks and an adjacent bank office became the Green House, a circular restaurant with meeting room facilities that can be disassembled [143].

Using salvaged and recycled materials has the added benefit of eliminating emissions associated with making and transporting new building materials [144]. Still, for the deconstruction process to truly close the materials consumption and production loop, there must be viable markets for the secondary materials being produced, to supply an adequate range of good quality options and to stimulate market demand (see Section 5.3.2 Secondary Materials Markets). Further, clear product descriptors and quality control criteria must be in place to ensure that industry can confidently purchase and use these materials in building projects.

5.4 Underutilized Circular Strategies

There are several currently underutilized strategies that building owners and project team members can feasibly adopt in the near term ("low hanging fruit").

5.4.1 Embedding Life Cycle Thinking into Real Estate Decision-making

Both life cycle assessment (LCA) and life cycle costing (LCC) are accepted methodologies for quantifying the full environmental and economic impacts of buildings. Yet, too often environmental considerations are restricted to operational efficiencies, not the embodied impacts of materials, and the economic focus is only on capital cost, not ongoing costs of operations, maintenance, and end of life. LCA and LCC have yet to be "hard-wired" into building policies or real estate decision-making practices. These topics are discussed in more detail in Section 7 Economic and Environmental Considerations and Trade-offs.

5.4.2 Digitalization of Design and Construction

Several digital technologies have the potential to transform how renovations are conducted and how building information is managed. In a 2021 report, the European Commission highlights digital technologies such as sensors, 3D scanning, 3D printing, the Internet of Things (IoT), drones, automated fabrication using robotics, and BIM [145]. 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 and over a building's entire service life. BIM is critical for reducing the environmental impacts of buildings through the use of low-carbon, prefabricated systems, and is key to unlocking the potential of the circular economy through the efficient collection and management of data throughout a building's life cycle. Adoption of BIM will help the construction industry make significant productivity and performance gains because it can document a project's assets in a single location using real-time data. 3D modelling of project data, design drawings, and development of the project specifications enhance the knowledge base upon which a project is founded and therefore enable more resource-efficient uses in the future.

The redevelopment of His Majesty's Revenue and Customs (HMRC) offices in Liverpool, UK, with the restoration of the 1920s India Buildings, 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, and ensuring that all of the information was collected during the design and construction process [146]. 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 [147].

When coupled with advanced reality-capture technology, BIM reduces the risks associated with building renovations. The digital twin of the finished project serves as the foundation for ongoing operations. A "digital logbook" of accurate, up-to-date data about the building can be compiled (see Section 7.1.4 Data Collection and Management). For example, a dynamic digital twin of the upcycled 49-storey AMP Centre (now the Quay Quarter Tower) in Sydney, Australia, enabled the effects of concrete loads and building shrinkage on the retained structure to be calculated when a new structure was "grafted" onto it. Data from concrete samples and sensors that calculated shrinkage and movement informed the engineering of the new portion. Retaining most of the original building allowed savings of about 12,000 tons of CO2 and US$102 million, and reduced the construction schedule by approximately one year [148].

When it comes to end of life, the notion of BIM for deconstruction is still in its infancy. Certainly, data related to assessing DfD, such as the recycling and reuse potential of components, how they are connected, and their accessibility, could all be captured within a digital model. However, until the mainstream use of BIM in Canada moves beyond the design and construction phases, BIM for deconstruction remains largely theoretical. In fact, Canada is a late adopter of BIM and remains the only G7 country without a national BIM mandate [149]. While familiarity with BIM is growing [150], Canada's lack of a national strategy has resulted in haphazard approaches to BIM, varying by company, public agency, or client requirements. Currently, progress relies on large organizations adopting BIM and then pushing owners, regulatory bodies, and their supply chain to do the same.

Because the construction industry has been slow to embrace BIM, few digital technologies have been widely adopted. However, advances in data capture technologies and BIM to Building Management System (BMS) integration solutions means that building data can be more easily and affordably created, managed, and maintained over the life of the building [151]. This is important because access to up-to-date data has the potential to transform how office renovations might be conducted, reducing the labour-intensive task of gathering data about the base building and the development of design options. With the costs of digital tools such as 3D laser scanners, LIDAR-enabled drones, 3D printers, and others steadily decreasing, design and construction firms of all sizes have access to a wide range of tools that can reduce the risks and costs associated with working on existing buildings. For example, reality-capture processes can produce a 3D model of an object, building, or site using static, mobile, or aerial laser scanning or photogrammetry. Reality capture is a precise and efficient way to capture existing field conditions that otherwise can be time consuming and inaccurate. This process can be used to build accurate virtual 3D models of existing buildings for which no digital information exists.

5.4.3 Innovative Leasing Models

Building owners and property managers in Canada are beginning to develop innovative leasing models and approaches that encourage more flexible use of real estate and unlock the potential for circular strategies.

Still, opportunities to do more remain [7]. In particular, green leases and asset-based or on-demand leasing allow owners and tenants to drive sustainable operations and upgrades and use the building more efficiently.

5.4.3.1 Green Leases to Incentivize Upgrades to Occupied Spaces

Leasing structures can affect how an office building is operated and how it is positioned in the market. The most prevalent form of commercial lease in Canada is the triple net lease, where the tenant pays the property taxes, insurance premiums, and structural maintenance and repairs in addition to the rent. While this might encourage the tenant to properly maintain their portion of the building and adopt energy conservation behaviour, it absolves the landlord of most of the risk of the lease. Indeed, with both net and gross leases, there are issues of the "split incentive" of the tenant paying the operating costs while the landlord pays most capital costs, resulting in the landlord having no incentive to upgrade the building.

To address this challenge, "green leases" have been developed to assist sustainability-minded landlords and tenants. Green leases can steer tenants to the preferred type of fit-out, stipulate what type of materials they can use (recyclable, etc.), and require proper sorting of CRD waste, etc. They can also specify energy-saving requirements of tenant fit-outs, such as in appliances or lighting. Tenants benefit from green leases through lower utility expenses, increased comfort and wellness, and potentially, increased employee productivity. Owners and landlords do not have to bear the entire cost of improvements, can more easily reduce partial vacancies and make spaces more attractive to future tenants, and can incentivize tenants to remain in their current space longer and renew expiring leases.

REALPAC has a green lease template for single building projects that includes a trajectory towards zero carbon operations as well as climate resilience [152]:

- "The 'sustainability' elements of this Lease contemplate a Landlord-centric lease structure, with the Landlord driving the sustainability objectives, sustainability decision-making and compliance. However, the 'sustainability' elements of this Lease are easily transposable to a tenant-centric model and can be negotiated into a 'shared responsibility' model as well" [152].
- The lease references "a Building Resilience Plan [that] exists as part of the Sustainability Management Plan as a way for the Project to respond to and mitigate possible Natural Hazards and Hazardous Events that may be experienced during the Term of this Lease" [152].

A green lease is an amendment to a current lease that specifies improvements to be made, costs incurred to the owner, and amortization of those costs into the leasing price over the expected life of the improvement. Amendments often specify data sharing to help benchmark goals and encourage collaboration with energy-saving strategies. Through data transparency, both parties can clearly see the efficacy of the improvements and can be motivated to ensure proper operation, such as of HVAC and other electrical equipment. Green leases do not currently take into circular strategies, but the available framework could be updated in the future.

5.4.3.2 Asset Leasing and On-demand Space

The upheaval caused by the COVID-19 pandemic and other macro market forces (e-commerce, automation, etc.) has meant that tenants returning to their offices are demanding different features and amenities, in particular, greater flexibility from their office spaces. Lease lengths are getting shorter [153] and, in a 2022 survey, Colliers International found that 77% of operators reported an increase in "hot desking" [154].

To remain economically viable, existing buildings need to accommodate new layouts and amenities that are responsive to the changing nature of office work, and building owners are considering new and creative ways to attract tenants. *The Elastic Office Building* [153] sets out three ways that a building owner can structure leases to respond to the dynamic nature of modern office management:

- "Co-working spaces" that offer tenants "move-in ready" spaces with short-term leases. The interior requires no custom improvements, eliminating waste from tenant fit-out projects. The tenant's company can expand and contract without the need to move any walls.

"The upheaval caused by the COVID-19 pandemic and other macro market forces (e-commerce, automation, etc.) has meant that tenants returning to their offices are demanding different features and amenities, in particular, greater flexibility from their office spaces."

- "On-demand spaces" that allow tenants to rent individual components of offices, such as project spaces, meeting rooms, conference facilities, and even kitchens or cafes, for days or 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 more comprehensive options.

Suncorp's new headquarters in Brisbane, Australia, was designed to support its commitment to flexible working. As part of the long-term lease, a key workplace requirement was the ability to expand and contract space over the term of the lease to meet changing business requirements [153]. The uniquely designed spaces and adaptable floors give Suncorp's personnel greater flexibility to choose where and how to work. Some of the floor plates and settings are reconfigurable to allow for different occupancy levels without affecting the overall office design. In addition, Suncorp specifically sought a co-working partner with whom 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 confidently keep pace with future business requirements.

Leasing of equipment and "product as a service" schemes are also ways to decouple office functionality from the traditional triple net lease. Lower costs and easier accounting can make equipment leasing attractive to companies [155]. Anything can be leased – IT equipment [156], office equipment such as furniture and printers [157], and solar panels [158]. Leasing is also an effective way for companies to reduce their impact on the environment. The companies receive full utility of the product without having to worry about maintenance responsibilities or disposal at the end of life because this is handled by the leasing company. For example, Mitsubishi Electric M-Use® is a "circular" elevator supply model whereby the owner leases the equipment, receives free maintenance, and does not pay to have it removed at end of life [159]. The equipment itself is energy efficient and designed for disassembly. At the end of the cycle of use, Mitsubishi takes back the elevators and, where possible, reuses them at different locations. The M-Use elevator system carries a Madaster materials passport (see Section 6.4 Information-based and Voluntary Approaches).

"Product as a service" schemes, innovative leasing, and other methods of financing, contracting, and operating could be applied to a wide range of building equipment and systems to facilitate the complicated transition throughout the entire building process to a circular economy. First, such practices would support the initial design and engineering of components so that they could be more easily maintained and replaced. Second, they would promote high-quality production, based on durability and performance, rather than lowest capital cost. Last and most importantly, they would enhance the operation and reprocessing of components, incentivizing a long-term ongoing collaboration between the suppliers of building technologies and the clients and users whose spaces are conditioned by the suppliers' systems.

6 Policies and Standards

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).

6.1 Civic and Regional Policies

There is a great deal that policymakers can do at the local and regional level to promote building reuse and encourage a circular economy. For example, the City of Vienna, Austria, 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 [160]. 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 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. By 2030, circular planning and construction for maximum resource conservation will be standard for new builds and renovations [160]. By 2040, the city will require that at least 70% of the components, products, and materials from demolished buildings and major conversions be reusable. 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 concept of a circular city in city operations and in the organizations within the city's sphere of influence.
- Recognizing the built environment as a long-lasting store of materials.
- Designing and constructing for future dismantling or separation.
- Creating the foundations for material transparency, i.e., which materials are used when, where, and how, in the built environment.
- Supporting the business case for and economic advantages of a recyclable built environment.

In Canada, policies that steer the project teams towards or away from certain materials are becoming more common. "Wood First" policies promoting the use of wood in buildings are in effect in several provinces. The City of Langford is the first jurisdiction in Canada to adopt a policy on low-carbon concrete; the aim is to accelerate the deployment of technologies to decarbonize the built environment. Effective June 1, 2022, all concrete supplied to city-owned or solicited projects and private construction projects greater than 50 m^3, will be required to be produced using post-industrial CO_2 mineralization technologies, or an equivalent that produces concrete with lower embodied CO_2 [161].

Many local governments can adjust zoning and land use policies to encourage building reuse. A report from the National Trust for Historic Preservation identifies the following issues with North American zoning legislations when it comes to preserving and reusing existing buildings [162]:

- **"Use limitations:** Older zoning codes separate urban neighbourhoods by use, typically residential, commercial, industrial. Converting older structures to alternative uses or mixing uses within a single building can require time-consuming approvals.

- **Incompatible development standards:** Development standards typically reflect an assumption that new development will, in time, replace older structures. Requirements for parking, unit sizes, setbacks, and open space can be impossible to achieve with an existing structure.
- **Non-conforming properties:** Many codes define structures that do not meet current development standards as 'non-conforming,' which can discourage investment. Defining small lots or historic uses as non-conforming may also block rehabilitation of existing structures.
- **Zoning mismatches:** When zoning allows new construction that is much larger than what currently exists, small buildings become vulnerable to demolition. Some of these structures may contribute to economic and social diversity."

Building codes rely on third-party standards to provide the material specifications, testing methodology, and guidance documents that serve as a common language for defining quality and for establishing safety and performance criteria. Discussion about whether and how to include existing buildings in Canada's building codes goes back to 2008 when the Provincial and Territorial Policy Advisory Committee on Codes (PTPACC) produced a scoping document on *Provincial and Territorial Interest for Building Code Requirements on Renovation-Alteration of Existing Buildings* [163]. The paper proposed the inclusion of specific requirements for existing buildings in the model National Building Code with the primary objective of facilitating the design, analysis, and approval of renovation work on existing buildings [163]. This was largely motivated by questions of how and when to require upgrades to existing buildings to improve energy efficiency performance.

The Government of Canada then created the Joint Task Group on Alterations to Existing Buildings, which found that the absence of clear code requirements for existing buildings is resulting in a patchwork approach to dealing with building alterations across Canada. This is causing confusion in the industry, among regulators and building owners/operators, and resulting in potentially unsafe practices [163]. The Joint Task Group also observed ambiguity with respect to the degree of work necessary on the unaltered portion of the building, which affected project profitability in the face of a growing market for altering existing buildings. Lack of standards were at the root of many of these concerns, starting with the variety of terms associated with alterations. Other standardization gaps in Canada's building codes relate to safety management of an existing building during a renovation process, the use of salvaged materials, and how to allow flexibility so as to encourage alterations to existing buildings (see Section 6.6 Standardization Gaps).

6.2 Economic Measures

Tailored incentive programs are vital to stimulating innovation and catalyzing market transformation. For example, the Downtown Calgary Development Incentive Program [164] offers owners of downtown office buildings $75/square foot, up to a maximum of $10 million per property, to convert to residential buildings. Calgary has allocated $45 million to this program in the hope of spurring on such conversions.

In Germany, the Federal Office for Economic Affairs and Export Control has set up a funding program to help with the roll-out of industrial prefabrication solutions for building renovation [165]. Financial assistance is available for (a) funding to conduct technical, legal, and economic feasibility studies of industrial prefabrication for specific buildings and properties; (b) support for research, development, and implementation of industrial prefabrication pilot projects along several points of the value chain; and (c) grants and financial assistance for the construction of new production facilities or for the expansion of existing facilities in order to adapt to the new process or products. This level of direct support, in particular related to production, addresses the risk incurred by manufacturers when entering the market.

6.3 Regulations

While economic measures offer inducements, or "carrots", to project teams to adopt new or unfamiliar practices, regulations impose the "sticks" by laying out required performance criteria and imposing penalties for non-compliance. Beyond regulations for energy efficiency, waste diversion, and embodied carbon reporting, few regulations in Canada impose requirements for pursuing circular strategies.

That said, extended producer responsibility (EPR) is an environmental policy approach in effect across Canada in which a producer's physical or financial responsibility for a product is extended to the post-consumer stage of the product's life cycle [166]. EPR shifts responsibility upstream in the product life cycle to the producer and away from regional waste authorities and local governments. EPR incentivizes producers to incorporate environmental considerations into their product design. It also shifts the historical public sector tax-supported responsibility for some waste to the individual manufacturer, brand owner, or first importer. In Ontario, the *Resource Recovery and Circular Economy Act* sets out a framework for individual producer responsibility (IPR) in the province, and the Ontario Government is responsible for designating materials for transition to IPR [167]. This Act currently addresses materials such as tires, batteries, electronic equipment, and hazardous materials, with Blue Box materials starting in 2023. The model could be extended to include construction materials in the future.

By comparison, the EU Regulation No 305/2011 lays down "harmonised conditions for the marketing of construction products" [168]. The "CE" marking is well understood by industry to mean that a manufacturer complies with the conditions set out within the Regulation. Of the "basic requirements for construction works" listed in the *Regulation, No. 7, Sustainable use of natural resources,* states that the "construction works must be designed, built and demolished in such a way that the use of natural resources is sustainable and in particular ensure the following:

- **a.** reuse or recyclability of the construction works, their materials and parts after demolition;
- **b.** durability of the construction works;
- **c.** use of environmentally compatible raw and secondary materials in the construction works."

Two further important provisions are set out in the Regulation:

- Item (25) says that, "where applicable, the declaration of performance should be accompanied by information on the content of hazardous substances in the construction product" [168].

  Though generally considered an essential provision, the Regulation is limited because the methods of testing many of the hazardous substances have yet to be agreed upon. Nevertheless, the Regulation lays down a basic compliance with those substances listed under Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH).
- Item (56) stipulates that where the declaration of performance includes an "assessment of the sustainable use of resources and of the impact of construction works on the environment, environmental product declarations (EPDs) should be used when available" [168].

As part of the declaration of performance when applying for a CE mark, manufacturers are required to submit evidence of the sustainable use of natural resources, their low environmental impact, and their energy efficiency from a life cycle perspective.

Regulations can be put in place to protect a building from demolition and from alterations that might affect its value to the community. The "listing" system in the United Kingdom identifies and promotes a building's special architectural and historic interest, and brings it under special consideration of the planning system, to protect it for future generations [169]. The older a building, and the fewer the surviving examples of its kind, the more likely it is to be listed. Still, the system also marks significant buildings that will become the "heritage of the future". Some of the youngest office buildings to be listed include Lloyd's Building [170] in the City of London, built between 1978 and 1986, and the Willis Building [171] in Ipswich, completed in 1975. Listing provides protection against demolition. Listed Building Consent is required for all work that involves alterations that will affect its character as a building of special interest.

6.4 Information-based and Voluntary Approaches

A number of programs, community initiatives, and voluntary schemes are designed to catalyze a circular economy for the built environment.

- TRUE is a certification for zero-waste performance available through the Canada Green Building Council [172]. 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.

- Madaster is an online registry for products and materials incorporated in a real estate asset or infrastructure (e.g., buildings and bridges) [173]. Registering every component provides insights into the degree to which an object can be dismantled, its embodied carbon, or the toxicity of the materials and products used in its production, installation, and operation. Registering also helps determine whether materials and products can be reused after disassembly. Currently, Madaster operates in Austria, Belgium, Germany, the Netherlands, Norway, and Switzerland. The platform blends well with prefabrication (see Section 5.1.1.5 Industrial Prefabricated Solutions for Building Renovations), BIM (discussed in Section 5.4.2 Digitalization of Design and Construction), and the emerging use of digital twins in construction [174].
- Zero Waste Canada is piloting a Zero Waste Construction Certificate that is intended to be specific to an individual construction project. The program has been formally recognized for following internationally accepted zero-waste principles and practices. The process begins by analyzing and understanding the demolition, renovation, and construction activities that support the creation of a built space (single or multiple buildings) on a single property in order to introduce a system of feedback that will inform targeted actions. The intent is for key decision-makers to identify opportunities to avoid waste and toxins throughout the design and construction process; ensure the proper management of discards and toxic materials generated during demolition or not successfully avoided during construction; and avoid waste generation if a building requires demolition in the future [112].
- In Brussels, Belgium, a group called Communa is working with owners to temporarily transform unused warehouse properties into community spaces [175]. They are attempting to address urban needs with facilities that public authorities cannot quickly accommodate. These spaces can be transformed into housing or social and cultural projects, determined by the needs of the residents in the area. Communa uses reclaimed materials; works with the existing architecture to save resources; and meets with local residents and associations to define the uses. These temporary spaces can help define future, more permanent projects for buildings that will successfully address the community interest.
- The EU Renovation Wave [176] is a policy strategy that fosters building renovation to address climate change, at least double renovation rates of all types of public and private buildings in the next 10 years to improve the reuse and recycling of materials, and contribute to employment and growth opportunities across the renovation supply chain, among other objectives. A key focus of the Renovation Wave is digitalization, in particular:
  - the introduction of digital logbooks to centralize all building-related information. Numerous data sources are already in operation, for example, Energy Performance Certificates (EPCs) and the forthcoming Building Renovation Passports, Smart Readiness Indicators, etc. The purpose of the logbooks is to standardize and harmonize the data-collection process and ensure data compatibility throughout the building life cycle;
  - the stimulation of investment in and adoption of digital technologies in the construction sector by building synergies with research centres and testing facilities across Europe; and
  - encouragement of the use of BIM by promoting digital technologies in public procurement for construction (including a methodology for public authorities to conduct cost-benefit analysis for the use of BIM)[12].

12 Digital industrial platforms allow stakeholders to collect and make better use of these data.

"Standardization is necessary to help ensure that the information and practices associated with products and buildings are consistently and accurately calculated and presented."

- The EU Circular Economy Action Plan [177] promotes circularity principles throughout the life cycle of buildings and construction by:
  - "addressing the sustainability performance of construction products in the context of the revision of the Construction Product Regulation[13], including the possible introduction of recycled content requirements for certain construction products, taking into account their safety and functionality;
  - promoting measures to improve the durability and adaptability of built assets in line with the circular economy principles for buildings design [178] and developing digital logbooks for buildings;
  - using Level(s) [179] to integrate life cycle assessment in public procurement and the EU sustainable finance framework and exploring the appropriateness of setting of carbon reduction targets and the potential of carbon storage;
  - considering a revision of material recovery targets set in EU legislation for construction and demolition waste and its material-specific fractions; [and]
  - promoting initiatives to reduce soil sealing, rehabilitate abandoned or contaminated brownfields and increase the safe, sustainable and circular use of excavated soils."

6.5 Standards

Standardization is necessary to help ensure that the information and practices associated with products and buildings are consistently and accurately calculated and presented. Many of the standards and practices in use in Canada and around the world could encourage a "renovation first" philosophy to office buildings or contribute to a circular economy for the built environment. The International Organization for Standardization (ISO) publishes the highest-level consensus-based international standards related to construction and the built environment. National and regional standards tend to be targeted to local issues and practices. It is important to emphasize that standards and practices are most effective when applied within a supportive policy context, which, for most of those listed below, is not necessarily the case.

6.5.1 Green Leases

- *REALPAC Office Green Lease* [152] is a template for single building projects in Canada that has in place a trajectory towards zero carbon operations and climate resilience. Green leases help building owners comply with government GHG emission reduction requirements because up to 80% of energy usage in a building can be controlled by a tenant [180].

13 Regulation (EU) No 305/2011 of the European Parliament and of the Council of 9 March 2011 laying down harmonised conditions for the marketing of construction products and repealing Council Directive 89/106/EEC, OJ L 88, 4.4.2011, p. 5 [171].

6.5.2 Standards for the Circular Economy

- ISO/TC 323, *Circular Economy* is in development. Its aim is "to develop frameworks, guidance, supporting tools and requirements for the implementation of activities of all involved organizations, to maximize the contribution to Sustainable Development" [181].

6.5.3 Standards for Low Embodied Carbon Design and the Use of Sustainable Construction Materials

- CSA Z762-95 (R2016), *Design for the Environment (DFE)* is intended to provide an environmentally responsible overarching framework for product, process, and service design without losing sight of other important factors such as marketability, efficiency, and productivity. Design improvement checklists expanding on five core principles provide the means to assess design parameters in an environmental context. A guide for the examination and evaluation of the design checklists is defined as a final step in the design for environment process [182].
- CSA Z782-06, *Guideline for Design for Disassembly and Adaptability in 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). It applies only to buildings (which can be of any type, including commercial, industrial, institutional, and residential) [183].
- CSA S478:19, *Durability in Buildings* sets out minimum requirements to assist designers in creating durable buildings. Durability is fundamental to ensuring a building is built to withstand the forces of nature and can be maintained to last. Annexes to CSA S478:19 provide a framework within which the design service life of a building or a building element can be determined and specified. Other annexes provide general guidance on the environmental and other design factors that affect the durability of a building, a building material, or a building component [184].
- ISO 21930:2017, *Sustainability in buildings and civil engineering works – Core rules for environmental product declarations of construction products and services* provides the principles, specifications, and requirements for developing an EPD specifically for construction products and services, construction elements, and integrated technical systems used in any type of construction works [185].
- ISO 22057:2022, *Sustainability in buildings and civil engineering works – Data templates for the use of environmental product declarations (EPDs) for construction products in building information modelling (BIM)* provides data templates for the use of EPDs for construction products in BIM [186].
- ISO 20887:2020, *Sustainability in buildings and civil engineering works –* Design for disassembly and *adaptability – Principles, requirements and guidance* provides an overview of DfD/A principles and potential strategies for integrating these principles into the design process. This document provides information for owners, architects, engineers, and product designers and manufacturers to assist in their understanding of potential DfD/A options and considerations, and for other parties who are responsible for financing, regulating, constructing, transforming, deconstructing, or demolishing construction works. ISO 20887:2020 is applicable to all types of buildings (e.g., commercial, industrial, institutional, and residential), civil engineering works (e.g., dams, bridges, roads, railways, runways, utilities, pipelines) and their constituent parts. It can be used for new construction, refurbishment, and renovation, and in the design of incremental improvements in, or complete redesign of, buildings, building systems, civil engineering works, and their constituent parts. This document also provides guidance on measuring performance regarding each DfD/A principle and related objectives [187].
- BRE *Environmental and Sustainability Standard: BES 6001 Framework Standard for Responsible Sourcing (2016)* is a UK model standard that provides a framework for the assessment of responsible sourcing of a construction product, from the mining and harvesting phases through manufacture and processing [188]. The document sets out requirements under organizational governance, supply-chain management, and environmental and social issues. To be certified under this standard, a product must be shown to satisfy certain compulsory elements. In

addition, there are higher levels of compliance that can result in being awarded a higher performance rating. The standard is used for products such as cement, steel, concrete pipes, blocks, windows, flooring, roof tiles, plastics, and wood products.

- PAS 2080:2016, *Carbon management in infrastructure* specifies requirements for the management of whole life carbon in infrastructure – defined as the transport, energy, water, waste, and communications, sectors – both in the provision of new infrastructure assets and programs of work and the refurbishment of existing infrastructure [14].
- CSA ISO 14040:06 (R2021), *Environmental management - Life cycle assessment - Principles and framework* describes the principles and framework for LCA including definition of the goal and scope of the LCA; the life cycle inventory analysis phase; the life cycle impact assessment phase; the life cycle interpretation phase; reporting and critical review of the LCA; limitations of the LCA; the relationship between the LCA phases; and the conditions for use of value choices and optional elements. CSA ISO 14040:06 covers LCA studies and life cycle inventory analysis studies. CSA ISO 14040:06 (R2021) neither describes the LCA technique in detail, nor specifies methodologies for the individual phases of the LCA [189].
- CSA ISO 14044:06 (R2021), *Environmental management - Life cycle assessment - Requirements and guidelines* specifies requirements and provides guidelines for LCA, including definitions of the goal and scope of the LCA; the life cycle inventory analysis phase; the life cycle impact assessment phase; the life cycle interpretation phase; reporting and critical review of the LCA; limitations of the LCA; the relationship between the LCA phases; and the conditions for use of value choices and optional elements. CSA ISO 14044:06 also covers LCA studies and life cycle inventory analysis studies [190].

6.5.4 Standards for Building Data Management

- ISO 19650-4:2022, *Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling – Part 4: Information exchange* provides detailed process and criteria for the exchange of information between information providers and receivers throughout the life cycle of an asset [191]. The standard is available for use in Canada and includes asset management (ISO 19650-3:2020 – *Part 3: Operational phase of assets),* which sets out the information management process for the management and collaborative production of information during the operational phase of assets [192]. (There are many other standards applicable to digital project delivery in Canada. buildingSmart Canada coordinates the development of BIM standards in Canada and has been actively involved in the standardization work at buildingSMART International[14] [193]. However, the lack of a national BIM strategy in Canada means that adoption of these standards is sporadic.)
- *European Union framework for digital building logbooks* is not an established standard but may be an important precursor [194]. Given that building-related data (e.g., physical characteristics, environmental performance information, and real estate transactions) continue to be scarce or unreliable in terms of quality, this framework represents the EU's first attempt to define and standardize the concept of a digital logbook as a common repository for all relevant building data. The objective is to facilitate transparency, trust, informed decision-making, and information sharing within the construction sector and among building owners and occupants, financial institutions, and public authorities.

6.5.5 Standards for Life Cycle Costing

- ISO 15686-5, *Buildings and constructed assets – Service life planning – Part 5: Life cycle costing* enables comparative cost assessments to be made over a specific time, taking into account initial capital costs and future operational costs [195]. Life cycle costing (LCC) takes into account cost or cash flows, i.e., relevant costs (and income and externalities, if included in the agreed scope) arising from acquisition through operation to disposal. LCC typically includes a comparison with alternatives or an estimate of future costs at portfolio, project, or component level. LCC is performed over an agreed

14 A complete discussion of BIM standards in Canada is outside the scope of this study. Information about the state of standards development along with a full list of standards in use is available on the buildingSmart Canada website [204].

period of analysis, clearly identifying whether the analysis is for only part of or for the entire life cycle of the constructed asset.

6.5.6 Standards for Deconstruction and Disassembly

- CSA Z783:12 (R2021), *Deconstruction of buildings and their related parts* has been developed to 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 [115].

6.5.7 Standards Development in Support of a Strategic Sustainability Vision: the 2,000-Watt Society

Developed by the Swiss Federal Institute of Technology (now ETH Zurich) in the 1990s, the 2,000-Watt Society is an important example of how the development of a strategic framework can support standardization. The 2,000-Watt Society concept proposes a vehicle for achieving domestic carbon reduction goals along with a vision of global equity in the face of finite resources. At the time, the primary energy consumption per capita worldwide was 2,000 watts. In Western Europe, the average was just under 6,000 watts. In the United States, it was 12,000 watts. If wealthy countries like Switzerland could decrease their energy consumption to sustainable levels, developing countries (e.g., Bangladesh, a 500-watt society in 2004) could bring its energy consumption up to 2,000 watts without surpassing planetary boundaries [196].

The 2000-Watt Society has a roadmap for bringing materials into the regulatory environment. In the early 2000s, the Swiss Society of Engineers and Architects (SIA) established targets, standards, and protocols for implementing the 2,000-Watt Society vision. The *SIA Energy Efficiency Path: Additions and Case Studies to the SIA 2040 Information Sheet* [197] and *Grey Energy – Life Cycle Assessment for the Construction of Buildings* [198] support the framework by defining the two impact categories for the built environment:

- Global warming potential measured in kg CO_2e/m^2/year.
- Non-renewable primary energy measured in kWh/m^2/year.

According to the 2,000-Watt Society, a building's energy and GHG footprint is deemed to include the materials and processes associated with construction, retrofits, maintenance, and operation during use, as well as deconstruction at the end of the building's useful life. Embodied energy and associated GHG emissions from the manufacturing and transportation of building components as well as the footprint created by the building's operation are counted continuously during the building's use.

The strategic framework of the 2,000-Watt Society was piloted in Basel, Switzerland, in 2001, and adoption has grown to encompass 20 cantons and 100 towns and cities, including the City of Zurich, Switzerland's largest city [199]. A review of the applicability of the 2,000-Watt Society to the Canadian context and the potential for setting caps on operating and embodied emissions was conducted by the City of Vancouver in 2012 [200].

6.6 Standardization Gaps

Based on a review of the standards listed above, Table 1 summaries key gaps, at a high level, that currently exist for owners, designers, builders, suppliers, and policymakers. In most cases, the gaps are extremely wide because little or no standardization is in place for renovations and adaptive reuse projects or for important market "influencers" such as regulators, insurers, and training institutions. ISO/TC 323, *Circular Economy* [181], currently in development, is intended as an overarching document that does not specifically focus on the built environment.

In the real estate and construction sectors, definitions and terms are inconsistently used. At the most elementary level, "restoration", "retrofit", "renovation", "alteration", "refurbishment", and "renewal" are used interchangeably when, in fact, they mean different things. Further, the standards that do exist operate on a "stand-alone" basis and are not coordinated with each other or with Canada's building codes as part of a larger coordinated effort to promote circularity in the built environment.

Table 1: Summary of Standardization Gaps Relating to Extending the Lives of Office Buildings and Establishing a Circular Economy

Standardization Gap	Description
Policies, land use and development bylaws, and building regulations	▪ There are no policies in Canada that foster building renovation and reuse ahead of new development. ▪ Municipal plans and development regulations, e.g., use limitations, requirements for setbacks, parking, etc., can stand in the way of conversions and creative solutions to building reuse. ▪ There are questions about whether, and to what the extent, renovations in Canada have to meet the same structural and seismic requirements of new buildings. ▪ Authorities that have jurisdiction over land use and development do not currently have a consistent way to incorporate building renovations and adaptive reuse into policies and regulations. ▪ Model bylaws are a proven means to standardize and facilitate the adoption of new policies in Canada. They can also add requirements such as LCA reports. ▪ Model codes can help jurisdictions update their building regulations to allow builders to work with salvaged materials.
Data collection and management	▪ There are no best practices for gathering and maintaining information for existing buildings. As such, information continues to be scarce, of unreliable quality, and of limited accessibility. Building-related data include physical characteristics, environmental performance information, operation and maintenance records, and real estate transaction information. ▪ At the industry-wide level, there are no common data repositories or standard annually published benchmarks, e.g., life cycle costs, costs for different types of renovations, conversions, etc. ▪ Currently, occupational health and safety organizations do not separate injury claims data by demolition and renovations versus new construction. Such a breakdown would be very valuable in determining if working on building renovations and disassembly projects is safer than working on construction projects. ▪ There are no agreed-upon metrics by which to evaluate buildings for potential renovation or adaptive reuse. ▪ There is a lack of common definitions and terminology related to improvements of existing buildings. ▪ There are no standards related to safety management of an existing building during a renovation process. ▪ Standards need to coordinate and support building codes (and therefore move in step with changes in energy efficiency and climate resilience requirements), yet allow flexibility so as to encourage alterations to existing buildings rather than placing an undue burden on owners. Similarly, building codes need to be updated regularly so that they reference the latest standards.
Building information modelling (BIM) standards for existing buildings	▪ BIM for renovation is not yet widespread in Canada, and is mostly limited to the design phase of large projects. Digital measurement and the digital building model are a starting point and requirement to produce prefabricated building elements for renovation. ▪ Unlike other G7 countries, Canada lacks a national BIM strategy.

Standardization Gap	Description
Procurement standards that promote a "renovation first" approach	▪ The public sector is an important real estate owner and has significant purchasing power. Green and social procurement standards have been developed to encourage green building practices, but most public procurement programs do not call for considering building reuse ahead of a new build, referencing specific durability standards (e.g., set a minimum service life for the building), or foster circular strategies. ▪ Fee structures for professional consultants need to be retooled to reduce the emphasis on building new.
Documentation of used materials, building adaptability information and disclosure	▪ EPDs, chain of custody programs (e.g., those used in the forest product sector), and extended producer responsibility (EPR) programs are making their way into new construction projects, but they focus on environmental or health impacts. ▪ Standards and assessment processes for salvaged materials are required – ideally in digital format for integration into BIM. ▪ Information is lacking about the traceability (e.g., EPDs or product category rules) and performance (notably, structural, fire rating, moisture, etc.) of materials and components so that they can be reused in the future. Where information exists, it is not presented in a standard form. ▪ Building codes in Canada are silent on the use of salvaged materials in construction projects, and designers have to either research alternative solutions or conduct tests themselves, which add time and risk to a project. ▪ There is no agency responsible for defining and setting standards for secondary materials or for reclassifying used construction materials as not waste. ▪ The development of empirical, research-based information on durability and longevity of structural and non-structural elements used in various building applications is needed.
Costing, insurance, and risk management	▪ Life cycle environmental costs (impacts) are not considered in LCC methodology, indicating a clear difference between LCA and LCC as currently structured. ▪ With an escalating cost of carbon, cost of climate risks, and cost of compliance with energy efficiency regulations, traditional valuation standards and practices may need to be updated. ▪ The insurance process is different when working with an existing building, but the insurance industry does not have access to robust historical data for assessing risk. For example, compared with conventional demolition, additional insurance is required when disassembling a building to cover the deconstruction, remediation, transportation, and reassembly processes. ▪ In the event of damage to a property, some insurance policies are structured to, in effect, favour demolition over restoration.
Industry training curriculum and professional certification	▪ There are very few professional training programs and no professional certification beyond some micro-credential courses for owners, property managers, designers, builders, and policymakers that focus on working with existing buildings, disassembly, and the circular economy. ▪ Only a few courses address design for manufacture and assembly and working with prefabricated and modular systems, and none explicitly connect modern methods of design and construction with the world of existing buildings. ▪ Trade apprenticeship training curricula are standardized across the country but do not accommodate renovation work explicitly.

7 Economic and Environmental Considerations and Trade-offs

Extending the lives of existing office buildings and pursuing effective circular strategies in the commercial real estate sector requires a broad holistic approach to capture the important economic and environmental considerations and deal with the unavoidable trade-offs.

7.1 Economic Considerations

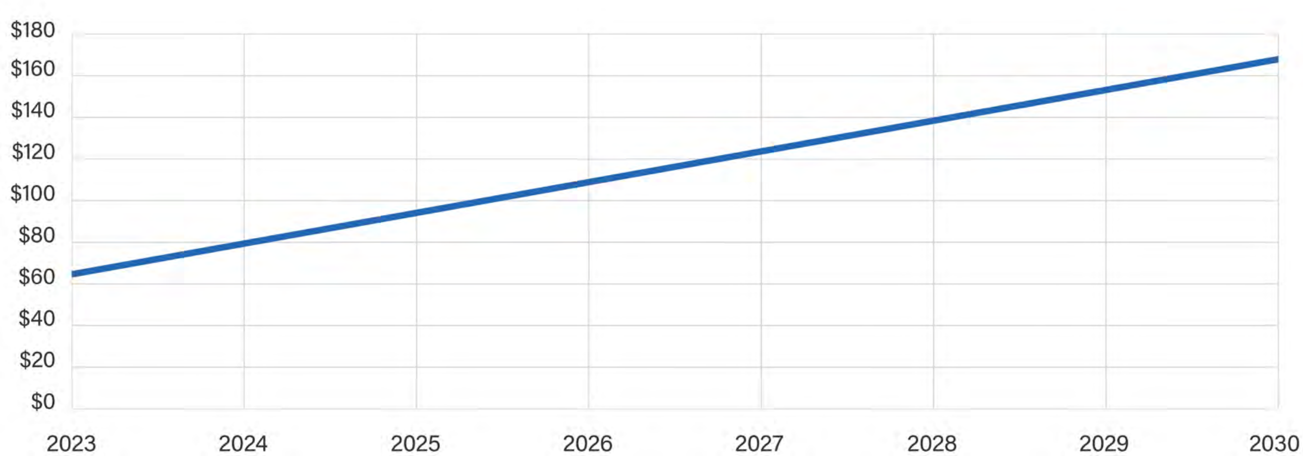
The successful upgrade of an existing office building can have major benefits in improved rents, employee engagement, cost savings, space utility, and overall productivity. However, upgrading these buildings can be risky, with uncertainty surrounding tenant demand in the post-pandemic commercial leasing market. At the same time, there is a 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. For example, clear long-range policy commitments have now been made regarding the decarbonization of Canada's building stock, and the price on carbon emissions will continue to rise to 2030 and likely through to 2050 (Figure 11). The cost of operations will increase, and an office building will become less attractive to tenants if decarbonization is not a core element of the asset management plan.

Life cycle costing (LCC) can provide a financial framework for evaluating the best investment trade-offs and operations and maintenance (O&M) solutions from a life cycle perspective. "Value-based procurement" can be used to define "best value" over a number of parameters for construction projects. Data and data management provide the metrics by which to reduce the risks associated with building alterations, benchmark performance, and measure success. Using these approaches can help to manage risk and optimize the performance of the building as it goes through maintenance and renewal cycles.

7.1.1 Life Cycle Costs

LCC is used to assess the total cost of facility ownership. It takes into account all the costs of acquiring, owning, and disposing of a building or building system. LCC can be a key enabler of the adoption of new and innovative construction products and techniques. Many innovative solutions may incur higher upfront costs, but once operating costs are considered, the overall investment may provide a better return. LCC methodology is laid out in ISO 15686-5 Buildings and constructed assets – *Service life planning – Part 5: Life cycle costing* [195], which describes how comparative cost assessments are to be made over a specific time, taking into account initial capital costs and future operational costs. LCC can be used as an evaluation tool within competitive

Figure 11: Projected Minimum Carbon Pollution Prices ($/tonne CO_2e) for Canada Through to 2030.
Source: Government of Canada [201].



"Life cycle costing (LCC) can be a key enabler of the adoption of new and innovative construction products and techniques."

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 and quantifiable criteria in terms of:

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

In practice, the recladding of the Simpson Tower in Toronto, completed in 2017, leveraged the need to refresh the look of the 1960s 33-storey building with a comprehensive energy retrofit [202]. A new curtain wall was hung outboard of the existing precast cladding to improve energy performance and comfort [203]. The cladding system reattached the cast panels (caused by failing ties) and provided anchor points for a new glass curtain wall. The business case was justified by saving on ongoing costs of envelope maintenance and energy. From an interview with the project team, "If an owner spends $1 million annually on repairs to cladding, a $15 million new system might be smart because it eliminates expenditures for 20 or 30 years."

Although LCC is required for federal building procurement, published life cycle cost analysis information for most building types is sparse, particularly for renovations and conversions.

Indeed, unlike new construction, there are no benchmark costs for building renovations in Canada, but only for tenant fit-outs[15]. Owners should therefore be aware that this combined lack of LCC research on renovations and conversions and the common availability of what appear to be non-research-based estimates of useful lives of materials can create an unwarranted bias against the upgrades and conversions. The development of definitive, research-based information on the durability and longevity of structural and non-structural elements used in various building applications is needed. Further, life cycle environmental costs (impacts) are not considered in LCC in current practice, indicating a clear difference between life cycle assessment (LCA) and LCC as structured [204].

Investing in innovation may have immediate short-term benefits in terms of the speed and cost of the project. It can also have much greater long-term economic and other impacts over the life of the building. In many construction projects, the initial capital cost may only account for about 20% of the total costs that the building owner will incur during the period of ownership – particularly when energy bills and maintenance costs are considered. If the costs of staff using buildings are included, then this is reduced to just 0.5% [205].

15 Tenant fit-out benchmark costs for major urban centres in Canada are included in the construction cost guides published annually by major quantity surveying firms.

7.1.2 Value-based Procurement

The costs of materials and labour have been increasing in recent years [206], so the cost of constructing a new building may be higher, and take longer, than buying a comparable existing building and renovating it. However, the procurement strategy is critical to realizing these benefits. Focusing simply on lowest price can make it very difficult to realize the benefits of novel products, processes, or solutions because the advantages may lie in achieving results such as improved life cycle costs, construction speed, or environmental performance. To encourage innovative solutions, owners need to award contracts based on both financial and non-financial criteria that, together, represent the "best value". Best value for money is defined as the most advantageous combination of cost, quality, and sustainability to meet customer requirements. Overlaying a life cycle cost approach means that best value must be delivered to the owner for the life of the asset.

In *Circular Economy in Commercial Real Estate – Focus: Circular Procurement,* BOMA Canada [26] references the ReSOLVE Framework [207] that identifies six actions that organizations can take to apply circularity in their work:

- "**Regenerate:** Conserve and enhance the earth's ecosystems by favouring renewable resources and returning biological nutrients to nature (e.g., implementing a robust organic waste program and contributing to composting).
- **Share:** Keep products in use in their original form for as long as possible through sharing, exchanging, and redistributing (e.g., instead of discarding unwanted office furniture, donating them to a charity that recovers and redistributes used office furniture to other organizations).
- **Optimize:** Avoid using resources or creating waste unnecessarily with products and operating practices that are efficient, and where the products' useful life is extended through repairability or upgradability and where reverse logistics are supported. [For example,] implement preventive maintenance to reduce the frequency of replacement or service of certain equipment that leads to creation of waste and increase in costs.
- **Loop:** Keep technical nutrients (e.g., plastic, metal) in perpetual use as long as possible. Use design that favours disassembly and re-manufacturability (into the original form or into a new product). For example, implement a comprehensive waste management program that will allow users to capture as much of the recyclables and return to further processing to convert them as raw materials to produce the same products or different products.
- **Virtualize:** Where practical and reasonable, replace physical products with their virtual counterparts. For example, instead of purchasing printed user manuals or printing instruction manuals, use digital copies. Provide meeting invitees the option of attending meeting[s] virtually, etc.
- **Exchange:** Swap out actions and products that have negative ecological consequences with those that favour the use of renewable energy and renewable materials (regenerative and biodegradable) inputs. For example, consider increasing the use of renewable power for your operation. Encourage the use of [electric] vehicles for business."

This process can be at odds with the traditional structure of design fees whereby architects and engineers get paid more to build new – a challenge that needs to be addressed in professional schedules of fees.

The procurement strategy adopted for a project outlines the means by which the objectives of the project are to be achieved. No matter what type of construction project is being undertaken, the final result achieved will greatly depend on the requirements and targets set by the owner, and how effectively these are defined and communicated to those carrying out the work. Evidence shows that $1 extra spent on design, is the equivalent of $20 savings in construction and $60 savings in operation [208]. Regardless of the procurement procedure and contractual model followed, it is important to set building performance goals and targets early and capture these within the owner's conditions of satisfaction. These conditions of satisfaction describe the owner's expectations in terms of quality and value, both of which can be highly subjective and need to be clearly defined.

The notion of "quality" is key to the success of a renovation project, but it means different things to different people: functionality, the absence of defects, performance, durability, fitness for purpose, and so on. The BC Construction Association defines is "a combination of functionality (how useful the project is in achieving its purpose); impact (how well the project creates a sense of place); and build quality (performance of the completed project). Quality in a finished building is generally a factor of the owner's proposal or briefing, design process, contract documentation and construction" [209]. In the context of the circular economy, quality also means taking a "buy once and buy well" approach to building design and product specification to avoid premature failure and replacement.

"Value" can be described as the relationship between what you get (or want) and what you pay. Thus, value can be increased by improving function or reducing whole life cost. For teams undertaking innovative construction projects, it is essential to define, manage, measure, and quantify value so that the benefits of the new technologies and processes can be evaluated.

Certainly, in a "new from the ground up" construction project, the project team has control over more variables, and therefore are more likely to achieve the owner's goals within budgetary constraints. By comparison, there are more potential "surprises" connected with renovating an older building due to hidden or unforeseen conditions. Most budgets add a contingency factor of 15 to 20% for a renovation project versus 10% for new construction [210]. Early planning that includes the construction team along with a detailed audit of existing conditions are key to reducing the amount carried for contingency. Collaborative project delivery methods that identify, evaluate, allocate, and track risk using tools such as a "risk register" can be valuable [211], and the use of technologies such as BIM and reality capture through 3D laser scanning can improve project predictability and reduce uncertainties.

Sustainable procurement is "a process whereby organizations meet their needs for goods, services, works and utilities in a way that achieves value for money on a whole life basis and generates benefits, not only for the organization but also to society, the economy and the environment" [209]. "Projects that plan to deploy innovative solutions to address energy efficiency and/or GHG emissions reduction set measurable and absolute standards to be achieved (in kWh, MJ, kg CO_2e, etc., per unit of gross floor area per year) to demonstrate that a return from the investment in innovation has been achieved. Incentives can then be put in place in the form of bonus[es] for exceeding the goal and/or a penalty for failure. This can work well where the upfront budget for construction work is restricted. The owner can set an intermediate minimum standard and indicate a higher aspirational target, which the project team can be challenged to achieve, either through setting incentives within their contract, or through running a design contest to win the contract" [209], [212].

For public building owners, the Government of Canada's Policy on Green Procurement 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 [213]. Some cost elements related to environmental factors that could be taken into account in assessing value for money in the evaluation of bids, offers, or arrangements include:

- Operation costs, such as energy or water consumed by the product over its life;
- Indirect costs (less energy-efficient IT equipment produces more heat, causing the building's air-conditioning system to work harder and increasing electricity costs);
- Administrative costs, such as health and safety compliance;
- Investing upfront to save costs later, such as specifying higher levels of insulation where extra expenditure can be recovered from lower energy costs; and
- Cost of waste disposal arrangements.

The Government of Canada uses Product, Resource, Operating, and Contingent (PROC) costs relating to procurement for Major Crown Projects and in procurement where operating costs are a major part of the total cost [214]. There is no such requirement for private projects in Canada.

7.1.3 Labour Shortages and Construction Workplace Risks

The supply-chain issues and labour shortages that arose during the pandemic continue to affect construction projects. The construction cost index for office construction projects in Canada[16] has risen to more than 10% year-over-year change in 2022 [215], and Deloitte estimates that, together, labour and materials costs in the US had increased by more than 26% year-over-year in June 2021 [216]. This rate of increase is likely to be similar in Canada. Although renovations are likely to be more complex than new builds, the fact that they use less raw materials may reduce a project's exposure to risks related to materials cost uncertainty.

Working on existing buildings tends to be more labour intensive than working on new construction projects because there has, to date, been less uptake of modern methods of construction such as prefabrication (See Section 5.1.1.5 Industrial Prefabricated Solutions for Building Renovations). Certainly, lack of training in deconstruction techniques is a major barrier to adoption. For example, in 2018 the City of Milwaukee, Wisconsin, required many of its older buildings to be deconstructed instead of being demolished. But implementation of the regulation has been put on hold through to at least 2023 because of the lack of local contractors who know how to take buildings apart. To address this shortage, the city's Department of Neighborhood Services has started to run certified training courses for both consultants and contractors [217] to help foster a local deconstruction "ecosystem". In particular, the city is hoping to increase the number of companies that can take apart structures; remove nails, strip paint, and re-mill the materials; and store or resell the salvaged goods, as well as companies interested in buying these salvaged goods. The British Columbia Institute of Technology (BCIT) has launched an "Applied Circular Economy: Zero Waste Buildings" micro-credential [218], and other schools across Canada are following suit.

Currently, occupational health and safety organizations do not break down injury claims data by demolition and renovations versus new construction. Such a data breakdown would be very valuable in determining if working on building renovations and disassembly projects is safer than working on construction projects. More than 40,000 construction workers are injured each year in Canada as a result of fall accidents [219]. Occupational health and safety organizations attribute these incidents to many factors, but working outside in the cold is key. In Ontario, there were more construction-related fatalities in November and December between 2016 and 2021 than during any other months [220].

7.1.4 Data Collection and Management

The availability of consistent and reliable data can contribute to better design, construction, and management of buildings, improved market information and transparency, development of innovative services and business models, and more effective policymaking. Canada's construction industry is underdeveloped in terms of overall digitalization compared with other industrial sectors [221]. Unlike other countries, Canada does not maintain and publish industry-level key performance indicators. Without relevant and timely data, gauging how companies are faring in the face of regulatory, technical, demographic, macroeconomic, and consumer change is challenging. This can make it challenging for investors, funders and policymakers to know if, or to what extent, support in the form of policies, economic development, investment in research and development, or education may be needed [222].

Canada also lacks a centralized repository for and, indeed, standardization for the collection and maintenance of building data. As noted in Section 5.4.2 Digitalization of Design and Construction, Canada is the only G7 country without a BIM strategy. Having such a strategy would establish a framework for the management of design, construction, and operational information for buildings, including materials. There is also a lack of information about the materials used in buildings in terms of traceability (where they are from, what they are made of, etc.), performance (what they can be used for) and environmental impact data. Where information exists, it is frequently not presented in a standard form.

16 Statistics Canada tracks construction costs for eleven census metropolitan areas across Canada and aggregates the data into a composite index that increased from 116.9 in Q3 2021 to 130.3 in Q3 2022. 2017 = 100.

Buildings as Material Banks (BAMB) is an EU-funded initiative that has developed an electronic "materials passport" to track what materials are available for recovery from buildings and for reuse [223]. BAMB-developed materials passports are sets of data describing defined characteristics of the materials in products that give them value for recovery and reuse. The goals include:

- To increase or keep the value of materials, products, and components over time;
- To incentivize suppliers to produce healthful, sustainable, and circular building products;
- To make it easier for developers, designers, and renovators to choose healthful, sustainable, and circular building materials; and
- To facilitate reversed logistics and takeback of products, materials, and components.

Currently, there are more than 300 materials passports in the system for various products, components, or materials. This pragmatic approach aims to operationalize circular potential, and by putting it into practice, provide incentives for innovation.

7.2 Environmental Considerations

The carbon reduction targets that Canada has committed to achieve under the Paris Climate Accord have resulted in the establishment of a series of net zero policy goals for new and existing buildings at the local, provincial, and federal level. These policies focus on the emissions associated with building operations, not the embodied impacts of materials and certainly not the interrelationship between the two. Embodied carbon has historically been overlooked by policymakers because operating carbon has comprised by far the largest portion of the total carbon footprint of buildings [224]. It has also been traditional practice to take a retrospective approach to energy efficiency modelling whereby building performance is assessed against historical climate data. In the face of more extreme weather events, and potential for natural hazards, extending the lives of existing buildings means ensuring that the buildings are durable and resilient.

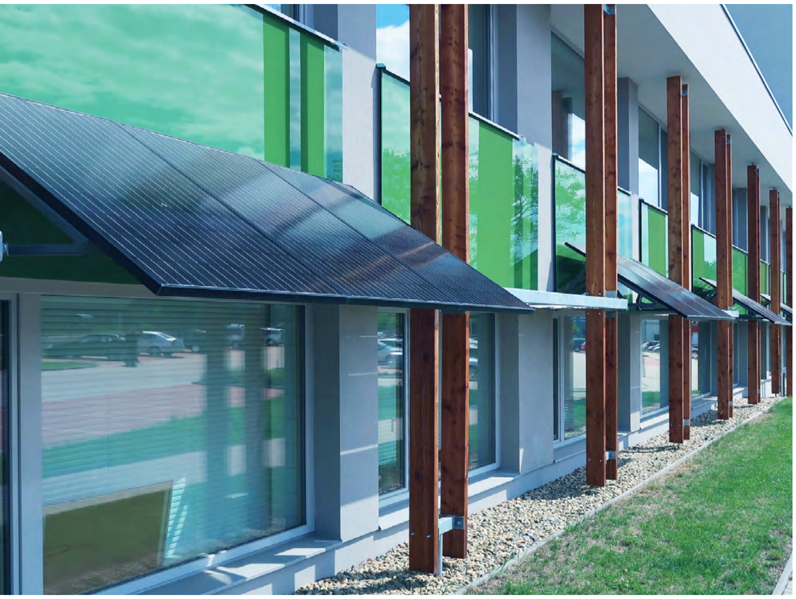
7.2.1 Operational Versus Embodied Carbon Trade-offs

Climate change policies are starting to prioritize those GHG emission strategies that can deliver results quickly. As operational energy use is minimized through high-performance design, construction, and systems, the embodied carbon in building materials and construction plays a larger role in the environmental impact of buildings. A critical component is the timeframe of the GHG emission savings. The sooner the savings can be realized, the better. As the timeframes to achieve GHG emission reduction targets get shorter, the embodied carbon portion becomes a much larger slice of the overall carbon emissions "pie" [225]. Maintaining existing buildings would not only address a significant portion of the carbon footprint of the buildings, it would also deliver measurable and reliable results more immediately than efforts aimed solely at reducing operating energy.

Achieving an operationally efficient building design through extra insulation and triple versus double glazed windows may be at odds with the circularity goals of resource reduction. LCA is the methodology by which quantitative analysis of the environmental impacts of a product over its entire life cycle – including both operational and embodied impacts. The principles and framework for LCA are set out in CSA ISO 14040:06 [189] and CSA ISO 14044:06 [190] (see Section 6.5 Standards). LCA is necessary for quantifying and evaluating a project's success in sustainable materials management. According to Architecture 2030, just three materials – concrete, steel, and aluminum – are responsible for 23% of total global emissions [226]. LCA can help pinpoint environmentally impactful materials and evaluate the performance trade-offs with materials with lower embodied carbon.

7.2.2 Climate and Natural Hazard Resilience Considerations

There are several links between circular strategies and climate resilience best practices for the commercial real estate sector. Although extending the lives of office buildings is known to reduce the carbon impacts of new construction, it is equally important to consider



"The carbon reduction targets that Canada has committed to achieve under the Paris Climate Accord have resulted in the establishment of a series of net zero policy goals for new and existing buildings at the local, provincial, and federal level."

the impacts on the life cycle of the interventions necessary to keep existing structures standing, particularly in the face of a changing climate. Most buildings have been designed for historical climate conditions, and more extreme weather events, changing seasonal temperatures, and the risk of natural hazards now have to be factored into the design so that the building is efficient to operate and maintain as well as resilient over the long term.

CSA S478:19, *Durability in Buildings* [184] provides a framework for addressing and organizing design related to building life and durability. CSA S478:19 assumes that the objective of the designer is to provide a building that will be durable and functional for at least the time period required by the owner. It has been developed so that it can be referenced in the National Building Code of Canada. However, designing for durability tends to focus on the maintainability and accessibility of specific equipment and components as opposed to a "whole building approach".

In 2019, the town of Straubenhardt, Germany, declared itself a cradle-to-cradle (C2C) community, aligning the entire town with circular economy principles. The new central fire station, the town's first cradle-to-cradle pilot project [227], was built as simply and naturally as possible, with everything 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. Concrete was selected for durability in those areas where equipment and vehicles are operated, and wood for the spaces people occupy. The concrete remains unsealed. The untreated, V-shaped glulam supports are over-sized to resist fire by charring. The timber elements were fastened with screws, and not nailed or glued. All building technology remains visible so that it can be easily repaired or replaced.

Historically, Canadian building design has been heating-led, focusing on insulation and heating systems. However, predicted climate data, reinforced by increasingly frequent extreme heat events experienced throughout the country, point to the need for architects to pay urgent attention to designing out overheating risks during building upgrades and renewals. Passive cooling and natural ventilation are foundational best practices for sustaining comfortable indoor temperatures; they need to be emphasized in ongoing plans for building upgrades, especially if there comes a point where even the best-designed building cannot remain comfortable with mechanical cooling alone – which could threaten its functional viability [228]. For example, exterior shading devices, which can be retrofitted onto buildings, play an important role in decreasing energy use, lowering peak demand, and improving glare conditions for the building occupants [229]. Indeed, the facade of the Hanwha headquarters office tower in Seoul, the Republic of Korea, has been retrofitted to hold solar panels and, at the same time, improve occupant comfort and energy efficiency [230]. The existing facade of flat, dark glass was replaced with clear glass in an aluminum frame and reconfigured so that the windows are angled away from direct sunlight to minimize heat gain and glare.

The parts of the facade that hold the solar panels are also angled to optimize natural daylight while shading the windows below.

Planning for a changing climate is critical to avoid premature demolition. The effects of climate change on buildings are already in full force in Canada, from the destruction in Port aux Basques by Hurricane Fiona in Newfoundland, to the razing of the town of Lytton by wildfire in British Columbia. British Columbia is expected to spend more than $2 billion in fiscal year 2022/23 to prepare for, respond to, and recover from floods, heat waves, and wildfires. The 2019 *Preliminary Strategic Climate Risk Assessment for British Columbia* lists 15 risk events, of which flooding, water shortage, extreme precipitation, coastal storm surge, extended wildfire season, heat waves, and increase in vector-borne diseases all directly affect buildings and those who live and work in them [231]. Hazards also frequently compound, so risks from water shortages, extreme precipitation, and wildfires overlap.

Natural disasters are not always climate related, and the experience of Christchurch, New Zealand, in 2011, illustrates the consequence of designing modern office buildings simply to meet life-safety standards during an earthquake. More than 60% of concrete buildings with three or more storeys in the Christchurch region were demolished after the 2011 earthquake [93]. This high rate of demolition, particularly of buildings with relatively little damage, illustrates the complex quantitative (e.g., building damage, year of construction, occupancy) and qualitative considerations (e.g., insurance and legislation) that influence the "repair-or-demolish" decision that building owners face after such an event. Seismic zones exist in Canada, and the lessons from Christchurch are particularly relevant to British Columbia, where building stock characteristics (age, size, structural design), regulatory context, and market dynamics are similar [232]. Industry is increasingly calling for plans that go beyond life-safety requirements and save the building as well as the occupants in the event of a disaster [233].

8 Conclusions

The commercial office sector is an important sector in Canada's real estate economy, and it has been one of the most affected by the pandemic. Office buildings owners from small businesses to global pension funds are all facing an extremely competitive market and an investment landscape that is increasingly informed by climate-related risks. The traditional emphasis in the commercial real estate sector on developing new buildings conflicts with achieving GHG emission reduction targets. Even constructing the most energy-efficient new building entails variable but significant upfront GHG emissions because of the resource-intensive nature of construction and the materials supply chain.

Of the $9.5 billion spent on office construction in 2021, more than $5 billion was for renovations, signalling that the sector is investing in upgrades as it grapples with the future of office work (see Figure 7 in Section 4 Overview of the Commercial Office Market in Canada). This is all happening in the midst of rising costs of construction materials and ongoing labour shortages. The conditions are ripe for the office building sector to focus on extending the lives of existing office building stock through upgrades, renovations, conversions, and other creative forms of adaptive reuse. Collectively, these approaches contribute to the emerging circular economy for the built environment.

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

Circular strategies applied to existing office buildings means rethinking the design, construction, usage patterns, operational processes, and end-of-life processes from the beginning, so that products and entire structures have a regenerative life cycle. In other words, they can be repeatedly repaired, reused, recycled, or transformed. That modern buildings are not typically designed to be adapted or reconfigured has meant that, historically, it has been easy to make the business case for demolition. However, industry now has available affordable tools and resources to facilitate adaptation and reconfiguration, for example, digital technologies (e.g., building information modelling [BIM]), Lean project delivery methods complete with standard forms of agreement and risk management approaches, innovative leasing structures, and industrial prefabrication methods.

Around the world, construction companies are slowly shifting to modern methods of construction. Supportive policies and standards are emerging, and a growing community of industry leaders is developing the knowledge and skills necessary to create new business cases for extending the lives of office buildings. Wide-scale adoption is still lacking, however, and the development and implementation of circular building design and construction strategies remains fragmented. A fundamental challenge has been the lack of consistent definitions of key concepts and parameters as they apply to buildings, as well as clear "system boundaries" for resource flows that define what is included. Other standardization gaps are in the following areas:

- Local and regional policies, zoning, land use and development bylaws, and building regulations;
- Collection and management of existing building data;
- BIM standards for existing buildings;
- Procurement standards that promote a "renovation first" approach;
- Documentation and certification of used materials;
- Building adaptability information and disclosure;
- Costing, insurance, and risk management; and
- Industry training curricula and professional certification.

A growing number of projects in Canada and around the world are fostering various aspects of the circular economy in order to create new and interesting lives for existing office structures. They illustrate how successful renovation and adaptive reuse can maintain the functional viability of an office building while achieving economic efficiency. A way to achieve this is to catalyze and then integrate the innovation economy in which the capital is used to invest in research and development of better products and services. However, several preconditions and process updates must be met to realize the full potential of the circular economy. Key drivers of such innovation are:

- Digitalization in construction and promoting the uptake of digital solutions (including advocacy for a national BIM mandate);
- Long-term policy support and regulatory reform that fosters renovation to ensure demand and supply-chain capacity, including building codes that allow for the use of salvaged materials;
- Tailored financing solutions to support research, product development, technology adoption, and renovations process improvements;
- Standardization strategy for maintaining and reusing existing buildings that brings together and coordinates existing standards, describes the desired Canadian standardization landscape, fills gaps (e.g., performance standards for salvaged materials), and aligns with international frameworks;
- Data collection, management, maintenance, and reporting needs to be initiated and standardized at the building scale in terms of physical information and at the industry scale and at the industry scale with consensus-based key performance indicators, benchmarks, etc.;
- Accessible training and education for all participants in the value chain;
- Government leadership through preferred procurement programs, investment in pilot projects; and
- Early adoption of model bylaws and policies by progressive local governments.

Inevitably, there are economic and environmental trade-offs. These need to be managed through the use of consensus-based analytical methods such as life cycle costing (LCC) and life cycle assessment (LCA) based on industry-accepted data. A combination of private sector financing, public authorities, standards development organizations, and industry could successfully implement and scale industrial prefabrication solutions for building renovations.

It is also important to not lose sight of the social dimension of the circular economy – it offers an important way forward in addressing climate resilience – and to ensure that strategies will increase the quality of life for all by developing new business models, products, services, and forms of production based on societal values and sustainable resources.

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CSA Group Research

In order to encourage the use of consensus-based standards solutions to promote safety and encourage innovation, CSA Group supports and conducts research in areas that address new or emerging industries, as well as topics and issues that impact a broad base of current and potential stakeholders. The output of our research programs will support the development of future standards solutions, provide interim guidance to industries on the development and adoption of new technologies, and help to demonstrate our on-going commitment to building a better, safer, more sustainable world.