City of Richmond

Report to Committee

To:	General Purposes Committee	**Date:**	January 26, 2024
From:	Peter Russell Director, Sustainability and District Energy	**File:**	10-6125-07-04/2023-Vol 01
Re:	**Reducing Embodied Carbon in the Built Environment**		

Staff Recommendation

That the industry engagement program outlined in the staff report titled 'Reducing Embodied Carbon in the Built Environment' dated January 26, 2024, from the Director of Sustainability and District Energy, be endorsed.

Peter Russell
Director, Sustainability and District Energy
(604-276-4130)

Att. 2

REPORT CONCURRENCE		
ROUTED TO:	**CONCURRENCE**	**CONCURRENCE OF GENERAL MANAGER**
Capital Buildings Project Development	☒	
Engineering	☒	
Building Approvals	☒	
Development Applications	☒	
Policy Planning	☒	
SENIOR STAFF REPORT REVIEW	**INITIALS:**	**APPROVED BY CAO**

Staff Report

Origin

This report supports Council's Strategic Plan 2022-2026 Focus Area #2 Strategic and Sustainable Community Growth:

> *2.3 Ensure that both built and natural infrastructure supports sustainable development throughout the city.*
>
> *2.5 Work collaboratively and proactively to attract and retain businesses to support a diversified economic base.*

This report supports Council's Strategic Plan 2022-2026 Focus Area #5 A Leader in Environmental Sustainability:

> *Leadership in environmental sustainability through innovative, sustainable and proactive solutions that mitigate climate change and other environmental impacts.*
>
> *5.1 Continue to demonstrate leadership in proactive climate action and environmental sustainability.*
>
> *5.2 Support the preservation and enhancement of Richmond's natural environment.*
>
> *5.3 Encourage waste reduction and sustainable choices in the City and community.*

This report supports the implementation of Richmond's Circular City Strategy through:

Direction 5: Adaptive Built Environment

Actions:

- ☑ Creates a database of information on the flow of construction materials in Richmond, including embodied carbon data.
- ☑ Promote the use of secondary and recycled materials in the construction of new buildings and infrastructure.
- ☑ Advocate for extending the lifecycle of buildings and infrastructure, supported by Total Cost of Ownership and Life Cycle Assessment methodologies.
- ☑ Support integration of buildings and infrastructure with green infrastructure and natural ecosystems to reduce maintenance and material use throughout their lifecycle.

This report supports implementation of Richmond's Community Energy and Emissions Plan 2050, and OCP emission reduction policies through:

Direction 3: Carbon Neutral New Buildings

Action:

- ☑ Support the construction of flagship high-performance, low-carbon buildings in Richmond.

Direction 8: Transition to a Circular Economy

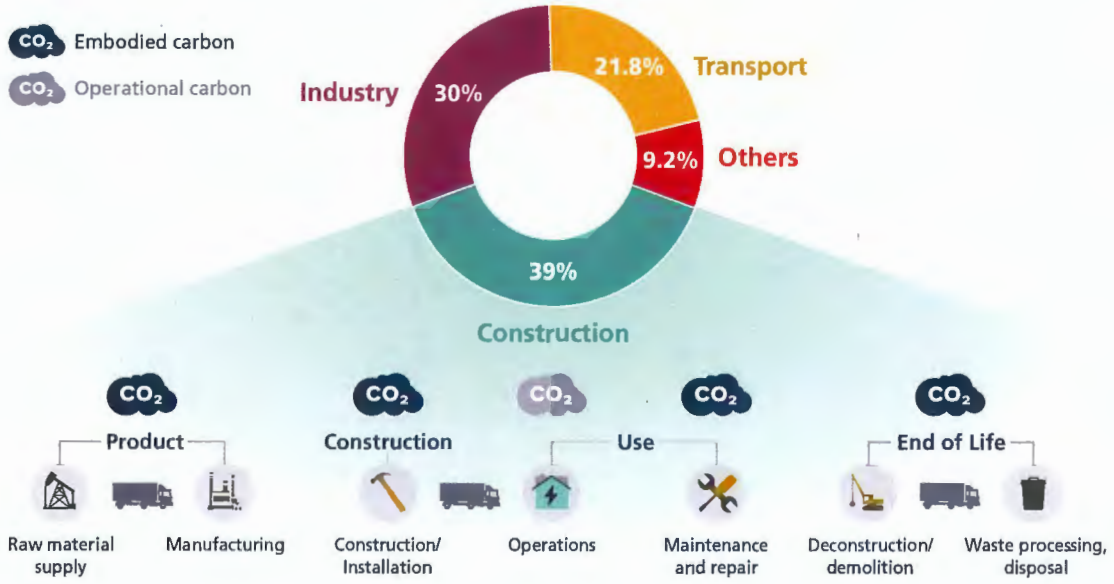
Action:

- ☑ Accelerate use of construction materials with low-embodied carbon content.

Analysis

The global economy's use of fossil fuels for producing goods and services contributes to greenhouse gas (GHG) emissions but not often in conventional GHG inventories and reporting. Embodied carbon, which accounts for these emissions, spans the entire lifecycle of building materials, including the energy used in extraction, manufacturing, transportation, and construction, as well as the emissions from maintaining and renewing building components through to the end of the building's lifecycle (see Figure 1).

Figure 1 - Embodied carbon in the construction sector[1]



Importance of reducing embodied carbon in new buildings

Reducing embodied carbon emissions from the construction sector has emerged as a critical strategy in a global effort to mitigate climate change and increase circularity in construction materials. Globally, buildings contribute 39% of annual carbon emissions[1], with 11% of these emissions stemming from embodied carbon. Eliminating operational GHG emissions from consumption of fossil fuels is an ongoing priority for climate mitigation and regulatory action by leading municipalities. In the context of European building emissions, operational carbon emissions typically represent less than 49% of a building's total emissions and embodied carbon emissions account for more than 51% of the total emissions, underscoring the substantial impact of embodied carbon in the overall emissions profile of a building[2]. In countries with low-carbon energy grids, such as Denmark or France, embodied carbon emissions can be 2-4 times greater than those associated with operational energy use[3]. As operational GHG intensities for new buildings are reduced to near-zero levels by 2030 provincially, and 2027 in Richmond via Zero Carbon Step

[1] Adapted from Carbon Leadership Forum, the Community Energy Association, the New Buildings Institute and the UN Environment Global Status Report

[2] The Net-zero buildings Where do we stand? (2021) - publication prepared by Arup in collaboration with World Business Council for Sustainable Development

3 United Nations Environment Programme. 2021 Global Status Report for Buildings and Construction: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector.

Code adoption, reducing embodied carbon content in construction materials becomes increasingly important to address if the goal is to achieve a truly near-zero carbon building.

Achieving deep operational emission reduction is achieved by using near-zero emission energy sources for the building's mechanical heating and cooling systems, and designing a highly energy efficient building envelope. Likewise, significant reductions in embodied carbon can also be achieved at the design stage, as part of decision-making on building design, material types and components, as this is the stage where opportunities exist to achieve cost-effective, whole-building carbon reduction (see more information in Attachment 1).

Much of Richmond's carbon footprint is directly related to the built environment and the associated demand. As buildings become more energy-efficient and the rate of global construction escalates, the relevance of embodied carbon is predicted to grow, potentially accounting for half of all building-related emissions by 2050. Additionally, recent studies conducted by leading organizations demonstrated that implementing embodied carbon reduction measures increase the opportunity to improve efficiency in the construction process and saving costs for owners and developers while increasing environmental and climate benefits. Projects and materials with lower embodied carbon often have upstream savings, leading to cost savings for manufacturers—a benefit that can be passed to consumers (see more information in Attachment 1).

Approaches by other jurisdictions

Richmond's pioneering circular initiatives, including the Richmond Circular City Strategy, the Circular Procurement Policy and Reclaimed Asphalt Pavement Project, have gained widespread recognition among peers and senior levels of government. Richmond's unique approach stands out by taking an integrated approach that combines climate considerations and circular strategies with economic efficiency. A Material Flow Analysis study is currently underway and includes stakeholder engagement as a means to build more local knowledge, facilitating a Richmond-centered implementation of embodied carbon requirements.

As the City embarks on working with industry stakeholders to reduce embodied carbon in the built environment, the City will benefit from the work of other jurisdictions across Canada. A growing number of jurisdictions in BC, elsewhere in Canada, and at the national level, are establishing policies and/or setting direction on performance targets for embodied carbon content in new buildings and major renovations as summarized below (additional detail provided in Attachment 2):

- **City of Vancouver:** A 40% reduction target for embodied carbon by 2030 was recently endorsed, applicable to new large building only such as such as high-rise residential buildings, large commercial or industrial buildings, and institutional buildings.
- **City of Toronto:** The Toronto Green Standard Version 4, mandatory since 2022, integrates embodied emissions limits to promote net-zero emissions in new developments.
- **City of Calgary:** Their Climate Implementation Plan for 2023-2026 focuses on reducing both embodied and operational carbon in buildings, with tools for progress evaluation to be introduced by summer 2024.
- **City of Nelson:** Nelson has launched initiatives like the Low Carbon Homes Pilot in early 2021, which analyzes upfront embodied carbon in low-rise residential buildings.

- **District of North Vancouver:** The District's Climate Ready Rezoning Policy, initiated in August 2022, requires a detailed lifecycle assessment to be submitted for new Part 3 building applications seeking a rezoning.
- **Resort Municipality of Whistler:** A new Green Building Policy was approved in December 2022, which has reducing embodied carbon emissions and encouraging use of sustainable materials as a key focus, guided by Whistler's Community Energy and Climate Action Plan.
- **Metro Vancouver Regional District:** MVRD is assessing requirements for embodied emissions in construction materials and forming a regional working group to lower embodied emissions in buildings. They are also advocating to the Province for inclusion of performance targets on embodied carbon within the BC Building Code.
- **Province of British Columbia:** BC requires new public sector buildings to achieve LEED™ Gold certification or equivalent, emphasizing low-carbon materials. In addition, a strategy for low-carbon building materials in public sector buildings is due for completion in 2023.
- **Government of Canada:** This new Federal strategy involves a comprehensive approach to reducing embodied carbon in concrete, including whole building lifecycle assessment and performance-based design, with a focus on low-carbon alternatives and recycled materials.

Industry Engagement Program

With Council endorsement, staff propose an industry engagement and capacity-building process, as follows:

- Participation in regional and industry working groups;
- Conducting interviews with peers and industry leaders;
- Organizing roundtable, workshops and webinars for local and regional industry actors;
- Distributing surveys;
- Hosting collaborative innovation labs that bring together industry experts and peers; and
- Organizing site visits to model projects that exemplify successful strategies.

Learnings and findings from the industry engagement activities will enable staff to achieve the following sequence of milestones:

1. **Emerging Policy and Regulation Review:** Staff will engage with builders on early-stage policies, regulations, and performance targets set for embodied carbon in construction materials. Staff will also assess quantitative tools usable by architects and energy modellers to compare the embodied carbon content of various products and report on the total design-stage embodied carbon of a project. The expected outcome is a set of reporting requirements and/or regulations for new constructions for Council consideration.
2. **Consultation on Richmond Demolition Bylaw Expansion**: This milestone will run concurrently with the first, ensuring simultaneous progress. Staff will identify and inform potential enhancements to the Richmond Demolition Bylaw through collaboration with industry experts, municipalities, and other organizations. As part of this, staff will assess other building types that can be incorporated, including recycling of critical materials and implementing online traceability tools to better track demolitions and secondary materials flows.

In 2025, staff will report back to Council a set of policy recommendations, regulatory amendments, and a suite of practical guidelines and toolkits to facilitate the effective implementation of embodied carbon policies.

Financial Impact

None. Resources required to undertake the recommendation in this report can be accommodated within existing budgets and staffing levels.

Conclusion

Embodied carbon in construction materials and components is a significant component of building sector emissions globally. With local implementation of the BC Energy Step Code and Zero Carbon Step Code, phased reduction in operational carbon emissions from new buildings is underway via adopted Bylaw requirements. Similarly, understanding the new policy, regulation and targets for embodied carbon in the built environment is necessary as part of achieving a robust and complete circular and carbon performance framework for the built environment sector in Richmond.

Staff are seeking Council endorsement to initiate an engagement process in 2024 that will feature collaboration with stakeholders and municipal peers, as well as knowledge-building initiatives with stakeholders to gain insight on effective strategies, and understand opportunities and challenges in achieving low embodied carbon outcomes in the construction sector. This initiative aligns with recommended actions from Richmond Circular City Strategy and Community Energy and Emissions Plan 2050.

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MB:mb

Att. 1: Reducing Embodied Carbon in Buildings: Low-Cost, High-Value Opportunities
2: Approaches by other Jurisdictions

ATTACHMENT 1

Reducing Embodied Carbon in Buildings: Low-Cost, High-Value Opportunities

The risk of rising or volatile energy and materials costs can be a significant threat to the profitability. Reducing embodied carbon of projects can help mitigate those risks by ensuring that materials are used optimally and that the manufacturing, transportation and construction processes are energy highly efficient. Integrating an embodied carbon perspective into a circular economy approach can lead to lower financial cost in many cases. This is important as it shows that operational energy use should not be viewed independently from embodied emissions: to optimize overall emissions, both operational and embodied emissions need to be considered together. The fact embodied carbon approach is about assessing the entire life cycle of a building and this can help builders and user better understand overall lifetime performance in both carbon emissions and cost terms. This will affect how buildings are valued, with an embodied carbon assessment becoming a fundamental part of due diligence in assessing future asset performance and value. Staff found relevant reports that highlights low-cost and no-cost solutions for reducing embodied carbon in buildings during a project's design and construction phases. In case studies, applying these solutions demonstrates an embodied carbon savings potential of 19 to 46 percent at cost premiums of less than 1 percent.

Embodied Carbon: Reducing Cost

The "Embodied Carbon: Reducing Cost" report[4], published by the Rocky Mountain Institute (RMI) provides an important analysis of cost issue of implementing embodied carbon reduction strategies. The findings of the report suggest that significant reductions in embodied carbon can be achieved with minimal financial impact. This report focuses on up-front embodied carbon, covering the A1–A3 life-cycle stages: raw material supply, transport to the manufacturing site, and manufacturing. Additionally, the report highlights that embodied carbon can be significantly reduced at little to no additional up-front cost, with a potential savings of 19%–46% and a cost premium of less than 1%. Effective circular strategies include optimizing ready-mix concrete design, choosing finish materials with low embodied carbon, and considering low-embodied-carbon or carbon-sequestering insulation options:

- **Concrete and Cement:** Concrete, a primary source of embodied carbon in buildings, is significantly impacted by the manufacture of portland cement. Strategies to reduce embodied carbon in concrete include using supplementary cementitious materials (SCMs) and high-quality aggregate.
- **Timber:** Timber, particularly with innovative design strategies and engineered wood products like cross-laminated timber (CLT), is emerging as a viable material option for low- and mid-rise buildings, offering environmental benefits and cost-effectiveness.
- **Steel:** The US steel industry has made strides in reducing its carbon footprint, largely through technological improvements and increased recycling of scrap steel. Specifying steel produced in facilities using low-emissions energy sources is a key strategy for reducing embodied carbon in steel.

[4] https://rmi.org/wp-content/uploads/dlm_uploads/2021/08/Embodied_Carbon_full_report.pdf

- **Insulation:** Insulation is another significant contributor to a building's embodied carbon budget. Options range from carbon-intensive petrochemical-based products to carbon-negative materials like cellulose and cotton.
- **Strategies for Reduction:** Effective strategies to limit embodied carbon in new buildings include whole-building design, one-for-one material substitution, and specification. Whole-building design can yield the greatest savings, while material substitution and specification are effective, especially for carbon-intensive materials like concrete and steel.
- **Early Design Decisions:** Setting embodied carbon goals and performing analyses early in the design process is crucial. Early decisions affect the fundamental design of a building and can lead to significant embodied carbon reductions.
- **Adaptive Reuse and Material Selection:** Considering the reuse of existing buildings or incorporating recycled materials can significantly impact embodied carbon. The embodied carbon impact of redeveloping an existing structure is 50% to 75% lower than constructing a new building.

The RMI presents the result of two cases, summarized as follows:

1. **Mid-Rise Multifamily Building Case Study:** The second case study focused on a six-story, 125,000 square foot mixed-use multifamily building with lumber framing above a steel-reinforced concrete slab. The goal was similar to the first case study: to significantly reduce embodied carbon with minimal cost implications. The project team employed a wide array of low-embodied-carbon measures across various building components including insulation, concrete, rebar, flooring, paint, doors, glazing, and steel. The result was a 41% reduction in up-front embodied carbon, achieved with a cost premium of less than 0.5% of the total project cost, aligning with the results of the first case study. This demonstrates the scalability and applicability of the strategies across different building types. The CO2e reduction quantified for this project was 1482 metric tons, reinforcing the effectiveness of the chosen approach in reducing the building's environmental footprint while maintaining economic feasibility.

2. **Mid-Rise Office Building Case Study:** This case involves a five-story, 200,000 square foot mixed-use office building, which exemplifies a remarkable achievement in reducing embodied carbon. The project team targeted a comprehensive range of building components including structural systems, glazing, roofing, interior wall materials (unfinished), and insulation. Through these targeted measures, they successfully achieved a 46% reduction in up-front embodied carbon. The project's approach was multifaceted, focusing on optimizing concrete mixes, employing high recycled content rebar, and selecting insulation materials with low or no embodied carbon. Notably, the cost premium for implementing these low-embodied-carbon measures was less than 0.5% of the total budget, a minor increase when considering the substantial environmental benefits. This reduction in carbon was achieved without compromising the structural integrity, aesthetics, or functional requirements of the building. The CO2e reduced in this process was 2228 metric tons, showcasing the substantial environmental impact of the applied measures.

These case studies illustrate the practical feasibility of significantly reducing embodied carbon in building construction. They demonstrate that with careful planning, selection of materials, and design strategies, substantial reductions in carbon emissions can be achieved with minimal

additional costs. These findings offer valuable insights for policymakers, architects, engineers, and developers, highlighting a path towards more sustainable and responsible urban development.

The RMI's report also explores how embodied carbon reductions can often:

- reduce material use and project costs,
- reduce energy consumption in raw material extraction, manufacturing, and transportation,
- help to meet green building certification requirements, and
- better position building owners for future code or policy changes that incentivize or require low embodied carbon.

Figure 2 – This infographic, which is part of the RMI report, shows the reductions in embodied carbon and their impact on cost.

Existing guidelines recognize that there are many strategies for reducing embodied carbon emissions at the design and constructions stages, providing flexibility for buildings across Canada – of all sizes and uses – to achieve results. Evaluating embodied carbon emissions across the building life-cycle, including construction, maintenance and end of life can identify critical opportunities to introduce circular approaches and increase material efficiency, increasing cost efficiency as well. part of a strategy to achieve this.

Integrating Embodied Carbon and Cost Reduction Strategies in Building Design: An Overview of the Carbon Value Engineering Framework

The "Carbon Value Engineering: A Framework for Integrating Embodied Carbon and Cost Reduction Strategies in Building Design[5]" by Mehdi Robati, Philip Oldfield, Ali Akbar Nezhad, David G. Carmichael, and Aysu Kuru, presents an innovative approach to building design that harmoniously reduces both embodied carbon and construction costs. This approach, known as Carbon Value Engineering (CO2VE), challenges traditional Value Engineering (VE) methods by focusing not just on cost but also on the environmental impact of building materials and design strategies.

The CO2VE framework proposed in the study aligns with the growing urgency to reduce embodied carbon in the construction industry. It uses Pareto Principles to identify major contributors to both capital costs and embodied carbon, offering alternative design strategies and utilizing Marginal Abatement Cost Curves (MACC) to visualize the impacts of these changes.
The framework was applied to an 18-storey mixed-use building in Sydney, Australia. The study found that embodied carbon makes up 27–58% of the building's total lifecycle emissions. By evaluating alternative structural systems, significant reductions in both cost and embodied carbon

[5] https://www.sciencedirect.com/science/article/abs/pii/S0360132321000330

were identified. For instance, a post-tensioned concrete structure showed an 8% reduction in embodied carbon and a 10% capital cost saving. A whole timber structure offered a 13%–26% reduction in embodied carbon and a 5% cost saving. The CO2VE framework demonstrates that it is possible to achieve significant savings in both embodied carbon and construction costs in building projects. This approach provides a much-needed pathway for the construction industry to build more while emitting less, aligning with global targets for reducing embodied carbon emissions. The integration of CO2VE in building design and construction can lead to more sustainable, cost-effective, and environmentally responsible building practices, a crucial step in addressing the climate change challenge in the built environment.

Cost-Efficient Strategies for Reducing Embodied Carbon in Construction: Insights from Microsoft's Whitepaper

The whitepaper titled "Reducing Embodied Carbon in Construction[6]" by Microsoft provides a comprehensive overview of how reducing embodied carbon can also reduce costs in construction and retrofit projects. The following points detail how the whitepaper supports this idea:

- **Early Design and Life Cycle Assessment (LCA)**: Microsoft emphasizes the importance of understanding and reducing embodied carbon from the early design phase through life cycle assessments (LCAs). This proactive approach helps in making informed choices about materials and construction processes that are both cost-effective and environmentally friendly.
- **Product Stage (A1-A3) Emissions Reductions**: The whitepaper outlines strategies for reducing emissions in the product stage by selecting materials with sustainable extraction and manufacturing processes. This includes choosing manufacturers who document less carbon-intensive processes. These strategies not only reduce emissions but can also lead to cost savings through efficient resource use and potentially lower material costs.
- **Construction Process (A4-A5) Emissions Reductions**: Focusing on efficient transportation and installation processes, and using energy-efficient and biofuel-powered equipment can significantly lower emissions. These methods can also reduce operational costs during the construction phase.
- **Material Selection and Procurement**: The whitepaper highlights the importance of material selection and procurement in embodied carbon reduction. By prioritizing materials with low embodied carbon in the procurement process, projects can achieve significant environmental and cost benefits.

Case Studies and Practical Applications:

1. **Material Alternatives**: Microsoft's campus modernization project found that switching to a different XPS insulation manufacturer reduced embodied carbon by 5–8% per building, indicating cost-effective material substitutions can make a considerable difference.

2. **Comparative Analysis in Bidding Process**: During the procurement process, comparing the embodied carbon impacts alongside cost, schedule, and responsiveness helped in selecting suppliers who offered the lowest cost and highest carbon reductions.

[6] https://query.prod.cms.rt.microsoft.com/cms/api/am/binary/RWGtgl

3. **Pilot Projects with EC3 Tool**: Microsoft utilized the EC3 tool in its campus modernization and datacenter projects. This tool helps to track and compare the embodied carbon of different materials from the schematic design phase, enabling greater impact and more seamless implementation.

4. **Setting Reduction Targets**: Establishing an achievable embodied carbon reduction target at the beginning of the project can guide the selection of materials and reuse opportunities, contributing to overall project goals.

5. **Tracking Construction Activity Emissions**: Tracking emissions during the construction process (A4 and A5 stages) highlighted their significant impact on the overall embodied carbon of a project. This tracking can lead to more informed decision-making for future emission reduction strategies.

6. **Zero Waste and Recycling Initiatives**: Microsoft's commitment to Zero Waste, focusing on reusing, donating, and recycling construction materials, not only reduces embodied carbon but also avoids landfill costs.

7. **Learning and Adapting Process**: The ongoing learning and adapting process during these initiatives demonstrates a progressive approach to reducing embodied carbon while considering cost implications.

8. **Pursuing Zero Carbon Certification**: The project's pursuit of ILFI Zero Carbon Certification, which requires disclosure and offsetting of all embodied carbon emissions, underscores the commitment to holistic sustainability, including cost-effectiveness.

The Microsoft whitepaper demonstrates that reducing embodied carbon in construction and retrofit projects is not only environmentally imperative but can also be aligned with cost-saving strategies. By integrating early design decisions, material selection, efficient construction processes, and innovative tools like EC3, significant reductions in embodied carbon can be achieved in a cost-effective manner.

Tackling embodied carbon

The report "Tackling Embodied Carbon within Australia's Construction and Infrastructure Sector,[7]"by KPMG, provides a comprehensive analysis of how reducing embodied carbon can also reduce costs in building and infrastructure projects:

1. **Enhanced Productivity and Efficiency**: By improving productivity and efficiencies in the construction process, there is a direct impact on cost savings. Efficient construction methodologies, including standardized measurements and collaboration on new materials, can significantly reduce waste and lower project costs.
2. **Green Construction Practices**: Using electric machinery and sourcing materials locally not only reduces emissions but also can lower the overall costs associated with transport and conventional fuel usage in construction projects. This approach aligns with the growing trend towards green construction, which often comes with long-term cost benefits.

[7] https://assets.kpmg.com/content/dam/kpmg/au/pdf/2023/embodied-carbon-australia-construction-infrastructure.pdf

3. **Collaboration and Technology Adoption**: Cross-collaboration between stakeholders and leveraging technology can streamline the design and construction process. Utilizing tools that track and report GHG emissions not only aids in achieving compliance with environmental standards but can also lead to more efficient use of resources, thereby reducing project costs.
4. **Regulatory and Reporting Frameworks**: Adhering to standards such as the Science Based Targets initiative (SBTi) and other global industry standards can guide companies towards more efficient and cost-effective methods of reducing emissions. These frameworks often encourage practices that are both environmentally sustainable and economically viable.
5. **Addressing Embodied Carbon in Early Project Stages**: Considering embodied carbon emissions in the planning and design phases of a project allows for more informed decisions about materials and design parameters. This foresight can prevent over-engineering and unnecessary material use, leading to considerable cost savings.
6. **Market Demand and Cost Benefits**: As the market demand for low-carbon projects increases, it leads to a correction in the pricing of such materials and technologies. This market shift can make circular, low carbon alternatives more financially accessible and cost-effective in the long run.

The report illustrates that addressing embodied carbon emissions in the construction and infrastructure sector not only contributes to environmental sustainability but also offers pathways to reduce costs. Through improved construction methodologies, efficient material use, collaboration, and adherence to regulatory frameworks, significant cost savings can be achieved alongside emission reductions.

Making Embodied Carbon Mainstream

The report "Making Embodied Carbon Mainstream[8]," by the Pacific Institute for Climate Solutions, offers a detailed analysis of embodied carbon reduction in construction and retrofit sectors, emphasizing the potential for significant cost savings. The report delineates two primary strategies:

- Material performance: technical solutions like reducing the carbon footprint of concrete
- Circular economy approaches: advocates for system-level changes such as extensive building and material reuse.

The integration of existing policies in waste management, equity, and preservation is identified as a key avenue for reducing embodied carbon. Policies enhancing waste diversion, expanding green demolition practices, and promoting the retrofitting of affordable housing align with sustainability goals and offer avenues for cost efficiency. The implementation of stringent waste regulations and green demolition requirements can effectively divert construction waste from landfills, addressing environmental concerns and offering tangible solutions to landfill capacity issues, potentially leading to substantial cost savings in waste management and material salvage.

Material salvage and reuse emit less than conventional demolition practices and are economically beneficial, especially in regions like British Columbia where the reclamation of old-growth timber from older buildings is not only environmentally prudent but also economically beneficial given current market conditions. The adoption of efficient construction practices, such as optimizing

[8] https://pics.uvic.ca/sites/default/files/PICS_Embodied_Carbon_Report_May-2021_FIN.pdf

material use and prefabrication, while initially more costly, is expected to become more cost-effective as they gain widespread adoption, thereby reducing overall material expenses.

Retrofitting existing affordable housing is presented as a more economical alternative to new construction, capable of significantly reducing emissions. This approach not only addresses environmental concerns but also offers a cost-effective solution to housing affordability challenges. The report underscores that reusing and retrofitting existing buildings typically result in lower environmental and economic impacts than new construction. Life cycle assessments have revealed that retrofitting can be more cost-effective, especially when considering medium-term climate targets. Capitalizing on existing policies, emphasizing material efficiency, and adopting principles of the circular economy, the construction and retrofit sectors can achieve significant cost reductions alongside substantial reductions in embodied carbon.

Approaches by other jurisdictions

Cities are in a prime position to implement regulations that will help reduce embodied carbon in their communities, but it is important to focus on the main drivers of embodied carbon and prioritize relevant actions. Below, it is summarized the key actions undertaken by cities in British Columbia to reduce embodied carbon in the new and existing building.

City of Vancouver

The City of Vancouver's commitment to reducing embodied carbon in the construction sector is a aspect of its broader climate action initiatives. The Climate Emergency Action Plan (CEAP) focuses on six major areas, with Big Move 5 specifically targeting Low Carbon Materials and Construction Practices. This includes the goal of reducing embodied emissions in new buildings and construction projects by 40% by 2030 compared to a 2018 baseline, and a 90% reduction in operational emissions from new buildings by 2025, with the target of being carbon neutral by 2050. To support these objectives, the City has developed seven guiding principles for action prioritization and implementation, ensuring consistency across all initiatives. This is complemented by the Vancouver Building Bylaw, which sets minimum standards for energy efficiency and emissions reductions in new buildings. In addition to these regulatory and policy instruments, the City of Vancouver also collaborates with other levels of government, industry associations, and stakeholders to advance its goals and objectives

In May 2022, the City of Vancouver introduced changes to the Building By-law to align with the priorities of the CEAP and the Climate Change Adaptation Strategy. These changes focus on three areas: reducing energy and carbon emissions limits for new residential and commercial buildings, implementing embodied carbon reduction requirements, and adding cooling requirements for new buildings. The bylaw sets an initial limit on embodied carbon impacts, to be followed by requirements for 10% or 20% reductions in 2025. These adjustments are deemed achievable without impacting construction costs, as confirmed by consultations with industry experts and material suppliers. Additionally, the Green Buildings Policy for Rezonings was updated to include requirements for Embodied Carbon Design Reports, demonstrating compliance with the expected embodied carbon limits. The City's roadmap includes various milestones up to 2030, aiming to progressively integrate low embodied carbon practices in construction, aligning with the 40% reduction target set. The Green Buildings Policy for Rezonings was also updated including requirements for all Part 3 building projects as defined by the Vancouver Building By-law:

- provide the design reports and worksheet at the time of the rezoning application
- complete the Embodied Carbon Design Report for each building to demonstrate that the project is on track to meet the Vancouver Building By-law life-cycle equivalent carbon dioxide emissions (i.e. global potential impact, or 'embodied carbon') limits expected to be in force at the time of the project's first Building Permit application. Embodied carbon is calculated for each building, in kgCO2e/m2 , as calculated by a whole-building life-cycle assessment using standard assumptions according to the City of Vancouver Embodied Carbon Guidelines.

District of North Vancouver

In July 2022, the District of North Vancouver approved Climate Ready Rezoning Policy that aims to account for embodied carbon emissions in new construction and establish minimum levels of mechanical cooling and air filtration in Part 3 buildings[9]. Effective August 1, 2022, the policy will apply to new rezoning applications seeking approval in the District.

The Climate Ready Rezoning Policy applies to new rezoning applications for buildings constructed under Part 3 of the British Columbia Building Code. The policy does not apply to Part 9 buildings or existing buildings or buildings that do not require rezoning. The policy sets out minimum standards for mechanical cooling and air filtration performance in residential dwelling units, refrigerant emissions and requirements for reporting embodied carbon emissions for all Part 3 building applications. The policy aims to encourage the consideration of embodied emissions in building design and to promote the use of low embodied carbon materials. The proposed updates to the rezoning policy aims to incentivize reductions in embodied emissions, potentially through a 10-40% reduction relative to a baseline building, and explore the development of supportive programs and incentives tailored to different building types and levels of reduction achieved.

To encourage low-carbon new construction, the District of North Vancouver has developed incentives and supportive programs in consultation with building industry stakeholders. These incentives are tailored to different building types (Part 9 vs. Part 3) and provided at different levels. For Part 9 buildings, incentives include reduced building permit fees, while for Part 3 buildings, incentives provide density bonuses or expedited timelines for development and building permits. The DNV is also developing dedicated training programs for local builders, designers, and developers to provide information on embodied emissions, incentives available, and strategies for achieving deep reductions.

Resort Municipality of Whistler

Adopted on December 2022, the Green Building Policy G-28 proposes a flexible, performance-based framework for new construction in buildings under Part 9 (houses and small buildings) and Part 3 (large and complex buildings) of the BC Building Code. The policy update includes a Green Building Policy Checklist for applicants to submit with rezoning applications, as well as with development permit and building permit applications where applicable. This checklist provides clear guidance to applicants and streamlines the application review process.

The updated Green Building Policy, organized around six sections, reflects significant input from Whistler 's building sectors. The Energy & Emissions section aims to reduce greenhouse gas (GHG) emissions from new buildings and encourage innovative strategies to decrease energy requirements and lower the share of energy supplied by non-renewable sources. The Building Materials section aims to reduce solid waste generation during demolition and construction and encourage the use of environmentally friendly materials and techniques. The Sustainable Site Design section aims to preserve, restore and enhance the site and surrounding areas, and encourage landscaping strategies promoting biodiversity and enhancing the natural spaces surrounding the built environment.

[9] These buildings generally have professional design and construction teams with greater capacity to adopt new technologies and comply with new requirements.

The Green Building Policy includes guidelines to address embodied carbon emissions at rezoning, including reporting of the life-cycle equivalent carbon dioxide emissions of new buildings. Exploring specific measures during design and construction to reduce embodied emissions and using low-carbon and plant-based building materials where feasible are also part of the guidelines. The draft Green Building Policy encourages sourcing renewable, recycled, and locally-sourced building materials, requires a minimum diversion/recycling rate for demolition and construction waste, and treats recycled and salvaged materials as a resource. Its flexible, performance-based framework for new construction encourages sustainable design approaches to reduce infrastructure demands and costs, environmental impacts, GHG emissions, and long term building operating costs.

City of Nelson

In late 2020, the City of Nelson initiated a comprehensive project to address the environmental impact of its building sector by focusing on both embodied and operational carbon emissions. Early in 2021, this initiative was supported with the launch of the Low Carbon Homes Pilot, backed by financial support from FortisBC and the City of Castlegar. This program aimed to enhance Nelson's energy efficiency strategies by targeting the reduction of embodied carbon in the building sector. A development in 2021 was a study to assess the average embodied carbon emissions from new constructions in Nelson and Castlegar. The findings, detailed in the Embodied Carbon Brief published in May 2021, served as an informative guide on embodied carbon for the building community and summarized the objectives of the Low Carbon Homes Pilot. The City planned to integrate embodied carbon considerations into its environmental strategies. This included reducing concrete use in construction, promoting natural building materials such as cellulose, timber, wood fiber board, cork, and bamboo, and avoiding foam products.

From 2021 to 2022, the City conducted an extensive analysis and policy scan focusing on embodied carbon and energy efficiency. This project aimed to provide actionable recommendations for optimal material use. Community engagement initiatives were also planned to develop effective policies and programs targeting embodied carbon reduction. The broader aim was to decrease the overall greenhouse gas footprint of the built environment. The project included establishing an Embodied Carbon Advisory Group, offering free embodied carbon analyses and consultations for regional projects, and organizing educational workshops on reducing embodied carbon emissions in building projects.

City of Toronto

Embodied carbon has become a focal point in Toronto's environmental strategy, particularly through the evolution of the Toronto Green Standard (TGS). The importance of embodied carbon emissions came into sharper focus with the update to TGS v4 in July 2021. This version began to address embodied carbon more directly, even though without establishing specific caps or performance targets. The advancement in the understanding and structuring of embodied carbon reporting within the TGS framework was marked by strategic research and studies conducted in 2022. These studies were essential in developing a structured reporting framework and deepening the understanding of embodied carbon impacts in the construction sector.

The TGS v4 serves as the primary tool for reporting embodied carbon in Toronto, with a specific focus on material emissions assessment or life cycle analysis for construction projects. This analysis concentrates on the envelope, structural materials, and assemblies of buildings, capturing a

comprehensive view of embodied carbon from inception to disposal. Initially, the reporting for higher tiers (Tier 2 and above) was voluntary, but the 2023 proposal indicates a transition towards making such reporting mandatory, particularly for new developments. The types of buildings affected by these standards include low-rise residential buildings, mid- to high-rise residential buildings, non-residential buildings, and City Agency, Corporation & Division-Owned Facilities. Each building category has specific targets and caps, reflective of their unique embodied carbon footprints. The TGS v4 sets out both short-term and long-term targets, aligning with TransformTO's objectives of achieving near-zero emissions by 2030 and substantial reductions by 2050. To establish these targets, benchmarking studies were conducted, involving collaboration with experts to set embodied carbon benchmarks for different building types.

An advisory committee, comprising architects, engineers, product manufacturers, and policymakers, played a crucial role in ensuring the targets set were both reasonable and acceptable within the industry. The lifecycle analysis approach adopted in these studies emphasizes the entire lifecycle of building materials, from sourcing to disposal, providing a holistic view of embodied carbon impacts. The City of Toronto plans further analysis and refinement of embodied carbon caps, with a report expected in Q2 2024 to assess the feasibility of mandatory caps and broader sustainability impacts in building constructions. Stakeholder engagement has been a cornerstone of this process, involving a wide range of participants from architects and engineers to builders, developers, and other stakeholders.

Metro Vancouver

Metro Vancouver is planning to take several actions to reduce embodied carbon in buildings, including the following:

- Establish requirements for embodied emissions of construction materials in local governments.
- Convene a regional embodied emissions working group to accelerate the transition to lower embodied emissions in buildings.
- Advocate to the BC government to incorporate embodied emissions into the BC Building Code by including stringent embodied emissions performance targets for new construction and retrofits.
- Work with the BC government and member jurisdictions to update or create policies that prioritize the use of building materials with low embodied emissions, including BC forest products.
- Establish embodied emission reduction targets for new construction projects in public sector organizations in the region ahead of BC Building Code and Retrofit Code changes.
- Work with member jurisdictions, the BC government, construction industry, and other regional partners to develop a regional working group that focuses on reducing the embodied emissions in new construction and building retrofits.
- Update its Sustainable Infrastructure and Buildings Policy to include increasingly stringent embodied emissions requirements and greenhouse gas performance limits that align with the corporate low carbon procurement policies.

Province of BC

The Province of British Columbia (BC) is actively addressing the challenge of embodied carbon in its built environment, focusing on reducing greenhouse gas (GHG) emissions from public sector operations and achieving carbon neutrality, as mandated by the Climate Change Accountability Act (CCAA). The Province's framework encompasses a range of initiatives and policies aimed at integrating low carbon and renewable building materials in the design and construction of public sector infrastructure.

Public Sector Organizations (PSOs) in BC are directed to construct facilities that meet or exceed the Leadership in Energy and Environmental Design (LEED®) Gold certification or its equivalent. The recent update to the LEED system, known as LEED v4, has further strengthened the emphasis on low carbon building materials. B.C. is developing a comprehensive Low Carbon Building Materials Strategy, due for completion in 2023. This strategy will outline specific carbon targets for public sector buildings, methods to measure the total embodied carbon of buildings, and pathways to reduce it. The strategy will initially focus on public sector buildings, supporting the development and implementation of embodied carbon targets for these buildings by 2030. The Canada Green Building Council , through its Zero Carbon Buildings Initiative, has identified the use of low carbon materials as a critical strategy for achieving zero carbon buildings. Examples include wood and wood products, which store carbon, and Portland-limestone cement , which generates lower carbon emissions than traditional cement. In addition, B.C. is working to quantify and analyze the total embodied carbon of the built environment and identify reduction pathways.

Government of Canada

The Government of Canada's commitment to reducing embodied carbon in construction, particularly in concrete, is a critical part of its environmental strategy. The following strategies for reducing embodied carbon in concrete are multifaceted and designed to be cost-effective with minimal impact on performance:

1. **Performance-Based Design Requirements**: These requirements emphasize flexibility in concrete mix design, prioritizing low-carbon options. It encourages the variation of concrete mix ingredients in the most carbon-efficient manner possible while meeting the project requirements.
2. **Material Efficiency**: This involves asking designers to prioritize materially efficient designs. In essence, using less material means less carbon. This strategy includes optimizing the aggregate used in concrete, which can reduce the cementitious content and, therefore, the overall carbon footprint.
3. **Portland-Limestone Cement**: Introduced in 2008, Portland-limestone cement (PLC) contains 5 to 15% limestone, reducing the amount of clinker required. Clinker production is one of the main contributors to CO2 emissions in cement production. Using PLC can reduce these emissions by about 10%.
4. **Maximizing the Use of Supplementary Cementitious Materials (SCMs)**: SCMs like blast furnace slag, silica fume, ground glass, natural pozzolans, and fly ash can partially replace Portland cement. These materials are generally added separately by the concrete producer in Canada. Most concrete mix designs in Canada contain slag or fly ash as partial replacements for Portland cement.

5. **Recycled Content in Reinforcing Steel**: Most rebar in Canada already contains recycled content. However, projects should aim for high levels of recycled content in rebar to minimize its embodied carbon.
6. **Adjusting Age Strength**: The strength of concrete increases over time; thus, allowing more extended periods before achieving full strength can lead to using less cement, thereby reducing embodied carbon.
7. **Water Reducing Admixtures**: These chemicals reduce the amount of water needed for a given cement quantity while maintaining good flow and improving concrete strength. They can also be used to reduce cement content due to improved dispersion and distribution of cement grains, thereby reducing the carbon footprint.
8. **Aggregate Optimization and Gradation**: This strategy reduces the cementitious content of concrete, meaning less cement is needed, and therefore, the embodied carbon is lowered.
9. **Recycling and Reuse of Crushed Concrete**: Encouraging the recycling and reuse of crushed concrete as a part of concrete mix can contribute to lowering embodied carbon.

These strategies, outlined in the primer, are designed to assist government officials in understanding and implementing changes in procurement policies to reduce the carbon footprint of concrete used in government projects.

Other jurisdictions outside Canada

The "City Policy Framework for Dramatically Reducing Embodied Carbon" report includes 52 detailed policies aimed at reducing embodied carbon. This report compiles best practices primarily from cities in Europe and North America, introducing new policies not yet implemented globally. This report was coordinated by the Carbon Neutral Cities Alliance and a steering group composed of world-leading cities: Copenhagen, Helsinki, Oslo, San Francisco, Seattle, Vancouver, London, Boulder, New York, Tampere, and Portland. Authored and edited by One Click LCA, with contributions from Architecture 2030, the project was funded by the Rockefeller Brothers Fund, the Ministry of Environment of Finland, the National Research Council of Canada, Construction Climate Challenge hosted by Volvo Construction Equipment, and the cities of Oslo, Helsinki, and Tampere.

The report highlights why cities must act now on embodied carbon. According to the C40 Cities, cities account for over 70% of global CO2 emissions. The UN Population Division estimates that by 2060, cities will add 2.75 billion residents, absorbing the entire global population growth projected for that timeframe. The construction sector's embodied carbon intensity must be drastically cut to prevent the embodied carbon from new buildings, renovations, and infrastructure until 2060 from exceeding 230 gigatons – more than six years of today's global fuel combustion carbon emissions.

The World Green Building Council's report "Bringing Embodied Carbon Upfront" sets 2020 as the deadline for all cities to start developing strategies to achieve a net-zero embodied carbon target. This strategy should include embodied carbon reduction targets, mandatory LCA of buildings, and targets and timelines for low carbon public procurement, with all actions being adopted by 2024.

Dramatic reduction of embodied carbon requires changes not only in the construction trade but also in the entire business environment surrounding it. It is not enough to reduce carbon from materials

alone; reduction also requires changes in what and where we build, how project requirements are determined, and how projects are designed and delivered. It also involves changes in materials recovery, waste handling, land use management, and optimization. Given the extensive scope of change and its impact on a major industry, it is necessary for all policy to start with actions on the main drivers and focus on relevant actions.

Cities, in an essential position, can implement regulations and calibrate policies aligned with local capabilities, solutions, purchasing power, construction costs, and prevailing conditions more closely than national regulators. The embodied carbon targeting policies are part of the necessary business environment for a zero-carbon construction sector. Focusing on embodied carbon supports economic development towards low-carbon business models, increases local business resource efficiency, and fosters the development of local circular businesses. In addition to supporting economic development, cities also benefit directly from increased livability.

The report provides a high-level overview of the legal powers and areas of control and influence for cities in Europe, the United States, and Canada. Most legal powers were found to be broadly comparable across these regions. However, variations in zoning and planning, public procurement, product market access, building codes, mandatory requirements, and clean air and greenhouse gas emissions regulations differ from region to region and are therefore discussed separately for each region. Legal powers available in other geographies may vary.

The report details 52 policies that cities can enact to reduce embodied carbon grouped into five categories within which cities set policies: Zoning & Land Use, Building Regulations, Procurement, Waste & Circularity, and Financial Policies. Two additional categories group policies by asset class: Municipal Buildings and Infrastructure. Many policies in the report fall into two or more of these categories. The following are a summary of the framework for reducing embodied carbon emissions implemented by leading cities:

San Francisco

San Francisco's approach to reducing embodied carbon emissions is primarily focused on construction and demolition (C&D) debris through the Construction and Demolition Ordinance. This ordinance mandates that all C&D debris material removed from a project must be recycled or reused, prohibiting the disposal of such debris in landfills or as garbage. To ensure compliance, the ordinance stipulates that all mixed C&D debris be transported off-site by a Registered Transporter and taken to a Registered Facility that processes all mixed C&D debris. This policy is part of San Francisco's broader efforts to manage waste more sustainably and reduce the city's carbon footprint by promoting the recycling and reuse of construction materials.

Helsinki

A specific zoning requirement in the Helsinki framework for reducing embodied carbon emissions requires the use of wood in construction. In the district zone of Honkasuo, for instance, all buildings are required to have a wooden frame and façade, with detached houses mandated to be built with massive wood. This zoning regulation emphasizes the use of wood as a key material in construction to help reduce embodied carbon emissions. The implementation of this wood requirement in Helsinki's zoning projects aligns with the broader goals of the Carbon Neutral Helsinki 2035 program. This program guides zoning officials to integrate carbon-reducing practices into zoning regulations, including the stipulation for using wood in building constructions. Such practices are

part of Helsinki's comprehensive approach to reducing the city's carbon footprint and moving towards carbon neutrality by 2035.

Portland

The Portland framework to reduce embodied carbon emissions includes specific zoning and planning policies that address parking and transportation demand management. An example of this approach is found in the Portland's Planning and Zoning code, specifically in the Parking, Loading, And Transportation and Parking Demand Management Chapter. Under this policy, for household living uses, the city has established minimum parking space requirements based on the number of dwelling units on a site. Notably, for sites with up to 30 dwelling units, no parking is required. This policy is a clear example of how Portland is using its zoning authority to manage transportation demand and, by extension, reduce embodied carbon emissions associated with the construction and use of parking facilities. This approach aligns with broader goals of reducing carbon emissions by encouraging more efficient land use and reducing reliance on private vehicles. By limiting the need for parking spaces, the policy indirectly promotes the use of public transportation, cycling, and walking, leading to lower overall carbon emissions.

Rotterdam

The Rotterdam framework focuses on implementing a circular concrete covenant in order to reduce embodied carbon emissions. This covenant, signed in 2019 by the City of Rotterdam along with other municipalities and partners in the construction sector, encompasses agreements on recycling building and demolition waste. The covenant represents a collaborative effort designed to create comprehensive strategies with a broader impact. At the heart of this covenant is a strong focus on recycling building and demolition waste, a critical initiative aimed at reducing embodied carbon emissions associated with the production and disposal of construction materials. To achieve this, the covenant outlines specific implementation strategies and methods, which includes detailed guidelines, best practices, and protocols focused on efficiently managing and recycling building and demolition waste. Furthermore, the covenant embraces a circular approach, aligning with the principles of a circular economy where materials are consistently reused and recycled, thereby minimizing waste and reducing the dependence on new materials.

Cities strategies to integrate frameworks for reducing embodied carbon emissions

Cities have recognized the significance of reducing carbon emissions throughout the lifecycle of buildings, which encompasses the manufacturing, transportation, use, and disposal of construction materials. Cities that have already developed climate action plans and circular city strategies, aligned with procurement policies, such as Richmond, have discovered better opportunities to integrate embodied carbon requirements. Strategies employed by local governments in British Columbia and other jurisdictions have demonstrated the effectiveness of integrating embodied carbon reduction goals and reporting requirements into rezoning policies, proving to be the best approach to reduce embodied carbon emissions. These strategies include as follows:

- **Policy Development:** Cities have incorporated embodied carbon requirements into their rezoning policies, establishing performance targets for embodied carbon emissions in new construction and retrofits. These requirements outline specific goals, guidelines, standards, and performance targets related to embodied carbon reduction. They may include criteria for energy efficiency, use of sustainable materials, waste management, and other

environmentally friendly practices. All the cities, including Whistler, Nelson, Vancouver, and the Metro Vancouver region, have developed or updated green building policies to address embodied carbon. These policies include guidelines, performance standards, and checklists to ensure sustainable building practices.

- **Material Substitutions:** There is a shared recognition among the cities that material substitutions play a significant role in reducing embodied carbon. They emphasize the use of low-carbon materials, such as wood and natural products, and avoid high-carbon materials like concrete and foam. The transition to low-carbon building materials may face challenges related to availability, cost, and industry adoption. The City of Nelson plans to limit the use of concrete and choose natural products where feasible. However, the adoption of alternative materials and practices may require concerted efforts to ensure their availability, affordability, and acceptance within the construction industry.

- **Collaboration and Engagement:** The cities actively engage with stakeholders, including builders, designers, and municipal staff, to develop and implement embodied carbon strategies. They also collaborate with organizations like the Carbon Neutral Cities Alliance and the Carbon Leadership Forum to exchange knowledge and best practices.

- **Research and Analysis:** The cities conduct studies and analyses to understand the embodied carbon emissions associated with construction materials and explore ways to mitigate those emissions. They rely on data and research to inform policy development and decision-making.

- **Education and Awareness:** The cities organize workshops, educational programs, and provide resources to increase awareness among builders, developers, and the community about the importance of addressing embodied carbon and the available strategies for reduction.

- **Increase Awareness and Knowledge**: The City of Nelson's efforts to address embodied carbon include conducting preliminary research and engaging with builders and city staff. This highlights a challenge in terms of awareness and knowledge about embodied carbon and its implications within the construction industry. Educating stakeholders and building professionals about the importance of embodied carbon reduction and providing guidance on best practices can help overcome this challenge.