MAKING EMBODIED CARBON MAINSTREAM

A guide for local and regional governments to reduce embodied carbon in the built environment

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FOR CLIMATE SOLUTIONS

May 2021

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This research was undertaken with the valued input and support of over 30 built environment stakeholders (listed in Appendix A). The views and recommendations in this report are those of the author and do not necessarily reflect the views of contributors to this project.

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Abstract

With anticipation building around embodied carbon as a "new frontier" of climate policy, it can be tempting to develop a whole suite of dedicated institutions and mechanisms to support its implementation. However, to do so risks placing an undue burden on already overstretched local and regional governments. In response, this guide proposes that embodied carbon policy in North America build on existing priorities that already galvanize resources and attention and have benefited from decades of policy development. Making strong links to a larger urban agenda offers a way to forge buy-in from a wide range of stakeholders.

CURRENT VISIONS FOR EMBODIED CARBON POLICY BROADLY FALL INTO TWO CATEGORIES:

1. Material performance strategies, or technical solutions that incrementally reduce emissions.
2. Circular economy strategies or more transformative solutions that avoid emissions.

Both of these areas have strong ties to existing strategies in the urban built environment for waste, equity, and preservation. Foundations in waste policy include increasing waste diversion, expanding green demolition, and increasing material efficiencies. Foundations in equity-oriented policy include retrofitting affordable housing, workforce development for deconstruction, and building lower carbon, lower cost housing. Foundations in preservation policy include incentivizing building reuse, supporting the use of low carbon materials for retrofits, and encouraging vertical infill.

This guide offers an approach for local governments to bring an embodied carbon lens to current policy development, develop an awareness of knowledge gaps, and identify first steps toward action.

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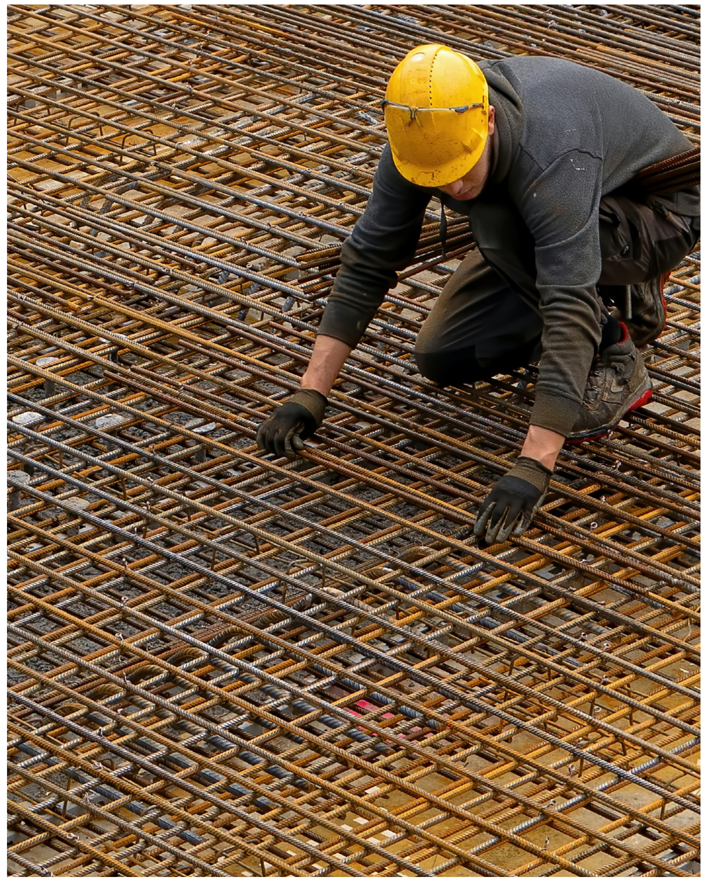
Executive Summary

Advancing embodied carbon policy is an important next step in climate policy for local and regional governments around the world. This report demonstrates that existing policy foundations laid out over decades can be gateways to achieving this. The construction industry will not be decarbonized unless these underlying emissions are eliminated.

The construction industry has made strides in reducing emissions from the heating, cooling and lighting of buildings through the adoption of energy efficient systems. However, strategies for addressing embodied carbon are less well understood and not yet extensively incorporated into practice. The construction industry is responsible for significant carbon emissions as materials are extracted, processed, and transported for construction and eventually disposed of when buildings are demolished. The embodied emissions from buildings alone are responsible for around 11% of annual global carbon emissions.

— *This integrative approach can help to forge buy-in from a wide range of stakeholders and maximize existing foundations to take this important next step in climate policy.*

Fortunately, the practitioners and policy makers with influence over the built environment are beginning to take notice of this emissions blind spot. Given the host of competing priorities, taking on embodied carbon can be a daunting step. Rather than developing a whole suite of institutions and mechanisms to support its implementation, this study finds a more feasible and effective way for local governments in North America to tackle this issue by building on foundations in existing policy domains. This integrative approach can help to forge buy-in from a wide range of stakeholders and maximize existing foundations to take this important next step in climate policy.



The current holistic vision for embodied carbon policies can be distilled into two key areas: material performance and circular economy strategies. **Material performance** reduces emissions from individual material or design choices through incremental technical improvements and solutions such as reducing the carbon footprint of concrete. **Circular economy** strategies avoid embodied emissions at a system or community-wide level through more transformative solutions such as widespread building and material reuse. Material performance reduces the carbon spike from building new while the circular economy values the carbon that has already been sunk in the built environment.

Stakeholder engagement revealed an interest in mobilizing existing strategies in **waste**, **equity** and **preservation** to tackle embodied carbon. Both material performance and circular economy strategies can build on these **existing priorities** that already attract resources and attention and have benefited from decades of policy development.

Top opportunities include:

WASTE

- Develop consistent waste regulations to divert construction waste from the landfill including putting a price on waste where there is none.
- Develop and expand green demolition requirements in the residential, commercial and industrial sectors with an emphasis on salvage over recycling.

EQUITY

- Develop regulations and incentives that support the retrofit of affordable housing, aging rental stock and public housing.
- For some new housing development, remove requirements for high-cost, emissions intensive underground parking and ensure that cost savings are passed on to renters or buyers.

PRESERVATION

- Fund incentives for retrofits, adaptive reuse and preservation through a tax or fee on embodied carbon for new developments.

This report is intended as a guide for local and regional government staff in North America to recognize current approaches to embodied carbon; determine synergies between waste, equity, preservation and embodied carbon relevant to their local context; develop an awareness of knowledge gaps; and identify first steps to integrating embodied carbon concepts into existing local priorities.

— *Both material performance and circular economy strategies can build on these existing priorities that already attract resources and attention and have benefited from decades of policy development.*

A Guide To Getting Started

Local and regional governments can take several simultaneous steps to develop embodied carbon policies based on existing foundations.

Ultimately, it may be useful to establish embodied carbon targets, but current building life cycle assessment data doesn't adequately support robust decision-making. This shortcoming together with the urgency of reducing emissions is all the more reason to turn immediate attention to how waste, equity and preservation policies can be enhanced to achieve embodied carbon goals. A review of existing policies can help in the short term to determine how they already provide a platform for reducing or avoiding embodied carbon and how those opportunities can be enhanced. Other local priorities may also offer synergies with embodied carbon goals.

Build On Waste Pathways

» **Examine the feasibility of implementing or expanding material disposal bans.**
- Do current waste regulations put a price on disposal?
- What materials are regulated and what materials are feasible to regulate?

» **Introduce green demolition requirements for limited building types and develop plans for phased expansion.**
- For which building types is material salvage most feasible?
- Where green demolition requirements exist, what types of buildings do they include?

» **Develop a strategy for supporting an expanded deconstruction hub.**
- What is the current capacity of material salvage businesses and how can it be increased?
- Are there opportunities to partner with building material supply companies or non-profits?

» **Pilot education and incentives for efficient construction.**
- Do existing policies support material efficiency in construction and if not, how could they be introduced?

Build on Equity Pathways

» **Identify opportunities to work with affordable housing organizations on retrofits.**
- Are there incentives in place that support the preservation and retrofit of affordable housing? How can these be introduced?

» **Explore partnerships with trades and technical institutions to support workforce development in deconstruction and reuse.**
- Do existing workforce development programs include deconstruction, material salvage and re-use?
- What partnerships could support this type of program?

- **Evaluate and improve active transportation policy with the goal of eliminating underground parking in some new construction.**
  - Can current underground parking requirements be removed in light of available low-carbon transportation options? How can adequate transportation be developed to make this a viable option?

- **Review current carbon accounting with an equity lens.**
  - What metrics or indicators are used in current carbon accounting, and do they include equity or social costs?

Build on Preservation Pathways

- **Review and expand existing development fees to include a fee for embodied carbon.**
  - What are the existing development fees that could be expanded to include a fee for embodied carbon?
  - What mechanisms exist or need to be created to direct those funds toward retrofits?

- **Review zoning bylaws and development plans for opportunities to incentivize additional preservation and full occupancy.**
  - How do plans and zoning bylaws address preservation?
  - For public building retrofits, are there opportunities to require low carbon materials?

- **Add incentives for vertical infill to zoning bylaws.**
  - Where do existing plans create opportunities for vertical infill and how can more opportunities be created?

Pathways To Develop Long-Term Technical Capacity

- **Development planning:** Require reporting on embodied carbon for rezoning, development permits and/or building permits to develop baseline data and awareness in the industry.

- **Procurement:** Require reporting on embodied carbon and eventually include embodied carbon as a selection criteria.

- **Financial decision-making:** Establish internal "shadow" carbon pricing to facilitate consideration in cost/benefit analysis.

An Easy First Step in Public Purchasing

- **Specifications: Use performance-based rather than prescriptive specifications for concrete.**
  - Conventionally, structural engineers write general notes that require a 28-day strength and a prescriptive water/cement ratio, precluding alternative cement mixes. Adopting emerging best practices that rely on final concrete performance can allow significant reductions in concrete emissions, while still producing the final required concrete strength.

SECTION 1

Building on Policy Foundations

Globally, leading practitioners in the construction sector are well equipped to reduce greenhouse gas (GHG) emissions from heating and cooling buildings.

Of course, this does not always translate into practice, weakening mitigation efforts. At least as importantly, many ambitious drives to "zero emission buildings" neglect the underlying emissions from extracting, processing, transporting and disposing of building materials (**Fig.1**). Breaking down global energy-related CO_2 emissions into the conventional categories of buildings, transportation, and industry, buildings comprise a hefty 39%. And 11% of the global total is due to embodied carbon from buildings[1-3]. If operational emissions continue to decline, embodied carbon will account for an increasing proportion of building emissions[4] (**Fig.2**). In conventional buildings, embodied carbon accounts for about 25% of the impact, but in high efficiency buildings, the share of embodied carbon can be upwards of 50%[4]. Net zero targets for the building sector have begun to include both operational and embodied emissions because buildings can only be considered "decarbonized" when embodied carbon is eliminated.

Infrastructure is another major challenge. As more roads, bridges and wastewater treatment plants are built, concrete consumption rises in tandem. Concrete consumption is expected to increase from 4 billion tonnes per year to 5 billion tonnes per year in the next 30 years[5]. Other analysis suggests that taken together, the embodied carbon of construction materials in buildings and infrastructure makes up 23% of total global emissions[1,6]. As this perspective begins to register within the construction industry, embodied carbon is emerging as an important piece of the climate agenda for local and regional governments.

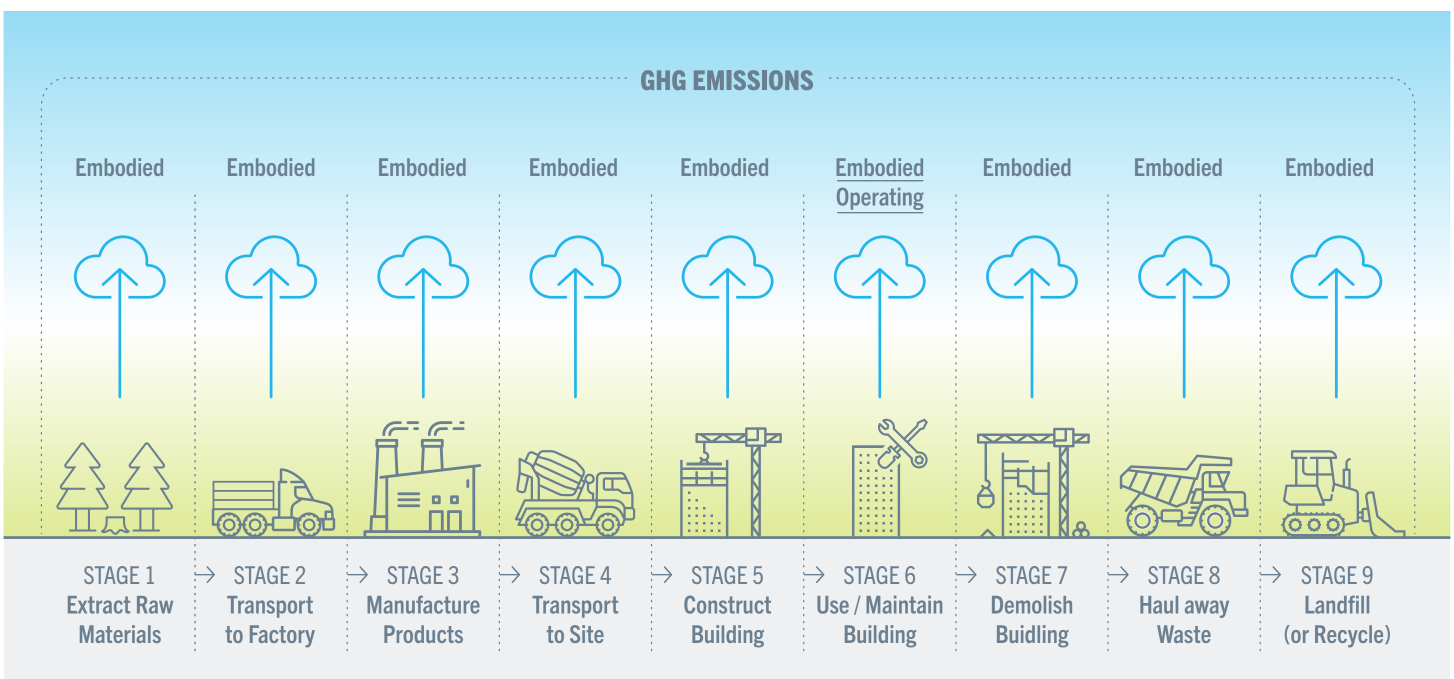


Fig.1 Considering embodied carbon offers a more holistic perspective on the impact of construction, extending to every stage of the lifecycle rather than the narrow perspective of operations alone. Diagram Source

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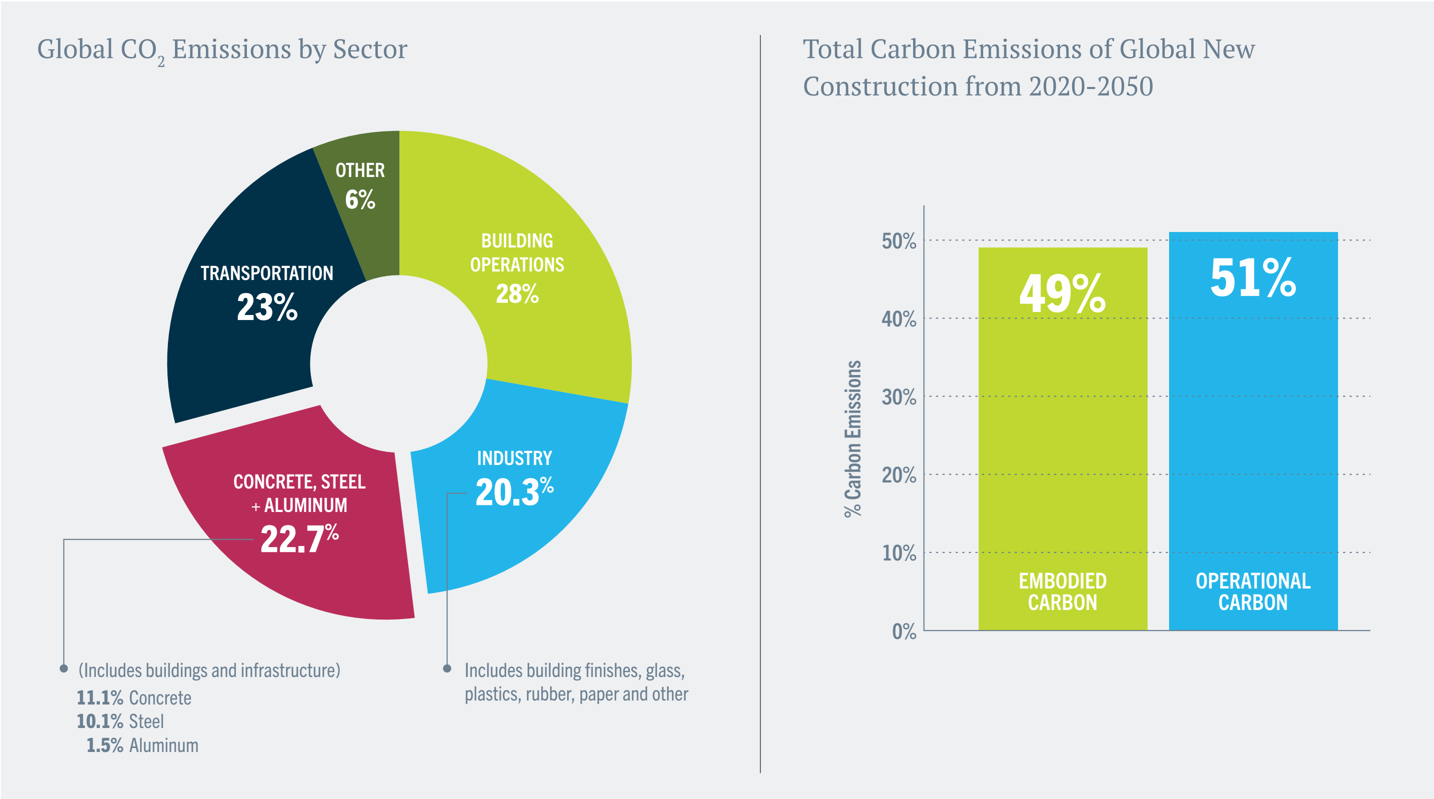


Fig.2 Embodied emissions for buildings and infrastructure approach 23% of total global emissions. As operational emissions decrease over time, embodied carbon will make up a larger proportion of emissions. Whether operational emissions decline or not, the contribution from embodied carbon is substantial.[6,7]

Leading city networks and green building organizations have been shaping a policy vision, laying out a roadmap for all built environment stakeholders to meet milestones on the path to global net zero carbon in 2050[8] and making a financial case for redevelopment and the flexible, adaptable use of buildings, or "buildings as a service."[9,10] One recent framework assembles specific policy measures for cities, ranging from requiring low carbon products to "redefining the solution." This could mean, for example, maximizing the use of under-utilized spaces rather than pursuing new construction.[10] There is no silver bullet; a wide array of these strategies will need to be used together.[12] Acting alone and in networks, cities may wield influence beyond their borders through their role in shaping demand in global supply chains.[13]

Before this latest round of policy leadership, urban organizations and researchers had been elevating the profile of consumption-based, or Scope 3 emissions for at least a decade (**Fig.3**). Accounting for consumption-based emissions often more than doubles a city's footprint.[14,15] Shifting standard emissions accounting practices may be too onerous at the international level, but for cities, simplified methods of consumption-based accounting can be feasible.[16] At the local level, this can be a practical lens to inform decision-making and help prioritize climate action.

— *Acting alone and in networks, cities may wield influence beyond their borders through their role in shaping demand in global supply chains.*

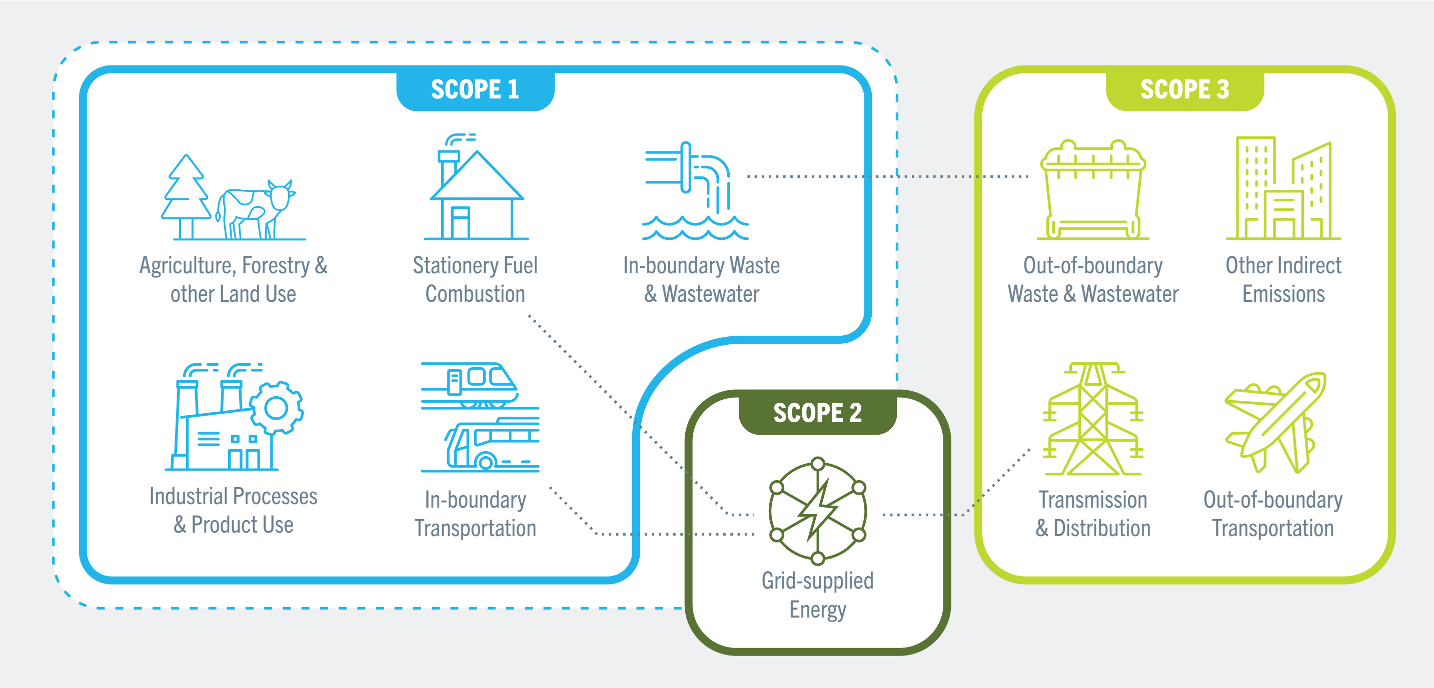


Fig.3 The Greenhouse Gas protocol provides the international standard that governments and organizations use to categorize their emissions. Scope 1 covers direct emissions within a city's geographic boundaries – these are emissions from buildings, industry and transportation. Scope 2 covers indirect emissions from electricity consumption and Scope 3 covers all other indirect emissions that occur as a result of activity within a city such as manufacturing building materials or food production. Scope 3 emissions are equivalent to embodied emissions.

The full scope of embodied emissions policy includes strategies ranging from incremental material improvements to shifting building norms to align with the circular economy. In spite of high-level commitments from global players, it is unclear how this vision will translate into practice, especially for organizations and cities that are not already dedicated to climate action.

Aligning Embodied Carbon and Existing Priorities

With expectations rising around embodied carbon as a "new frontier" of climate policy, the research informing this guide initially focused on how, why, and to what effect local and regional governments in BC were implementing embodied carbon policy. However, it became apparent that outside of the City of Vancouver, and perhaps Metro Vancouver, there was in fact very little traction. For governments and organizations with less capacity, the prospect of yet another climate agenda item risked shutting down conversations, let alone policy development.

Consulting with built environment stakeholders in the public and private sector, analyzing plans and policies, and reviewing current best practices led to reframing the question: how can local governments pursue reductions in embodied carbon even without dedicated, robust technical infrastructure?

This research revealed opportunities for local governments that do not have in-house GHG accounting specialists and life-cycle analysis capacity. Instead of developing a whole suite of dedicated institutions and mechanisms, local policy-makers have opportunities to build on existing priorities that already galvanize resources and attention. Waste, equity, and preservation are current priorities that present significant substantive overlaps with embodied carbon policy (**Fig.4**).

WASTE

Globally, landfills are nearing capacity and represent a toxic risk, contaminating groundwater, degrading habitat and posing an immediate threat to human health. In environmental policy, the entire premise of "waste" is being questioned with a drive to "zero waste." The circular economy concept proposes that materials already in circulation should be repurposed, largely replacing extraction.

EQUITY

Fights over inequity have recently gained new urgency as rising income inequality, xenophobic nationalism, and conspicuous racism galvanize political attention. Calls for global climate justice and local environmental justice centre the connections between multiple forms of discrimination, rising emissions and vulnerability. In the policy world, this has motivated versions of a Green New Deal, more attention to the disproportionate impact of energy infrastructure and industrial emissions on marginalized communities, and an increasing focus on affordable housing.

PRESERVATION

A less urgent, but longstanding concern in urban development, preservation presents an opportune foundation for embodied carbon policy. Preservation encompasses not only heritage conservation, but also adaptive reuse, renovations, retrofits and even simple maintenance. All of these can contribute to a larger vision of sustaining history, culture and a sense of place in a layered built fabric constructed over time. Historically, preservation values have been integrated into zoning and development planning.

Fig.4 Waste, equity and preservation are existing policy domains of urgent and longstanding concern which present significant overlaps with central strategies for reducing embodied carbon.

BUILDING ON EXISTING POLICY FOUNDATIONS CAN BRING EMBODIED CARBON FROM THE MARGINS TO THE MAINSTREAM

- Making strong links to a larger urban agenda offers a way to forge buy-in from a wide range of stakeholders and build coalitions with interest groups already taking a stand around waste, equity and preservation.
- Creating a realistic pathway for cities with less capacity helps address disparities in climate action between high profile cities and smaller, under-resourced communities.
- Cities with low growth can make progress on climate action by focusing on their existing building stock.
- While technical life cycle assessment tools and data catch up, local governments can take immediate action.
- Local governments can use this momentum to enhance their profile as climate champions, taking responsibility for emissions beyond their own borders. [17]

Embodied Emissions: Current Strategies

Dominant approaches to embodied carbon in the building sector fall under material performance and circular economy strategies.

In simple terms, material performance strategies reduce embodied emissions through incremental technical solutions such as reducing the carbon footprint of concrete. Circular economy strategies avoid embodied emissions through more transformative solutions such as widespread building and material reuse and shifting land use norms. They do face social and technical hurdles, however both approaches are beginning to be integrated into land use plans, zoning and building codes, laying the groundwork for more transformative change (**Fig.5**). While some in the building sector place more emphasis on one or the other, most do take a holistic approach that considers them as complementary. Both present opportunities for greener forms of development, requiring more labour and expertise to deliver all of the solutions from lower carbon materials to deconstruction.

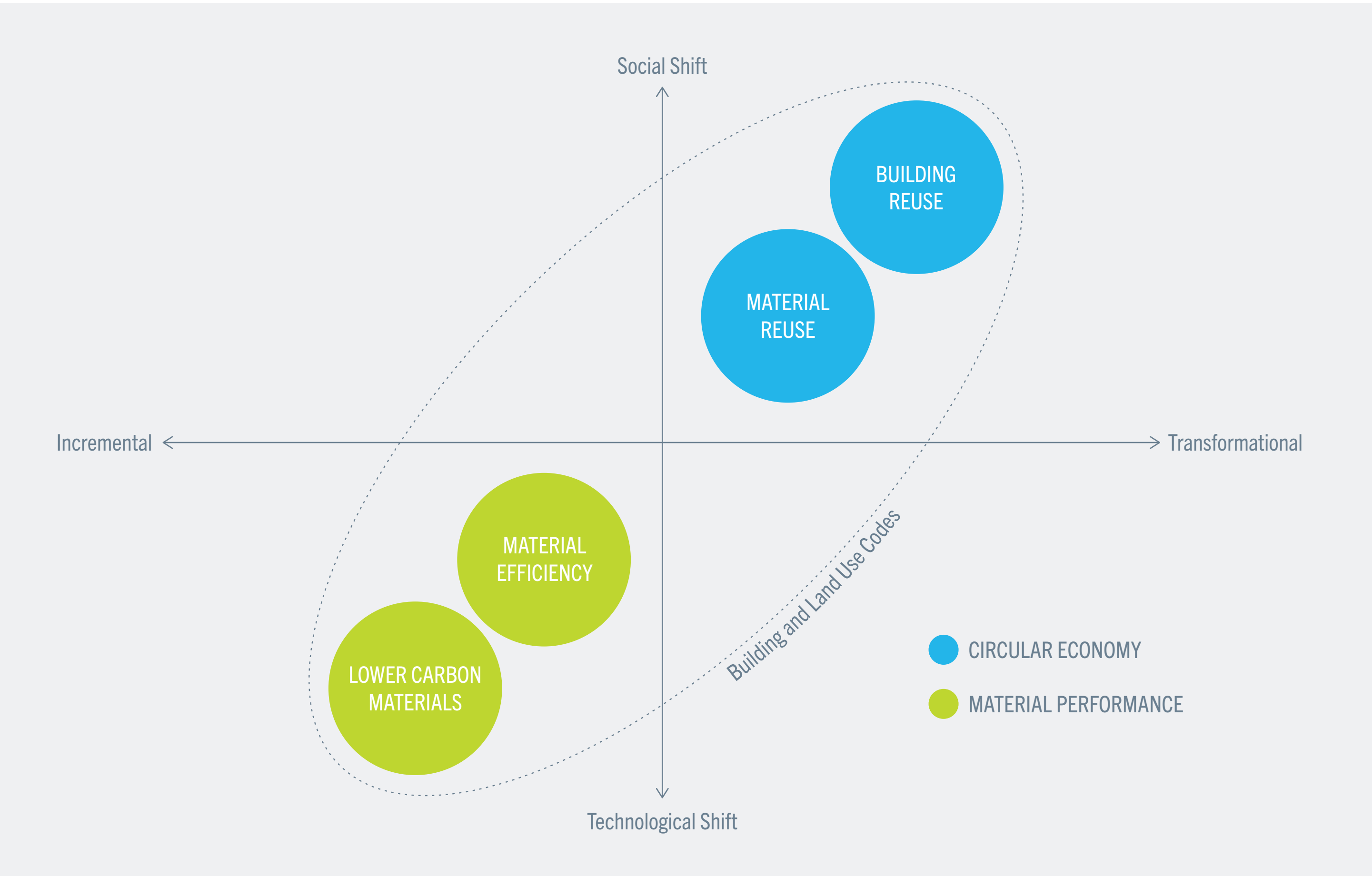


Fig.5 Embodied carbon planning draws from strategies in material performance and the circular economy. Material performance strategies tend to involve technological developments that produce incremental emissions reductions. Circular economy strategies involve a more transformative shift in construction and land use practices. Both can be enabled through codes and standards, laying the groundwork for more significant change.

Material Performance

MATERIAL PERFORMANCE STRATEGIES REDUCE EMBODIED CARBON

Material performance includes substituting lower carbon and carbon sequestering materials for conventional construction materials. It can also mean reducing overall material use by modifying the fabrication of individual building components and designing for material efficiency at the whole building scale.

LOW CARBON MATERIALS

These include lower carbon concrete[18], [a], steel produced in an electric arc furnace, and timber produced from sustainably harvested wood. At times these materials can become “carbon positive,” sequestering more carbon in a material such as timber than was emitted in the extraction and manufacturing process.[19] Lower carbon concrete and mass timber are becoming more common in BC as municipal and provincial codes now enable them. Synergies may be found in using them together; building with mass timber allows for lighter concrete foundations.

MATERIAL EFFICIENCIES

This includes avoiding oversizing structural components, using concrete technologies[b] which reduce the use of concrete per unit area, using offcuts, eliminating construction waste, and prefabrication in a controlled factory setting. Reducing materials may conflict with passive house or energy efficient construction which requires thicker assemblies.

Circular Economy

CIRCULAR ECONOMY STRATEGIES AVOID EMBODIED CARBON

Circular economy strategies avoid embodied carbon by reducing resource extraction and repurposing materials already in circulation. For the built environment, circular economy strategies include not only salvaging and reusing building materials, but re-using the core and shell of existing buildings. Achieving a significantly circular economy would entail a massive shift from disposability to durability, largely in high-income countries. But the feasibility of this also rests on reducing material throughput, as the material currently in circulation cannot meet growing demand. In North America, this would require a shift in building and land use norms such as reducing the building area per occupant, prioritizing efficient occupancy of existing buildings, and removing provisions for private transportation. Much like energy efficiency, material efficiency and circularity are predicated on demand reduction. Throughout the guide, this approach is classified as more transformational than material performance because historically technical shifts in engineering and construction standards have been easier to achieve than social and cultural shifts toward sustainability.[20,21]

— *Much like energy efficiency, material efficiency and circularity are predicated on demand reduction.*

[a] Concrete can be produced with a “supplementary cementitious material” such as fly ash or slag instead of Portland cement, reducing emissions by 20-50% depending on the percentage used in the cement mix. Lower energy intensity kilns and furnaces powered by renewable energy can also reduce emissions. These strategies are central to Buy Clean policies in the U.S.

[b] Biaxial slab systems such as bubble deck require less material by replacing concrete with voids (bbdna.com).

DECONSTRUCTION

Deconstruction means disassembling buildings so that materials can be recycled or salvaged. Much typical waste diversion actually results in downcycling, so serious deconstruction efforts focus on achieving material reuse at the highest level possible[22]. Implementing this effectively at scale requires more experience and expertise in everything from physically reclaiming the materials to inspecting and regrading them. It also requires significant industrial space to warehouse materials and systems to facilitate their reuse, such as material passports[c]. In addition to retaining the value of non-renewable resources such as old growth timber, deconstruction and reuse have co-benefits in terms of reducing landfill use and improper disposal of hazardous waste. Material reuse can extend from buildings into infrastructure; for example, salvaged concrete from buildings can be used to build roads with a lighter material footprint.

BUILDING REUSE

Building reuse ranges from energy retrofits to adaptive reuse and heritage preservation. While this could potentially conflict with densification goals, existing buildings can also provide a basis for vertical infill. Where it is not practical to repurpose whole buildings, material reuse is an alternative.

Codes and Standards

All of these approaches can be influenced through procurement, land use policy, zoning and building codes, and waste management plans.[23-26] For example, request for proposals (RFPs) for public buildings can require low carbon materials, building codes can allow for salvaged and regraded material to fulfill structural standards, and zoning can require or incentivize building reuse. Rating systems such as LEED and the Living Building Challenge include credits for low carbon materials, and these can be directly integrated into local policy as requirements. Leading policies in North America, reviewed in the appendix, provide examples of how to take steps toward requiring deconstruction, waste diversion, low carbon materials and whole building life cycle assessment. The cities of Portland and Vancouver require deconstruction for older single-family homes. The Buy Clean California Act establishes maximum Global Warming Potential for steel, glass and insulation in public construction[27] while Marin County California goes further with a Low-Carbon Concrete Code.[28] These early incremental steps are providing a valuable baseline for research and practice.

— *Leading policies in North America provide examples of how to take steps toward requiring deconstruction, waste diversion, low carbon materials and whole building life cycle assessment.*

[a] Material passports are typically digital documentation of the characteristics of building components that facilitate their recovery and reuse. They are most commonly used in the Netherlands which has a more advanced circular economy sector (metabolic.nl/news/circular-economy-materials-passports/).

Building on Waste, Equity, and Preservation Policies to Reduce Embodied Carbon

Years of policy development in waste, equity and preservation can serve as a foundation for embodied carbon policy (**Fig.6**). All three of these areas coalesce in an emerging model of growth that veers toward the circular economy, shifting energy and resources to retrofit and reuse. This can contribute to a green transition as it demands additional expertise and labour throughout the building sector from material design to on-site construction knowledge.

Fig.6 Embodied carbon policy can build on existing priorities. This approach is rooted in the circular economy and can be enhanced with material performance strategies. Building on waste policy includes increasing waste diversion, expanding green demolition to more building sectors, and increasing material efficiencies. Building on equity-oriented policy includes retrofitting affordable housing, workforce development for deconstruction, and building lower carbon, lower cost housing. Building on preservation policy includes incentivizing building reuse, supporting the use of low carbon materials for retrofits, and encouraging vertical infill.

Foundations in Waste: Waste Diversion, Green Demolition, Efficient Construction

Zero waste goals have become a feature of local policy over the last decade. While this serves environmental objectives, it has more tangible urgency because landfills across North America are reaching capacity and will have to either be closed or expanded[29-30]. Even in a region like Metro Vancouver where construction and demolition waste diversion is high, it still makes up over a quarter of the waste going to local landfills.[31] Waste strategies can help reduce embodied emissions in three main ways: material salvage, green demolition, and more efficient construction methods.

MATERIAL SALVAGE

In their current state, waste regulations are more comprehensive and have a greater impact on waste diversion than green demolition bylaws.[32] However, both approaches could be significantly expanded. Currently, waste is only regulated in limited jurisdictions and for some materials. For example, Metro Vancouver introduced a clean wood ban[d] in 2015. Typically, the success of waste management is measured by the diversion rate rather than the end use of materials; material reuse is not carefully tracked, if at all. Tracking material reuse would assist regional governments in elevating this strategy. It could be easier to implement than emissions accounting because it is more concrete and does not require the same level of technical expertise.

GREEN DEMOLITION

Where green demolition regulations that mandate diversion and deconstruction are in place, they concentrate on older single-family homes, representing a small fraction of demolition waste. This is justified by the assumption that older buildings contain the most valuable materials and that processing and storage capacity is insufficient for a greater volume of material.[33-34]

Across BC, houses were often constructed with old growth timber through the 1970s, so there could be great value in reclaiming those materials. Current lumber supply shortages and price spikes demonstrate that even newer recovered materials could have substantial value.[35]

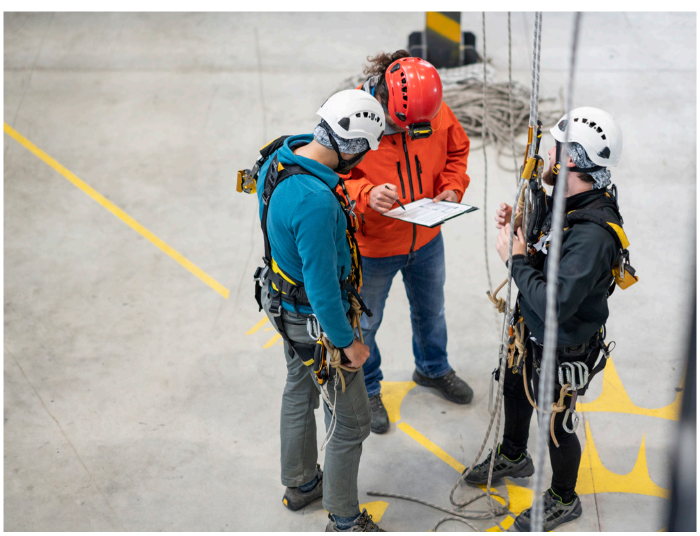
Material salvage and reuse are known to emit less than conventional demolition, but further analysis of precise quantities would be necessary to determine results for a specific region.[36] One study of the relative impact of new lumber for framing and flooring found a greater Global Warming Potential (GWP)[e] of three times and

[d] This policy added a surcharge on loads of garbage containing over 10% clean wood, that is solid wood, lumber and pallets that are unpainted, unstained, free of glue and untreated but which may be pierced with nails or other metal fasteners.
[e] Global Warming Potential (GWP) provides a common unit of measure across different greenhouse gases.

five times on average than that of reclaimed lumber across various regions. If the woody biomass used to fuel kilns for drying the new wood were also taken into account, the GWP would rise to 10 to 16 times more than reclaimed wood.[37] While some argue that burning wood is carbon neutral, that is increasingly disputed as it neglects the long timeframe for forests to adequately reabsorb carbon as well as the need for responsible forest management.[38-40]

As one of the earliest jurisdictions to implement a deconstruction ordinance, the City of Portland has been able to study the results. Analyzing material salvage from 36 houses, they found that deconstruction yielded a net benefit of 7.6 tonnes of CO_2 equivalent per house.[22] This benefit is largely a result of avoiding production of new materials and carbon sequestration in wood. At 100 houses a year, they equate this to removing 161 cars from the road.[f]

In Portland, the highest salvage rate was most strongly correlated with the level of contractor experience rather than house age or size. That suggests that where green demolition does occur, further training and capacity building are necessary to divert materials into their highest and best use.[33,41] Both deconstruction workers and engineers would need to further develop methods and skills for effectively salvaging and reusing materials which could be accomplished with training centers developed with industry and technical colleges. Deconstruction hubs, or depots for the storage and marketing of reclaimed materials, would also need to scale up, providing adequate space to store, sort and display the increased volume of materials.[42] In addition, disposal facilities could provide space for the collection of wood and other construction materials.



While single-family deconstruction could be significantly expanded, other building types are also an opportunity. Expanding to multifamily, commercial and industrial buildings could be tested with pilot projects to determine the salvage potential for different building types and inform the reuse market.[43] A recently formed network of building professionals, All for Reuse[44], is developing an agenda for the reuse of commercial building materials and could help support this effort. For all building types, developing technical capacity and a sizable market for salvaged material remain substantial challenges.

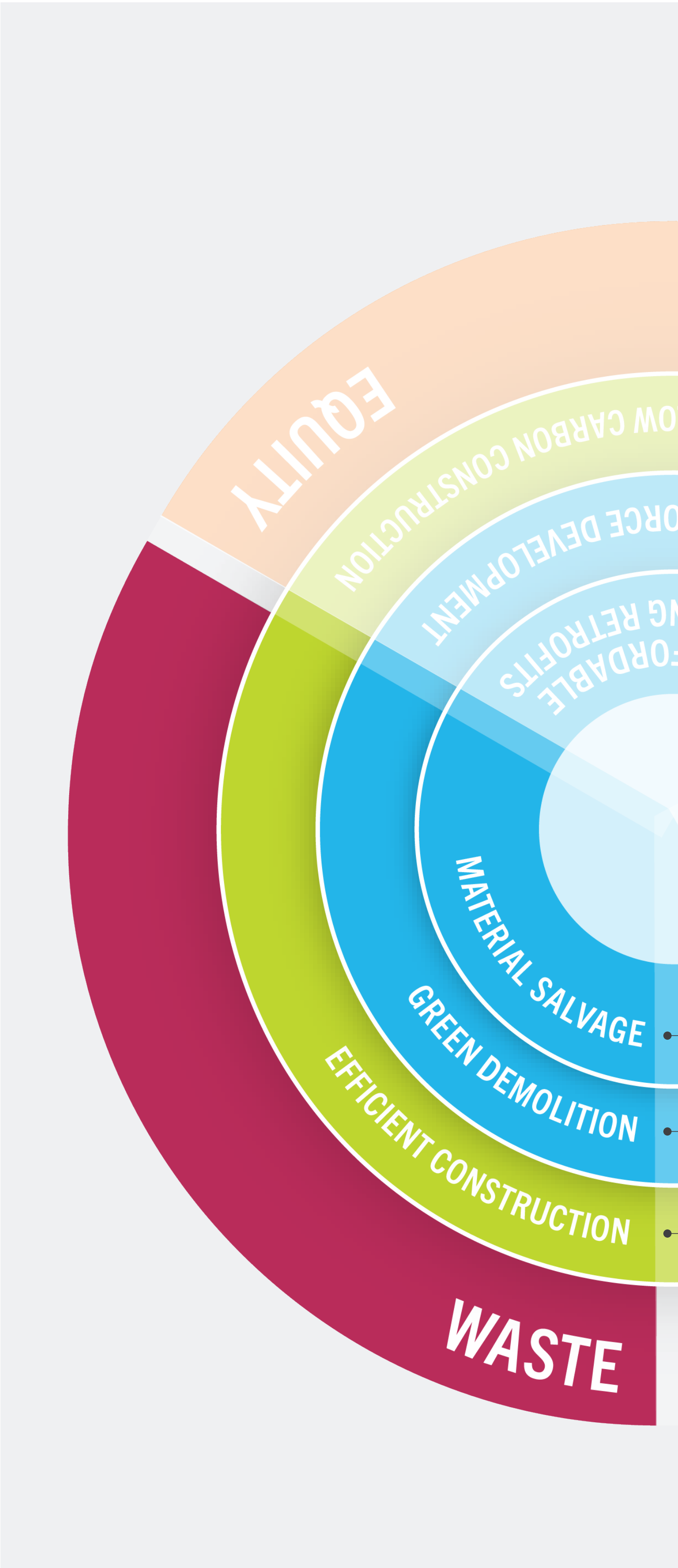
EFFICIENT CONSTRUCTION

Best practice for new construction includes waste management. This tends to focus on demolition and minimizing off-cuts, but can also extend to "right-sizing" structural and mechanical systems and prefabrication in a controlled factory environment. Putting material efficiency into practice will incur an innovation premium as it initially requires more time in the design and construction phases. Currently, building a high-rise with less concrete by making use of a system such as bubble deck actually costs more than building in a conventional manner.[45] However, just as in other areas of green building, as material efficient construction becomes normal and widespread practice, the innovation premium will likely dissipate. In the meantime, incentives and financing mechanisms could support more efficient building.

[f] These results do not directly translate to other regions given differences in building materials and recovery rates.

PICS

BUILDING ON WASTE PATHWAYS



1. Develop consistent waste regulations to divert construction waste from the landfill including putting a price on waste.[g] Regional districts could develop sample bylaws in collaboration with municipalities. Support the development of widespread industry capacity and compliance with waste diversion goals.

2. Develop and expand green demolition requirements.

- Extend green demolition to more residential categories including renovations as well as commercial construction.
- Emphasize salvage over recycling in waste and green demolition regulations. Track material salvage and reuse.

3. Create or scale up deconstruction hubs and support a market for salvaged material.

- Use public buildings to lead by example, using salvaged materials as structure, cladding and other major components.

4. Incentivize more efficient material use in new construction by subsidizing the initial higher cost (the so-called "innovation premium") for contractors to learn how to build with less material intensive construction methods

[g] This has already been done in some jurisdictions in BC including Metro Vancouver and the Capital Regional District.

UNBUILDERS: ELEVATING DECONSTRUCTION AS POLICY AND PRACTICE

Adam Corneil, the founder of Unbuilders, the largest deconstruction company in the Lower Mainland of BC, laments the fact that we are "still building single use buildings." He goes so far as to say that discarding old growth lumber is like "throwing diamonds in the garbage." He has built a business on the back of Vancouver's Green Demolition Bylaw, deconstructing the single-family homes that trigger either reuse and recycling or full deconstruction requirements.

However, he has set his sights beyond that. Not only does he aim to demonstrate a competitive business model for deconstruction, he is conducting outreach to influence policy. Having recently expanded his business to southern Vancouver Island, he is in active conversation with the cities of Vancouver and Victoria about their waste regulations. He is also seeking to expand deconstruction practices across Canada, noting that the cities of Calgary, Toronto, and Halifax are watching to see how deconstruction progresses in BC.

Image: Courtesy Unbuilders

> — *Ultimately expanding deconstruction is about more than recovering materials—it's about recovering a practice which requires more labour and less fossil fuel.*

Image: Courtesy Unbuilders

Corneil's policy work was initially rooted in the circular economy, but he has more recently expanded into embodied carbon as well. He chose to establish his business in Vancouver because it has been a leader in green demolition, but emphasizes that it has a long way to go to realize the full potential of deconstruction. He advises a set of changes for the practice to scale up:

1. Regional waste policy must ban drywall and clean wood in the landfill to create a market for deconstruction.
2. Green demolition bylaws must mandate salvage rather than recycling, because recycling often results in wood being burned for fuel.
3. Green demolition must expand beyond residential to commercial and industrial buildings.
4. Appropriately sized deconstruction hubs must be created to store and resell materials because typical reclaimed wood shops are simply too small.

Large-scale machine demolition only became common after World War II. Ultimately expanding deconstruction is about more than recovering materials—it's about recovering a practice which requires more labour and less fossil fuel.

Foundations in Equity: Retrofit Affordable Housing, Workforce Development, Build Lower Carbon Housing

As housing prices have climbed exponentially in cities across North America, low and moderate-income residents have been increasingly squeezed out of urban centers. Policy-makers have been focusing on affordable housing to enhance equity and accessibility within regions. Inclusive economic development, especially for workers being displaced from carbon intensive sectors, is another equity priority.

RETROFIT AFFORDABLE HOUSING

For operational emissions, NGOs and utility programs have directed some retrofit programs to lower-income, rental housing to enhance equity. When embodied carbon is taken into account, retrofitting affordable housing reduces emissions more than previously considered. Retrofitting can reduce emissions by at least 35% compared to new construction (discussed in more detail in the preservation section). As of 2020, BC Housing is pursuing this strategy through the Reframed Lab initiative [46], and a Toronto-based organization is currently pursuing the retrofit of mid-century affordable housing towers in several cities across Canada (see p.23), an effort that could be scaled up further.

WORKFORCE DEVELOPMENT

Training and capacity building to salvage materials can address equity in addition to waste. Workforce development policy could target both skilled and unskilled labour pools for demolition, material salvage, and processing. Researchers and policy-makers project that the deconstruction industry would generate five to eight jobs in place of a single job in machine demolition.[36,42,43] This approach could benefit workers dislocated by the transition away from fossil fuels and increasing automation. It also offers an opportunity to build on alliances between environmental and labour organizations which are already developing around "buy clean" policy and the green economy.[47]

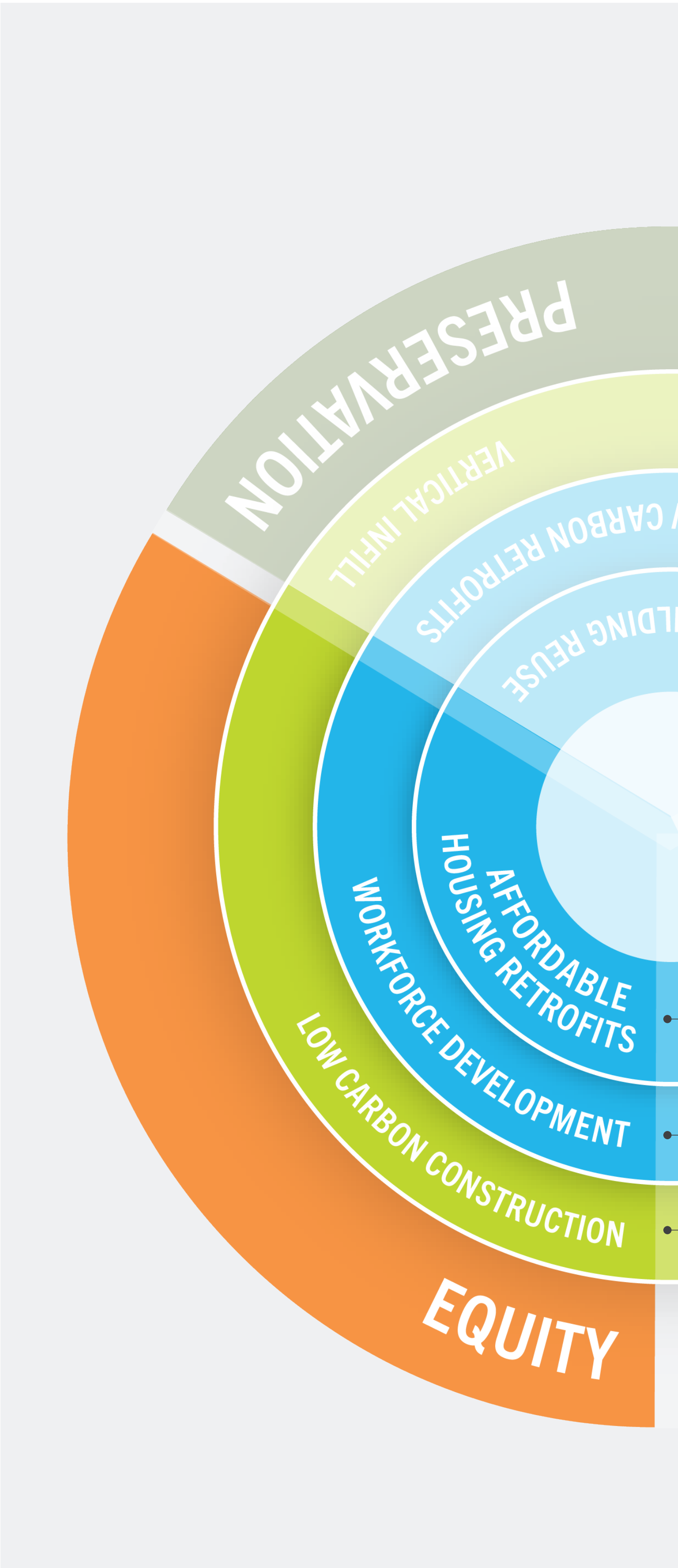
BUILD LOWER CARBON HOUSING

Retrofitting existing housing will clearly not fulfill current housing demand. For new housing, the simpler immediate way to reduce embodied carbon is through material substitution. Prioritizing lower carbon materials can provide the additional benefit of reducing toxic emissions from manufacturing which disproportionately impact marginalized communities.[48]

> — *In multi-family housing development, underground parking requires a major outlay of concrete and can cost upwards of 40,000 USD per space.*

For more transformative change, local land use policy can be a tool to reduce embodied carbon. In multi-family housing development, underground parking requires a major outlay of concrete and can cost upwards of 40,000 USD per space. [49,50] Avoiding this expense can be a means to build more affordable housing in urban areas. Limiting dwelling unit size can also be an important, and often overlooked, carbon reduction strategy.[51,52] This can often be achieved through densifying the existing building stock and can be built into reporting through measuring emissions per capita rather than per floor area. Where new construction proceeds, cities may consider incentives such as density bonuses for lower carbon construction and regulations that include floor area maximums in addition to minimums. Where underground parking is eliminated, this would have to be accompanied by robust investment in alternative transportation options.

BUILDING ON EQUITY PATHWAYS



1. Develop regulations and incentives that support the retrofit of affordable housing, aging rental stock and public housing.

2. Make workforce development an essential piece of a construction waste salvage strategy, prioritizing training and jobs in demolition, salvage, and material processing. Build coalitions with trades and unions to maximize synergies between labour and environmental interests.

3. For new housing development, remove requirements for underground parking and ensure that cost savings are passed on to renters or buyers. Tie this to active transportation policy, ensuring that housing without on-site parking is adequately served by alternative, lower-carbon transportation modes.

4. Require reporting on embodied carbon to include equity indicators, for example measure carbon per capita rather than per square metre.
   - » Implement regulations for dwelling units with a maximum floor area per capita.

5. Acknowledge differential responsibility both locally and globally. The embodied carbon perspective offers an angle for municipalities to enhance their climate leadership through transparency about outsourced emissions and leveraging influence beyond their boundaries.

TOWER RENEWAL:
EMBODIED EMISSIONS HELP MAKE THE CASE FOR TRANSFORMING SOCIAL HOUSING

Post-war apartment towers form an essential supply of purpose-built rental stock in cities across Canada, housing over half of Canadian high-rise households. Many of these units serve lower income and marginalized populations, but their livability and affordability are increasingly threatened by rising utility costs and deferred maintenance. The Tower Renewal Partnership, a cross-sectoral collaboration of architecture, research and social purpose organizations, advocates for renewing these buildings through deep retrofits. The Ontario-based organization analyzes policy options across Canada, engaging with social housing agencies about their retrofit strategies.

Image courtesy: ERA Architects

Putting Tower Renewal into practice, ERA Architects is currently transforming the Ken Soble Tower, a once deteriorating 18 storey multi-residential building from 1967, into a model of renewed social housing. When CityHousing Hamilton was deciding how to address the decline of their oldest high-rise, they determined that a low energy retrofit would be the most cost-effective option; doing so provided access to low-carbon and housing renewal funding through the National Housing Strategy, the Federation of Canadian Municipalities, and the provincial government. With the project designed to a Passive House standard, operational GHGs have been modelled to decline by 94%. At the same time, a back of the envelope calculation shows that new construction would take 180 years to offset the carbon saved through building reuse. Improved occupant comfort and ventilation are also critical benefits for the residents sheltering in place through the Covid-19 pandemic.

> — *A back of the envelope calculation shows that new construction would take 180 years to offset the carbon saved through building reuse.*

The project was primarily motivated by creating healthy, resilient housing. However, Graeme Stewart, Architectural Principal for the Ken Soble Tower and one of the founders of the Tower Renewal Partnership, suggests that reducing embodied emissions helps make the case. When social housing agencies across the country confront decisions about their aging housing stock, avoiding embodied carbon offers an additional benefit on top of avoiding displacement of vulnerable populations and saving on construction costs through retrofits. Spillover benefits accrue beyond the individual buildings, as projects like this increase demand within a larger retrofit economy.

Foundations in Preservation: Building Reuse, Low Carbon Retrofits, Vertical Infill

Heritage preservation has been a persistent interest for cities and neighbourhood advocates for decades, if not centuries. Given this long history, the definition of heritage has expanded beyond turn of the twentieth century cast-iron towers and streetcar era bungalows to mid-century modern buildings. Even when buildings have not been officially designated as heritage, there is a widely recognized value to maintaining historic layers in the urban fabric. And retaining buildings extends beyond historic preservation to retrofit and adaptive reuse. Reuse can be a vehicle for reducing embodied carbon, neatly conveyed in the claim that "the greenest building is the one that is already built."[53]

BUILDING REUSE

Life cycle assessment is more commonly applied to new construction, however several studies have assessed the impact of retrofitting buildings, generally finding lower environmental impacts.[54] One study of a whole range of building conversions across the US found that in almost every case[h], reusing buildings reduced climate impacts compared to energy efficient new construction. Depending on the building type and grid mix, it can take from 10-80 years for new construction to compensate for climate impacts as compared to an upgraded existing building.[55,56] A study of a new conventional residential development in Finland revealed that over the 50-year time horizon relevant to climate targets, the emissions from a comparable renovation were 35% lower. In light of medium-term climate targets and the carbon spike produced with new construction, this research shows that new buildings simply do not provide a means to achieve climate goals.[57]

The Climate Heritage Network is developing a simple whole-building life-cycle assessment (LCA) tool that would allow municipalities or project teams to make the determination "to build or not to build" for themselves. The tool, planned for release in late 2021, will allow comparisons of the carbon impact of building reuse, green retrofits, and new construction.[58]

Limiting the construction of new floor area is virtually guaranteed to avoid emissions,[59-60] but clearly demand for new space will persist. Therefore, new construction could be leveraged to create a financial reward for building reuse. Incentives for retrofit and reuse could be funded through a tax or fee on embodied carbon for new development.

— *In light of medium-term climate targets and the carbon spike produced with new construction, this research shows that new buildings simply do not provide a means to achieve climate goals.*

[h] Except warehouse to multifamily residential because of the quantity and type of materials used to improve energy efficiency in multifamily housing.

— *Depending on the building type and grid mix, it can take from 10-80 years for new construction to compensate for climate impacts as compared to an upgraded existing building.*

Making reuse financially more attractive than new construction would offer significant leverage to avoid carbon expenditures. In addition to financing, zoning and development planning can be more actively leveraged to meet the expanded intent of reducing emissions. Zoning bylaws can incentivize the retention and conversion of zero lot line buildings by allowing additional uses or more density than would otherwise be approved in that location. Where development decisions are discretionary, building reuse can be given greater weight than other factors. To achieve substantive reuse rather than simple preservation of historic facades, reuse would need to be defined rigorously to include the structure, envelope, and other feasibly reusable components. Where buildings are preserved, full occupancy would deliver the greatest carbon benefit. For public and private building owners, this would depend on a commitment to strategic asset management.[60]

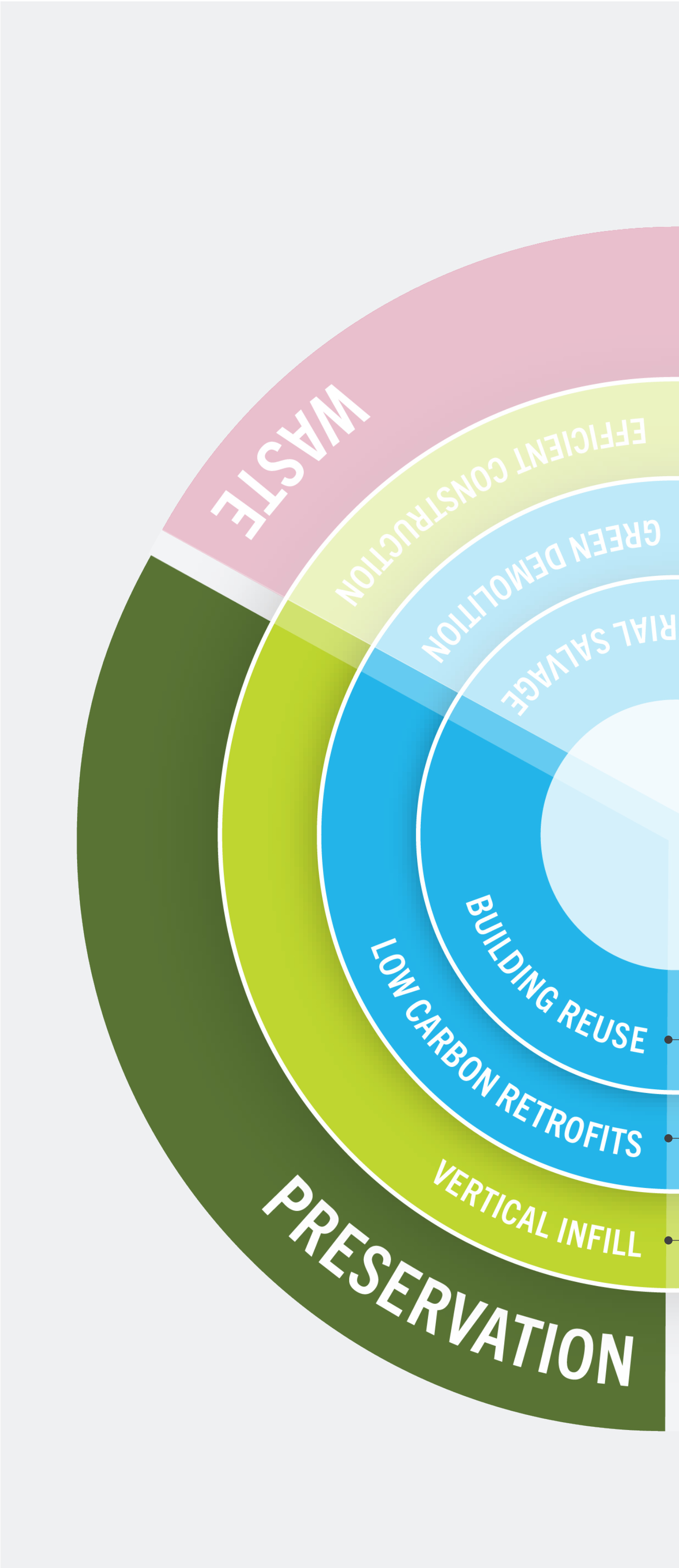
LOW CARBON RETROFITS

In renovations, materials matter. Using carbon intensive materials can undermine the benefit of retrofitting over building new.[55,61] This highlights a key opportunity for low carbon materials to be used in building retrofits. For example, residential retrofits could incorporate cellulose insulation and commercial retrofits could include lower carbon drywall and flooring. Replacing mechanical systems presents an opportunity to mitigate leaks and use newer refrigerants with lower global warming potential. Where whole-building life-cycle assessment (LCA) reporting is beginning to be required for new developments, it could also be required for major retrofits

VERTICAL INFILL

Another way to bridge the gap between demand for new space and building reuse is with vertical infill, or building on top of existing buildings. This is already common practice in some cities that are highly built out where real estate is at a premium. Where existing bearing capacity is adequate, this can be an efficient way to add new space. This type of infill helps to avoid the additional embodied carbon associated with new foundations and new infrastructure and can also be constructed with lower carbon materials.

BUILDING ON PRESERVATION PATHWAYS



1. Fund incentives for retrofits, adaptive reuse and preservation through a tax or fee on embodied carbon for new development.[i] Structure public funding for capital projects to incentivize renewal over new building.
   - When buildings are reused, facilitate full occupancy through alternative approaches to fulfilling accessibility requirements.
2. Leverage zoning and development planning for preservation beyond historically significant buildings. Make latent incentives for retaining existing buildings, such as greater floor area or zero lot line development, explicit. Create additional incentives by offering use changes such as retail at grade. Give building retention greater weight within the range of factors considered in conditional development decisions.
3. Support the use of low carbon materials for retrofits.
   - When public buildings are retrofitted, take the opportunity to lead by example by specifying low carbon materials.
4. Develop regulations and incentives that support low carbon vertical infill.

[i] This fee could begin as a flat price per square foot and then be refined as better life cycle assessment data becomes available.

THE FRIEDMAN BUILDING RENEWAL: PRESERVATION AS A GATEWAY TO REDUCING EMISSIONS

With its stark modernist façade, the Friedman building is a far cry from conventional notions of heritage. Yet, UBC saw an opportunity in retrofitting this building for 75% of the cost of a new build, transforming dingy anatomy labs from 1961 into a state-of-the-art physiotherapy training facility.

In 2006, when the project began, avoiding embodied emissions per se was not one of the project goals, though reducing construction waste was part of the plan for achieving a LEED Gold rating. In a 2010 review of the project, the Vancouver Heritage Foundation posed embodied energy[j] as a factor in considering the energy efficiency of replacing versus rehabilitating existing windows. The same review notes that reusing the building resulted in 1.5 million kg of waste diverted from the landfill, and avoided emissions of 822 tonnes of CO_2.

Funding for the project came from the UBC Renew Program, a UBC/Provincial/Federal partnership which extended the life of twelve buildings by an additional 40 years for just over half the cost of new buildings. The goals of the program were to preserve heritage buildings, address deferred maintenance, reduce environmental impacts and save money. In retrospect, maintaining the steel and concrete block also represented a significant savings of embodied carbon. This building did not broadcast its remarkable historic character or great potential for adaptive reuse, yet the project demonstrates how renovating quotidian buildings can offer real mitigation value.

Image courtesy: Acton Ostry Architects

[j] There is not a one-to-one correlation between embodied energy and embodied emissions because the energy source dictates the emissions levels, but they represent related concepts.

Opportunities to Deepen Knowledge

The emerging suite of embodied carbon strategies are promising, but they would benefit from deeper knowledge. The gaps listed here offer immediate opportunities for applied research, but these gaps should not stand in the way of developing policy now. Building on foundations in waste, equity, and preservation means that making existing policies more comprehensive and robust clearly delivers co-benefits.

WASTE

1. Evaluate the relative emissions impact of waste regulations and green demolition requirements.
2. Assess the emissions impact of material reuse versus improved material performance in new construction.
3. Develop efficient methods for rating salvaged materials so they can be used to their highest potential, for example as structural members rather than as finishes.
4. Determine barriers to green demolition requirements for commercial construction.

EQUITY

1. Evaluate the embodied carbon of underground parking.
2. Analyze the community economic development potential of large-scale salvage and reuse.
3. Identify opportunities and methods to re-purpose common, off-the-shelf lower carbon building materials that could expand market opportunities and facilitate ease of construction.
4. Review, establish and synthesize equity indicators for emissions such as per capita carbon.

PRESERVATION

1. Develop a reference standard for embodied carbon by building type and assembly to inform municipal fee structures.
2. Develop economic analysis of adaptive reuse and asset management for the development industry.
3. Assess the economic and emissions implications of a shift toward retrofits over new building against a baseline of typical retrofit volume.
4. Document and define “latent incentives” that can be leveraged to reduce embodied carbon.

BIG PICTURE LIFE CYCLE ASSESSMENT (LCA) GAPS

1. Develop rules of thumb based on better LCA data to inform order of magnitude decisions where detailed LCA is not feasible. Include evaluation of new build versus retrofit.
2. Determine awareness of life cycle assessment (LCA) and environmental product declarations (EPDs), and their strengths and weaknesses among policy-makers to improve decision-making.
3. Determine the typical degrees of difference between design and as-built LCAs, taking into consideration decisions made during construction.
4. Measure global warming potential over a realistic timeframe of use, accounting for the frequency of tenant improvements.

(CONTINUED)

INTERACTIONS BETWEEN EMBODIED AND OPERATIONAL EMISSIONS

1. Develop integrated models for valuing operational and embodied carbon together. Typically this is done in different types of models with inconsistent inputs.
2. Determine the embodied carbon effects of building electrification policy, for example the impact of refrigerants in heat pumps commonly sourced for fuel switching.
3. Determine how to consistently include mechanical, electrical and plumbing systems in whole building life cycle assessment.

Conclusion

As a new climate policy area, embodied carbon can be daunting to tackle. Building on existing foundations in waste, equity and preservation will make it more feasible while also delivering co-benefits. Even where precise emissions accounting is impractical, thinking through an embodied carbon lens is useful in evaluating order of magnitude trade-offs.

To fulfill the need for affordable housing, retrofit existing high-rise housing rather than building new. To maintain historical character in cities, pursue robust adaptive reuse. To reduce waste going to the landfill, expand material salvage and reuse. These strategies to bring embodied carbon from the margins to the mainstream are not necessarily simple, but within the current policy landscape they are achievable. They all contribute to maximizing the value of the carbon already sunk into the built environment. And if they are taken to their full potential, they can lay the groundwork for the more transformative change implied in tackling embodied carbon. The building industry will not be decarbonized — nor will cities or countries reach their net-zero targets - unless these underlying emissions are eliminated.

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Appendix A: Stakeholders Consulted

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Appendix B: Leading Embodied Carbon Policy in BC and North America

BRITISH COLUMBIA

CITY OF VANCOUVER

The City of Vancouver has set a target of reducing embodied emissions by 40% by 2030 as "Big Move 5" in its Climate Emergency Response from 2019 and is developing mechanisms to achieve that.

The Green Buildings Policy for Rezonings requires that all rezoning applications pursue one of two low emissions pathways. One of the pathways requires embodied emissions reporting as part of a larger package. The reporting requirement covers "cradle-to-grave" impacts for envelope and structural components including the parking structure. The City requests a breakdown of impacts by product category, material type, life-cycle stages and activity. This detailed information is intended to inform future policy development.

The Green Demolition Bylaw includes a deconstruction requirement for pre-1910 and heritage homes and a reuse and recycling requirement for pre-1950 homes. For houses falling under the recycling requirement, materials salvaged for reuse are given credit for five times the recycling volume. A permit fee of $14,650 is refunded if the requirements are met. The City plans to expand the bylaw to all homes when there is adequate market capacity for recycling and salvaged materials.

UBC

UBC sustainability policies will reduce embodied emissions through the following strategies:

- Construction waste diversion
- Life cycle assessment and incremental reductions in embodied carbon
- Improved material extraction and reuse practices
- Design service life requirements
- Deconstructability

The UBC Climate Action Plan 2020 focuses on energy supply and operational energy efficiency. In addition, the plan identifies that Scope 3 emissions, which include building lifecycle, exceed Scope 1 and 2 emissions from Vancouver campus buildings. Scope 3 emissions are reported but they are not addressed in UBC's GHG targets.

The UBC Zero Waste Action Plan aims to reduce waste disposal through minimizing waste generation and increasing diversion. In 2014, the university created a waste diversion target of 90% for major construction projects. As a longer-term action, the plan proposes incorporating waste diversion requirements into Development, Building and Occupancy permitting processes. The Green Building Action Plan establishes that 100% of construction and demolition waste should be diverted from the landfill by 2035. The waste management plan template requires estimated waste generation and diversion for all of the common construction materials. Waste diversion is tracked, but the outcomes of diversion are not. According to the UBC LEED Implementation Guide, all projects that fall under the LEED Gold mandate must conduct a whole building life cycle assessment and follow "leadership extraction practices" for raw materials. Major renovations may pursue the "historic building reuse" option instead of whole building LCA.

In the UBC Green Building Action Plan: pathway to a net positive campus, embodied emissions are considered through the holistic view of the environmental footprint of materials and resources.

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For institutional buildings, reporting and incremental reductions will be required for embodied carbon and Environmental Product Declarations will be required "as they become more available," though a timeline is not laid out. Details should be addressed in the upcoming Policy for Embodied Carbon in Buildings.

For both institutional and residential buildings, UBC plans to support the development of the circular economy through material reuse during a building's lifetime, though there are no implementation details. Some short-term priority actions for institutional buildings include: reviewing benchmarks for construction waste, developing guidelines for deconstructability, and developing a realistic approach to using life cycle assessments for new construction based on experience with Brock Commons Tallwood House. In the residential sector, an additional short-term priority is to implement design service life requirements for new buildings. The UBC Technical Guidelines for institutional buildings already require that wood and concrete structures be designed for a service life of 100 years.

METRO VANCOUVER

Metro Vancouver is developing Climate 2050, a strategy to guide the region's climate policy and action. Metro Vancouver plans to replace its five-year reporting cycle with annual GHG reporting. This will include a consumption-based emissions inventory which would expand the current inventory to include Scope 3 emissions. Metro Vancouver is engaging the province and municipalities as it reviews accounting methods including the Global Protocol for Communities.

According to a draft solid waste management discussion paper from June 2020, Metro Vancouver already views waste management partially through an embodied emissions lens and has developed multiple policies and initiatives to address that.

- The National Zero Waste Council was initiated by Metro Vancouver to advance waste prevention and the circular economy across Canada in collaboration with business, industry, communities and governments. The Construction, Renovation and Demolition Working Group is focusing on building capacity for deconstruction, with one of the benefits being a reduction in embodied emissions.
- Recycling and reuse requirements for demolition and construction are now in place in eight municipalities across Metro Vancouver: Coquitlam, New Westminster, City of North Vancouver, Port Moody, Surrey, Richmond, Vancouver, and West Vancouver. Five of them require various forms of a "green demolition fee" which is refundable based on the level of compliance. Working with municipalities, Metro Vancouver developed a sample municipal bylaw for construction and demolition waste recycling.
- The Carbon Price Policy considers GHGs in cost/benefit analyses for corporate projects.
- Metro Vancouver and Lafarge Canada entered into an agreement to use water treatment and solid waste residuals in cement manufacturing to reduce emissions.

Proposed strategies to reduce embodied emissions in construction include:

- Considering embodied emissions in construction procurement.
- Eliminating sales tax for the reuse and repair of goods.
- Using buildings as material banks.
- Employ Cradle to Cradle certification which prioritizes products that minimize disposal.

Metro Vancouver introduced a disposal ban on clean wood July 1, 2015. As of 2017, a 50% surcharge for tipping applies if over 5% of a garbage load is clean wood. Clean wood recycling has been added to regional facilities.

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The wood is recycled into landscape mulch, compost, alternative industrial fuels. Wood is sometimes reused in construction, however reuse is not tracked. Due to a lack of wood processing capacity, Metro Vancouver relaxed the surcharge from December 2018-September 2019. (Integrated Solid Waste and Resource Management Plan Biennial Report, January 2020)

Metro Vancouver adopted a Sustainable Infrastructure and Buildings Policy effective October 2018 which applies to new construction and major renovations of its own facilities. Infrastructure includes water and wastewater treatment plants, transfer stations and other industrial facilities. While requiring that construction projects meet specified levels in green rating systems, they also establish priority performance objectives to be weighed in all projects. Those relevant to embodied emissions include: reducing embodied energy of construction materials, reducing lifecycle GHG emissions, facilitating access to low carbon and active transportation, using reclaimed or recycled materials, diverting construction and demolition waste from landfills.

CANADA: OTHER LOCAL

TOWNSHIP OF DOURO-DUMMER SUSTAINABILITY DEVELOPMENT GUIDELINES

Program participants must use the Builders for Climate Action embodied carbon calculation tool to compute the embodied impact of building materials. When the project achieves the targeted emissions reductions, the permit fee is reduced.

CANADA: OTHER PROVINCIAL

QUÉBEC WOOD CHARTER

Promotes the use of wood based on climate change mitigation for publicly funded projects. The charter also requires the reporting of embodied emissions through a comparative analysis to determine the performance of a project's mitigation strategies compared to a baseline scenario.

ONTARIO'S PLAN FOR INCORPORATING LCA

Ontario's Long-Term Infrastructure Plan from 2017 proposed that Ontario use LCA results to determine whether it was better to retrofit or build new. However, that plan has been superseded.

CANADA: FEDERAL

PUBLIC SERVICES AND PROCUREMENT CANADA

Whole-building LCA is required for new projects.

US: LOCAL

CITY OF PORTLAND CONCRETE EPD POLICY

All Portland Cement Concrete used in Portland must comply with the EPD standards set by the city's material testing lab or have third party verification. Starting April 1, 2021, contractors using PCC material must also submit a Global Warming Potential (GWP) score bellow the city's maximum allowable content.

CITY OF PORTLAND DECONSTRUCTION ORDINANCE

A certified deconstruction contractor must deconstruct primary dwelling structures that were built in or before 1940 and primary dwelling structures with historical significance. Salvaged material may be sold, donated, or reused on site.

BEND, OREGON COMMUNITY CLIMATE ACTION PLAN

Uses an incentive program based on concrete EPD calculations to encourage developers to use low carbon concrete. Overall the city plans to use 30% low carbon material in 50% of municipal projects.

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MARIN COUNTY LOW-CARBON CONCRETE CODE

The program aims to reduce embodied emission in the built environment through low carbon concrete specification programs. Contractors must submit a complete "Low Carbon Concrete Compliance Form" that is reviewed by the municipal building department.

PALO ALTO DECONSTRUCTION ORDINANCE

All residential and commercial projects must be deconstructed if a structure is being completely removed. Building materials must be delivered to a certified green processing facility and utilized by Green Waste of Palo Alto, a municipally run salvage and recycling system.

US: REGIONAL

SOUND TRANSIT AUTHORITY

A minimum of 75% of the cast-in-place concrete mix must transmit an EPD in accordance with the Carbon Leadership Forum's Product Category Rules. Additionally, contractors must perform a benchmarking analysis of the concrete's GWP according to the National Ready Mix Concrete Association's Pacific Northwest Regions standards.

US: STATE

BUY CLEAN CALIFORNIA ACT

State agencies awarding construction contracts will be required to evaluate the Global Warming Potential (GWP) of structural steel, concrete reinforcing steel, flat glass, and mineral wool board insulation in accordance with standards set based on a review of Environmental Product Declarations (EPDs). As of January 2020, contractors must submit material EPDs as evidence of the embodied emissions. It is likely that other materials will be added in the future. Requirements are introduced incrementally, moving from voluntary to mandatory submission of EPDs and compliance with GWP thresholds which will come into force in July 2021.

THE NEW YORK STATE LOW EMBODIED CARBON LEADERSHIP ACT

The objective of this legislation is to base state procurement decisions for public infrastructure projects on the embodied carbon content of concrete. Bids for state infrastructure projects with the lowest GWP will be selected if they meet the state's structural criteria and do not add to the cost of procurement relative to conventional concrete. Additionally, concrete bids with material that sequesters carbon will be given selection priority.

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