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More Housing, Less Carbon: Policy Principles to Reduce Embodied Carbon in Canada's Housing Sector

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Executive Summary

How can Canada build millions of new homes over the next decade to address the housing crisis, while reducing embodied carbon in housing construction to address the climate crisis?
The short answer: housing must be built differently.

Current climate plans overwhelmingly focus on reducing operational energy use in buildings (heating, cooling, and lighting) or retrofitting existing housing stock rather than on carbon emissions generated by new construction, ignoring the environmental impact of different construction methods and materials. Technical solutions are readily available; the challenge is how to translate these solutions into public policy.

This report proposes four policy principles to reduce embodied carbon in Canada's housing sector, based on the latest academic research and lessons from leading jurisdictions in Canada, Denmark, France, the United Kingdom, and the United States.

Focus on provincial policy, not federal or municipal

Provinces are responsible for the most important elements of housing construction and have the legislative authority, regulatory capacity, and fiscal resources to lead.

Focus on more intensive use, not reuse

Governments should update building codes and land use regulations to encourage compact infill development and multi-unit housing.

Focus on sectors, not end-products

Governments must take a sectoral approach, raising standards industry-wide, not simply for individual projects.

Focus on building design now, not future technologies

Governments should prioritize space-efficient design that can be implemented immediately, rather than long-term, unproven technologies.

Most new housing projects are fundamentally unsustainable to build, using large amounts of primary resources, and therefore emitting large amounts of embodied carbon.

1. Introduction

Across Canada, governments at all levels are grappling with the dual crises of housing and climate change. The Government of Canada has committed $82 billion to increase housing supply nation-wide, while separately promising to reduce greenhouse gas (GHG) emissions by 45% below 2005 levels by 2030.[1] In 2022, Ontario promised to build 1.5 million homes over the next ten years, while committing to reduce emissions by 30% below 2005 levels by 2030.[2] In 2023, British Columbia committed $12 billion for housing over the next ten years, and $3.4 billion to reach net-zero emissions by 2050.[3] Quebec is developing similar housing targets and has committed to reducing GHG emissions 37% by 2030.[4] And in 2023 Alberta committed $9 billion for housing over the next decade and set an "aspiration" to become carbon neutral by 2050.[5]

Cities are also making big promises. Toronto aims to build 285,000 new homes by 2031, while promising a 65% emissions reduction by 2030.[6] Vancouver has plans to build 72,000 new homes over the next ten years, while reducing emissions 50% by 2030.[7] Quebec City hopes to build 80,000 new housing units by 2040, while reducing emissions 45% by 2030.[8] And Calgary has committed to building 3,000 housing units per year while reducing emissions 60% by 2030.[9]

None of these targets are achievable or reconcilable if prevailing methods of housing construction continue. Research in both the UK and Australia indicates that planned increases in housing construction challenge the viability of climate commitments.[10] Current climate plans overwhelmingly focus on reducing operational energy use in buildings (heating, cooling, and lighting) or retrofitting existing housing stock rather than on reducing emissions generated by new construction, ignoring the environmental impact of different construction methods and materials.

The Canada Mortgage and Housing Corporation (CMHC) estimates that 3.5 million new, additional housing units will be required by 2030 to keep up with population growth.[11] The problem is, most new housing projects are fundamentally unsustainable to build, using large amounts of primary resources, and therefore emitting large amounts of embodied carbon. As of 2018, construction accounted for approximately 90 megatonnes (Mt) of GHG emissions nationally. Scaling up housing construction without changing the way housing is built will lead to 30–40% of Canada's 2030 GHG budget being consumed by new housing construction.[12]

This report aims to answer the question: "How can Canada build millions of new homes over the next decade *and* address the climate crisis by reducing embodied carbon in housing construction at the same time?" The findings and recommendations here are based on a review of the latest academic research, as well as a scan of policy frameworks in leading national and international jurisdictions.

First, a brief overview of how embodied carbon factors into GHG emissions and how the housing and climate crises intersect, including estimates of how much new housing Canada needs to build, and how much emissions need to be reduced to meet existing policy objectives. A review of the current policy landscape follows, investigating the legislative and regulatory environment that governs housing development and climate policy in Canada. Third, a survey of the literature identifies leading examples of national, subnational, and local policy frameworks that target housing and embodied carbon in Canada, Denmark, France, the United Kingdom, and the United States. Finally, recommendations apply these international lessons to reduce embodied carbon in Canada's housing sector.

2. Background: Embodied Carbon and Housing

What are *embodied carbon emissions?* How much do they contribute to global GHG emissions? And how does housing construction impact these emissions? These questions have been studied at length by the engineering and scientific community but are rarely discussed amongst members of the policy community.

2.1 Understanding Embodied Carbon

Embodied carbon (or more accurately, embodied greenhouse gas) refers to emissions that occur during the upstream processes of creating a product. In the construction sector, this includes emissions created by mining and supplying raw material and transporting it to the manufacturing plant, any related manufacturing processes, transportation of materials to the construction site, and energy consumption by construction machinery onsite.

The European Standard EN 15978 classifies embodied carbon emissions from construction into different stages, represented by letter–number codes corresponding to a building's life cycle (Figure 1).[14] Stages A1–A3, referred to as the "product" stage, and A4–A5, the "construction process" stage, capture upfront emissions before and during building construction. After construction, during the building's "use" stage, embodied carbon will continue to increase as part of regular maintenance, repairs, and refurbishments (Stages B2–B5) — sometimes referred to as *recurring* embodied GHG.[15] This is distinct from *operational* carbon emissions (Stages B6–B7), generated by day-to-day heating, cooling, and lighting.

Embodied Carbon vs Operational Carbon

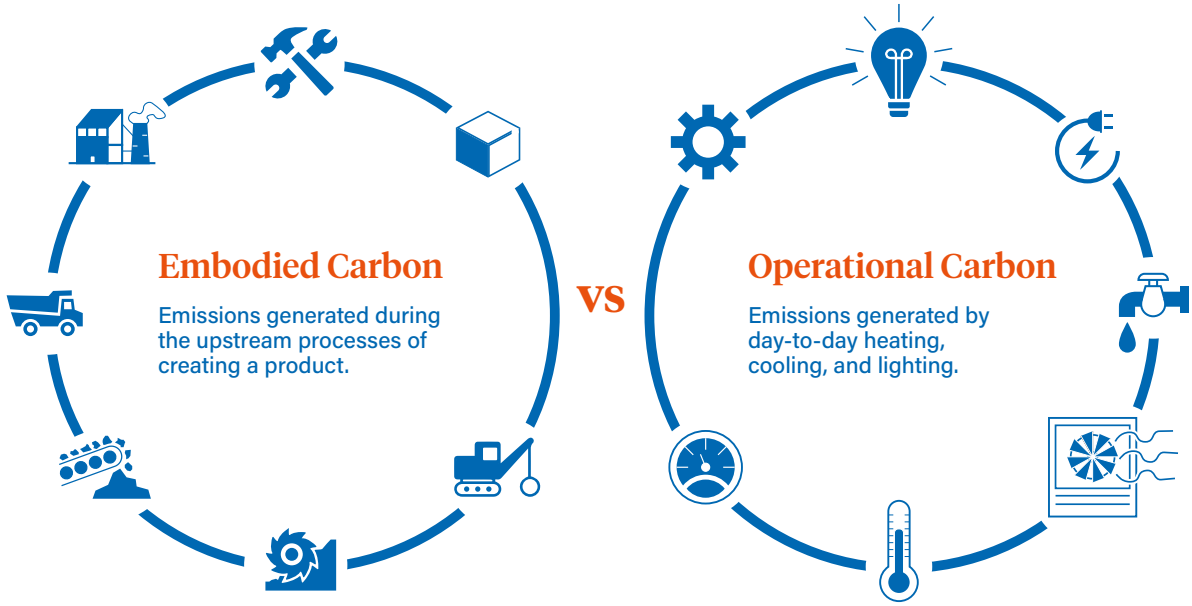
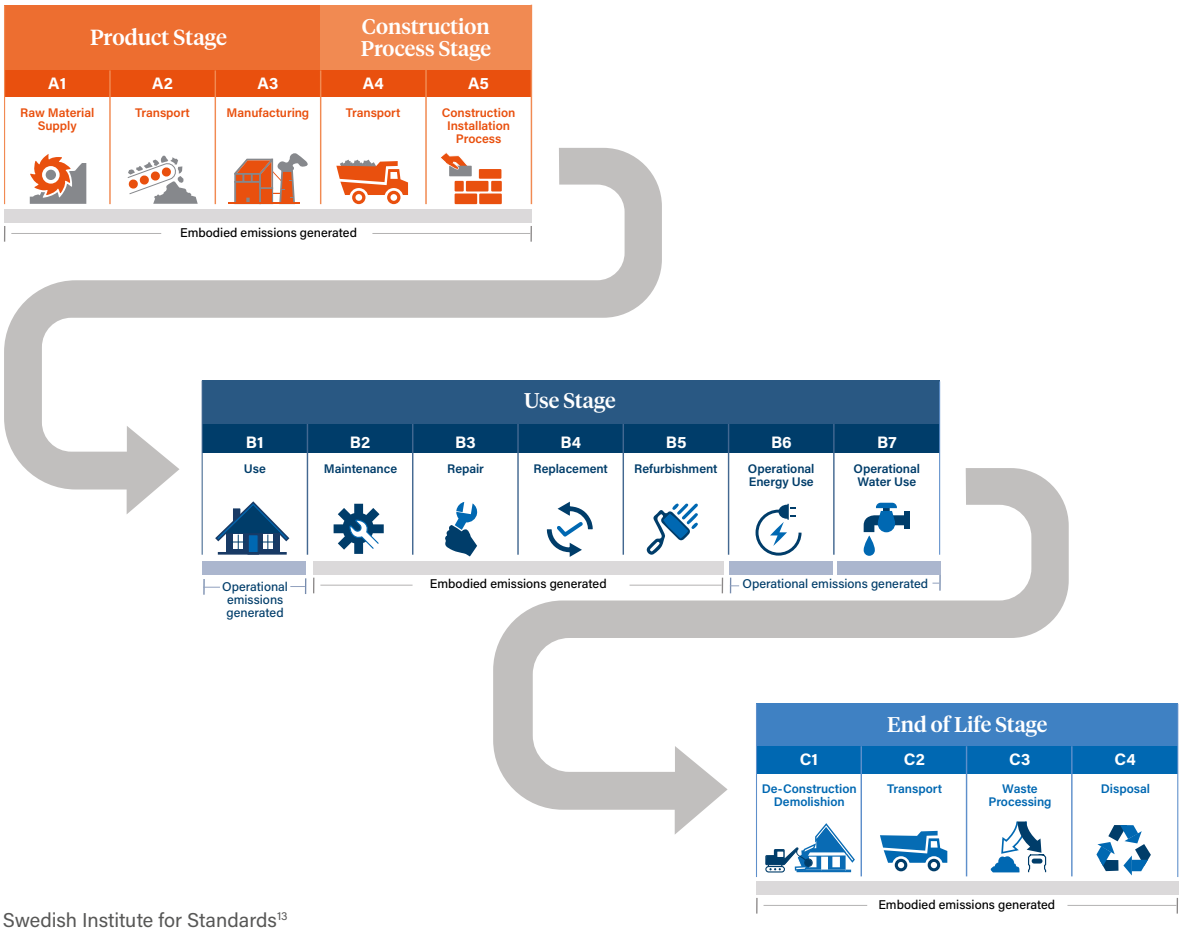


Figure 1: Building Life Cycle



Source: Swedish Institute for Standards[13]

At the end of a building's lifespan, demolition and disposal (Stages C1–C4) may release further emissions but also provide opportunities for material recovery and reuse.

Approximately 80–90% of a building's upfront embodied emissions are generated by mining and materials manufacturing (A1–A3), the remainder by transport and construction energy (A4 and A5). Emissions from materials manufacturing are created by chemical processes used to turn raw materials into construction materials (e.g., iron to steel, limestone to cement), as well as the burning of fossil fuels to create the high temperatures that enable these chemical reactions.

Calculating embodied emissions associated with use stages, such as maintenance and refurbishment, remains challenging as it depends on what timeframe is considered (the longer the time, the more materials are used). End-of-life emissions receive less attention and are even more difficult to calculate given the long life of buildings and the high uncertainty of what will occur potentially 50+ years in the future, when a building is torn down.

2.2 Global Impact of Embodied Carbon

Materials production and consumption are important contributors to global annual GHG emissions. In 2015, material production accounted for 23% of global GHG emissions, up from 15% in 1995.[16] Cement production and steel manufacturing, in particular, make up 8% and 7–10% of annual global emissions, respectively.[17]

Moreover, increases in total material production far exceed improvements in manufacturing efficiency. Steel manufacturing, for example, produces 3.2 times fewer GHG emissions than 100 years ago, yet production has increased 17-fold.[18] Similarly, the rapid increase in wood harvesting — a product often considered carbon neutral or even carbon negative — produces 3.5–4.2 gigatonnes (Gt) of annual GHG emissions globally (more than 8x Canada's total annual GHG emissions).[19]

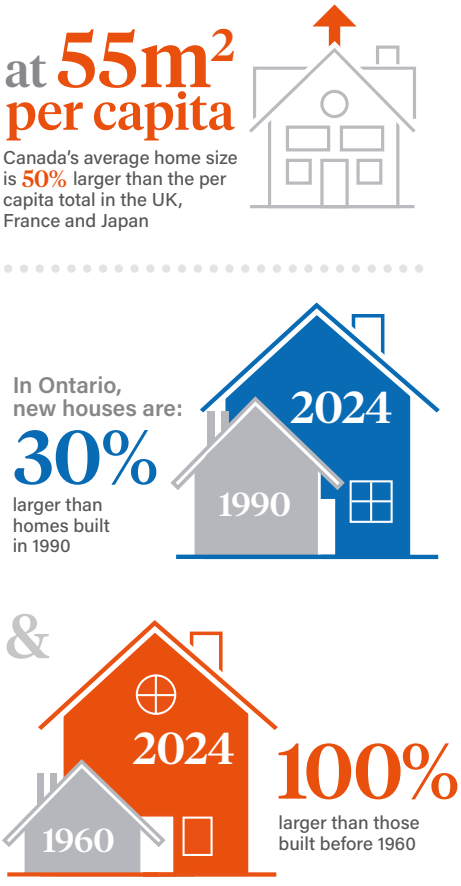
Until quite recently, the focus of sustainable building research and policy, particularly in North America, was on managing operational energy use and associated emissions intensity. Building lifecycle assessments in the early 2000s concluded that, over decades of use, the embodied greenhouse gas impact from construction was marginal compared to the operational emissions from heating, cooling, lighting, and powering buildings.[20] But as the transition to low-carbon energy sources such as wind and solar accelerates and buildings become more energy efficient, the relative share of embodied carbon in the lifetime emissions of buildings has begun to increase. It is now estimated that over the next 50 years, the embodied emissions of new buildings will make up between 20% and 50% of lifetime emissions.[21]

2.3 Embodied Carbon and New Housing in Canada

New housing construction is a major driver of resource consumption and embodied carbon emissions in Canada. On average, 77% of residential construction dollars in Canada go toward new construction, rather than refurbishment or renovation.[22] This drives up embodied carbon emissions because, by global standards, Canadians tend to build very large, single-family homes and live in single- rather than multi-unit buildings.[23] Canadian homes average more than 55m^2 per capita, roughly 50% larger than per capita total in the United Kingdom, France, and Japan; only Americans live bigger.[24] And the trend is worsening: in Ontario, for example, new houses are 30% larger than homes built in 1990 and 100% larger than those built prior to 1960.[25]

To give a sense of the scale of the problem, consider that every new single-family detached house in Toronto creates an average of 62,800 kg CO_2e from materials used in construction (Stages A1–A3), plus 9,420 kg CO_2e from transportation and onsite construction emission (Stages A4–A5).[26] Extrapolating from these figures, building 5.8 million new homes by 2030, as recommended by CMHC, would lead to 419 Mt CO_2e of embodied GHG emissions using current practices — equivalent to 95% of total allowable economy-wide emissions in 2030 under current federal commitments — without even accounting for operational energy needs in the buildings or the embodied emissions that would be generated by construction of new infrastructure, like roads and sewers, to service new housing supply. Of course, this total is exaggerated because Canada builds a mix of housing types, not just single-family homes. In fact, the percentage of single-family homes constructed in the last two decades has fallen from 62% of housing construction in 2000 to 32% in 2022.[27] But the point remains: for Canada to meet both housing and climate commitments, housing must be built differently.[28]

Canadians' homes are large and getting bigger



Until very recently, housing and climate have been understood as two distinct policy domains.

From an embodied carbon perspective, building better means designing differently and building less space on average per capita. Good design means constructing buildings that are boxy in shape, with straight load paths that avoid materially inefficient transfer slabs (usually made of steel reinforced concrete) and use floor space efficiently, minimizing underused circulation space in and between units. Most importantly — and perhaps controversially — good building design means smaller basements or, better yet, no basements at all. Basements are the most GHG-emission-intensive area of buildings because soil and water loading require much thicker walls. Hence full height basements in single-family homes and underground parking garages in multi-unit buildings, which, in addition to their climate impacts, do nothing to increase housing stock, should be avoided. In short, the technical solutions are readily available; the challenge is how to render these solutions in public policy.

3. Current Policy Landscape

Neither housing nor climate change is explicitly mentioned in the *Constitution Act, 1867, 1982,* meaning that jurisdiction over housing and climate policy is shared, and often contested, by different orders of government. Responsibilities have evolved through a combination of judicial interpretation and political negotiations. Moreover, until very recently, housing and climate have been understood as two distinct policy domains — it is rare, for example, for a single federal or provincial ministry to be simultaneously responsible for both housing and climate portfolios.[29] The result is a convoluted legislative and regulatory environment that complicates policymaking in both areas.

3.1 Housing Policy

Canada's housing spectrum encompasses a broad range of housing types, from temporary emergency shelters to transitional/supportive housing to public or social housing to private rental housing and ownership. No single government authority oversees all forms of housing supply. Responsibility is instead shared among federal, provincial/territorial, and municipal governments to different degrees across the country.[30]

Each province/territory has its own set of legislative and regulatory frameworks for housing that regulate the actions of local governments. This includes land use regimes (e.g., *Ontario Planning Act*), building codes and standards (e.g., B.C. Building Code), and supply strategies (e.g., Saskatchewan Housing Action Plan). In addition, provinces/territories make rules that indirectly impact housing construction, such as tax policy (e.g., land transfer taxes, sales tax rebates), development charges (e.g., permit fees, density payments), accreditation (e.g., trade certifications, contractor licensing), labour standards (e.g., health and safety, minimum wage), infrastructure (e.g., roads, water supply), and real estate law (e.g., title registration, property assessment).

Provinces/territories also play a large role in new housing supply through direct funding and financial incentives. For example, most provinces/territories own and operate their own public housing agencies (e.g., Manitoba Housing Authority, Nova Scotia Provincial Housing Agency, Newfoundland and Labrador Housing Corporation).[31] They also offer targeted grant programs to incentivize private home construction, such as British Columbia's Secondary Suite Incentive Program, which offers homeowners up to $40,000 to create new secondary suites on their property.[32]

Municipalities have delegated regulatory authority over land use and building standards, but only within the legal and regulatory confines set by provincial governments.[33] For example, development charges in Ontario must follow fee schedules laid out in the *Development Charges Act*.[34] Similarly, Montreal and other Quebec municipalities may only levy property taxes on two categories of residential property — those with at least six dwellings, or those with fewer — according to the provincial *Act Respecting Municipal Taxation (loi sur la fiscalité municipal)*.[34]

As a result, municipal governments have neither the legal autonomy nor the fiscal capacity to drive new housing construction on their own. Although municipalities routinely experiment with a variety of innovative land use planning, financing, and partnership schemes to encourage or subsidize new housing construction — for example, the Downtown Calgary Development Incentive Program, which aims to convert 665,000 square feet of empty office space into 700 housing units, or Toronto's Housing Now initiative, which aims to build 10,000 affordable rental homes on city-owned lands — ultimately, any municipally led housing initiative inevitably requires either amendments to provincial planning legislation or formal funding partnerships with other orders of government.

The principal role of the federal government in housing policy is financial, functioning as regulator of the housing market, mortgage insurer of last resort, and funder of provincial and local housing programs. It is also responsible for First Nations housing. Most of these functions are undertaken by the CMHC, a crown corporation established in 1946 whose mandate, as defined in the *National Housing Act,* is to promote the stability, "efficient functioning, and competitiveness of the housing finance market."[36] The CMHC is accountable to Parliament through the Minister of Housing, Infrastructure, and Communities.

In 2019, the Liberal government announced a $22 billion National Housing Strategy, which aims, among other priorities, to fund the construction of up to 90,000 new affordable housing units.[37] In most cases, such as the $7.5 billion Canada Community Housing Initiative to expand and renovate provincial social housing units, federal funding flows through federal–provincial bilateral agreements. To a lesser extent, the federal government occasionally provides direct funding to municipalities, as seen with the Rapid Housing Initiative, which transferred $2.5 billion to municipalities for urgent housing needs in response to COVID-19, as well as the $4 billion Housing Accelerator Fund, to which municipalities can apply directly. The federal government also indirectly — and sometimes, unintentionally — influences housing construction through decisions taken in other areas of federal jurisdiction, such as monetary policy (e.g., interest rate and inflation targets), tax policy (e.g., mortgage interest deductions, first-time home buyer incentives, GST rebate on new rental construction), or investments in social infrastructure (e.g., community, cultural, and recreational facilities) and Indigenous services.

3.2 Climate Policy

Jurisdiction over climate policy, and environmental policy more generally, is hotly contested in Canadian politics. Like housing, climate change is not explicitly listed in the *Constitution Act, 1867.* Various sections — for example, Sec. 92.10 (local public works), 92.13 (property and civil rights), and 92A (non-renewable natural resources, forestry, and electrical energy) — plainly grant provinces jurisdiction in several important areas of climate policy. After all, infrastructure projects such as roads, highways, and transit systems, the built environment, mining, oil and gas, and energy production are important sources of carbon and other GHG emissions.

However, other sections of the *Constitution Act 1867* — such as Sec. 91.1A (Crown lands, including national parks), 91.2 (international and inter-provincial trade and commerce), 91.3 (taxation), 91.10 (shipping and ports),

91.12 (fisheries), 91.27 (criminal law), and 132 (foreign treaties) — could be interpreted as granting the federal government principal jurisdiction over climate policy. Thus, it often falls to the courts to step in to provide clarity. For instance, in 2021, the Supreme Court of Canada ruled on a reference case that confirmed the constitutionality of the federal carbon pricing law as a matter of national concern, over the objections of several provinces, under the Constitution's "peace, order and good government" clause.[38]

Even in cases where federal jurisdiction is limited by the courts, Ottawa still holds considerable *de facto* jurisdiction on environmental issues via the federal spending power. That is, even if the federal government cannot pass laws in areas deemed provincial jurisdiction, it can still set conditions on how provinces spend federal funding. As a result, most federal climate action comes in the form of spending programs such as the Net-Zero Accelerator Fund, the Net-Zero Challenge for Large Emitters, the Low Carbon Economy Fund, the Natural Climate Solutions Fund, the Climate Action and Awareness Fund, and the Zero Emission Transit Fund, to name just a few.

The federal government is also involved in standard setting and regulatory harmonization, publishing clean fuel regulations, energy efficiency standards, and certification schemes (e.g., Energy Star® appliances and building materials). Most relevant to housing construction is the National Building Code (or National Model Code) published by the federally funded Canadian Board for Harmonized Construction Codes, under the auspices of the National Research Council of Canada. Although the National Building Code is non-binding, it forms a model for provinces to adopt or adapt and integrate into their own codes as minimum legal requirements for construction practices and the built environment.

For their part, municipal governments, particularly large urban municipalities, provide a broad range of services in areas that impact GHG emissions, including roads and highways, transit and active transportation, zoning and urban design, building permits, parks and forestry, and in many cases, local energy distribution.[39] Yet, as is the case with housing policy, funding is a major impediment to municipally led decarbonization efforts. Municipalities are heavily dependent on a narrow set of revenue sources, largely property taxes and user fees, that are rarely sufficient to meet cities' aspirational climate targets. As a result, municipalities typically focus on small-scale emissions reduction projects and rely heavily on provincial and federal governments for support.[40]

The upshot of this jurisdictional maze is that federal, provincial/territorial, and municipal governments generally pursue separate climate agendas based on their own interpretations of relevant jurisdictions, with minimal coordination or alignment — especially embodied carbon emissions. The 2030 Emissions Reduction Plan, which commits the federal government to reduce Canada's overall GHG emissions 40–45% below 2005 levels by 2030, focuses on energy retrofits, incentives for zero-emission vehicles, a cap on oil and

Based on current construction practices, massive growth in new housing construction will only lead to massive increases in embodied carbon emissions.

gas sector emissions, and investments in renewable energy. Embodied carbon is mentioned just nine times in the 240-page report, chiefly "as a key opportunity to further lower emissions in the buildings sector" that is not accounted for in estimates of current building sector emissions.[41] Similarly, the federal government has committed to publish a net-zero emissions National Building Code by the end of 2024, but it will be focused on energy efficiency of operations, not new construction.[42]

4. Mitigation Strategies and Policy Instruments

To date, the federal government has released just one emissions reduction plan that explicitly targets embodied carbon, specific to concrete production (which we return to in Sec. 5). Emission reduction plans for other major construction materials (e.g., steel) are in development but moving slowly. No provincial government has published anything similar, whether for housing construction or other industrial sectors. What, then, might targeted mitigation strategies to reduce embodied carbon actually entail, and what policy instruments could be used to realize these strategies?

4.1 Mitigation Strategies

An embodied carbon mitigation strategy refers to a technical or design choice that leads to a substantial reduction in material and energy use, and therefore embodied carbon emissions. The literature identifies several types of mitigation strategies (Table 1).

1. Intensive Use: Designing buildings more efficiently, with smaller floor plans, reduces the quantity of material needed for construction, thus reducing embodied carbon emissions.[44] Currently, few existing construction standards, land use policies, or building programs in Canada explicitly employ this strategy to target embodied carbon emissions.[45]

2. Lifetime Extension: The embodied carbon of refurbishing a building is roughly one-third of building new.[46] Building standards and technical regulations could require the completion of lifecycle assessments to improve material and component durability, or new research and capacity-building initiatives could enhance material and component durability using new and improved lifecycle assessment methodologies. Moreover, legislative or regulatory controls could prohibit the demolition of still-functional buildings.[47]

Table 1: Types of Embodied Carbon Mitigation Strategies

Strategy	Action	Example
1. Intensive Use	Use space more efficiently	Single stair access to reduce hallways
2. Lifetime Extension	Extend the life of existing structures	Refurbishment of existing buildings
3a. Light-weight Design	Use less material to build	Column alignment to reduce transfer slabs
3b. Low-carbon Materials	Use less carbon-intensive materials	Cellulose instead of XPS insulation
4. Reuse	Reuse building components	Reuse of brick walls
5. Reduce	Reduce construction waste	Prefabrication
6. Recycle	Use recycled materials	Recycled steel

Source: Adapted from Hertwich et al., 2019.[43]

3a Light-weight Design: Close attention to the shape, height, and depth of structural components (e.g., spacing between columns), as well as reducing the load that must be supported by other parts of the structure, enables builders to use less material to accomplish the same function. This includes aligning columns to reduce transfer slabs, reducing underground construction, reducing the weight of concrete slabs by using proprietary void systems, I-beams instead of rectangular beams, or structural lightweight concrete made from lighter aggregates — or other lighter-weight materials, such as wood.

3b. Low-carbon Materials: New technologies, such as low-GHG concrete (i.e., cement replacement with ground granulated blast-furnace slag or fly-ash), cross-laminated timber, and bio-based materials (e.g., wood, cellulose, and straw-bale insulation) — in addition to old-fashioned, light-gauge or recycled steel — can lower a building's embodied carbon footprint. Governments can accelerate the uptake of these technologies through various means, including public procurement programs that prioritize low-carbon construction materials in public works projects, or research and development projects that test the feasibility of different low-carbon construction materials.

4-6. Reuse, Reduce, Recycle: Initiatives that aim to reuse, reduce, or recycle building materials include regulatory requirements to reduce construction waste through prefabrication, reuse construction materials such as brick walls, or use recycled products such as steel — or even the development of a waste disposal index to monitor the emission profiles of waste generated, reused, or diverted during the construction process.

4.2 Policy Instruments

Policy instruments are tools used by government to achieve public policy objectives — namely, to change behaviour. The defining feature of a policy instrument is not whether it is voluntary or compulsory but rather how it generates behaviour change.[48]

1. **Authority Tools:** Laws, permits, regulations, standards, and other authority tools that grant permission or require behaviour change based on a government's formal authority.

2. **Incentive Tools:** Financial incentives (e.g., grants, tax credits) or disincentives (e.g., fees, charges, taxes) that motivate behaviour change through tangible payoffs.
3. **Capacity Tools:** Research initiatives, technical assessments, feasibility studies, and skills programs that provide information, training, or capacity building that enables behaviour change.
4. **Symbolic Tools:** Education and persuasive marketing campaigns that change perceptions of behaviour change through appeals to intangible values.
5. **Learning Tools:** Expert commissions, task forces, and advisory boards that build knowledge or consensus in cases where a problem is not well understood or there is no agreement about what behaviour change is required.

All forms of policy instruments can be applied to realize different forms of embodied carbon mitigation strategies. But not all mitigation strategies have the same impact. The strategies listed in Table 1 should be seen as hierarchical: good policy will prioritize strategies 1 through 6, in that order. This is particularly the case in fast-growing countries, like Canada, where new construction outstrips demolition. Policies that focus on intensive use, for example, will have more impact in reducing embodied GHG than those that encourage use of low-carbon materials. At the bottom end, materials and component recycling can replace only a very small percentage of new material use, given that in Canada, a lot more is built than is torn down. In Toronto, for example, even if 100% of construction and demolition waste could be reused for new construction, it would displace just 2% of new construction material mass.[49]

Put simply, to achieve Canada's housing and climate goals simultaneously, we must prioritize efficient design and intensive use by encouraging multi-unit buildings and limiting basements, followed by light-weight design and (to a lesser degree) low-carbon materials, by encouraging uptake of new design standards and advanced technologies. That much is clear. Less clear is the mix of policy instruments required to achieve these ends. Ultimately, there is no single blueprint or "best practice" approach that Canadian government must follow. Embodied carbon policy borrows good ideas from many jurisdictions, both in Canada and abroad.

5. National and International Best Practices

A recent review by consulting firm One Click LCA identified 105 local, subnational, national, and international initiatives across 26 countries that directly target embodied carbon emissions.[50] The following section briefly reviews some of the most promising and ambitious policy frameworks targeting embodied carbon, both in Canada and internationally.

5.1 Canadian Initiatives

5.1.1 Vancouver Embodied Carbon Guidelines: The City of Vancouver's Climate Emergency Action Plan, approved in November 2020, outlines six "big moves" the City will take to respond to the climate emergency, including reducing embodied emissions in all new buildings by 40% below 2018 levels by 2030 — marking the first municipal by-law in North America aimed at reducing embodied carbon emissions.[51] The plan builds on a previous Zero Emissions Building Plan, adopted in 2017, that began quantifying embodied emissions in housing construction and signalled the City's intention to move from voluntary to compulsory emissions limits.[52]

Under Embodied Carbon Guidelines that went into effect October 1, 2023, all rezoning applications for new housing must report embodied carbon emissions, and by 2025, reduce those emissions by 10–20% by using wood or low-carbon concrete/steel construction materials, or by diverting 75% of construction waste (authority tool).[53] The guidelines are consistent with the Government of British Columbia's "Energy Step Code," an addendum to the BC Building Code that enables municipalities to require or incentivize builders to meet incremental performance standards in new construction and are estimated to eliminate 18,900 tonnes CO_2e of embodied carbon per year.[54]

5.1.2 Toronto Green Standard Version 4: The Toronto Green Standard, part of the City of Toronto's TransformTO climate strategy, establishes performance standards for new housing construction that exceed the minimums set out in the Ontario Building Code (authority tool). Performance standards are divided into distinct tiers, which, after subsequent revision every four years, become progressively more stringent. The standard was originally adopted as a voluntary standard in 2006, strengthened as a mandatory minimum requirement for large buildings in 2010, 2014, and 2018, and enhanced in April 2023, to focus on upfront embodied emissions.[55]

Version 4 of the Green Standard mandates that all new City buildings be designed to net-zero standards, follow the Canada Green Building Council's Zero Carbon Building Standards, and all new privately constructed buildings meet an embodied emissions intensity cap of between 250 $kgCO_2e/m^2$ (Tier 2) to 350 $kgCO_2e/m^2$ (Tier 3).[56] Builders that meet higher performance tiers are eligible for financial assistance through a Development Charge Refund Program that offers cash incentives from approx. $1,900 to almost $8,300 per unit, depending on the type of housing development (incentive tool).[57] The Green Standard is

A growing number of policy frameworks targeting embodied carbon have been adopted around the world.

complemented by a recent zoning by-law, adopted by Toronto City Council in 2021, that eliminates parking minimums and sets parking maximums for new condo and rental buildings, guiding builders to design smaller, or do without, underground garages, thus consuming less concrete during construction.[58]

***5.1.3 Federal Roadmap to Net-Zero Carbon Concrete*:** The Roadmap to Net-Zero Carbon Concrete by 2050, released in 2022, commits the federal government and fifteen industry signatories to reduce 15 Mt of cumulative emissions across the sector by 2030, and a further 4 Mt of annual reductions to reach net-zero by 2050.[59] Drafted "to provide certainty to industry," the Roadmap advances several mitigation strategies and policy instruments to compel industries to switch to lower-carbon fuel sources, optimize clinker substitutes, and use recycled materials during the concrete manufacturing process, as well as promote market uptake of low-carbon alternatives, such as:

- Introduce a new Buy Clean Strategy consistent with the federal Greening Government Strategy,[60] which requires the disclosure of embodied carbon in major federal construction projects starting in 2022, and reduction of embodied carbon in federal projects by 30% starting in 2025 (authority tool)
- Create an investment tax credit for carbon capture/storage technologies (incentive tool)
- Produce a research and development strategy for low-carbon concrete technologies, develop sector-specific, national lifecycle assessment tools, and launch training and education programs to encourage market uptake of low-carbon products (capacity tools)
- Establish a low-carbon market development task force to position the Canadian concrete industry as a global leader in low-carbon building materials (symbolic and learning tools)

5.2 International Initiatives

A growing number of policy frameworks targeting embodied carbon have been adopted around the world. The European Union has recently taken steps toward Europe-wide embodied GHG regulations, starting with mandated reporting.[61] Several other national and subnational governments have adopted, or are considering, caps on embodied GHG, including New Zealand, Sweden, and Finland.[62] Denmark was the first country to introduce mandatory embodied carbon regulations, followed by the United Kingdom, France, and the United States. Although by no means a systematic review, the case vignettes illustrate a range of approaches taken by leading jurisdictions.

5.2.1 National Strategy for Sustainable Construction (Denmark): Denmark was one of the first countries to enact mandatory embodied GHG targets as part of full lifecycle limits on building emissions, for both embodied and operational carbon. The National Strategy for Sustainable Construction, released in 2021, aims to align emissions reduction targets for the construction sector with Denmark's overall emissions reduction target of 70% below 1990 levels by 2030.[63] The plan highlights the need to think

holistically about housing and climate and the importance of higher-quality construction to the overall climate footprint of the building sector. It also actively encourages business leadership in policy development and implementation — an approach that has since become a model for several other European, particularly Nordic, countries.[64]

Denmark's strategy builds from early voluntary initiatives designed in partnership with the business community. For example, in May 2020, a voluntary building lifecycle assessment standard was established to invite industry to test the feasibility of new mandatory standards scheduled for initial implementation in 2023, to be scaled up in various phases through 2029 (capacity tool). Starting in 2023, new buildings larger than 1000 m^2 must meet a maximum lifetime CO_2 limit of 12 $kgCO_2e/m^2$/year, with all new buildings subject to the same standard in 2025 (authority tool). Every two years the allowable lifecycle GHG emissions will be further reduced, falling to 7.5 $kgCO_2e/m^2$/year by 2029.[65] Local building authorities are responsible for enforcing these national standards through the building permit process, verifying that the climate promises made on the permit application have been realized.[66]

An important feature of the Danish strategy is a focus on design quality. The approach and regulations are purposely designed to raise the quality of buildings built across Denmark so they will last longer (i.e., lifetime extension), thus reducing the need for future energy and resource use in their operation, maintenance, and replacement. The Strategy also sets out changes in planning law and land use regulations (e.g., reducing parking requirements) to manage the demand-side component of material use in building design.

5.2.2 Carbon Budgets for Construction Sector (United Kingdom): The United Kingdom has taken a top-down, legislative approach to reducing GHG emissions. In 2008, the national government passed the *Climate Change Act* with broad cross-party support that remains in effect today, surviving several changes in government. The Act sets legally binding, economy-wide carbon budgets and reduction targets for all industrial sectors — a world first. A carbon budget places a precise limit on the total amount of emissions the UK can emit over a 5-year period and allocates

portions of this amount by economic sector.[67] The advantage of this approach is that it focuses on absolute emissions reductions rather than relative reductions based on efficiency gains alone.

Each UK carbon budget is based on analysis by the Climate Change Committee (CCC), an independent scientific advisory body mandated to study cost effective ways to achieve the government's climate commitments (learning tool). To date, six carbon budgets have been set, covering different time periods between 2008–2037; each successive carbon budget includes decreased GHG allowances.[68] The most recent requires a 78% reduction in UK-wide GHG emissions by 2035.[69] The overall carbon budget is supplemented by several sector-specific carbon budgets, including a specific budget for the manufacturing and construction sector, which accounts for 12% of total UK emissions.

The sixth carbon budget for the manufacturing and construction sector, housing construction, calls for a 70% reduction in sectoral GHGs by 2035 and 90% by 2040. The budget proposes mandatory disclosure of embodied carbon emissions in all construction activities, as well as adoption of a mandatory minimum "whole-life carbon standard" for new buildings and infrastructure projects that strengthen over time (authority tool).[70] It also recommends measures to improve "resource efficiency" (i.e., light-weight design) and incentivize material substitution (i.e., increased use of low-carbon materials such as wood and low-carbon concrete) and reuse — though notably, it overlooks opportunities to reduce end-user resource consumption through intensive use and design of smaller homes.[71]

5.2.3 Environmental Regulation RE2020 (France): Jointly announced by France's Minister of Ecological Transition and Minister Delegate for Housing in January 2020, Environmental Regulation RE2020 aims to reduce GHG emissions from the construction sector by 52% by 2031.[72] The regulation replaces "thermal" regulations first adopted in 2011 (RT2012) that targeted energy efficiency in buildings, expanding construction standards to account for all building emissions over its life cycle (authority tool). This builds from an earlier "E+C-" (energy positive, carbon negative) voluntary certification scheme, a four-year pilot program whereby builders were encouraged by the national government to meet higher construction standards in exchange for permission to build up to 30% more units per parcel of land (incentive tool).[73]

RE2020 requires environmental lifecycle assessment for all new building permits, as well as threshold limits for embodied emissions according to building type and floor area, in three phases. Phase One focuses on residential homes, Phase Two on office and school buildings, and Phase Three on other commercial buildings. For houses, maximum allowable emissions begin at 640 $kgCO_2/m^2$ in 2022, decreasing to 415 $kgCO_2/m^2$ in 2031; for multi-unit buildings, the limit begins at 740 $kgCO_2/m^2$ in 2022, decreasing to 490 $kgCO_2/m^2$ in 2031.[74] RE2020 will require builders to demonstrate that they meet targets before construction, as part of the building permit process, and at the end of construction, upon inspection by a qualified professional.

Currently, most new buildings in France easily meet the initial emissions caps. But as the targets become stricter over time, the limits will require more sustainable approaches to design and resource use. RE2020 leaves the methods for meeting the targets up to the designers and builders but includes incentives for builders to increase use of biobased materials, and temporary storage of GHG in natural construction materials such as wood.

European Standards and Sustainable Construction

The development of consistent European standards has helped provide market clarity and stability across the EU, driving leadership in sustainable construction. It is very common in North America for engineers, architects, and builders to utilize language or specifications from European construction standards, including lifecycle assessment methodologies used to calculate embodied carbon emissions.

The European Union has published approximately 450 harmonised standards for construction products covering seven aspects of construction, including sustainable use of natural resources. These standards have been developed at the framework level (e.g., EN 15643 Framework for assessment of buildings and civil engineering works), the building or works level (e.g., EN 17472 Sustainability assessment of civil engineering works), and the product level (e.g., EN 15804 Environmental Product Declarations core rules).[75] The closest comparable framework in Canada is the NRC's National Guidelines for Whole Building Life Cycle Assessment, which in part draws on European Standard EN 15978:2011.[76]

5.2.4 Elimination of Mandatory Minimum Parking Regulations (United States): For decades, local zoning and land use regulations across the United States required one or more parking spaces per new housing unit.[77] Roughly four-fifths of new single-family homes in the United States (a good proxy for Canadian houses) are built with two-car garages.[78] New mid- and high-rise residential buildings (condominiums and apartment towers) typically require large below-ground parking structures, which can account for 20–50% of a building's total volume of concrete, and thus embodied emissions.[79]

Since 2015, more than 1,900 local municipalities in the United States have reduced parking minimums — or conversely, established parking maximums — for various kinds of new construction projects. Fifty-two of these cities have eliminated all parking minimums citywide, starting with Buffalo, NY, in 2017, followed by Minneapolis, Portland, San Francisco, San Jose, and, most recently, Austin.[80] While not explicitly an embodied GHG reduction policy — planning justifications range from reducing construction costs to discouraging sprawl — the associated reduction of underground parking structures makes it arguably the single most effective embodied GHG reduction strategy in North America. Several Canadian cities followed suit, including Edmonton and Toronto.[81]

6. Analysis and Recommendations

There is no shortage of technological and design solutions to the problem of embodied carbon in construction. Hundreds of academic studies, government reports, and industry strategies aimed at reducing embodied carbon emissions, and, more generally, accelerating the transition to a circular economy have been published around the world. Numerous policy toolkits, mainly geared toward cities and local governments, have been developed by international consortia, engineering firms, and environmental organizations such as the Carbon Neutral Cities Alliance, C40 Cities, and the Carbon Leadership Forum.[82]

The challenge for Canadian policymakers is how to take the best ideas and effectively translate them to the Canadian context, a complicated policy environment defined by a constitutional framework that splits legislative and regulatory powers between federal and provincial, but not local, governments; a polarized political landscape where public opinion on climate change is divided; a construction sector that lags its international peers in technology adoption and innovation; and a general track record of failing to meet emission reduction targets.[83]

What, then, is the way forward? As the foundation for a broader conversation on the policy pathways required to reduce embodied carbon in housing construction in Canada, four principles could begin to link ambition with action.

6.1. Focus on Provincial Policy, Not Federal or Municipal

To date, provincial governments have shown little interest in leading policy development on embodied carbon emissions, even less so regarding housing construction. Research did not uncover a single provincial climate change plan or housing strategy that directly addresses the problem of embodied carbon in the housing or construction sector. This must change.

As of 2024, Canadian climate policy relies too heavily on leadership by municipal governments. There is no doubt that cities are where the impact of climate change is most acute and where housing need is greatest. But from a policy perspective, local governments are not well placed to lead. They have neither the requisite authority to reduce embodied carbon emissions on their own, nor the capacity or financial resources required to develop sophisticated policy responses. And even if they did, a city-by-city approach cannot meet the nature and scale of the challenge.

Both housing markets and climate emissions extend beyond municipal borders. The optimal scale for both climate and housing interventions is thus the city-region, that is, the metropolitan scale. The trouble is, Canada has a poor history of metropolitan governance. Although Canada's ten largest city-regions are home to more than 55% of the national population — a number set to grow in the coming decades as immigration targets rise — metropolitan areas are inconsistently governed by hundreds of local governments and dozens more arm's-lengths agencies and intergovernmental authorities.[84] Exceptions exist, of course. Metro Vancouver, for example, is a high-functioning metropolitan-scale political authority. But in most cases, provinces end up functioning as *de facto* metropolitan governments.

Ultimately, provinces are responsible for the most important elements of housing construction, namely, land use planning, building and labour standards, and in some cases, direct provision of public housing. And despite recent political and judicial controversies over federal climate legislation, there is no dispute that provinces have shared a responsibility for the environment and a right to act on climate change. Provincial governments must step up. That means convening industry stakeholders; drafting new legislation; updating regulatory frameworks, including building codes; and allocating sufficient resources to enforcement and evaluation.

The federal government, for its part, should act on its shared responsibility by supporting and encouraging provincial action through financial support and regulatory streamlining. For example, the most recent federal mandate letters call for the Minister of Innovation, Science. and Industry, as well as the Minister of Natural Resources, to lead the development

of new model building codes to guide, but not dictate, provincial codes. The adoption of lifecycle assessment requirements and direct embodied carbon caps should explicitly inform this work, thereby encouraging similar changes at the provincial level.

6.2. Focus on Sectors, Not End-Products

Most embodied carbon regulations in Canada (and much of the world) focus on design specifications for individual buildings, that is, limiting emissions per m^2 constructed. This overlooks the total m^2 constructed, and more broadly, how much is being built across the sector. Designing and constructing a building that is, say, 40% less carbon-intensive leaves Canada no better off, in terms of total emissions, if overall housing supply increases by 40%. Worse, focusing on efficiency improvements per m^2 might incentivize over-construction, because, from an engineering perspective, attaining low GHG per m^2 is easier when using large building footprints with lower wall-to-floor area ratios. In other words, any plan to double housing construction must also double the rate of GHG emissions reduction per product across the whole sector (i.e., 80% less GHG emissions per building, rather than 40% less GHG emissions).

Canada's Roadmap to Net-Zero Carbon Concrete, noted earlier, is a good start toward a sectoral approach. As are other sectoral initiatives aimed at encouraging the use of wood products in construction where appropriate, such as the Quebec Wood Charter and BC Mass Timber Action Plan.[85] But these must be part of a larger policy framework that guides the housing and construction sector as a whole, similar to Denmark's National Strategy for Sustainable Construction, rather than individual construction materials.

Ideally, policy should focus on reducing total GHG emissions on a national, economy-wide basis, with GHG allowances for specific economic and industrial sectors over time, as is the case in the UK, by using sectoral GHG budgets. How these sectoral carbon budgets should be set is open to debate. One approach is to maintain the proportion of GHG emissions per sector and provide uniform reductions to all sectors. In Canada, this would mean allowing the construction sector to annually emit 34 $MtCO_2e$ by 2030.[86] Another approach would be to allocate greater emissions to economically important sectors or sectors that are particularly difficult to decarbonize (one could argue that housing construction qualifies as both) and assign lower allocations to other sectors with greater decarbonization potential (e.g., transportation, energy).

6.3. Focus on More Intensive Use, Not Reuse

Leading European jurisdictions have adopted embodied carbon reduction strategies that encourage refurbishment of existing buildings, otherwise known as lifetime extension. This is sound public policy — extending the life of existing structures dramatically reduces future embodied carbon emissions from new construction. But this approach will have much less of an impact in Canada.

The challenge for Canadian policymakers is how to take the best ideas from around the world and effectively translate them to the Canadian context.

Europe's building stock is aging and often under-utilized, whereas Canada's stock is relatively new and already over-capacity. Europe's population is also stagnating, while Canada's is spiking, necessitating a huge increase in housing supply. The fact is, Canada currently builds, and must continue to build, much more housing than will be torn down. Effective waste management generates sustainability side benefits (e.g., diverting waste from landfill), but the "carbon dividend" of material reuse or recycling will remain negligible. The same is true for large-scale lifetime extension and renovation schemes (e.g., converting office buildings for residential uses), which yield only marginal benefits in the context of building millions of homes in less than a decade.

As Canada aims to build more housing, provinces must be intentional about building space-efficient, low-carbon housing. This is largely a planning and design problem, not an engineering challenge. The solutions are technically straightforward but require updating building codes/standards and land use (zoning) regulations — two policy instruments that are firmly the responsibility of provincial governments. Here, Canadian provinces could follow California, which recently updated the California Green Building Standards Code (known as CALgreen) to require a 10–20% reduction in embodied carbon emissions from large commercial and educational (though not yet residential) buildings.[87] Similarly, California also recently eliminated minimum parking requirements near transit stations and encouraged residential infill construction by allowing multi-family housing as-of-right in all areas previously zoned for commercial uses.[88] Though not directly intended as embodied GHG regulations — the stated goal is to encourage more affordable housing — the end result will be more people housed with lower embodied carbon emissions.

Perhaps the most impactful policy intervention would be the elimination of single-family zoning and construction of new single-family homes, replaced by multi-unit housing.[89] Single-family homes use much more material to house a small number of people and take up more space, requiring more supporting infrastructure per person (e.g., more length of sewer pipe). In parts of Canada where basements are the norm, single-family houses also have a disproportionate amount of underground floor area, and thus embodied carbon. On average, multi-unit buildings are less embodied GHG intensive than single-family homes, due to shared walls, foundations, and roofing.[90] Homes in multi-unit buildings also tend to be more compactly and efficiently designed, though there is large variation in the GHG intensity of built multi-unit buildings. The best buildings have limited underground space (e.g., no underground parking, no basement), use low-carbon insulation, avoid transfer slabs, and have efficient layouts to avoid low utility space (e.g., hallways).[91]

Only a handful of city governments in North America, including Toronto and Vancouver, have adopted such radical planning reforms. States and provinces have only gradually stepped in and must continue to do so. The State of Oregon passed legislation in 2019 legalizing duplexes on land zoned for single-family homes; California, fourplexes, in 2021; Ontario triplexes, in 2022; and British Columbia, six-plexes, in 2023.[92]

6.4. Focus on Current Building Design, Not Future Technologies

Advances in materials science take time. New forms of biobased and low-carbon construction materials will come, but slowly. Only moderate improvements in GHG intensity are expected before the mid-2030s. More aggressive gains will depend on rapid and widespread rollout of carbon capture technologies — technologies whose efficacy and scalability remain uncertain.[93]

In short, Canadians cannot wait for technological fixes; better buildings can be designed now. When it comes to embodied carbon, design efficiency is more important than material type. Yet current construction standards focus more on material choices than design choices. Recent changes to provincial building codes that permit mass timber construction have gained lots of attention, and with good reason: wood products provide a powerful opportunity to reduce embodied carbon emissions (as a lighter material, wood requires less structure to support dead weight). But similar results can be achieved with conventional materials (e.g., concrete and steel) by designing well. For example, by eliminating unnecessary, resource-intensive elements of standard building design, such as seldom used hallways and inefficient floorplates, basements, and transfer slabs.

To achieve Canada's housing and climate goals simultaneously, we must prioritize efficient design and intensive use.

This is a major gap in current policy discourse regarding embodied carbon. Taking embodied carbon seriously means questioning design orthodoxy, including planning regulations that require building "step-backs" intended to create space between buildings or "angular planes" meant to avoid building shadows, fire and building codes that prevent single-staircase construction of mid-rise buildings, and accessibility standards that require lifts encased in concrete elevator shafts. These technical standards are well-intentioned but are often counterproductive to good climate policy. Governments must therefore work with the construction industry to shift prevailing norms and practices. In leading jurisdictions like Denmark, behaviour change was driven by legislative and regulatory frameworks adopted by central governments, supported by financial incentive programs, research and development networks, and standards regimes at the European Union level. A parallel system in Canada would see provinces lead, supported by federal investments, information sharing, and capacity-building initiatives.

7. Conclusion

Governments across Canada are making big promises when it comes to climate and housing policy. Federal, provincial, and local governments are all aligned in principle: Canada needs more homes and lower carbon emissions. The trouble is, Canada's housing and climate ambitions do not match. Based on current construction practices, massive growth in new housing construction will only lead to massive increases in embodied carbon emissions.

It is possible to build millions of new homes while meeting our GHG reduction commitments.[94] But it will require concerted effort — plus a degree of culture change (there is no sustainable future where most Canadians live in a single detached home with a two-car garage.) Architects, engineers, and builders must start designing more efficient buildings with more intensive uses (less floor area per capita, more units closer together); use buildings for longer (less demolition, more refurbishment and repair); use less materials more efficiently; experiment with new, low-carbon materials; and, in the rare instances when building demolition will be required, recover and recycle construction materials for reuse.

All these behaviour changes demand wide-ranging policy reforms. First and foremost, it will require provincial governments to step up. Provinces are responsible for the most important elements of housing construction and have the legislative authority, regulatory capacity, and fiscal resources to lead. Second, governments must take a sectoral approach, raising expectations and requirements industry-wide, not simply for individual projects. Third, governments should update building codes and land use regulations to encourage compact infill development, multi-unit housing, and lower material use. Finally, governments should prioritize space-efficient design that can be implemented immediately, rather than long-term, unproven technologies.

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