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Is the Greenest Building the One Already Standing: A Synthesis Map

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Project 2: Synthesis Map Design Brief

Is the Greenest Building the One Already Standing?

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Table of Contents

Acronyms

CO2 - carbon dioxide, a greenhouse gas

EPD - Environmental product declaration

GHG - Greenhouse gas

GWP - Global warming potential

IGU - Insulated glass units

IPCC - Intergovernmental Panel on Climate Change

LCA/LCIA - Life Cycle Assessment or Life Cycle Impact Assessment

LEED - Leadership in Energy and Environmental Design, an internationally recognized green building certification system

NDC - Nationally Determined Contribution, part of the Paris Climate Agreement

OSB - Oriented strand board

VOC - Volatile organic compounds

Land Acknowledgement

We pay respect to the Algonquin, the Mississaugas of the Credit, the Haudenosaunee, the Anishinaabe, and the Huron-Wendat people, who are the traditional guardians of this land.

We acknowledge their long standing relationship with this territory, which remains unceded.

We pay respect to the Blackfoot Confederacy - comprising the Siksika, Piikani, and Kainai Nations - the Tsuut'ina First Nation, and the Stoney Nakoda - which includes the Chiniki, Bearspaw, and Wesley First Nations - who are the traditional guardians of this land on which the City of Calgary sits.

We pay respect to all the Indigenous peoples of Turtle Island. We acknowledge the traditional knowledge keepers, both young and old.

And we honour their courageous leaders: past, present, and future.

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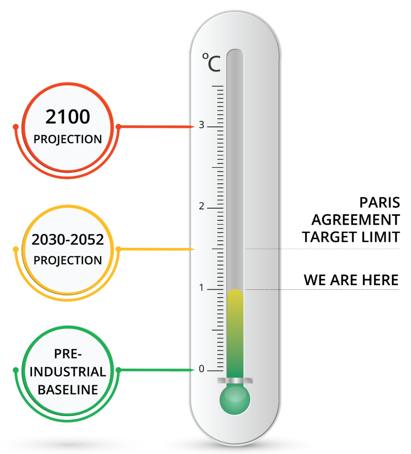
Introduction

“No challenge poses a greater threat to future generations than climate change”

– Barack Obama

Climate Targets

Climate change touches all aspects of life on Earth; it is a complex social, environmental, economic, and ecological challenge. According to the Intergovernmental Panel on Climate



Projected global mean temperature increase by 2100

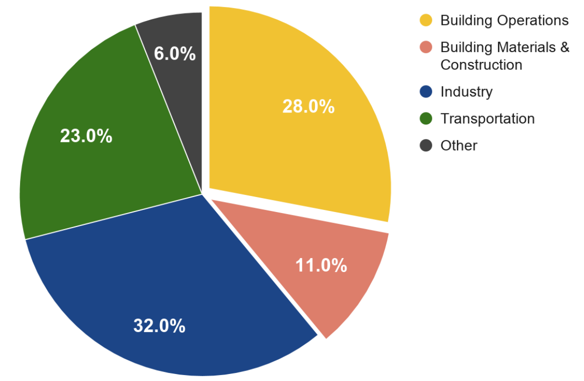
Change (IPCC), the world is on pace to warm more than 3°C by the end of this century (Gazdar, 2020), which could have catastrophic consequences. Humans need to take immediate action to reduce anthropogenic greenhouse gas (GHG) emissions and slow the pace of global warming.

In 2015, over 190 countries signed on to the Paris Climate Agreement, which collectively committed us to trying to limit global warming to 1.5°C by 2100. Each nation submitted its own emission reduction targets (called Nationally Determined Contributions, or NDCs) and is required to update its targets every five years. Due to the COVID-19 pandemic, many nations - including Canada - did not send their updated targets in 2020, but these are expected to be made public before the next international climate conference in November 2021 (Government of Canada, 2021).

Current global commitments will likely only reduce global warming to 2.6°C, far exceeding the original target. Worse still, many nations are on pace to *miss* their NDCs, some by a significant margin (Gazdar, 2020). The longer nations delay taking action, the more expensive, disruptive, and technically unfeasible it becomes to reach our original goal.

GHG Emissions from Buildings

Buildings contribute 39% to global GHG emissions (Architecture2030, 2018). Based on population and economic growth projections, our existing building stock will **double** by 2060, with construction of more than half of these buildings expected to happen in the next two decades (World Green Building Council, 2019).



Global CO2 emissions by sector (Architecture2030, 2018)

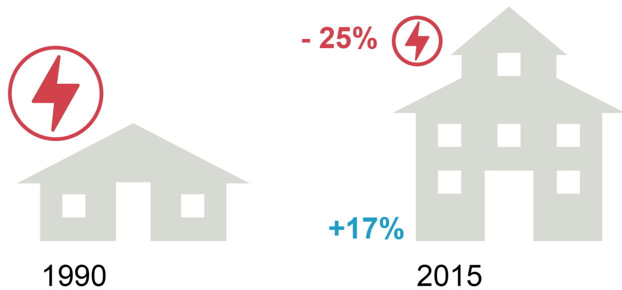
There are two primary sources of GHG emissions connected to buildings: *embodied carbon*, which is the carbon emitted in processes related to materials extraction, manufacturing, transport, construction, and decommissioning; and *operational carbon*, which is the carbon emitted to power and heat the building while in use. Taken together, these two types of emissions are called *whole-life carbon* and can be quantified through a life cycle assessment (LCA). An LCA is a standardized methodology for identifying and assessing the global warming potential of greenhouse gas emissions from materials and processes.

Addressing carbon emissions from the built environment is an urgent, critical need to make progress towards our global climate targets. Many nations have set goals to reach net zero carbon emissions by 2050; in November last year, the Canadian government followed suit and tabled the *Canadian Net-Zero Emissions Accountability Act* in the House of Commons to signal Canada’s commitment to reach net zero emissions by 2050 (Government of Canada, 2020).

The Challenge

Buildings in Canada

Canada has approximately 14.1 million residential buildings and 482,000 commercial and institutional buildings, a number expected to grow to 19.6 million total buildings by 2030 (Canada Senate, 2018). Over the same time period, Canada's population is projected to hit 41.1 million, a 12.6% increase from 2017 (Euromonitor International, 2018).

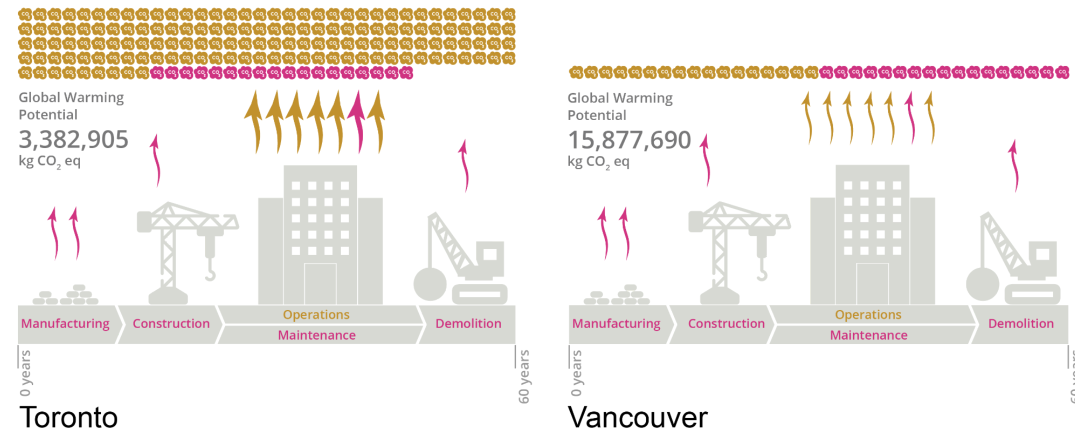


Comparison of dwelling size and energy use between 1990 and 2015 in Canada

Even as our population grows, our household occupancy is falling and our homes are getting bigger. Between 1990 and 2015, home sizes grew by 17% and floor space per person increased by 30%. However, thanks to the rise in renewable energy and more energy efficient buildings, the average household energy use has decreased by 25% (Canada Senate, 2018).

As with many other developed countries, the majority of the building stock Canada will have in 2050 already exists, and most new builds are expected to occur in the next decade (Senate Report, 2018). Thus, meaningful action towards Canada's climate targets must include policies for existing buildings in addition to new builds.

In Canada, buildings account for 17% of our total GHG emissions (Canada Parliament, 2018), which includes both operational and embodied carbon. The relative proportion of each varies significantly across jurisdictions in Canada, primarily due to variations in the carbon intensity of power grids and in regional climate (Canada Green Building Council, 2019). For example, the same five-storey building has a very different carbon profile in Toronto, a jurisdiction with a high carbon grid and a colder climate, than in Vancouver, where the power grid is primarily hydroelectricity and the milder climate reduces the need for heating (Marceau et al., 2012).



Comparison of embodied and operational carbon emissions of a 5-storey mixed-use building between Toronto and Vancouver

As power grids decarbonize and on-site energy generation becomes more common, embodied carbon will become a more significant component of a building's carbon profile and a more impactful avenue for intervention (Zizzo Strategy, 2017). However, delaying action on embodied carbon risks "locking in" a higher carbon profile for the next 50 to 60 years, the lifespan of a typical Canadian building.

For our inquiry, we chose to look at the whole carbon profile of buildings to better understand the influences, challenges, and opportunities to reduce carbon emissions from the building sector.

Project Scope

When people talk about “green” buildings, they often think of this:

But what if the greenest building is the one already standing? What if a retrofit to electrify a building’s heating systems more effectively reduced its operational carbon footprint than demolishing and rebuilding with new materials?

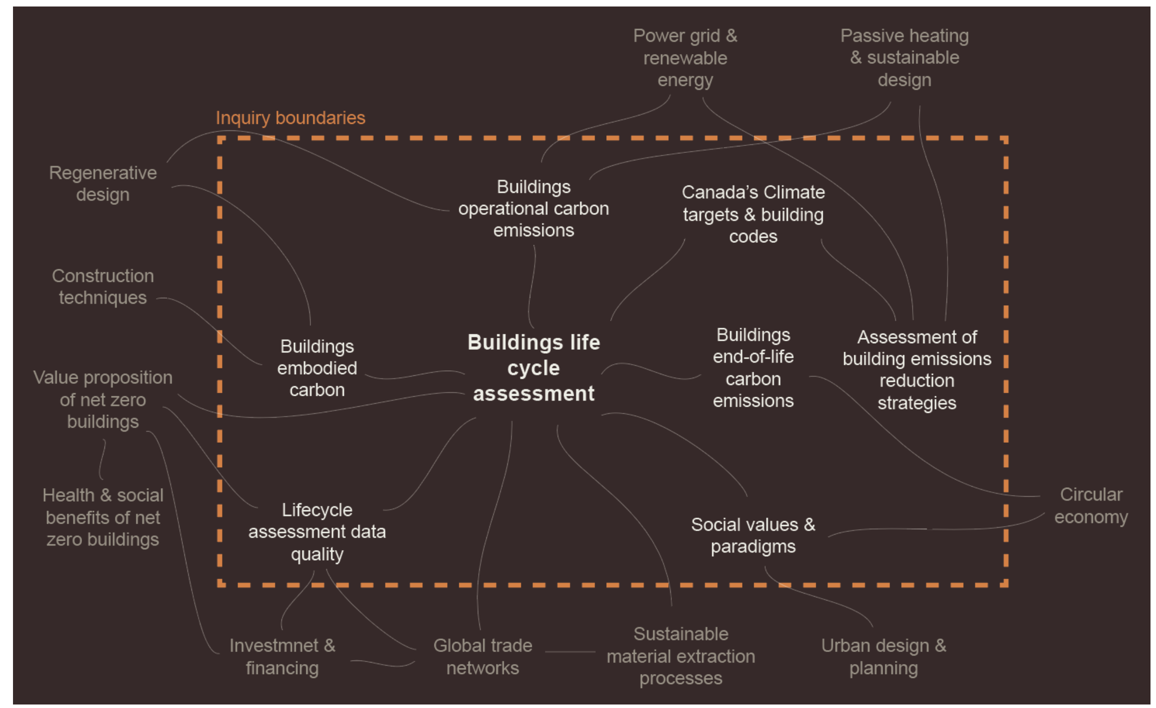
In this project, we hope to shift the conversation of what it means to be “low carbon” by drawing focus to the importance of considering the entire carbon life cycle of a building - embodied and operational - and factoring this assessment into decisions about the building’s lifespan and ongoing use.

Our system analysis examined the life cycle of a building through the four phases of its existence: the product phase, construction phase, in-use phase, and end-of-life phase. We modelled the processes and carbon emissions for four common structural building materials (concrete, insulated glass units, oriented strand boards, and steel rebar) as a representative sample of embodied carbon and identified the operational carbon emissions of different energy sources used to operate buildings. Finally, we mapped the relative needs, power, and influence of key stakeholders in the system.

Based on this understanding of the system, we more closely analyzed some of the underlying structures. We identified two behavioural archetypes driving emissions in the sector: the mentality that newer means greener and corrosive effect of insufficient policy interventions to meet our climate targets. Next, we looked at how the lack of data for carbon emissions is impeding investors in making informed decisions. To deepen our understanding of the challenges, we used a causal layered analysis to identify the societal values and paradigms underpinning how we build. Finally, we mapped the existing and proposed policy commitments for the built environment under the *Pan-Canadian Framework on Clean Growth and Climate Change* on an intervention strategy map to highlight the different leverage points targeted by each policy.

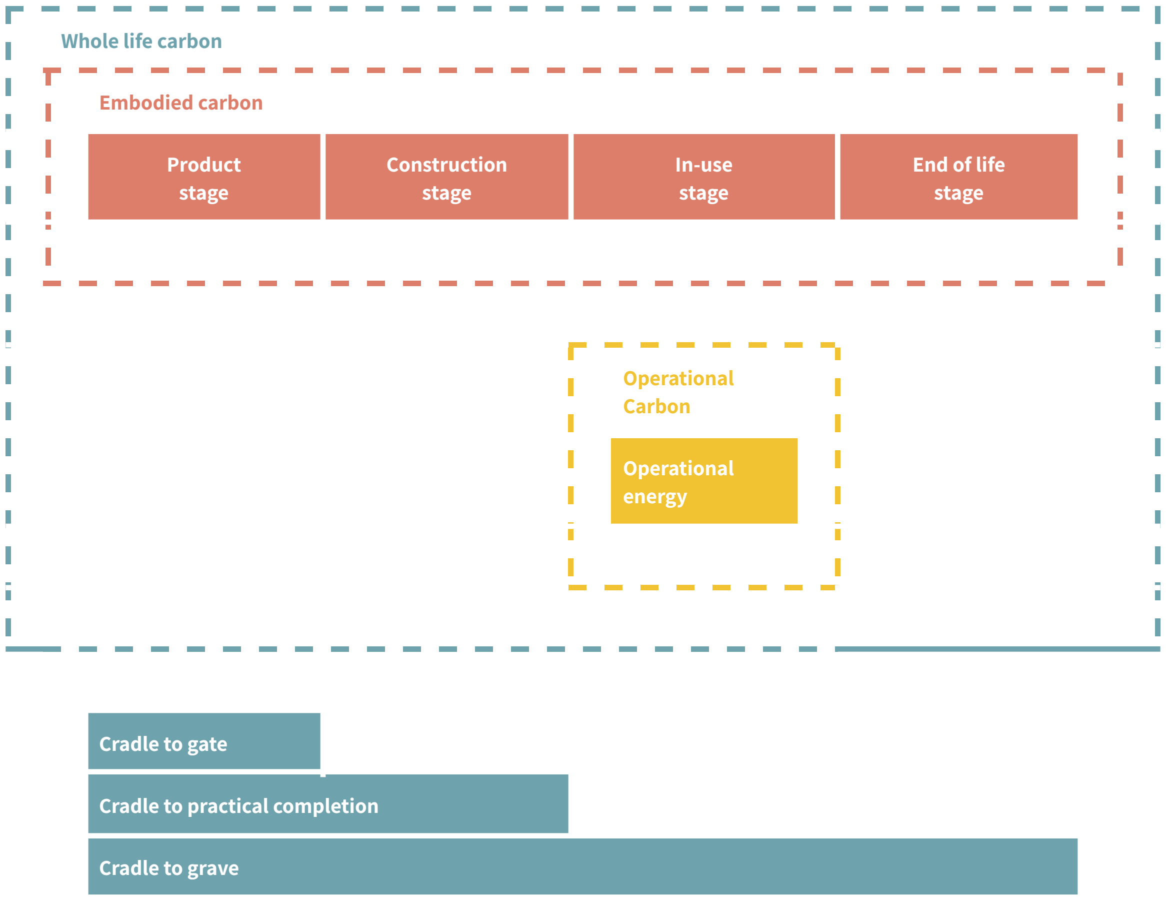
Following this analysis, we developed a set of recommendations using a 3 Horizon lens to imagine a net zero carbon building world in 2050 and identify the necessary changes and interventions to realize that vision.

The built environment is an integral part of many overlapping and interconnected systems. We used the following boundary map to focus the scope of this project on our key question: is the greenest building the one already standing?



The System: Whole-Life Carbon Emissions of Buildings

Our synthesis map explores the systems related to carbon emissions from buildings. From material extraction through mining or harvesting to the eventual end in a landfill, every step of the process emits carbon. To truly understand carbon emissions from the building sector and determine effective interventions for reducing them, it is essential to take a whole carbon perspective:



Adapted from London Energy Transformation Initiative, 2017

On our synthesis map, the primary graphic depicts a snapshot of the life cycle of a stereotypical multi-storey building, from raw material extraction, transportation to manufacturing plants, manufacturing processes, to transportation to building sites, demolition, recycling and reuse, and transportation to landfills. We focused on four common materials used to construct building foundations and frames: concrete, steel rebar, insulated glass units (IGU), and oriented strand boards (OSB).

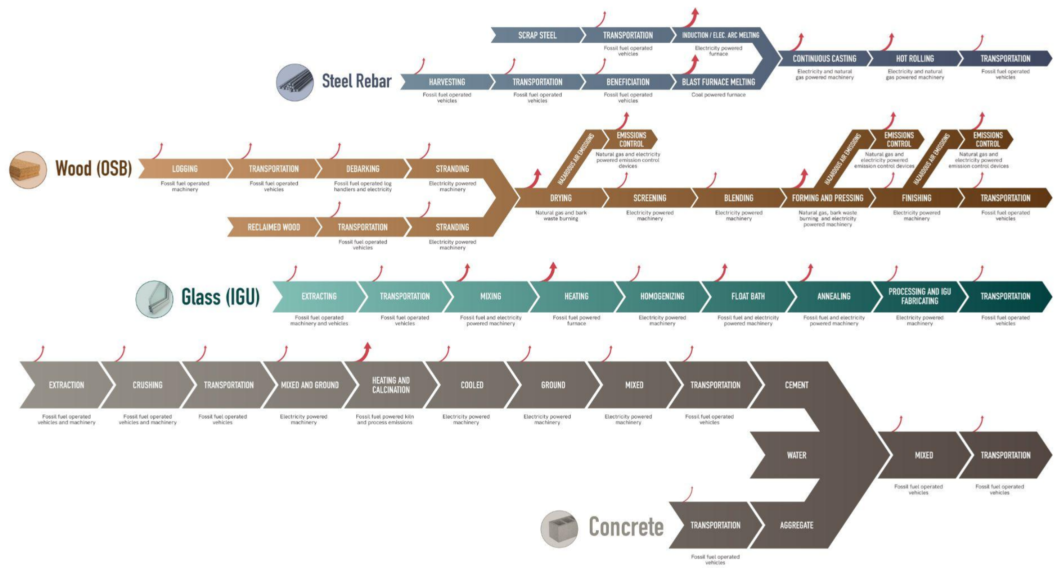
The System in Action

The term "throw-away" building is sometimes used to refer to high-rise condos with window-wall systems (floor to ceiling glass), which are more and more popular in cities like Toronto. This system is cheaper and faster to build, and attracts buyers as people prioritize the aesthetics of the building over longevity, carbon emissions, or energy efficiency. However, these towers require extensive retrofits costing millions of dollars in a mere 15-25 years.

There is nothing stopping the proliferation of these buildings. They are code-compliant because our existing codes do not set goals for energy efficiency, longevity, or carbon emissions. Even if buyers want to make responsible environmental decisions, energy-efficiency information is not available for condo towers.

Source: AllOntario Team, 2014 and CBC News, 2011

This section of the report provides a detailed description of the carbon emissions for each stage of the building process.



Product Stage: Embodied Carbon

The accurate assessment and measurement of carbon emissions from the procurement and manufacturing of specific building materials is extremely complex and not particularly accurate for a number of reasons:

- Raw materials are extracted and procured from diverse sources and through diverse processes, each associated with a different carbon footprint;
- Emissions from the transportation of raw and manufactured building materials may or may not be included in a country's transportation GHG emissions reporting, making it difficult to accurately account for the contribution of building materials to overall carbon emissions;
- Transportation is powered by different types of fuel and sources of energy, each with a different associated carbon footprint;
- Manufacturing processes have associated waste products and emissions, the processing of which can take various routes, each with its own carbon footprint; and
- Many manufacturing processes are powered by electricity, and the emissions associated with these processes depend on the power grids that supply the manufacturing plants.

Despite these challenges, it is possible to see which processes contribute the most to carbon emissions. Our analysis focused on four common structural building materials through the most carbon-intensive processes in their manufacturing.

Concrete

Concrete is the most commonly used building material in the world because of its strength and versatility, and is used for foundations, flooring, columns, beams, and even walls. Manufacturing cement, an essential ingredient for concrete, contributes 5-6% of total anthropogenic CO2 emissions (Akan, Dhavale, & Sarkis, 2017) and is the most carbon-intensive aspect of the concrete supply chain because of two key processes: heating and calcination.

Heating

To produce cement, the raw materials of limestone, clay and sand must be heated to almost 1500°C. The resulting clinker, a stony residue, is combined with gypsum to create Portland cement. Attaining such high kiln temperatures requires a plentiful fuel source; coal is the most popular choice, a key reason why this process emits so much carbon.

Calcination

The production of clinker releases direct carbon dioxide emissions through the chemical reaction of calcination ($CaCO_3$ + heat → $CaO + CO_2$) (Di Filippo, Karpman, & DeShazo, 2019). Each ton of calcium oxide produces half a ton of CO2 (Flower & Sanjayan, 2007).

All told, calcination accounts for 50% of total cement carbon emissions and heating is responsible for 40% (Di Filippo, Karpman, & DeShazo, 2019).

Insulated Glass Units

Insulated Glass Units (IGU), sometimes called double-glazed or double-paned glass, are used in place of single-pane glass windows to reduce heat transfer between the building interior and exterior, thus keeping a building warmer in the winter and cooler in the summer (Vitro Architectural Glass, n.d.). The melting process requires intense heat.

Heating

Melting batch materials for the production of molten glass ribbons is the most energy and carbon-intensive processes in the production of IGU. The process requires intense heat from natural gas or oil-powered furnaces, and produces numerous hazardous air emissions, including sulfur dioxide and nitrous oxide in addition to carbon dioxide (International FInance Corporation, 2007). Melting comprises more than 75% of the carbon emissions of glass manufacturing (Ecofys, 2009).

Oriented Strand Board

Oriented strand board (OSB) is a type of engineered wood that is particularly useful as a load-bearing structural support. It is most commonly used as sheathing in walls, floors, and roof decking and is more popular than plywood for structural applications. The most carbon-intensive processes of OSB production are drying, forming and pressing, and finishing.

Drying

Wood strands undergo a drying process powered by natural gas and the burning of bark waste from earlier debarking of wood logs. Due to the kind of fuels used in the drying process, it is extremely carbon-intensive. Moreover, this drying process has a substantial output of hazardous air emissions - including particulates and Volatile Organic Compounds (VOC) - which require the use of emission control units that are natural gas and electricity-operated, adding additional carbon emissions (Puettmann, Kaestner, & Taylor, 2016).

Forming and Pressing

Forming and pressing the strands and resin mix into mats also depends on natural gas and the burning of bark waste, and has an output of hazardous emissions that require emission control units, which themselves emit carbon (Puettmann, Kaestner, & Taylor, 2016).

Finishing

The finishing of OSB produces additional hazardous emissions that require emission control (Puettmann, Kaestner, & Taylor, 2016).

Steel Rebar

Steel rebar is used to add strength to structural concrete, which has high compressive strength, but weak tensile strength. Steel rebar significantly increases the tensile strength of structures. Steel rebar is produced by melting, combining, and casting scrap steel and, to a lesser extent, metal ores (Özdemir et al., 2018). These processes require high temperatures.

Induction or Electric Arc Melting

Scrap steel is melted in induction or electric arc melting furnaces, which is energy-intensive and has high carbon emissions.

Blast Furnace Melting

Metal ores require blast furnaces to melt them, which is much more energy intensive than induction or electric arc melting. It also produces a much higher carbon footprint because coal is the primary heating source (Özdemir et al., 2018).

Construction Stage: Embodied Carbon

Though not depicted on the synthesis map, different types of construction techniques emit different levels of carbon. Our analysis explored two primary construction methods: conventional and prefabrication. Conventional construction is where materials are transported to a building site and constructed in place. Prefabrication means much of the construction is done off-site, at a manufacturing plant, and transported to the site for the final installation. Few buildings are fully prefabricated off-site (these are sometimes called modular buildings) but more builders are turning to semi- or full-prefabrication to augment conventional techniques.

Prefabrication has a number of benefits. It can lower cost, reduce construction times, limit disruption to traffic and neighbours, reduce the potential for on-site accidents, and is not at the mercy of weather-related delays (Padilla-Rivera, Amor, & Blanchet, 2018). However, the issue of whether pre-fabrication reduces GHG emissions during construction is still an open question.

We found several studies suggesting prefabrication reduces the amount of materials needed for construction and the need for so much on-site construction equipment, which is typically powered by fossil fuels (Padilla-Rivera, Amor, & Blanchet, 2018; Abey & Anand, 2019; Kong et al., 2020). However, prefabrication pushes construction activities to the manufacturing site, which may rely on a carbon-intensive electrical grid for power and fossil fuels for heat. As a result, the final calculation of GHG emissions does not universally favour prefabrication.

One Canadian study compared two prefabricated houses to one conventional house and that while the prefabricated homes had fewer emissions during the production phase, one significantly exceeded conventional construction GHG emissions during the construction phase due to carbon-intensive processes at the factory (Kamali, Hewage, & Sadiq, 2019). In the final calculation, one prefabricated building reduced its carbon footprint, while the other had equivalent emissions to conventional construction. Aside from factory conditions, the design of the building (the lesser GHG emitting home had a more open concept with fewer walls) and transportation emissions of workers also played a role in the ultimate results.

Thus, while prefabrication has the potential to reduce construction stage GHG emissions, much of the emission reductions will depend on decarbonizing other aspects of society, such as the power grid and transportation network.

In-Use Stage: Operational Carbon

While the building is in use, materials used for maintenance, repair, and replacement count towards its embodied carbon costs. However, this typically accounts for a small fraction of the total embodied carbon of the building and pales in comparison to the building's operational carbon emissions during this stage.

As the two charts below indicate, the majority of operation carbon emissions in Canada come from space heating:

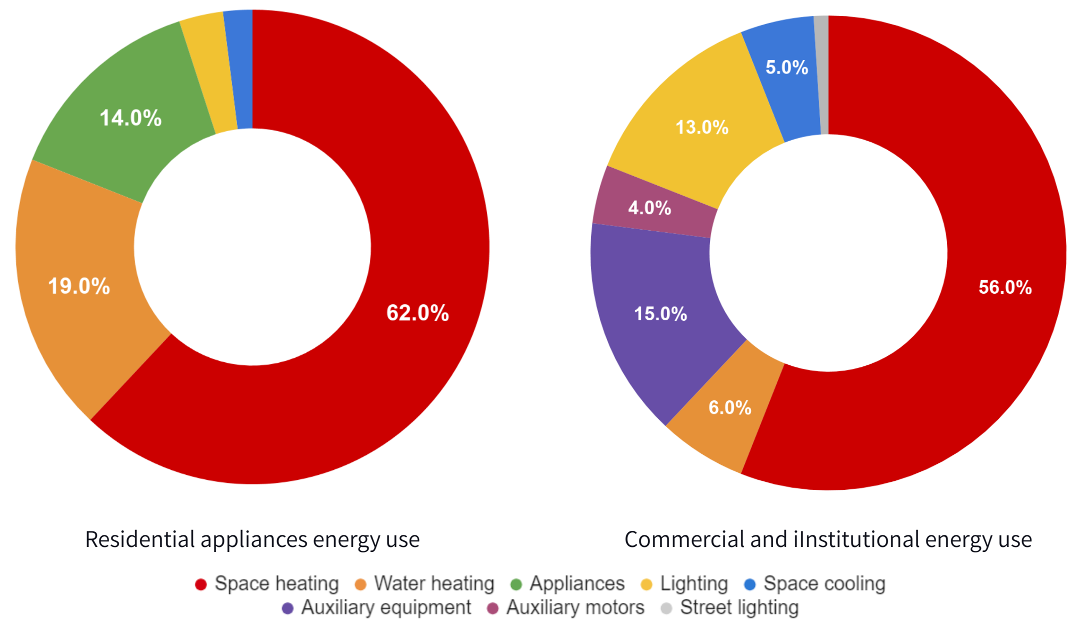
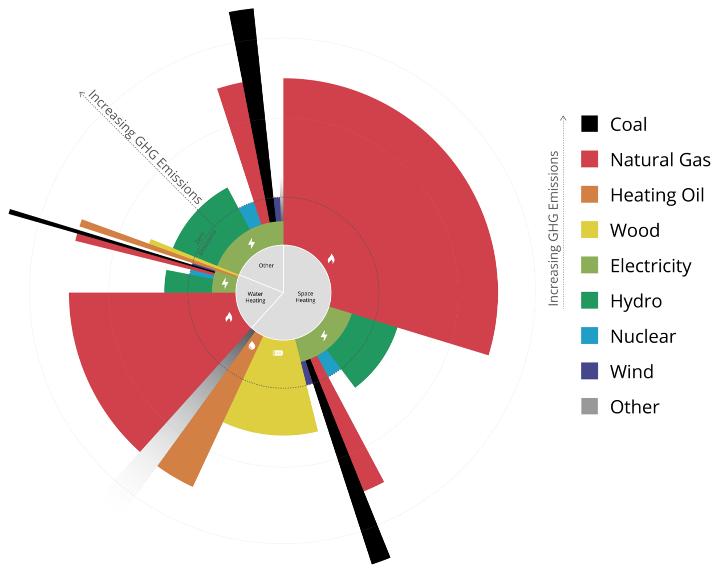


Image Source: National Resources Canada, 2020

Operational carbon emissions are a product of the carbon-intensity of the electrical grid that powers the building, as well as its use of natural gas or electricity as a heat source. The carbon emissions of the energy grid vary greatly across Canadian jurisdictions. For example, 96% of electricity in Ontario is produced from zero-carbon emitting sources while Alberta produces 91% of its electricity from fossil fuels (Canada Energy Regulator, 2021). On the whole, fossil fuels generate 17% of electricity in Canada (Canada Energy Regulator, 2021).

The synthesis map shows the energy consumption by use and the sources of energy and associated GHG emissions for Canadian residential buildings. The larger the diameter, the greater the GHG emissions.



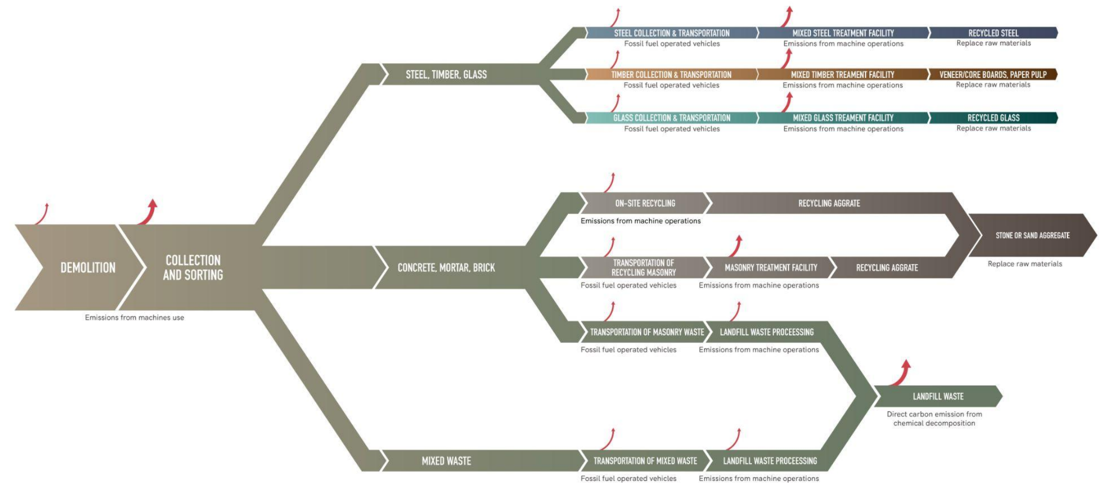
Residential buildings energy consumption profile and associated GHG emissions in Canada (Data from National Resources Canada ENergy Fact Book 2020-2021

As seen in the diagram, coal is by far the worst power source for carbon emissions, followed by natural gas. Nuclear and wind are low-carbon sources. Hydropower is typically considered low-carbon, but the design of individual power stations may result in unnecessary emissions and thus add to hydro's carbon emission profile (Ocko, 2019). Some energy sources are identified as "others" in datasets, so it is unknown whether they are clean or carbon-heavy sources, which is why they are depicted as gradients.

As this analysis shows, the shift to net zero carbon emissions will depend on the replacement of natural gas furnaces with electric heat pumps, in addition to the decarbonization of the provincial electrical grids.

End of Life Stage: Embodied Carbon

The final sources of carbon emissions come from the end of a building's life, and are considered embodied emissions. A complete life cycle assessment must account for the emissions generated by its removal after ceasing operations. The building demolition process can be divided into four stages: demolition, on-site treatment, transportation, and disposal.



Demolition

The carbon emission cost of recycling demolition waste varies based on the material. For example, recycling masonry waste only contributes to 1% of the overall demolition emissions (Wang et al., 2018), whereas recycling steel or aluminum can save up to half of the embodied carbon emissions (Ng, 2015).

On-Site Treatment

Collecting and sorting waste on site produce the most carbon emissions within the end-of-life stage. Primarily, these emissions are associated with equipment usage and are equal to the carbon created by landfilling waste (Wang et al., 2017). Recycling masonry on site leads to lower emissions by avoiding the carbon generated by fossil fuel-based vehicles transporting the waste to treatment facilities. For example, sorted concrete on a demolition site can be reused as coarse aggregate for a new construction.

Disposal

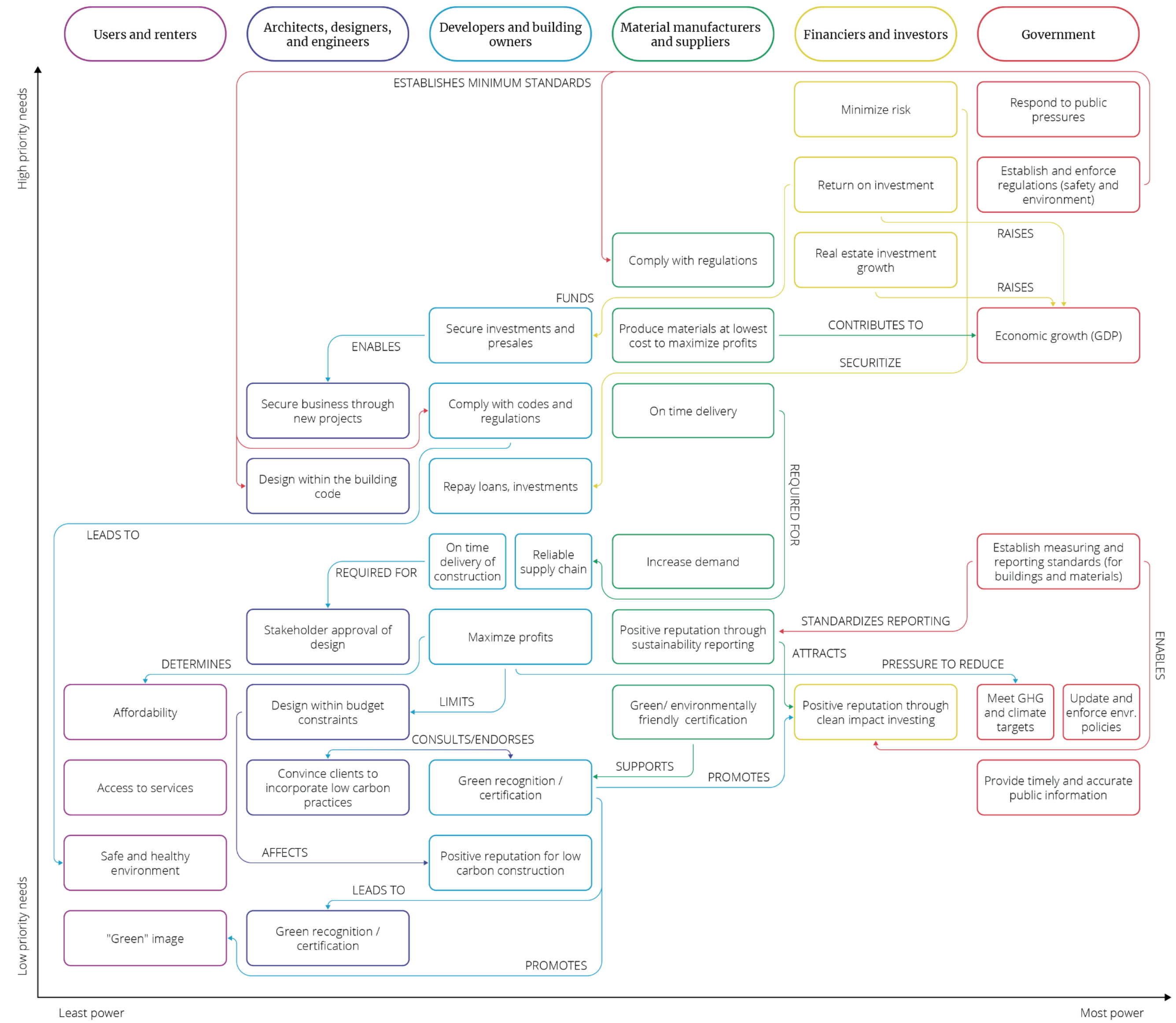
Building material waste that ends up in landfills contributes to carbon emissions through transportation and direct emissions from chemical decomposition. Most construction waste that goes to landfills includes wood products, asphalt, drywall, concrete, and masonry (Yeheyis et. al, 2012). Many of these materials could be reused or recycled, which would reduce the embodied carbon of new construction.

Key System Stakeholders

There are several key stakeholders in the building and construction sector, including:

- Consumers - the users and renters of buildings, and homeowners;
- Architects, designers, and engineers - responsible for designing buildings and building systems;
- Developers and building owners - responsible for securing financing for new building projects, approving designs and budgets, overseeing construction, and (for owners) securing tenants and managing building operations;
- Material manufacturers and suppliers - create the materials needed to construct buildings and sell them to developers and construction contractors;
- Financiers and investors - provide funding for construction and retrofit projects with expected returns on investments, often risk averse; and
- Government (including policymakers and regulators) - establish mandatory codes as minimum standards for buildings, inspect sites to ensure code compliance, develop climate targets, and implement policies to reduce GHG emissions.

We used a stakeholder hierarchy matrix to map the relative needs, power, and influence between the key stakeholders. This diagram highlights how influential mandatory building codes are in establishing the minimum requirements and how motives for maximizing profits take precedence over and can limit action towards low carbon construction. The positive reputation developers and manufacturers earn from environmental certifications currently has much less influence that existing market forces.



Unpacking the Challenge

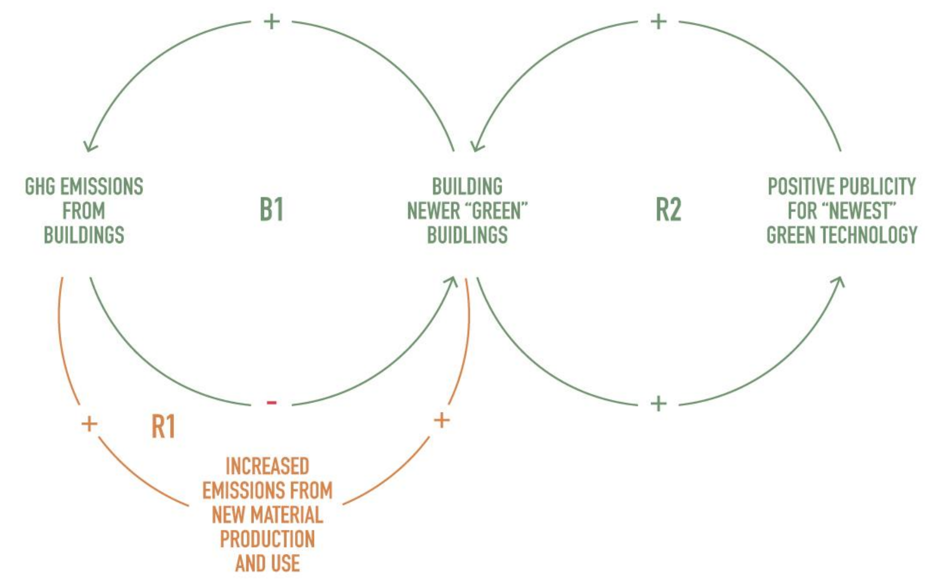
In this section, we explore key aspects and attributes of the whole-life carbon system of buildings to better understand the challenge and what it might take to successfully intervene and reduce our building emissions.

Behavioural Archetypes Contributing to Carbon Emissions

System archetypes provide insights into the underlying structure of a system and can help to diagnose patterns of behaviour (Braun, 2002). We explored two system archetypes that contribute to increasing emissions in the building sector.

New is Greener than Old: Fixes that Fail

New buildings contribute less to GHG emissions than existing buildings (Canada Senate, 2018; Canada Green Building Council, 2017). Depending on the design, a new building may create more GHG emissions than it saves because of the embodied carbon of materials, when an energy retrofit may have been sufficient to reduce emissions. The mentality that newer is greener is a contributing factor to the GHG emissions of the building sector.



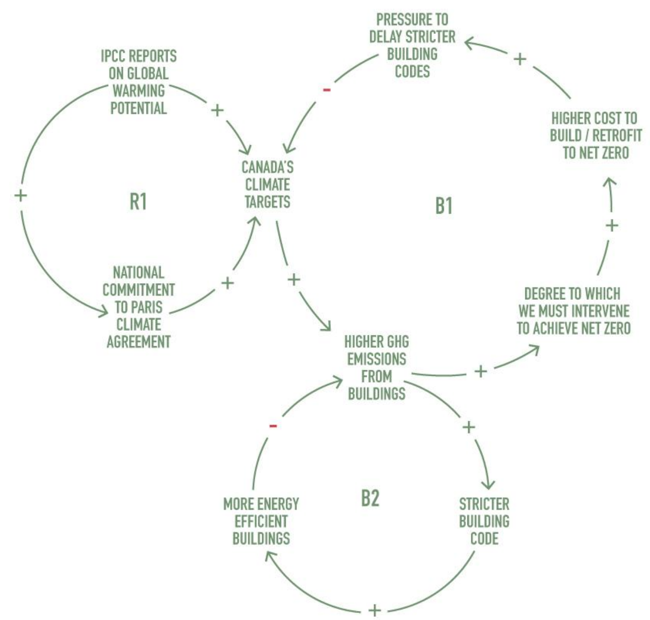
Newer is greener mentality is contributing to the continued emissions from the building sector

Elusive Climate Targets: Eroding Goals

In a typical Eroding Goals archetype, the pressure from missing targets leads to reducing the goals to fit current operations. In this instance, however, Canada set targets that fell short of its goal to begin with: our 2016 NDC will not sufficiently reduce the nation's GHG emissions enough to do Canada's part in keeping global warming to 1.5°C. Though the goal has not changed - at least, no political figure has publicly admitted that Canada cannot meet its 1.5°C goal - the policies agreed to in the *Pan-Canadian Framework on Clean Growth and Climate Change* will fail to meet our NDC (which is already insufficient to meet our stated goal), thus eroding the goals.

The longer Canada delays meaningful action in reducing its emissions, the more expensive and technically difficult it becomes to make the necessary changes to meet the original goal. The economic impact then creates pressure to further reduce the goals (or in this case, the policies intended to get us to the goal) or delay the implementation of new policies.

The external pressure of IPCC reports and our annual disclosures under the Paris Climate Agreement keep Canada from lowering its stated goal without losing face to the international community; however, its policy actions clearly follow the Eroding Goals archetype.



The delayed action in reducing building emissions is eroding the policies needed for our climate targets

Tracking and Reporting Carbon Emissions

Regulators, builders, and consumers continue to ask what can be done to maximize a building's sustainability and minimize its environmental impact. To answer this question, it is essential to understand the environmental impact of buildings, both now and in the future. This is where the Life Cycle Assessment (LCA) process becomes critical: to track and report the whole carbon footprint - operational and embodied carbon - during each stage of a product's life cycle.

Life Cycle Assessments

In the building context, an LCA can be a powerful decision-making and reporting tool for design teams, building owners, and investors alike, offering a broad and meaningful set of metrics to answer key questions about the impacts of energy and materials, on-site processes, building systems, and procurement (Summers & Paleshi, 2019).

Historically, operational performance has been the primary focus of green and sustainable building initiatives. However, as we get a handle on optimizing operational performance, the ability to track and minimize embodied carbon is becoming increasingly important. LCAs can track the whole-life carbon footprints of materials and processes and can help identify carbon hotspots and opportunities for the most impactful GHG emission reductions.

Emissions Reporting

While the infrastructure to support the information flows required to conduct an LCA has been built, large emitting facilities are not legally obligated to responsibly track and report their emissions. If emitting facilities do opt to track emissions, they can choose from a number of tools and methodologies with ranging degrees of accuracy. Moreover, accurately tracking carbon emissions of complicated manufacturing processes and global supply chains is a challenge in itself. As a result, reported data is still not as accurate as it needs to be.

Once the data has been tracked, emitters are responsible for reporting this information according to provincial and national guidelines, which are informed by international standards published by the IPCC. In countries like Canada and the US, federal environmental protection agencies have created GHG reporting programs that outline reporting guidelines for different types of emitters. These agencies are also responsible for quality control of the data they receive and for publishing annual official GHG inventories detailing GHG sources and sinks. These inventories provide the data required by LCA tools.

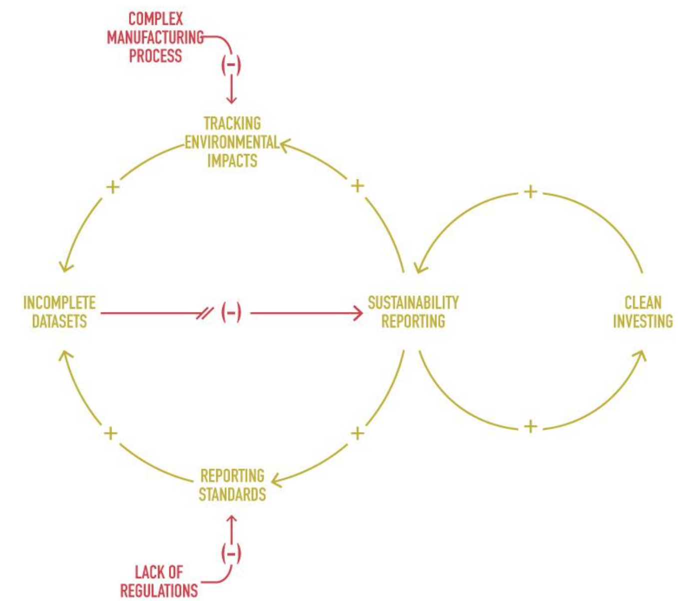
GHG emissions reporting examines two categories (*Calculation Tools | Greenhouse Gas Protocol*, n.d.):

1. *Direct GHG emissions*: Emissions from sources that are owned or controlled by the reporting entity.
2. *Indirect GHG emissions*: Emissions that are a consequence of the activities of the reporting entity, but occur at sources owned or controlled by another entity.

Since the appearance of LCA tools, building professionals have become increasingly aware of the carbon footprint of materials. Sustainability rating systems for the build environment, such as BREEAM and LEED, reward projects that put in the effort to examine whole-life carbon impacts. Thus, a growing demand for net zero construction is driving the need for data and increasing the pressure on industry to provide transparency on their direct and indirect emissions.

Financial Incentives

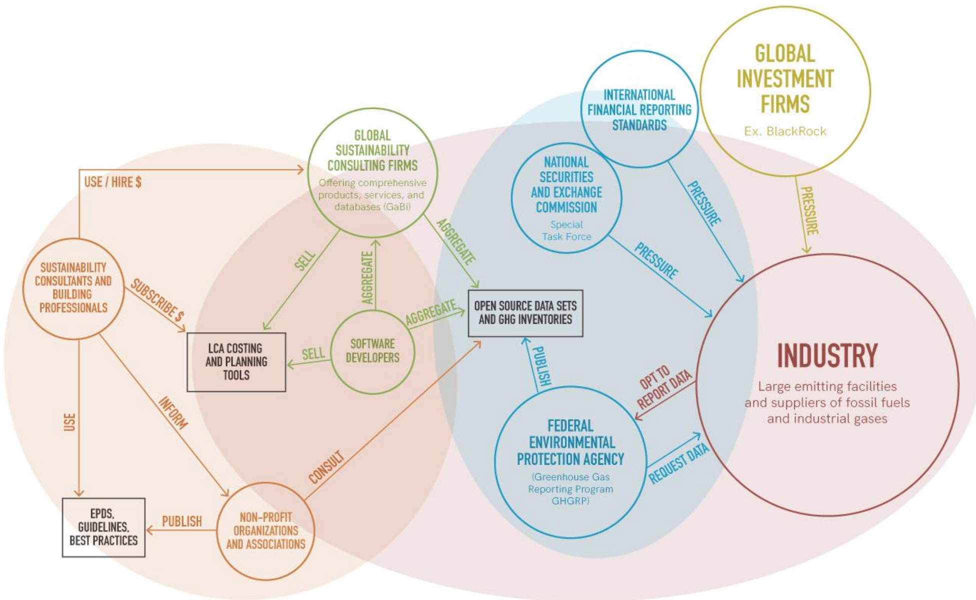
Besides governments and builders, another influential stakeholder is calling for more accurate and transparent reporting of emissions data: the financial community. The interests and barriers for investors in sustainability reporting can be mapped through an Attractiveness Principle system archetype:



Sustainability reporting supports clean investing, but is hindered by the lack of comprehensive datasets

Large asset management firms are seeking investor-grade sustainability data that will help them make “cleaner” investment decisions. They argue that the current annualized sustainability reporting does not provide sufficient data sets to truly make sound investment decisions. Rather, they are seeking accurate, real-time information that can be forecasted into the future. With this caliber of data, they could find cost savings and new business opportunities that will not only advance sustainability, but also corporate fortunes (Mohin, 2021).

Carbon Data and Information Flows



The Infrastructure to Support Decision Making is Developed, but We are Missing Data

With the rising interest in LCAs, a variety of software platforms have been developed to serve the growing market. These can be used to create a building using an LCA model that considers where materials come from, how they are manufactured, where and how they are transported, and how the building is constructed on site. The model then tallies the impacts from each step in each material's life cycle to calculate the building's cumulative whole-life carbon impact. Design decisions can be informed by looking at the whole building model, or by examining and comparing relative impacts for specific materials. These platforms source their LCA information from publicly-available ledgers of aggregate data, including precise GHG and energy-use footprints. Government agencies are the ones responsible for acquiring and aggregating industry information into publicly-available ledgers. They also analyse the data for the purpose of reports and policy recommendations based on national and global climate targets.

In order for the LCA information flow to work, we need regulated industry accountability that ensures the responsible tracking and reporting of GHG emissions. With pressure on industry to report their GHG emissions, we are starting to see an influx of data. But this is not happening anywhere near the scale and speed we need to help manage industry emissions. Furthermore, as highlighted by the financial community, the data being reported is not accurate enough to inform strategic financial decisions that could help advance sustainable manufacturing practices.

Societal Values: Why We Build This Way

A Causal Layered Analysis Exploring the Societal Reasons Behind the Way We Build

There are a number of forces that influence why we build the way we do in Canada, depicted here in a causal layered analysis. Market forces, such as the importance of real estate and development to economic metrics like GDP and a capitalist growth mindset that seeks to minimize costs and resist regulation, play a significant role. Demographic forces, such as the rise of urbanization and the growth of single-person households, influence the quantity and quality of buildings we will need to house our population. Social values, even deeply-cherished values such as individualism and freedom of choice, drive behaviours such as consumerism, conspicuous consumption, and instant gratification.

At the core, two collective metaphors shape the way we choose to build in Canada:

1. The Ant and the Grasshopper: An Aesop fable contrasting a fastidious ant, who spends the summer collecting corn and shoring up supplies for winter, with a hedonistic grasshopper, who eats everything in sight because fields are plentiful and spends the summer maximizing pleasure in the moment. In Canada, our deep-seated entitlement to enjoy life in the moment at the expense of the future shapes our built environment.
2. Anthropocentrism: The belief that the world revolves around humans, that we are separate from and above the rest of the ecosystem and entitled to use all of it for our own purposes. This collective metaphor sanctions our rapid and accelerating extraction of materials and pollution of the environment, leading us to discard and demolish the old rather than find ways to regenerate and adapt.

These forces are not inevitabilities. For example, the table below shows the remarkable contrast between the longevity of our buildings in Canada versus the United Kingdom, a nation that shares many of our values, social structures, and political and economic structures, not to mention widespread devastation and reconstruction after World War 2.

Residential Building Age

	% of Residential Buildings – Canada	% of Residential Buildings – UK
Pre-1946	10%	35.6%
1946-1960s	7.3%	19.2%
1960s-1980s	26.1%	20.0%
1980s-1990s	19.5%	8.0%
Post 1990	37.1%	17.3%

Data Sources: Piddington et al., 2017 and Natural Resources Canada, 2018

If we have a hope of meeting our net zero 2050 target, we need to shift the underlying social metaphors and paradigms about how and why we build.

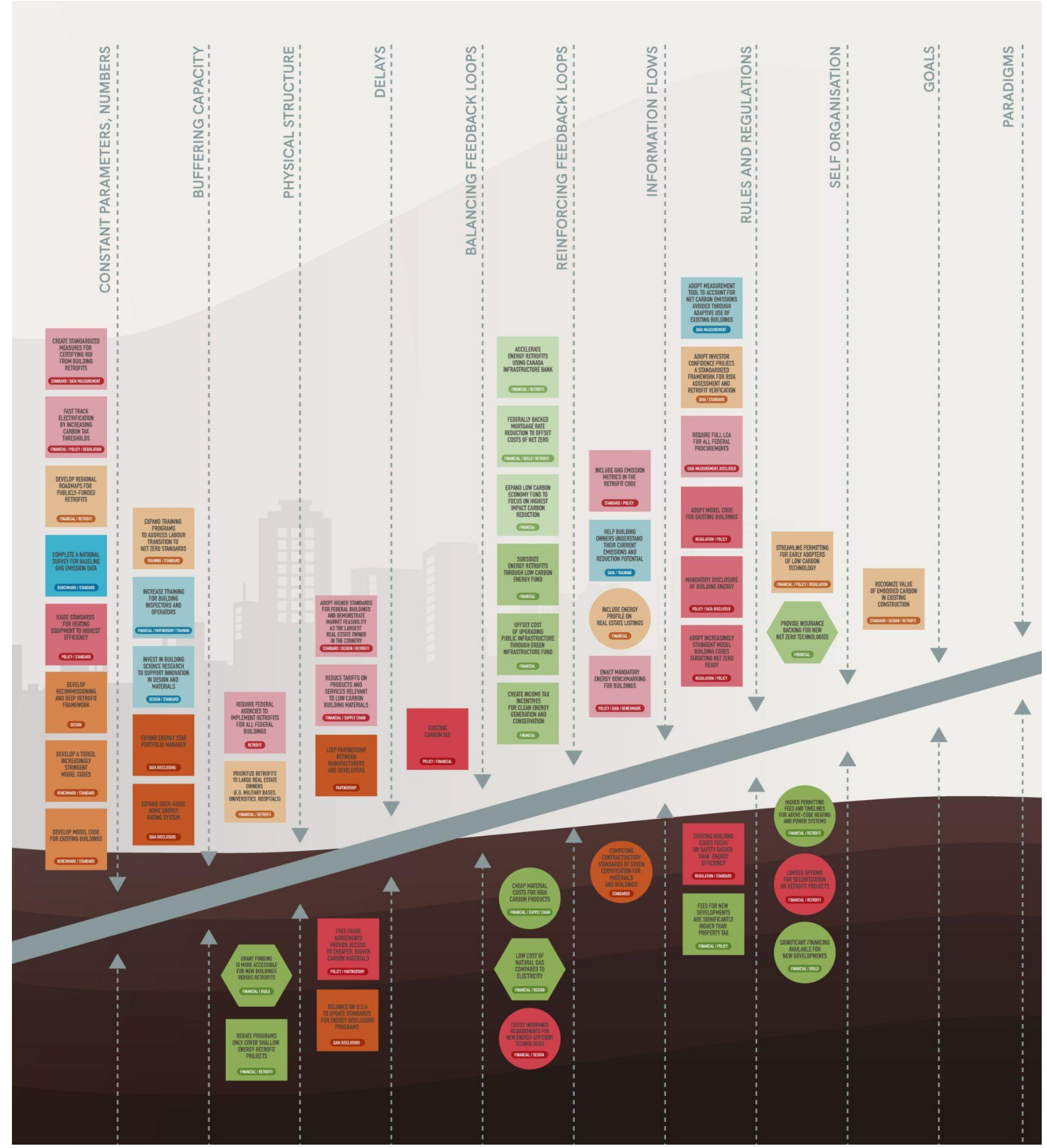
Intervention Analysis

Because climate change is such a pressing issue, and buildings contribute a significant amount to global GHG emissions, numerous recommendations on how to reduce carbon from buildings already exist. However, change in the sector remains slow. To better understand why, we mapped existing and recommended policy interventions on a leverage strategy map based on Donella Meadows' hierarchy of leverage points, then mapped counter-incentives embedded in the existing system that are opposing potential interventions.

We focused on three different sources of policy recommendations for reducing carbon in buildings:

- *Canada's Build Smart Strategy (2017):* The policy framework for reducing building emissions attached to the *Pan-Canadian Framework on Clean Growth and Climate Change (2016)*. This strategy has been agreed to by all provinces and territories and the federal government as the roadmap to reduce carbon emissions from buildings. It also forms part of the planned emission reductions in Canada's NDC submitted under the Paris Climate Agreement.
- *Better Buildings for a Low-Carbon Future (2018):* A report to the House of Commons recommending additional actions needed beyond the Build Smart Strategy in order to reach Canada's climate targets. The federal government has accepted this report but has not agreed to implement any of the new recommendations.
- *A Roadmap for Retrofits in Canada (2017)*: A report from the Canadian Green Building Council in response to the *Build Smart Strategy* to add detailed policy options and recommendations for existing buildings. The Canadian Green Building Council represents the members of the building industry interested in sustainable development, and its inclusion allowed us to provide an industry lens. The federal government has not agreed to implement the recommendations in this report.

We chose not to include other industry standards, such as LEED or Green Globes, because these standards are voluntary and focused at the building level. We were more interested in system-level interventions and policies.



Analysis of the relative leverage strength of different interventions in the system

Analysis

- The entrenched system has interventions at higher leverage points than most of the adopted or proposed recommendations for changing the system. Policymakers and industry players need to find incentives that can overcome existing forces in the system to make meaningful change.
- Not enough recommendations focus on leverage points for existing buildings, which contribute more to GHG emissions than new buildings. Developing and adopting a building code for existing buildings would provide a needed framework, but is relatively limited in its change potential without mandatory retrofit triggers (i.e. the new code requires retrofits for low performing buildings, rather than only coming into force during a renovation).
- Because whole-life carbon calculations are still relatively rare, the carbon savings associated with adapting an existing building rather than building new are not included in cost calculations. Although many of the government's planned interventions will address this data gap, there are no meaningful policy incentives attached to changing how we value existing buildings. Assuming that the market will respond once it can see comparative carbon calculations overlooks the fact that most buildings in North America are demolished well before their material end of life due to changes in land value or building functionality requirements (O'Connor, 2004), not structural failure. Changing the valuation of existing buildings would be a goal or paradigm-level intervention and could have a powerful effect on the entire system.
- The current permitting and insurance processes, which punish variations from conventional standards through higher fees and regulatory scrutiny, are actively slowing the adoption of low carbon technologies. Removing these disincentives by allowing more code variation for proven technologies could be as powerful as financial incentives because it would allow the system to self-organize, rather than interfere with the emerging market for low carbon construction.

This analysis shows that the current planned and recommended policy interventions are heavily weighted on the lower end of the spectrum, while existing forces are more prevalent at the higher end. Improving data, standards, and information flows are all necessary steps to unleash the potential of the low carbon construction industry, but likely will not be sufficient to overcome the strong market and social incentives working in the opposite direction. According to Meadows, "The higher the leverage point, the more the system will resist changing it" (1999, p. 19). If Canada truly intends to meet its GHG emission reduction targets for the building sector, it needs to be intentional in addressing the incentives opposing change.

Recommendations

This section outlines our key recommendations for how to address carbon emissions in the building sector. It will require significant contributions and concerted effort from all of the key stakeholders, as well as a clear roadmap on how to get to net zero carbon by 2050. A critical first step is to align our policies within our stated goal of keeping global warming to within 1.5 °C, thus signalling to industry, funders, and consumers the types of changes that will be needed to avert the worst impacts of climate change.

Stakeholder Roles for Net Zero Carbon

Achieving net zero carbon by 2050 will require alignment between all of the stakeholders in the building sector towards that shared vision. This table summarizes the role each stakeholder can play in order to reach such an ambitious target. Many of these recommendations are adapted from the World Green Building Council's report *Bringing Embodied Carbon Upfront* (2019).

<table>
<tr><th></th><th>Consumers</th><th>Architects & Designers</th><th>Developers & Owners</th><th>Manufacturers & Suppliers</th><th>Financiers & Investors</th><th>Government & Regulators</th></tr>
<tr><td>2020</td><td>• Request carbon data from buildings
• Utilize energy efficiency features of buildings to fullest extent</td><td>• Encourage clients to invest in low carbon projects
• Integrate low carbon at the design stage</td><td>• Conduct LCAs for projects
• Push manufacturing industry for better emission data and reward suppliers who do</td><td>• Require data disclosure from supply chain for embodied emissions</td><td>• Integrate whole-carbon assessment into valuation of investment opportunities
• Request LCAs from new investments</td><td>• Publish updated model code for new buildings and new model code for existing buildings (federal)
• Establish a firm timeline to implement model codes so industry can plan (provincial)
• Incentivize retrofit and adaptive development through tax credits, rebates</td></tr>
<tr><td>2025</td><td rowspan="2">• Demand carbon profiles for real estate and rental unit listings
• Incorporate energy efficiency into planned renovations
• Reduce energy consumption
• Consider environmental impacts in purchasing decisions
• Become informed on LCAs and EPDs to be able to demand better carbon data and disclosure from industry</td><td>• Publicly share LCAs of projects
• Promote adaptation of existing buildings over new construction
• Integrate existing building structures into new designs as much as possible</td><td>• Publish LCAs for all projects
• Incorporate embodied carbon into design decisions</td><td>• Declare embodied carbon emissions for the common products through EPDs
• Electrify factory processes
• Prioritize investment and innovation for most carbon intensive processes</td><td rowspan="2">• Only finance projects compliant with carbon reduction targets
• Require LCAs from new investments</td><td>• Adopt increasingly stringent codes
• Increase inspections for code compliance
• Establish regulatory framework for better carbon data assessment and disclosure
• Lead by example in establishing an energy retrofit program for government buildings
• Accelerate decarbonization of power grids</td></tr>
<tr><td>2030</td><td rowspan="3">• Propose all projects be net zero embodied carbon</td><td rowspan="3">• Only build net carbon zero ready projects</td><td>• Source all power from renewable or low carbon sources</td><td rowspan="3">• Mandatory net zero embodied carbon codes
• Remove energy inefficient products from market
• Increase carbon pricing to disincentivize non low carbon construction and operation</td></tr>
<tr><td>2035</td><td rowspan="2">• Focus upgrade and renovations on energy retrofits and adapting existing buildings</td><td>• Require renewable power for all transportation</td><td>• Divest from non-carbon compliant projects</td></tr>
<tr><td>2040</td><td rowspan="3">• Publish EPDs for all products</td><td rowspan="3">• Only finance projects built to net zero carbon standards</td></tr>
<tr><td>2045</td><td rowspan="2">• Demand on-site renewable power generation to the extent possible</td><td rowspan="2">• Only design net zero carbon projects</td><td rowspan="2">• Only build net zero carbon projects</td><td rowspan="2">• All codes should be mandatory net zero carbon
• Mandatory retrofits for carbon emitting buildings</td></tr>
<tr><td>2050</td></tr>
</table>

The Roadmap to 2050

The following roadmap uses the 3 Horizons model to chart the course towards net zero carbon. This map is a synthesis of our key findings and recommendations for how to address whole-life carbon in the building sector and is primarily focused on policymakers and industry players, although contains recommendations for other stakeholders such as financiers and building owners.

The vision for 2050 re-integrates many of the systems that were out of scope for this inquiry, showing how a circular economy, decarbonized power grid, and regenerative design all work together to create a future where our buildings are no longer part of the problem of climate change, but are contributing to the solution.

Value

2020 | 2030 | 2050

CURRENT SYSTEM CONCERNS

- Reliance on fossil fuel in manufacturing
- Focus of manufacturers on cost savings over sustainability
- Building codes overlook buildings' longevity & environmental impact
- Shipping materials over long distances to save costs
- Reliance on fossil fuel for space & water heating
- Carbon intensive grid in some provinces
- Lack of clarity on emission reduction methods & strategies
- High cost of net-zero construction & retrofit
- Policies fall short of meeting GHG emissions reduction targets
- Lack of industry transparency in sustainability reporting
- Lack of accurate real-time sustainability data
- Lack of whole-building LCA tracking & reporting regulations
- Market preference for less durable buildings styles
- Perceived tradeoffs between economy & environment
- Market preference for new construction vs retrofit
- Prioritization of immediate benefit over long-term benefits

INTERMEDIATE INTERVENTIONS

- Update education & training for building professionals for low carbon construction
- Roadmap of incremental updates for raising standards in building codes to reach net zero construction & retrofit
- Model code for existing buildings with GHG emissions metrics
- Streamlined permitting for early-adopters of low carbon technologies
- All social housing buildings retrofitted to low carbon
- Existing buildings are retrofitted for zero operational carbon & with low-carbon materials
- Federally backed mortgage rate reduction to offset costs of net zero
- Income tax incentives for clean energy generation & conservation
- Green Infrastructure Fund to offset public infrastructure upgrade costs
- Insurance backing for new net-zero technologies
- Reflect embodied carbon costs in the pricing of materials & services
- Invest in tech innovation in real-time sustainability reporting
- Regulation & standardization of carbon emissions tracking & reporting
- Mandatory benchmarking & disclosure of a buildings energy consumption
- Measurement tool of carbon emissions reduction achieved through adaptive use of existing buildings
- Mandatory LCA for all federal procurement processes
- Cost share structure for municipalities to benefit from carbon tax revenue to reduce incentives for them to approve new construction
- Increasing buyers awareness of different construction styles durability
- Demolition tax

VISION (IDEAL FUTURE)

- Buildings contribute to carbon sequestering
- Buildings contribute to the energy grid
- All new construction is operational & embodied carbon neutral or carbon positive
- Renewable energy sources are used in all manufacturing processes
- NDC have net positive targets
- Carbon emitting buildings are too costly to construct & operate
- Tracking & reporting emissions is standard practice
- Fully transparent tracking & reporting of emissions
- Market favours buildings for longevity & low maintenance
- Consumers and markets value environmental products over other measures (such as price)
- Decarbonized power grids
- Regenerative design
- Wholistic thinking
- Circular economy

POCKETS OF THE FUTURE IN THE PRESENT

- Alternative sustainable materials
- Carbon capturing technologies
- City of Vancouver Zero Carbon Building Policy
- Pilot net zero buildings by for profit companies (Evolv1)
- Green building certification programs & competitions
- Growing consumer demand for green materials/practices
- Some jurisdictions require LCAs for new buildings
- LCA costing and planning tools
- Open source LCA datasets
- Materials innovation for durability and efficiency
- Factoring historical and cultural value of buildings

ELEMENTS OF THE CURRENT SYSTEM THAT CAN BE REUSED

- Heating equipment standards
- Current building code (update)
- Optional compliance codes
- Energy rating systems
- Local Energy Efficiency Partnerships (LEEP)
- Building certification programs
- Low Carbon Energy Fund to subsidize energy retrofits
- Cap & trade systems
- Carbon tax
- Open source LCA data sets & reports
- LCA costing & planning tools
- Recommissioning & retrofit frameworks
- Heritage & historical value designations

ELEMENTS OF CURRENT SYSTEM WE NEED TO SUSTAIN

- Micro grids
- "Green" as a real estate selling point
- Measuring & monitoring carbon footprints
- Reusing foundations & existing architectural features
- International collaboration/ efforts towards preserving Earth
- Appreciation of the role buildings play in our communities
- Appreciation of the environment
- Believing individual choices matter & individuals can make a difference
- Environmental awareness

Time

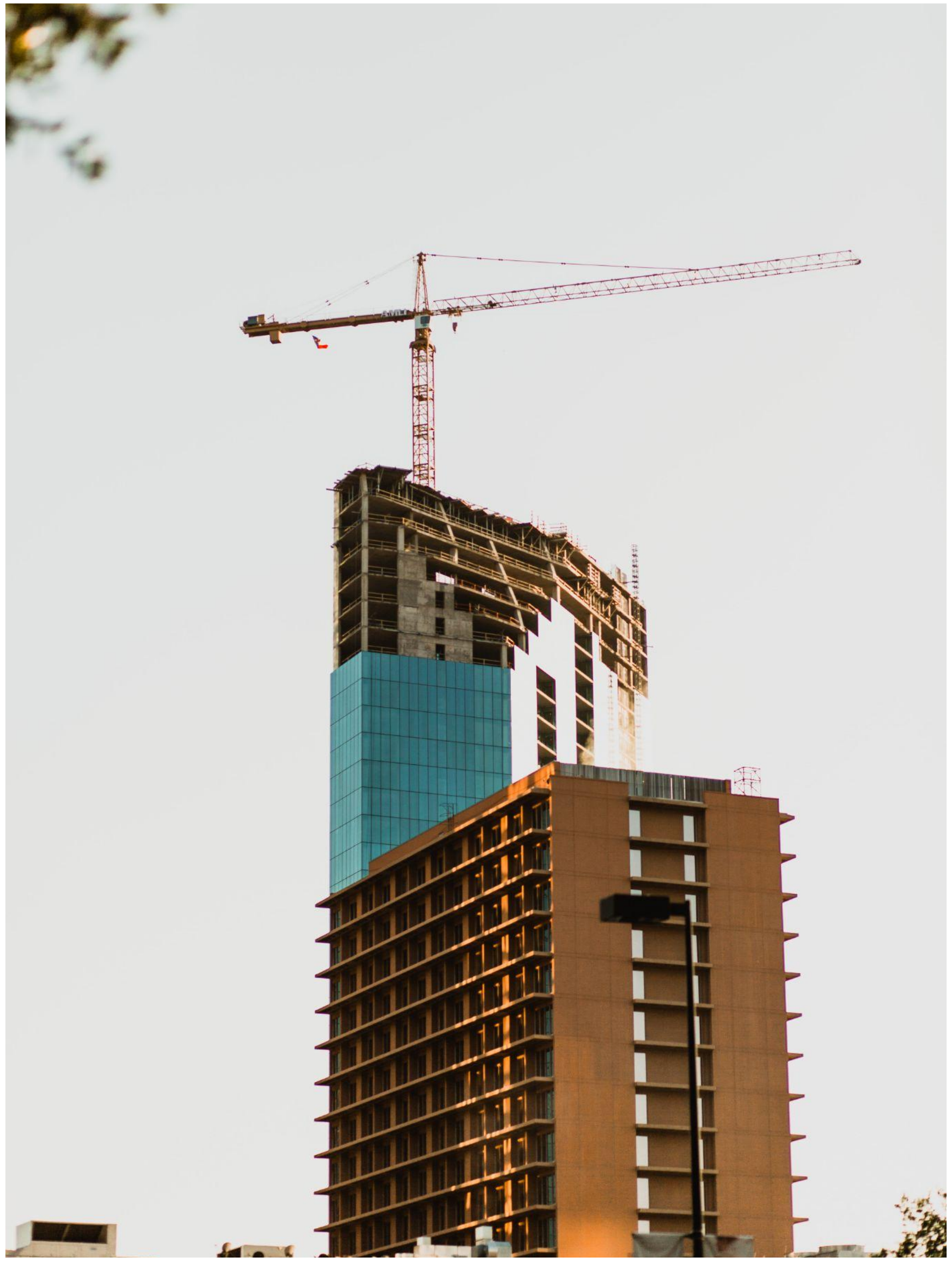
Whole-Life Carbon Emissions of Buildings | Climate Targets | Tracking & Reporting Carbon Emissions | Social Values | Connected systems

Conclusion

So, is the greenest building the one already standing? Without analyzing the whole-life carbon emissions of buildings, the question is impossible to answer. The complexities and challenges of life cycle assessments in the current system mean that analyses are a best guess, but still a step in the right direction. Better data and standardized reporting regulations will help to close the knowledge gap and make it easier for investors, developers, and consumers to understand the true carbon impacts of their decisions.

We hope this analysis brings attention to the importance of considering whole-life carbon in decisions and policy interventions for the building sector. Reaching our 2030 climate targets and a net zero carbon building sector by 2050 are possible, but only by addressing the underlying structures and societal values of our current system. Decarbonizing the built environment does not require us to rebuild 15 million structures in Canada to a new low-carbon standard, but rather to shift our perspective and learn to value carbon emissions *avoided* as much as we value the latest in building design and technology.

And from that lens, the greenest building may just be the one already standing.



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Appendix

Net Zero Costs More to Build

HIGH INITIAL CAPITAL COSTS

A net zero carbon building may add up to 20% in capital construction costs, depending on the design.

THE MARKET OPPORTUNITY

As investors look more closely at carbon emissions through ESG reporting, developers at the forefront of low carbon construction may be well positioned to realize the opportunities of the untapped private sector market.

GOVERNMENT-LED CONSUMER DEMAND

Consumer demand is the leading reason why developers create net zero carbon buildings. However, more than 60% of green building projects in Canada are for institutional buildings – funded by taxpayers.

OPERATIONAL SAVINGS

Some of this initial investment can be recuperated over the lifecycle of the building, as low carbon buildings:

- Attract higher rents
- Have lower vacancy rates
- Have higher resale value
- Reduce operating costs for heat and electricity by up to 90%