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Understanding the Role of Embodied Carbon in Climate Smart Buildings

Platte Fifteen | Oz Architecture.
Photo courtesy: JC Buck

Report on Carbon Reduction Policy and Design Best Practices

THINK WOOD®

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ABOUT THINK WOOD

Think Wood is a communications campaign providing commercial, multi-family and single-family home design and build resources to architects, developers and contractors with continuing education, research, design tools, and innovative project profiles.

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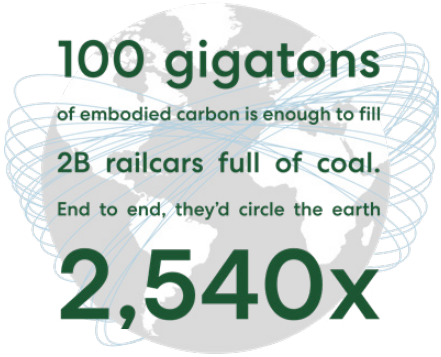
The Opportunity to Lead

The need to reduce carbon emissions is increasingly urgent. Since the 1980s (and perhaps, even as far back as the 1800s[1]), scientists have understood that global temperatures are rising as a result of increases in atmospheric carbon. There is overwhelming consensus that this increase is attributable to human activities.[2] Now is the time for every emitting sector to evaluate their emissions, and consider how to lower their carbon footprint.

An estimated 80% of the embodied carbon attributable to building materials comes from structural products, making it vital to have accurate information when selecting structural building elements.[3] Without decisive action, building materials used in new construction in cities across the globe will generate 100 gigatons of embodied carbon by 2050.[4] That's the equivalent of burning enough coal to fill more than two billion railcars.[5]



Although carbon reduction is a global challenge, the solutions (and in effect, the real work) are found at the local level. Buildings and their construction account for 39% of global carbon dioxide emissions; 28% of those emissions come from operational carbon – or from the energy used to power, heat and cool a building. Reductions in operational carbon are tackled through energy efficiency measures and are where policymakers, developers, architects and engineers have made significant advances. The remaining 11% of carbon emissions are from building materials and construction.[6] This "embodied carbon" can account for half of the total carbon footprint over the lifetime of the building.[7] (see figure 2)

The decisions on what to build, where to build, and how to build are made by architects, engineers and developers/ builders. Those decisions are heavily influenced by planning and development departments, county boards, and other local commissions, which in turn are influenced by state and national plans and programs. By taking smart steps on how buildings are constructed, local leaders can make significant strides in meeting carbon reduction targets.

"By taking smart steps on how buildings are constructed, local leaders can make significant strides in meeting carbon reduction targets."

It is often said that the hardest part of any journey is the first step. Fortunately, the journey of carbon emission reduction has already begun in many parts of the world, with local leaders employing strategies and tactics that are proving successful over time.

This document offers a compendium of those best practices for the benefit of leaders who are considering climate smart buildings as part of their overall climate strategy. It presents a starting point and reference guide for community leaders to make informed decisions as they aim to reduce their communities' carbon footprint. Policy makers at the municipal, county and state levels can draw on this document to inform their decisions about community planning and individual buildings. While not a comprehensive analysis, the intent is to provide resources and inspiration to inspire that first step in the journey. Readers are encouraged to consult with local environmental, architecture, and development groups for more information.

Global CO_2 Emissions by Sector

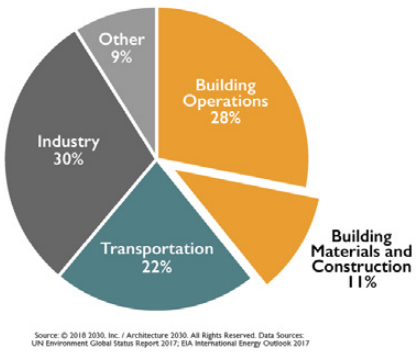


Figure 2

Embodied Carbon + The Built Environment

Executive Summary

WHAT IS IT?

Embodied carbon for building materials is a measure of the greenhouse gas (GHG) emissions associated with one or more life cycle stages. Total embodied carbon is attributed to the entire life cycle of the building material, including the manufacturing, maintenance, decommissioning and end of life of a building.[8] Embodied carbon is different than operational carbon, which is the carbon emissions from producing the energy used to operate a building once it is completed. Examples of operational carbon sources include HVAC systems, water heaters, pumps, fans and other critical motors.[9]

Embodied carbon can include a portion of or the entire life cycle of the materials used in a construction project, from the moment that material is either harvested (trees for wood) or excavated (mined minerals for steel and concrete) to the moment it is returned (e.g. landfilled or composted), recycled, or reused.

WHY IS IT IMPORTANT?

The built environment is growing at a record pace in the United States. In just one sector, it is estimated that 2.5 million new housing units are needed to make up for the nation's housing shortage.[10] To reduce the GHG emissions associated with that construction, communities need to act now to create embodied carbon strategies that reduce environment impacts from buildings we'll use well into the future.

WHERE IS IT?

Embodied carbon can be determined for most products by evaluating each step in its life cycle. Besides building products, it can be measured for roads, vehicles, and even bananas.[11]

The amount of embodied carbon can be significant in buildings. Building materials all require energy to be extracted and processed. Energy is needed to transport materials to a job site and during construction. As the building is decommissioned, the process of deconstruction, recycling, repurposing or landfilling produces emissions for the various building materials.

Embodied carbon varies dramatically between concrete, steel and wood, making product decisions key in achieving lower carbon buildings. Manufacturing wood products is less energy intensive than the process for concrete or steel, which contributes to their low embodied carbon.

HOW IS IT MEASURED?

Embodied carbon is determined by conducting a life cycle assessment (LCA) of a product, assembly or the building over declared life cycle stages. An LCA study returns results for a number of environmental metrics, including the potential to impact climate or "global warming potential" (GWP). Embodied carbon is the GWP result. Embodied carbon is measured for each stage of the product's life cycle, allowing comparisons across any combination of stages.

"To reduce the GHG emissions associated with that construction, communities need to act now to create embodied carbon strategies that reduce environment impacts from buildings we'll use well into the future."

WHO IS WORKING ON IT?

Embodied carbon is a priority for many environmental, architecture, and urban planning organizations including C40 Cities,[12] Architecture 2030,[13] Urban Land Institute,[14] and the World Green Building Council.[15] Of particular note are two international policy reviews of embodied carbon by Forestry Innovation Investment and Bionova, sponsored by the Finnish Ministries of the Environment and Transport.[16] [17]

Many experts believe addressing embodied carbon for buildings and building materials is critical to achieve the goals of the Intergovernmental Panel on Climate Change (IPCC) and the 2016 Paris Climate Agreement.

WHEN IS THE BEST TIME TO ACT?

In short, by making embodied carbon reduction a priority today, builders, architects, planners and city leaders can reduce the environmental impact of new construction and create a healthier community for generations to come. The first step of any strategy begins with a commitment to change. Planners can advocate for climate smart buildings and projects. Government agencies can invest in tools to assess building carbon footprints and compare design scenarios to identify the best options. Local leaders can develop programs and policies to support and incentivize reducing the carbon footprint of the built environment.

The costs of delaying any longer are too high. Greenhouse gas emissions have increased by 90% since 1970.[18] A 1.5% increase in global warming will have catastrophic results for ecosystems and people around the world, including the United States.[19] Communities can't afford to wait.

In fact, many U.S. states and cities have created their own carbon action plans that can provide a roadmap for action. Recognizing there is no one-size-fits-all solution, the authors of this report instead present a snapshot of the current embodied carbon landscape — both policies and design best practices — in the U.S., Canada and Europe in order to facilitate a better understanding of embodied carbon and the impactful role it plays in climate smart buildings.

Photo credit: Erna Peter

T3 Minneapolis

Project: T3 Minneapolis (Timber, Transit, Technology)
Architect: Michael Green Architecture
Engineer: Magnusson Klemencic Associates

Standing at seven stories tall, T3 was the first commercial property in the U.S. to use timber for its structure and interior. It demonstrated the ability of large timber projects to lower the carbon footprint of the built environment, while providing a warm and innovative commercial space. Approximately 2.2 million board feet were used in the structure, which will sequester about 700 tons of carbon for the life of the building. It was also built in significantly less time than conventional steelframed or concrete buildings, completed in just two and a half months at an average of nine days per floor. Given timber's light weight, lower production time and costs, T3 developer Hines has replicated this building prototype in Atlanta, with plans to expand to other markets including Chicago, Denver, Toronto and Melbourne.[20]

Photo credit: Erna Peter

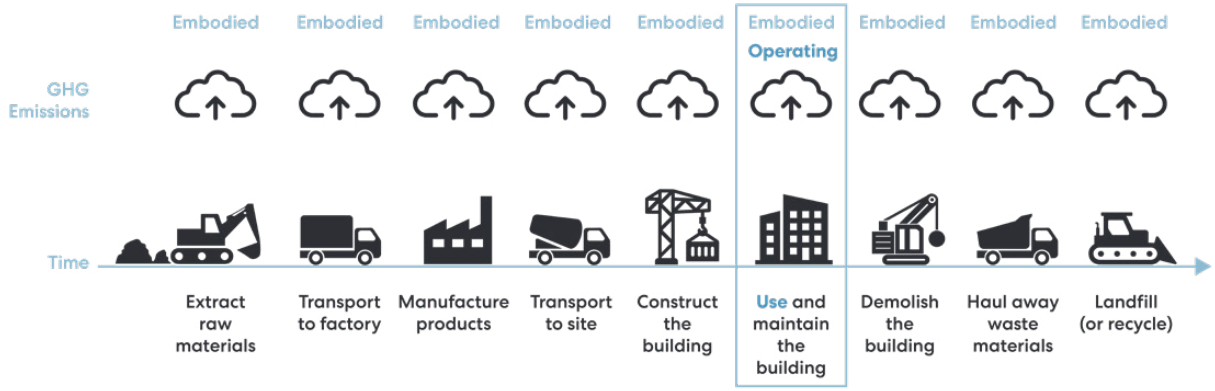
Embodied Carbon in a Building's Lifecycle

Embodied carbon comprises the greenhouse gas emissions from the declared stages of the life cycle including resource extraction (e.g., mining and harvesting), processing and manufacturing of materials, building construction, building maintenance and repair, demolition, and disposition of materials at the project's end of life (e.g., landfilling and recycling).

As buildings become more energy efficient, the upfront embodied carbon from materials begins to account for a higher proportion of a building's carbon footprint.[21] Very soon, embodied carbon is likely to become the dominant source of building emissions.

Cradle to gate embodied carbon is attributed to the harvest/extraction, transportation and manufacturing of the product. This is also referred to as upfront embodied carbon. Most environmental product declarations are based on this scope.

For in-depth studies comparing structural products and systems, the LCA scope might include transportation of the product to the job site and assembly of the core and shell (structure of an enclosure).[22] Whole building life cycle assessment is a study of the entire lifecycle of the materials in the building and includes embodied carbon emissions from operation energy and deconstruction. For primary structural material comparison and selection, this level of assessment is not necessary.

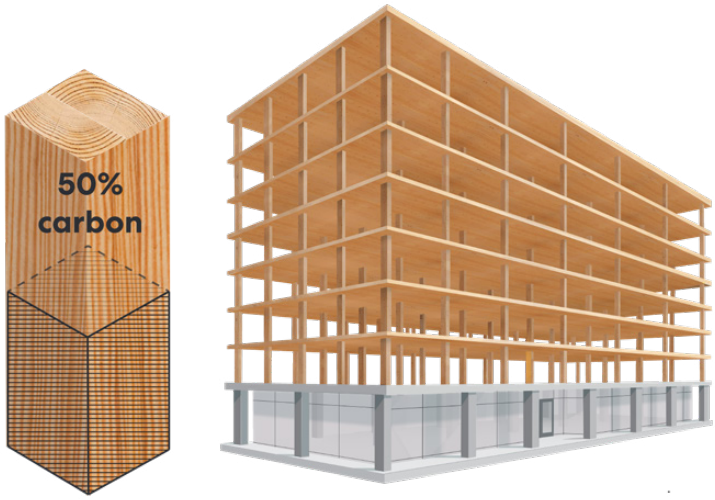


Embedded Carbon in Wood Products

Embedded carbon is the storage of carbon for long periods of time. Wood products are approximately 50% carbon by dry weight.[23] The use of wood products in buildings provides an additional environmental benefit by storing carbon removed from the atmosphere. This ability to sequester, or "embed", carbon makes wood the ideal product for buildings, which are designed for long service lives. Essentially, a wood building is an enormous carbon sink. This storage of carbon is a unique environmental attribute that does not exist in competing structural products.

Sequestered carbon is removed from forests as trees when harvested to produce logs for processing. Forest carbon remains behind as tree roots and slash. Over time, forest carbon is captured in the soil or is released back to the atmosphere through disturbances of the forest floor, photosynthetic growth, and decay. Logs are transported to mills, where they are sawn into lumber or veneered. The final product contains embedded carbon that once shipped to the construction site is stored in the building's structure.

The American Wood Council Environmental Product Declaration for sawn lumber[24] provides an average sequestered carbon calculation for the product. When sequestered carbon is considered along with embodied carbon, many wood products can have a negative CO2eq value.



Lower Carbon: Design Best Practices

There are various design options available to reduce the embodied carbon throughout the lifecycle of a building. This section examines best practices recommended by third party organizations, including the Urban Land Institute and American Institute of Architects.[25,3]

Reuse or Optimize Existing Construction

Overbuild, a technique that adds stories on top of an existing building, is a creative way to use existing buildings to provide new homes and offices. As city populations grow, developers are using overbuild designs to optimize existing structures and quickly provide housing. Timber can be a smart choice for overbuild designs as its light weight allows for greater heights, without compromising the original architecture or design of a building.[26]

Limit Carbon Intensive Materials and Opt for Low Carbon or Carbon Sequestering Alternatives

LCAs have shown that wood performs better than other materials in terms of embodied energy, air and water pollution, and GHG emissions. In fact, substituting wood for concrete and steel in structural systems of commercial buildings can reduce fossil fuel use and cut GHG emissions on average 60%, according to analysis by Oregon State University.[27] The benefits of wood were further confirmed by a study commissioned by the Canadian Wood Council, in which the environmental impact of wood, steel and concrete structures were considered. The results were clear: "wood does an excellent job for virtually every component of a building and has the least impact on the environment."[28]

Regardless, when built correctly and in accordance with the most up-to-date codes, all materials meet the standards for public health and safety. It is important that builders, developers, and architects have a choice to select the right materials for their specific project needs. Carbon measurement tools can help compare design systems to encourage project owners to choose sustainable materials.

Reduce the Amount of Materials Used and Minimize Waste

Pre-cut structural members and modular designs can help ensure project owners account for only what is necessary to complete a project. Less material can result in lower costs, less construction time, less equipment needed and fewer workers onsite.

Lower Carbon Impact from End of Life

Select building materials with end of life options ranging from re-use and recycling to carbon capture opportunities for renewable energy sources (e.g. landfill gas or bioenergy). Specifiers can increase recycling by using recovered materials and by making it clear in their construction documents that clean job site waste should be separated and taken to a local recovery center.

"Substituting wood for concrete and steel in structural systems of commercial buildings can reduce fossil fuel use and cut GHG emissions on average 60%, according to analysis by Oregon State University."

End of life for forest products includes a combination of recycling and reuse, burning for energy to replace fossil fuels, and landfilling. Organic waste, including wood, in landfills can also provide a climate change mitigation opportunity — methane gas resulting from wood's decomposition can be captured and converted to generate energy or electricity, which can replace the use of non-renewable sources of energy. Landfills can also serve as a significant carbon sink — carbon that is of plant origin (including wood and paper) is not degraded after disposal. Rather, it permanently stores (or sequesters) in the landfill.[29,30]

Photo: David Lauer

The Alliance for Sustainable Colorado

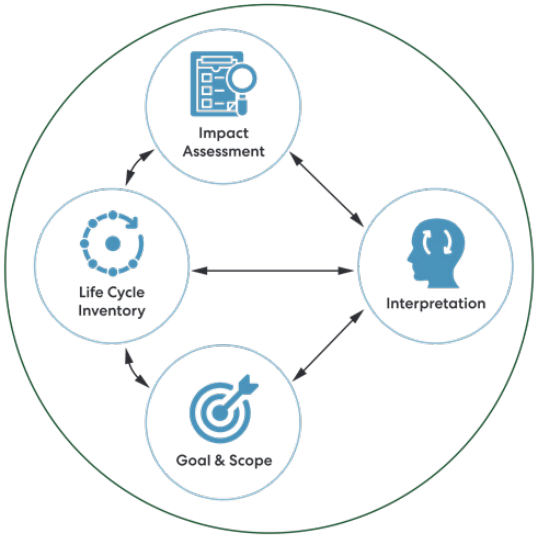
Project: The Alliance for Sustainable Colorado
Architect: Gensler

The Alliance for Sustainable Colorado was developed with one critical question in mind: can a person leave a building healthier than when they entered? The design team re-purposed a 100-year-old building to achieve their sustainability and occupant well-being goals. They used the original heavy timber and implemented biophilic design features, including natural wood elements, to reinforce health and wellness in the workplace. By re-purposing existing structural beams, the design team achieved the maximum reduction of the building's carbon footprint and has been awarded considerably for their efforts. The Alliance for Sustainable Colorado is the recipient of more than 10 awards showcasing its sustainable, carbon mitigating features, including LEED v4 Existing Buildings Operations + Maintenance Platinum Recertification, Certifiably Green Denver Organization and Event Space, Colorado Office of Energy Management and Conservation: Energy Champion, and more.[31]

Life Cycle Assessment

A life cycle assessment (LCA) assesses many different environmental impacts, but the one that many builders and architects are interested in from a climate perspective is carbon footprint. A building carbon footprint includes both operation emissions and the emissions associated with producing the material.

LCAs incorporate environmental impacts of materials over declared life cycle stages, from extraction of raw materials through disposal or recycling. LCAs for any products or structures are estimates of environmental impacts using best available science. They are universally accepted as the most effective tool for understanding the environmental impacts of building materials, inform decision-making on materials and have been integrated into green building standards globally, including Building Research Establishment Environmental Assessment Method (BREEAM USA), Leadership in Energy and Environmental Design (LEED), and Green Globes.



The phases of a Life Cycle Assessment are defined in the ISO standards 14040 and 14044.

LCA reports can be created for products or completed buildings, though different models are applied for each. For buildings, LCAs are typically measured from "cradle to grave," meaning from raw material extraction to reuse or recycling. For products, they can be measured "cradle to grave" or "cradle to gate," the latter meaning from raw material to the factory gate as the manufacturer would not be able to characterize how the product would be used after it is sold. LCAs are measured cradle to gate for use in Environmental Production Declarations.

"Because variables such as raw material sources, harvesting methods, supply chain processes, transportation distances, construction practices, design choices, location, and climate and operating practices all combine to determine the lifetime carbon footprint of a building, it's important to consider LCAs in the project planning phase. "

In the past, LCAs have typically been conducted on the impact of a structure after construction, rather than during the design and planning process when the data could influence design decisions. Because variables such as raw material sources, harvesting methods, supply chain processes, transportation distances, construction practices, design choices, location, and climate and operating practices all combine to determine the lifetime carbon footprint of a building, it's important to consider LCAs in the project planning phase.

Whole Building LCAs (WBLCA) cover all stages in the life cycle of a building and its components, from raw material extraction (cradle) and transportation; product manufacturing, transportation, building construction and operation; and eventual recycling or disposal (grave), which can provide carbon impact throughout project design and completion. Metrics are generated that summarize resources consumed and pollutants emitted over the life cycle and their potential impact on the environment, helping to inform effective decision-making. [32,33,34]

Environmental Product Declaration

Environmental product declarations (EPDs) are third-party verified documents that summarize the results of a product LCA. There are many EPDs available for construction products (industry-average EPDs that represent a product group as well as brand-name manufacturer-specific EPDs). The publication of EPDs is a relatively new trend in North America that has been increasing rapidly. Different background data sources, variations in data quality, and LCA method make it difficult to compare EPDs across products. However, the growth in EPDs is a promising trend because it is a sign that the building industry is using LCAs more often.

An EPD for a commodity product like lumber or concrete is typically cradle to gate because the manufacturer cannot characterize how the product is used after it is sold. Having an EPD for a product does not necessarily mean that the product is environmentally better than others, but it is a way to obtain transparent information on the environmental impact of the product through the declared life cycle stages.

What is an EPD?

An environmental product declaration, or EPD, is a standardized report of environmental impacts linked to a product or service. An EPD is similar to a nutritional label on food. It communicates the environmental performance of a product to consumers.

EPD "Nutritional" Label – Wood Product

AMOUNT PER UNIT – CUBIC METER

LCA IMPACT ASSESSMENT	UNIT	TOTAL	FORESTRY OPERATIONS	WOOD PRODUCTION
Global Warming Potential	kg CO_2 eq.	143	11	132
Acidification Potential	SO_2 eq.	1.60	0.15	1.45
Eutrophication	kg N eq.	0.06	0.01	0.05
Smog	kg O3 eq.	25	5	20
Total Energy	MJ	7,425	165	7,260
Non-Renewable Resources	kg	6	0.01	6
Renewable Resources	kg	640	0.00	640
Water Use	L	1,061	11	1,050

The EPD "nutritional label" for a sample wood product[35]

The Difference Between Biogenic and Fossil Carbon

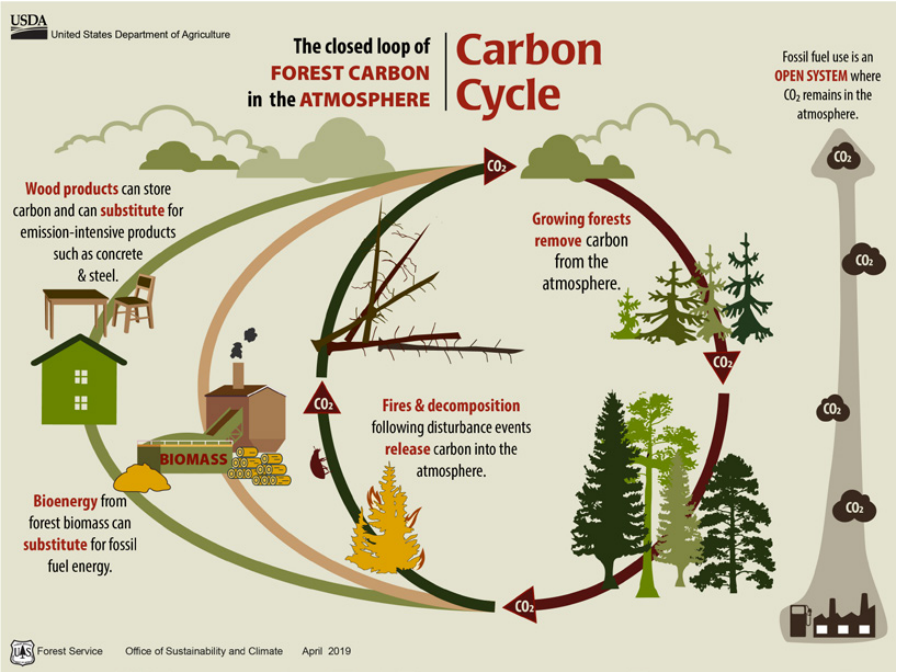
Wood EPDs are underpinned by the biogenic carbon cycle — in product storage and energy for manufacturing as well as impacts in the forest. This contrasts with the fossil carbon cycle, which underpins materials such as concrete and steel. The complexity of the biogenic cycle warrants detailed explanation.

As trees grow, they clean the air we breathe by absorbing CO2 from the atmosphere. Trees release the oxygen (O2) and incorporate the carbon (C) into their twigs, stems, roots, leaves or needles, and surrounding soil. Young, vigorously growing trees take up carbon dioxide quickly, with the rate slowing as they reach maturity (typically 60–100 years, depending on species and environmental factors). As trees mature and then die, they start to decay and slowly release the stored carbon back into the atmosphere.

Growing forests absorb, store, and release carbon over extended periods of time. This cycle is a closed loop cycle through natural processes of growth, decay and disturbances like wildfires and insects. It is also a closed loop cycle when forests are harvested for use in products or energy as shown in the USDA figure below.

"The biogenic carbon cycle (coming from a living organism) fundamentally differs from the one-way flow of fossil carbon to the atmosphere. Whether trees are harvested and used for products or decay naturally, the cycle is ongoing, as forests regenerate and young trees once again begin absorbing carbon."

However, when trees are manufactured into products and used in buildings, a new phase of carbon mitigation begins and some carbon is never returned to the atmosphere.



The closed loop cycle of forest carbon in the atmosphere vs. the one-way system of fossil fuel[36]


Photo: Nordic Structures and Sotramont

Arbora

Project: Arbora
Architect: Lemay + CHA (Phase 1), Provencher Roy (Phase 2 and 3)
Engineer: Nordic Structures

The all-wood Certified LEED® Platinum Arbora project is the largest mixed use, multi-family complex of its kind in the world built from mass timber. Encompassing nearly 600,000 square feet, Arbora includes 430 residential units of varying size, in addition to ground floor retail and hospitality spaces. With exposed wooden post-and-beam design in every unit, the structure offers both biophilic and carbon reduction benefits. Prefabricated timber components cut to the required dimensions were shipped to the site from a plant in Québec, resulting in savings for cost, time to develop, and carbon emissions due to transport. The significant volume of wood used in this project acts as a carbon sink and reduces embodied carbon compared to steel and concrete structures of this size.[37]


Photo: Nordic Structures and Sotramont

Carbon Reduction Policies

North America

The marketplace is growing for climate smart buildings. A number of North American cities and states have passed laws and issued directives to reduce greenhouse gas emissions from all sectors, with many focused on reducing emissions from the construction and operation of buildings. In addition to reviewing the following examples, planners are encouraged to review local efforts to determine what works best for their community.

California

In 2017, Governor Jerry Brown signed Buy Clean California into law, representing the first time a state sought to reduce its own emissions as well as emissions embodied in products that it imports.[38] This legislation mandates that state agencies consider embodied carbon of the full supply chain for new construction or infrastructure projects, in turn rewarding manufacturers that produce materials with lower embodied carbon levels. The legislation requires assessment of embodied carbon within material categories, driving improvement after the design phase when materials have already been chosen. Buy Clean California applies to suppliers' emissions performance for steel, glass and insulation purchased by the state of California and requires:[39]

- California Department of General Services (DGS) set a maximum acceptable level or intensity of emissions for each material
- State agencies take into account environmental impacts in planning and investment decision making, using full life cycle assessments to evaluate and compare infrastructure investments and alternatives
- Companies bidding on projects with the state submit full LCAs of materials used in projects

City of Los Angeles

In February of 2020, Los Angeles Mayor Eric Garcetti released Executive Directive No. 25, L.A.'s Green New Deal, committing all new or substantially rehabilitated buildings owned by the city of Los Angeles to being 100% carbon-free. This includes using less carbon-intensive materials in the construction process. Los Angeles was the first local government to adopt the Buy Clean California Act, requiring carbon emissions reductions from construction materials, beginning in 2021 for buildings such as fire stations, civic centers and libraries.[40]

"For construction of new state-owned facilities, state agencies shall ensure they are designed to be zero-energy and consider embodied carbon."

Also in Los Angeles, the Central City Association (CCA) is an example of a local community organization advocating for mass timber affordable housing developments. CCA released Mass Timber: A Faster, More Affordable, and More Sustainable Way to Build Housing. The report includes actions that government agencies, developers and architects can take to catalyze this new market and begin delivering jobs and housing.

CCA's proposal outlines city policy recommendations, including updating the building code to include 2018 rules adopted by the International Code Council Ad Hoc Committee on Tall Wood Buildings in accordance with the International Building Code update; creating land use and zoning incentives to encourage use of mass timber for affordable and mixed-incoming developments; developing staff training programs for mass timber development; and tapping into local funding such as the city's Affordable Housing Trust Fund and the county's Housing Innovation Fund.

Washington State

In 2018, Governor Jay Inslee signed the "State Efficiency and Environmental Performance" executive order that outlined emissions reduction initiatives. The order requires state agencies to consider the benefits and costs of available options to minimize GHG emissions in making purchasing, construction and leasing decisions; and where possible, select lower emissions options. For construction of new state-owned facilities, state agencies shall ensure they are designed to be zero-energy and consider embodied carbon.[42]

That same year, the state's legislature provided funding for a collaboration between the UW College of Built Environments, the Central Washington University Construction Management Program and the Washington State University Architecture and Engineering School. The result was the Buy Clean Washington Study, which analyzed existing carbon policies and proposed a policy framework for considering embodied carbon in procurement for the State of Washington. The study also offered investment opportunities for Washington state to support non-regulatory programs that advance transparent manufacturing practices and reduction of embodied carbon.[43]

Seattle, and the state of Washington, have become early adopters of the 2021 building codes, which became effective in July 2019. Akari House, in Seattle's Capitol Hill neighborhood, is planned for 18 stories – becoming the tallest mass timber building in the city. Various mass timber projects are in the works in Seattle and around the state.

Minnesota

The Buildings, Benchmarks and Beyond (B3) guidelines are sustainable building guidelines to be used from pre-design through operation of a building and are required for projects receiving state funding. They can optionally be applied to any project.[44]

The B3 Material and Waste guidelines are intended to reduce the embodied environmental impact and toxicity in building materials. New buildings and renovation projects must demonstrate reduction in global warming potential through three proposed compliance pathways and submit a WBLCA using approved LCA software.[45]

The Sustainable Buildings (SB) 2030 Energy Standard is an energy conservation program designed to significantly reduce the carbon in commercial, institutional and industrial buildings. Buildings must meet energy standards that reduce use of carbon producing fuel in operations by 100% by 2030.[46] If the B3 Guidelines are used, the SB 2030 Energy Standard is automatically included in the process.[47]

City of Minneapolis

In December of 2019, the city released a Climate Emergency Resolution following a report showing it was not on track to reach its goals of reducing GHG emissions by 80% by 2050. The city pledged to establish a "social cost of carbon," described as "a scientific, monetary measurement of GHG emissions' damages to human health, food production, homes and businesses, and energy costs." The city also committed to starting a sustainable building policy to make all new buildings constructed in the city as energy efficient as possible. The city will also push for "advanced building energy performance standard(s)" with other cities, while also seeking cooperation on other climate actions.

Minneapolis is also home to the first tall wood building in the U.S., T3. Standing at seven stories tall, T3 demonstrated the ability of large timber projects to lower the carbon footprint of the built environment, while providing a warm and innovative commercial space. Given timber's light weight, decreased construction time and labor costs, T3 developer Hines plans to use the building as a blueprint for future timber structures. The Bureau of Business and Economic Research at the University of Minnesota - Duluth's campus ran a feasibility study showing that the state of Minnesota and/or its Arrowhead Region has the capacity to introduce mass timber manufacturing. This is driven by increasing demand for multi-family housing construction and trend toward sustainable building materials as a viable solution for lowering carbon emissions. The Great Lakes region has a sufficient supply of lumber and the mills are able to meet market demand.[48]

"The city pledged to establish a 'social cost of carbon,' described as 'a scientific, monetary measurement of GHG emissions' damages to human health, food production, homes and businesses, and energy costs.'"

City of Boston

Boston's Climate Action Plan (recently updated in 2019) outlines actions to become carbon neutral by 2050.

The Plan notes the goal of adopting a Zero Net Carbon standard for new construction by 2030, retrofitting and electrifying at least 80% of existing buildings, and pursuing strategies to reduce building emissions over the next five years such as a zero net carbon standard for new municipal buildings and City-funded affordable housing, strengthening green building zoning requirements to a zero net carbon standard, investing in energy efficiency and renewable energy generation in existing municipal buildings, decarbonizing existing large buildings and advocating for state building policies that align with carbon neutrality by 2050.

The Plan also states that becoming carbon-neutral requires looking at consumer, business and institution decision-making as well. With this premise, over the next five years, the City will take steps to reduce consumption-based emissions by conducting a consumption-based emissions inventory, promoting sustainable consumption, exploring actions that increase material reuse and use of carbon sequestering materials, and encouraging policies that support neighborhood retail and Boston-based startups so residents can meet their basic needs close to home and live car-free.

City of Denver

Denver's 80x50 Climate Action Plan includes the goal of reaching an 80% reduction in emissions by 2050 and aims for all new buildings to achieve net zero energy by 2035. Denver has set building efficiency benchmarks which require all buildings in Denver at or over 25,000 square feet to annually assess and report their energy performance. Less efficient buildings must make periodic cost-effective, incremental energy improvements to be compliant.

On December 23, 2019, the City of Denver voted to adopt the 2019 Denver Building Code, which includes the tall mass timber code provisions approved for the 2021 International Building Code (IBC). The city recently completed Platte 15 and is currently working on a new T3 project in the RiNo neighborhood.

"The Sustainable Procurement Policy outlines best practices to be incorporated into City purchasing activities such as requesting Environmental Product Declarations (EPDs) to identify options with lower impacts; developing and applying a shadow price for carbon to inform decision-making on capital projects and purchases of goods and services; utilizing sustainably sourced wood for City-owned building and landscape projects..."

City of Portland

In their 2015 Climate Action Plan, the City of Portland and Multnomah County committed to reducing carbon emissions 80% below 1990 levels by 2050, with an interim goal of a 40% reduction by 2030. The 2017 progress report specified energy efficiency goals to be reached by 2030, such as reducing total energy use of buildings built before 2010 by 25%, achieving zero net carbon emissions in all new buildings and homes, and supplying 50% of all energy used in buildings from renewable resources, such as solar, with 10% produced on-site within Multnomah County. The City's draft Climate Emergency Declaration issued February 12, 2020 amends carbon reduction targets to at least 50% by 2030 and net-zero carbon emissions before 2050.

The City has both a Sustainable Procurement Policy and Green Building Policy for City-owned facilities in place. The Sustainable Procurement Policy outlines best practices to be incorporated into City purchasing activities[49] such as requesting EPDs to identify options with lower impacts; developing and applying a shadow price for carbon to inform decision-making on capital projects and purchases of goods and services; utilizing sustainably sourced wood for City-owned building and landscape projects; specifying low-carbon services; and supporting manufacturer take-back, leasing, and similar practices for products.

The Green Building Policy aims to "incorporate green building practices into the design, construction, remodeling and operation of all City-owned facilities." All new, occupied City-owned buildings must register and certify for the US Green Building Council's LEED Building Design and Construction (BD+C) at the Gold level and/or achieve Living Building Challenge status.[50]

Oregon became the first state to adopt the 2021 International Building Code to allow tall mass timber. The current tallest cross-laminated timber building in the U.S. is Carbon 12 in Portland, standing at eight stories high.

"D.C. was the first city in the nation to pass a law (the Green Building Act of 2006) requiring green building certification for both public and private sectors."

Washington, D.C.

The District of Columbia's Sustainable DC initiative is committed to reducing greenhouse gas emissions 50% below 2006 levels by 2032 and 80% by 2050. They aim

to retrofit 100% of existing commercial and multi-family buildings to achieve net-zero energy standards by 2032, while new buildings and major renovations will be subject to the latest green construction codes. All new buildings must be net zero or net-positive.

D.C. was the first city in the nation to pass a law (the Green Building Act of 2006) requiring green building certification for both public and private sectors. As of 2017, it had more LEED-certified projects per capita than any state, and became the first city in the world to receive a LEED for Cities Platinum leadership certification, the U.S. Green Building Council's highest award.

D.C. also supports a Green Building Fund Grant Program to support innovative projects that "green" the built environment in the District. Grant projects include research, data analysis, training, or engagement that help the District lead the way in enacting innovative policies that drive toward greater social, environmental and economic sustainability for the city.

Canada

Canada has implemented a strategy called the Pan-Canadian Framework on Clean Growth and Climate Change with the goal of reducing the nation's greenhouse gas emissions by 30% below 2005 levels by 2030. This framework was designed with the joint cooperation of Canada's provinces and territories as well as its indigenous peoples.

These carbon reduction targets will be achieved through the Low-Carbon Assets Through Life Cycle Assessment (LCA2) initiative. This initiative, a collaboration between the National Research Council and other federal government departments, academia, non-government organizations, industry partners, and low-carbon asset experts from across Canada, will create infrastructure-specific life cycle assessment (LCA) guidelines/tools and related procurement specifications, low-carbon benchmarks and a Canadian life cycle inventory (LCI) database. This will support the move to low-carbon procurement of materials and designs while maintaining lowered costs. The focus will be primarily on buildings, with the potential to include roads and other civil infrastructure.[51]

City of Vancouver

In 2019, the City of Vancouver approved a Climate Emergency Response report calling for a 40% reduction of embodied carbon emissions in new buildings and construction by 2030, and a reduction in operational emissions from new buildings by 90% by 2025, with the target of being carbon neutral by 2050.[52] The report recommends a shift to use more mass timber and low carbon concrete as well as to rely more on prefabricated and modular construction. Regulatory barriers to increased mass timber construction will be removed, such as the city's June 2020 amendment of building bylaws to allow mass timber construction up to 12 stories, and requirements for lower embodied emissions will be introduced. There will also be incentives for early adopters, industry capacity-building and city leadership. To ensure further industry buy-in, the city built the Zero Emissions Building Centre of Excellence, a local learning hub that hosts designer and builder dialogues, produces case studies, and delivers training to optimize solutions for best practice and industry scalability. Thus far, the city's progress has produced significant economic benefits: Vancouver's Economic Commission released a report stating that Vancouver and British Columbia's zero emissions and net-zero energy building policies are stimulating a $3.3 billion market for high-performance building products and technologies in metro Vancouver.[53]

"In 2019, the City of Vancouver approved a Climate Emergency Response report calling for a 40% reduction of embodied carbon emissions in new buildings and construction by 2030, and a reduction in operational emissions from new buildings by 90% by 2025, with the target of being carbon neutral by 2050."

In 2016, the city introduced a new rezoning policy: *Green Buildings Policy for Rezoning*.[54] It included a compliance path that requires reporting of embodied emissions, as calculated by a whole-building LCA. Projects applying for rezoning are required to either be designed to and apply for an emissions building standard or meet numerous low-emissions green building requirements, including being designed to and registering for LEED Gold. Applicants must submit embodied carbon calculations during multiple phases of the development for low emissions green buildings, including for the rezoning application, building permit, and occupancy permits.[55]

Province of Quebec

The Quebec Wood Charter is an initiative that aims to increase the use of wood in construction to grow employment, reduce GHGs and enrich the province as a

whole. For provincially funded projects (wholly or partly), project managers must consider the possibility of wood before the project begins and complete a comparative analysis of GHG emissions for structural materials, using the Gestimat tool.[56,57] The emissions data, derived from Quebec's life cycle inventory database, will be required at the funding application stage, not the building permit stage. Funding is dependent on the analysis being conducted and not on the project manager ultimately choosing lower carbon materials.

In May of 2019, the Quebec government released Gestimat to the public and private sectors. Gestimat calculates the GHG reductions resulting in the selection of wood in construction and the reductions related to concrete or steel structures. The Minister of Forests, Wildlife and Parks for Quebec mandated the Centre d'expertise sur la construction commerciale en bois (Cecobois) to develop the tool, with funding under Quebec's 2013-2020 Climate Change Action Plan. Cecobois supports and advances the reliance on wood in multi-family and non-residential construction in Quebec by offering technical services and training to building industry professionals. Going forward, Quebec's intention is to support fellow Canadian provinces and territories who wish to adapt Gestimat for their use.[58]

International Green Construction Code

The International Green Construction Code (IgCC) is a model code that is available to any jurisdiction and is intended to set a minimum level of performance.

It is a voluntary performance-path alternative to prescriptive material requirements and may be seen by design teams as an incentive to avoid the restrictions and documentation inherent in prescriptive requirements. Compliance requires that the "final design" have lower impacts than a "reference design" for at least three LCA measures.[59]


Photo: SOM © Benny Chan

Long Beach Civic Center

Project: Long Beach Civic Center – Billie Jean King Main Library, 2020 WoodWorks Design Winner for Wood in Government Buildings
Architect and Engineer: SOM | Skidmore, Owings & Merrill

The Billie Jean King Main Library is a hybrid building, developed over an existing parking structure. It includes an exposed glulam roof system over steel framing. To achieve LEED Platinum Certification, the highest U.S. Green Building Council certification, the building leverages timber construction, rooftop photovoltaic cells, daylighting strategies, controlled air ventilation systems, and extensive glazing with architectural overhangs for solar protection. The library is part of the Long Beach Civic Center Master Plan, designed by SOM to revitalize 22 acres of downtown Long Beach by creating a vibrant, mixed-use district.[60]

Embodied Carbon Policies

Europe

Building embodied carbon is the focus of a number of policies found throughout Europe and the United Kingdom. While each country takes a distinct approach to carbon mitigation, LCAs and EPDs are critical components in most plans.

European Union

The European Union covers 27 countries and provides regulatory authority and influence over much of Europe. Although not ratified, the EU's 2019 Green Deal establishes the goal of designing buildings that align with the circular economy that keeps materials in use as long as possible and repurposes them at the end of their service life. Given that embodied energy comes from key elements in the life cycle of a product or structure — not only harvest, manufacture, transport, installation, but also disposal and recycling — timber can help advance goals for a circular economy. When forest products are used in construction, they continue to store carbon for the life of the structure.[61]

France

France's Energy Transition Law (Transition Energétique pour la Croissance Verte, or TECV) encourages new construction to be low energy and low carbon. To meet the goals of the Paris Agreement, the French government collaborated with the building industry to launch an experiment to produce positive energy and lower carbon footprint in the built environment, which would inform future regulations. The program, called "Energie Positive et Réduction Carbone" (formerly "Energie Carbone" or E+C), was supported by France's Ministry of the Environment, Energy and the Sea, and the Ministry of Housing and Sustainable Habitat. The program has two main objectives: to generate positive energy from buildings and lower the carbon emissions of buildings throughout their life cycle, from design to demolition. "Energie Positive et Réduction Carbone" outlined three main components:[62]

1. Experimentation: A voluntary national building pilot program offers incentives to builders and developers in exchange for meeting certain energy- and carbon-performance benchmarks, including embodied life-cycle carbon. This will help the French government test the technical and financial feasibility of low carbon and energy efficient building construction. The government offers various incentives to motivate builders and developers to meet energy and carbon-performance benchmarks. For instance, new buildings that opt into the pilot program can apply for additional rights to construction density above zoning limits if they show proof of meeting energy and life-cycle carbon (including embodied) performance targets;
2. Consultation: Success of the program relies heavily upon industry participation and buy-in. Builders, developers, contractors, energy companies, NGOs, and associations are given a year of consultation for achieving the below labels; and
3. Labeling: Builders and developers can receive a national building label, "Energie Carbone (E+C-) which indicates various performance levels based on energy efficiency and low embodied carbon. They may also receive financial assistance to support LCA studies. The program relies on the national EPD database. Manufacturers wishing to make environmental marketing claims must submit an EPD to the database.

"A voluntary national building pilot program offers incentives to builders and developers in exchange for meeting certain energy- and carbon-performance benchmarks, including embodied life-cycle carbon."

As of February 2020, President Emanuel Macron announced that all new public buildings should use 50% timber or another bio-sourced material after 2022. According to Julien Denormandie, the French minister for cities and housing, this move was inspired by Paris' mandate to use timber in structures eight stories or higher for the 2024 Olympic games to achieve lower carbon footprints. The Olympic Village will come to life through mid-rise developments including 2,400 units of

housing, offices, shops, restaurants, and activity centers constructed with wood or other sustainable materials.[63]

These moves follow President Macron's 2019 proposal to achieve carbon neutrality for France by 2050, through initiatives such as urban farm development and planting trees near architectural landmarks.[64]

"As of February 2020, President Emanuel Macron announced that all new public buildings should use 50% timber or another bio-sourced material after 2022."

Belgium

Belgium's carbon policy relies on LCAs as a foundation. Belgium's three regions worked with universities, government agencies and the Flanders' public waste agency to create a cohesive LCA framework for calculating and reporting environmental impact of construction materials. The result of this coordination was TOTEM, an LCA tool that was launched in 2018 to help professionals "assess environmental impacts of building projects during the design phase."[33]

Belgium also has an EPD program to "provide interested organizations with a framework for developing and making available EPDs in accordance with the Royal Decree on EPDs." The B-EPD program is applicable to building products that are placed or made available on the market in Belgium or that can be used in buildings on the Belgian territory.[65,33] Manufacturers are required to conduct LCAs and submit EPDs for construction products.

Netherlands

The Netherlands' embodied carbon policy is the first known instance of public policy requiring whole-building LCA for non-government buildings. Bouwbesluit 2012 requires embodied carbon reporting at the building-permit-application stage for new residential and office buildings over 100 m^2. A building's total environmental profile, including estimated embodied carbon, must be submitted by project teams for a permit. As of 2018, the policy also implements a threshold for these estimates that the environmental profile must not exceed. This is an example of a country moving beyond monitoring and reporting to requirements for meeting reduction targets.

The Netherlands also has a national EPD database, a standardized method for whole-building LCA, and several software tools that conform to the standardized method. The National Environmental Database was developed and managed by the Stichting Bouwkwaliteit (SBK - Foundation for Building Quality) with input from industry professionals to ensure buy-in and transparency. The Environmental Performance Construction and Civil Engineering Works provides a national WBLCA methodology to calculate material-related environmental performance of buildings and civil engineering works over their entire life cycle.[33]

"The Netherlands' embodied carbon policy is the first known instance of public policy requiring whole-building LCA for non-government buildings. Bouwbesluit 2012 requires embodied carbon reporting at the building-permit-application stage for new residential and office buildings over 100 m^2."

Sweden

Sweden's 2009 Integrated Climate and Energy Policy (ICEP) introduced the goal of increasing energy efficiency in buildings by 20% in 2020 and 50% in 2050. In order to support these targets, the building code has rigorous energy requirements for both new buildings and retrofits.[66]

"The report does not advocate for any specific material or renewable energy source but recognizes the importance of using materials that are less carbon intensive."

Following EU and Swedish directives, the Swedish Government instructed Boverket, the Swedish National Board of Housing, Building and Planning, to investigate the carbon footprint of buildings from a lifecycle perspective. Boverket released a report, The Climate Impact of Buildings from a Life Cycle Perspective, in 2015 on climate change effects over the life cycle of a building, which concluded that net-zero can only be reached by looking at the full life cycle of the building — production and extraction (including choice of materials), operation of the building (including heating, cooling, water, electricity, etc.) and end-of-life operations (including demolition and recycling). The report does not advocate for any specific material or renewable energy source but recognizes the importance of using materials that are less carbon

intensive. The report notes cement as being responsible for 5% of global emissions. The report discusses wood (pros and cons) and shows it as less energy intensive than concrete, but no material is cited as "the answer" to zero carbon.

In 2018, Sweden announced it would reach overall net-zero emissions by the year 2045.[68] And in 2019, the Government also announced a "Climate Declaration When Constructing Buildings," which will enter into force on January 1, 2022. The declaration introduces a reporting requirement for construction of new buildings and involves the development of a national database containing climate data to inform decision making.[69] To help reach nearly net-zero buildings, the Swedish government, under the Ministry of the Environment and Energy, implemented a number of measures, including:

- Minimum energy performance requirements for various buildings (multi-family, etc.);
- An energy performance certificate for single-family and multi-dwelling buildings (implemented by Boverket);
- The Information Center for Sustainable Building to promote energy efficient renovation and construction using sustainable materials and low climate impact from a life-cycle perspective;
- Government grants to support renovation of apartments and schools to be energy efficient; and
- EU financial support including loans, equity and guarantees as well as technical assistance for project development.

Switzerland

Minergie is the most widely used Swiss national green building rating system, with many versions of the standard. Minergie-Eco requires WBLCA for all new government buildings in several municipalities, including Zurich, with an embodied carbon performance target for some building types. While voluntary, the City of Zurich requires all new government buildings to obtain Minergie-Eco certification. In addition, some public and private organizations have made it a requirement for new buildings or major renovations.

Created by the Swiss Federal Institute of Technology, 2000 Watt Society is an environmental call-to-action that hopes to reduce per-capita energy usage to 2,000 watts per day. It has been voluntarily adopted by over 100 cities, towns and cantons across Switzerland and Germany, and recognizes embodied carbon as being an important element to understanding personal energy consumption. The City of Zurich has incorporated this in their municipal code and set a 2050 target for life cycle embodied carbon in residential buildings.[36,45]

United Kingdom

In 2017, the Royal Institution of Chartered Surveyors (RICS) published guidance on embodied carbon to ensure consistency in carbon reporting, *Whole Life Carbon Assessment for the Built Environment Professional Statement*.[70] It was built around a whole life carbon approach, which posits that it is necessary to understand not only operational and embodied emissions independently, but the interaction between them. It is mandated for industry professionals and provides recommended methodology for calculating embodied and operational emissions over a building's life cycle. It can be used for structural elements, buildings, and infrastructure, both existing and new. The RICS methodology relies upon LCAs to EPD data for embodied carbon in materials and systems, in accordance with British Standard BS EN 15978:2011, which outlines the principles of embodied and whole life carbon measurement in the built environment. The RICS guidance also recognizes the importance of development of mass timber products and incorporates biogenic carbon in its methodology (assessing carbon sequestered in timber structures and other products), as well as the impact of end of life emissions.[71]

The UK Green Building Council offers guidance to help professionals measure embodied carbon. In 2012, they worked with the UK Government to establish a joint industry-government board focused on green construction, the Green Construction Board. This board created The Low Carbon Routemap for the Built Environment, a tool accounting for both embodied and operational emissions which outlines policies and actions to advance the government's goal of cutting GHG emissions by 80% by 2050.[33]

Photo: Clover Creek Elementary, Bethel School District, WoodWorks

Bethel School District

Project: Bethel School District
Architect: Erickson McGovern
Structural Engineer: PCS Structural Solutions

Bethel School District proved they could reduce construction costs and build energy-efficient schools at the same time, leaving more money for educating students. The School District's Director of Construction and Planning credits wood framing for construction costs per square foot that are much lower than the average for other schools in the region. The School District's philosophy is to reduce costs for framing, which allows them to invest in better, more efficient lighting and HVAC systems. The District has an 81% ENERGY STAR rating overall, with several of the 17 elementary and six of the middle schools with ratings between 95-98%.[72]

Green Building Certification

Certifications can influence building practices, offering recognition for achieving carbon mitigation in the built environment. The following certifications are used in the U.S. and worldwide.

Building Research Establishment Environmental Assessment Method (BREEAM USA)

BREEAM is an internationally recognized certification that provides independent third-party assessment on the performance of individual buildings, communities and infrastructure projects. Assessment and certification are offered at various stages in a building's life cycle and based on a series of categories, ranging from energy to ecology. BREEAM certification in the United States is provided by BRE Global.[73]

The materials category promotes "steps taken to reduce the impact of construction materials through design, construction, maintenance, and repair." The category is focused on "procurement of materials that are sourced in a responsible way and have a low embodied impact over their life." Performance of an LCA can provide up to 20 credits, including recognition for the use of EPDs.

Each category includes a range of issues, each with its own target and benchmarks. When these are reached, project owners receive credits that ultimately impact a category score and final BREEAM performance rating.

LEED V4

LEED is the dominant voluntary green building rating system in North America and is also used extensively around the world. The newest Building Design & Construction (BD+C) version is LEED BD+C v4. It includes a new materials credit — Building Life Cycle Impact Reduction. Option 4 (Whole Building Life-Cycle Assessment) is worth at least three points (out of 110) and serves as an incentive for design teams to undertake whole-building LCA. The three points are awarded provided that the "final design" has at least 10% lower impact than a "reference design" for at least three LCA measures, and no measure performs 5% worse than the reference design. Two additional points can also be achieved through exemplary performance and regional priority.

Green Globes

This green building assessment and certification program from the Green Building Initiative (GBI) generates a building score based on a 1000-point-based rating system. Green Globe certification recognizes responsible material selection and waste reduction, as well as efforts to conserve energy and reduce water consumption over time. The assessment is verified by a third-party, then awarded a rating based on accumulated points — either One, Two, Three or Four Green Globes.

Green Globes have several qualification categories: new construction, existing buildings, core & shell, sustainable interiors plus multi-family new construction and existing buildings. The certification process evaluates multiple assessment areas, including project management, site, energy, water, materials and resources, emissions and indoor environment. An architect's choice of wood for structure and finish falls under the Materials and Resources category.

Excellence in Design for Greater Efficiencies (EDGE)

EDGE tracks and rewards certifications to projects that show reductions in embodied energy. It was developed by the International Finance Corporation, a member of the World Bank Group, and enables developers and builders to identify cost-effective ways to reduce operational energy, water use, and embodied energy from materials. EDGE offers certification as well as a software tool for exploring cost-efficient design options for projects.

International Living Future Institute (ILFI) Living Building Challenge

The Living Building Challenge[74] is an emerging green building rating system developed in the United States and administered by the International Living Future Institute. It is primarily used in the United States and Canada, although the system is intended for international applicability. Within the materials requirements, projects must calculate the total embodied carbon due to construction materials and processes and purchase an offset from an approved provider of offset credits. This task requires a WBLCA, although only the carbon portion is reported.

The Living Building Challenge Version 3.1 rewards embodied carbon benchmarking and reduction in the LBC Materials Portal. LBC Version 4.0 rewards benchmarking and reduction in the LBC Energy Portal.

ILFI Zero Carbon Certification

The International Living Future Institute's (ILFI) Zero Carbon Certification is the first third party-verified standard worldwide. The Certification requires:

- 100% of the operational energy use associated with the project must be offset by new on- or off-site renewable energy; and
- 100% of the embodied carbon emissions impacts associated with the construction and materials of the project must be disclosed and offset.

Projects must account for total embodied carbon impact from any new construction and materials through a one-time carbon offset by an approved source. They must also demonstrate a 10% reduction in embodied carbon of foundation materials, structure and enclosure, and can do so by reporting actions taken during design and construction (e.g. considering carbon in specification of materials, sourcing local materials, use of low carbon assembly in construction). Calculations should be done using an approved life cycle assessment with a standard 50-year lifespan, and embodied carbon emissions must not exceed 500 kg-CO_2e/m^2.[75]

The Canada Green Building Council (CaGBC) Zero Carbon Building Standard

CaGBC Zero Carbon Building Standard provides Canada's first green building program to make carbon emissions the key indicator for building performance. Launched in May 2017, the CaGBC standard supports Canada's commitment to reduce GHGs by 30% from 2005 levels by 2030.[76] There are two certifications offered under the standard: the Zero Carbon Building - Design certification and the Zero Carbon Building - Performance certification.

New construction and retrofit projects can earn the Zero Carbon Building - Design certification by modeling a zero-carbon balance, highly efficient envelope and ventilation systems that meet a defined threshold for thermal energy demand intensity. Onsite renewable energy systems must be able to provide a minimum of 5% of building energy consumption. Existing buildings that meet a zero-carbon balance and additional requirements can earn the Zero Carbon Building - Performance certification. Verified annually, project teams must evaluate and report on electricity impacts and GHG emissions associated with structural and envelope materials. However, the certification does not require a minimum of onsite renewable energy or thermal energy demand performance, due to challenges with retrofitting existing buildings.[77]

Reporting on embodied carbon has been included as a requirement for both certifications due to its growing importance to the carbon footprint of a building, particularly as operational emissions are reduced. As of now, reporting is the only requirement, to encourage growth and capacity around the use of LCA software to track embodied carbon. Certification applicants must conduct a cradle-to-grave LCA of the project, which assumes a building life of 60 years and encompasses all envelope and structural elements including parking structure, footings and foundations, structural wall assemblies (from cladding to interior finishes, including basement), structural floors and ceilings (not including finishes), roof assemblies, and stairs construction. The LCA must measure resource extraction, product manufacturing and transportation, building construction, product maintenance and replacement, and building demolition/ deconstruction/ disposal. CaGBC recommends the Athena Impact Estimator for Buildings or Tally as LCA tools.[78]

Photo: Chad Davies; Marshall Andrews; SmithGroup

DPR Construction Office

Project: DPR Construction Office, 2020 WoodWorks Design Winner for Regional Excellence
Architect: SmithGroup
Structural Engineer: Buehler Engineering

Choosing mass timber for their office building, DPR Construction sought to offer their employees the benefits of biophilic design through an overbuild project. Using CLT sheer walls, a first for California, this project added a second story to a 1940s-era concrete and masonry building. DPR erected this structure to achieve both net zero energy as well as reduced embodied carbon, with mass timber acting as a carbon sink.[79] It also exceeds regulatory requirements, targeting net-positive energy—which reduces its carbon footprint from the standpoint of operations and maintenance.

Private Sector Case Studies

In early 2020, large corporations released climate change plans, and many doubled down on their commitments to not only track and report but take significant action to reduce their GHG emissions. Companies have also shifted gears to focus on a broader range of direct and indirect emissions for which they are responsible.

Walmart

Set to open in phases between 2020 and 2025, Walmart's New Home Office in Bentonville, Arkansas aims to achieve three sustainability goals: "to create zero waste, operate with 100% renewable energy and focus on products that sustain resources and the environment." The new campus will achieve these goals in a number of ways, including:[80]

- A smart building design with high-performance building materials, energy-efficient lighting and HVAC systems;
- Incorporating regionally sourced materials, including mass timber construction;
- 15+ acres of lakes for stormwater collection for irrigation, thermal exchange, wildlife habitat and rainwater reuse;
- Native and drought-tolerant plants to minimize watering;
- Thousands of trees, shrubs and grasses — mostly native, low-maintenance plantings — to provide habitat and reconnect associates with nature; and
- Solar panels across select buildings and parking decks.

"When we think about the future, it's crucial that we also think about how we are going to preserve our planet and resources for the next generation, while promoting well-being for our associates both today and tomorrow."[83]

Dan Bartlett, Executive Vice President, Corporate Affairs

Walmart chose Structurlam[81] mass timber products in order to create a modern and sustainable feel for the new campus, while reflecting the beauty and benefits of surrounding Arkansas nature. Structurlam sources its softwood lumber from sawmills that extract from sustainably managed forests. For the Walmart New Home Office, they will source from within Arkansas state, where they have expanded operations. By regionally sourcing the mass timber, Walmart can significantly reduce the emissions associated with the transport of raw materials from the forest to the plant to the construction site, a significant share of embodied carbon emissions.[82]

Google

Google embarked on a movement toward healthy building materials that started with the questions "What are we breathing? How is it affecting our health? Why is it in our offices? How much do we know about the contaminants that we're exposed to every single day in our buildings?" Then they seamlessly tied it to their broader mission of organizing and making information accessible to the world. To increase transparency, Google set out to develop a database that would streamline the data collection process around the chemical makeup of building products and leverage industry standards for disclosure. This led to the creation of Google's Healthy Materials Program, which focuses on building products closest to employees, found mostly in the building's interior — paint, carpet, resilient flooring, ceiling tile, insulation and gypsum board. Products are specified across most Google projects, and have to be proven to deliver healthier outcomes across the lifecycle.

Google instituted a reporting requirement for projects to disclose costs and quantity of materials used in order to track impact. They also incorporated the program into the entire building project process, noting in the project description: "We're streamlining our approach to make sure healthy materials are specified in the design phase, purchased during the construction phase, and monitored to ensure that they're performing as expected during operation." Google intends to disclose information about the building product categories, manufacturers, and standards they are leveraging to build these healthier facilities.

Google's Charleston East complex in Mountain View, California is the largest facility to ever receive the Living Building Challenge Materials Petal Certification. This means that every building product used in the facility has been vetted against a list of chemicals from the Living Building Challenge that pose a risk to humans and the environment. It also means that Google has accounted for total embodied emissions impact from the facilities' construction and will neutralize them through carbon offsets.[84]

Microsoft

Microsoft has outlined two ambitious goals: to achieve carbon negativity by 2030, and by 2050 to remove from the environment all the carbon that the company has emitted directly or by electrical consumption since it was founded in 1975. In January 2020, they announced they would halve their carbon emissions — both direct and those related to their entire supply and value chain — by 2030. Starting in 2021, carbon reduction will be an official component of the procurement process for Microsoft's supply chain.

Microsoft recognizes that its largest bucket of emissions comes from scope 3 or indirect emissions from activities in which the company is engaged. Out of the anticipated 16 million metric tons of emissions Microsoft will generate this year, 12 million fall into scope 3, accounting for business travel of employees, materials in corporate buildings, manufacture of products purchased and more.

As part of its carbon commitments, the company announced it will pursue both LEED Platinum and International Living Future Institute Zero Carbon status for the retrofits going on at its Silicon Valley and Puget Sound campuses.

> **"When it comes to carbon, neutrality is not enough. We have to get ourselves to net zero."[87]**
>
> **Robin Bass, Sustainability Programs Team Lead, Google's Real Estate and Workplace Services**

In July of 2020, Microsoft will begin phasing in their internal carbon tax to cover all scope 3 emissions. This fee is paid by each business division and is used to pay for sustainability improvements across the company. By increasing the carbon tax over time (until scope 1, 2, and 3 taxes are the same), Microsoft hopes to encourage and incentivize the reduction of scope 3 emissions and use funds to pay for additional carbon reduction and removal activities.[86]

Photo Chuck Choi, courtesy Maryann Thompson Architects"

Walden Pond Visitors Center

Project: Walden Pond Visitors Center, 2018 WoodWorks Design Winner for Wood in Government Buildings
Architect: Maryann Thompson Architects
Engineer: RSE Associates Inc.

The Walden Pond Visitors Center is a net-zero energy, LEED Gold-certified, all-wood building. Given it is a national historic landmark frequented by many tourists, the architects sought to teach the public about the benefits of using wood in buildings. The structure employs a mix of heavy timber and light wood frame in public areas and staff offices. All of the material was certified by the Sustainable Forestry Initiative or Forest Stewardship Council, and nearly all finish materials were locally sourced, milled and manufactured, minimizing embodied carbon emissions due to transport.[88]

Photo: Chuck Choi

Carbon Measurement Tools

Measurement tools are used by decision makers (owners, architects, engineers, designers) during the design and planning phase to select materials that help meet carbon reduction goals. They can also be leveraged to qualify for various certifications discussed earlier in this review.

Athena Impact Estimator for Buildings

Developed by the Athena Sustainable Materials Institute, the Athena Impact Estimator for Buildings is a free software tool in North America that evaluates whole buildings and assembles based on the LCA methodology. It helps architects, engineers and other specifiers compare environmental impact of industrial, institutional, commercial and residential designs. Athena does not rely on EPDs, but has built its own database. All Athena tools comply with LCA methodology standards developed by the International Organization for Standardization (ISO) 14040 and 14044 series. The Impact Estimator and EcoCalculator use data from Athena's own datasets and from the US Life Cycle Inventory Database. Users input basic information about building geography, size, and height. A building model is developed by creating a series of assemblies, such as walls, floors, and roofs. Materials in these assemblies can be altered to determine relative impact on total building impacts. Typically used in the conceptual stage of a project, it can model 95% of North American building stock and assesses cradle-to-grave impacts related to embodied carbon.[89]

The Estimator provides the following results:

- Global Warming Potential;
- Acidification Potential;
- Human Health Respiratory Effects Potential;
- Ozone Depletion Potential;
- Photochemical Smog Potential;
- Eutrophication Potential; and
- Fossil Fuel Consumption.

Tally Life Cycle Assessment App — Revit® Plug-In

The Revit® BIM, created by Autodesk, is a physical and digital representation (3-D model) which provides information on the materials' ingredients that go into a building. However, it is limited in its ability to provide contextual information for a completed structure (e.g. a BIM model might recognize a steel assembly, for example, but it would not take into account that most steel assemblies use a significant amount of concrete as well; and it would not incorporate emissions).

Developed by KieranTimberlake affiliate KT Innovations, in partnership with Revit, Tally offers project teams a way to calculate environmental impacts of building materials within the Revit model. Using Tally, project teams can conduct whole building LCAs or use LCA data to run comparative analysis of various design options and their environmental impacts to land, air, and water systems.[90]

One Click LCA

One Click is an LCA and costing software created by Bionova Ltd, a sustainable construction consulting company. The tool relies on published EPDs, which some experts warn may be not well suited for whole building LCAs due to inconsistencies across product categories. It can be used in all stages of a project from early design to commissioning of a building.

One Click LCA delivers WBLCA for LEED v4 and v4.1, and supports 40+ other rating systems and standards, while also integrating with Autodesk Revit, IES-VE and other software and data formats.[91]

Woodworks Carbon Calculators

The Carbon Calculator for Wood Buildings[93] focuses on the volume of structural wood in a building, then estimates how much carbon is stored in the wood, the GHG emissions avoided by not using steel or concrete, and the amount of time it takes North American forests to grow that volume of wood. It does is this in one of two ways:

- If the volume of wood products is known (including lumber, panels, engineered wood, decking, siding, and roofing), the carbon calculator will provide a detailed estimate for that specific building. The more detailed the information, the better the results.
- If volume information is unknown, users can select from a list of common building types and receive an estimate based on typical wood use.

Embodied Carbon in Construction Calculator (EC3)

The Embodied Carbon in Construction Calculator (EC3) is a free, cloud-based, open-access tool that offers building owners, engineers, and contractors benchmarking and assessment capabilities for reduction of embodied carbon for construction materials. It will facilitate review of product EPDs within the same material categories.

EC3 relies on building material quantities from construction estimates and/or BIM models, as well as digital, third-party verified Environmental Product Declarations. Work is being done to properly characterize wood EPDs. It is primarily a supply management tool. It can be used in the design and procurement phase of projects, allowing users to access material carbon emissions data to encourage selection of low carbon materials.

Glossary

Embodied carbon emissions, embodied carbon: The GHG emissions associated with the manufacturing, maintenance, and decommissioning of a structure.

GHG Protocol: A global standardized framework to account for GHGs created by The World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). The GHG Protocol outlines emissions in three scopes, the third of which includes embodied carbon.,

Greenhouse gases (GHG): Gases that trap heat in the Earth's atmosphere. Commonly these are carbon dioxide, methane, nitrous oxide, and fluorinated gases such as CFCs, HCFCs and HFCs.

International Organization for Standardization (ISO): Comprised of 164 national standards organizations, the ISO is an independent group that creates standards for industry, including testing, codes of practice, management practices and guidelines.

Life cycle assessment (LCA): Compilation and evaluation of the inputs, outputs, and the potential environmental impacts of a product system throughout its life cycle.

Life cycle impact assessment (LCIA): Phase of life-cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout its life cycle.

LCIA/EPD database: A database of results from LCA studies that does not contain a complete list of LCI flows and instead presents the calculated impact assessment results for a database of products that have previously completed LCAs often leading to published EPDs. These databases are typically based on EPDs and may differ in underlying methodology and assumptions depending on the PCRs that the EPDs are based on.

Life cycle inventory (LCI): Phase of life-cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle.

Life cycle inventory (LCI) database: A database of LCI flows for individual unit processes or for a portion of a product life cycle. In the case of unit process data, the data includes intermediate flows of materials between processes, whereas system process data is a "black box" that does not specify intermediate flows. LCI databases track hundreds of inventory flows.

Net Zero Building, Zero Net Energy (ZNE) building, net-zero energy building (NZEB), or zero-energy building: An energy-efficient building where the annual delivered energy is less than or equal to the on-site renewable exported energy.

Operating emissions: GHG emissions that are generated from the burning of fossil fuels used to heat, cool and power a building during its service life.

Product category rules (PCR): A set of specific rules, requirements and guidelines for developing Type III environmental declarations for one or more product categories.

Type III environmental product declaration (EPD): Provides quantified environmental data using predetermined parameters and additional environmental information. Predetermined parameters are based on the ISO 14040 series of standards. The additional environmental information may be quantitative or qualitative.

Embodied Carbon Research & Resources

Embodied Carbon of Buildings and Infrastructure: International Policy Review

This report from the Forestry Innovation Investment is perhaps the best "next step" in an organization's journey toward embodied carbon reduction. In addition to providing technical resources and design strategies for reducing embodied carbon, the report provides a detailed review of global successes in Europe and North America. Download the report (and learn more about the benefits of forest products in construction) at https://www.naturallywood.com/resources.

City Policy Framework for Dramatically Reducing Embodied Carbon

Developed by Carbon Neutral Cities Alliance and One Click LCA, in cooperation with Architecture 2030, the report details 52 policies for zoning and land use, building regulation and supervision, procurement, infrastructure, waste and circularity, municipal buildings, and financials. The report is free to download at http://embodiedcarbonpolicies.com.

The Embodied Carbon Review: Embodied carbon reduction in 100+ regulations and rating systems globally.

Developed by Bionova Ltd. and sponsored by the government of Finland, the document provides an excellent review of embodied carbon-focused regulations and certifications around the world. Published in 2018, the report is available for download and occasionally updated at http://embodiedcarbonreview.com

Embodied Carbon in Building Materials for Real Estate

This report by the Urban Land Institute offers the business case for reducing embodied carbon and provides simple steps to get started in the process. Download the free report at:
https://americas.uli.org/research/centers-initiatives/greenprint-center/greenprint-resources-2/best-practices-in-sustainable-real-estate/embodied-carbon-in-building-materials-for-real-estate/

Global Status Report 2019: Towards a zero-emission, efficient, and resilient buildings and construction sector

Commissioned by the Global Alliance for Buildings and Construction, and coordinated by the United Nations Environment Programme, the report offers the most recent snapshot of the state of sustainable development around the world. Although it doesn't provide specific, actionable solutions, the report effectively demonstrates why embodied carbon reduction should be at the forefront of any development discussion. The report is available on several websites including https://www.unenvironment.org/resources/publication/2019-global-status-report-buildings-and-construction-sector

Embodied Carbon: Developing a Client Brief

Created by the UK Green Building Council, this guide is designed "for those who need to write effective briefs for commissioning their first embodied carbon measurements, but who may be at an early stage of embodied carbon knowledge." Download at https://www.ukgbc.org/sites/default/files/UK-GBC%20EC%20Developing%20Client%20Brief.pdf

Assessing the Impacts of Climate Change on the Built Environment under NEPA and State EIA Laws: A Survey of Current Practices and Recommendations for Model Protocols

This 2015 report from the Sabin Center for Climate Change Law at Columbia Law School provides "protocols describing how government agencies and other decision makers can account for the impacts of climate change in environmental impact assessments and related planning documents." This and a variety of other reports are available at https://climate.law.columbia.edu/content/model-protocols-climate-change-impact-analysis

Solving the Climate Crisis: The Congresional Action Plan for a Clean Energy Economy and a Healthy, Resilient, and Just America

Released in June 2020, this report by the U.S. House of Representatives Majority Staff includes policy recommendations for the built environment as well as transportation, energy, water and telecommunications sectors. The report is available at https://climatecrisis.house.gov/report.

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