Forest Carbon and Climate Program
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Embodied Carbon Policies

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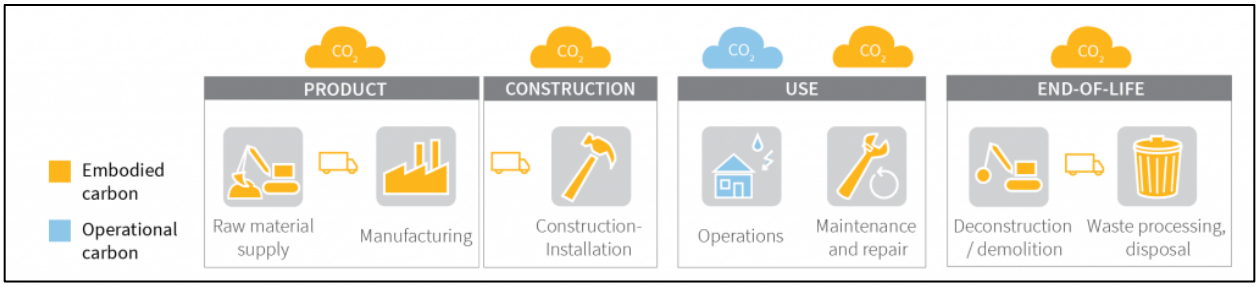
Introduction

Carbon emissions associated with construction and other infrastructure projects occur in two forms: operational carbon and embodied carbon. Operational carbon refers to greenhouse gas (GHG) emissions arising from energy consumption (Hutton, 2020). This includes activities like heating, cooling, lighting, and powering electronic systems. Embodied carbon relates to GHG emissions associated with the "manufacturing, transportation, installation, maintenance, and disposal of building materials" (CFL, 2020a). In simple terms, embodied carbon considers emissions derived from the building materials and manufacturing processes used to complete an infrastructure project, as well as emissions arising from maintenance and waste disposal. **Figure 1** demonstrates the relationship between both categories.

Figure 1. Embodied and Operational Carbon



Source: CFL, 2022

Embodied carbon has become an increasingly salient topic in climate discussions, receiving attention from industry stakeholders and policymakers alike, due to the large carbon footprint incurred by building and infrastructure projects before they can be utilized. According to the 2019 Global Status Report for Buildings and Construction Sector published by the United Nations Environment Programme (UNEP), approximately 30% of global carbon emissions can be attributed to the building sector, with 8% of total emissions resulting from construction and manufacturing of materials (UNEP, 2019). With global building stock expected to double by 2060, pursuing means to minimize emissions will be crucial to avoiding climate catastrophe (CFL, 2020a). Unlike operational carbon, it is impossible to decrease embodied carbon after a building has been constructed: the issue must be urgently and proactively addressed to ensure long-term sustainability in the construction sector.

This paper explores the mechanisms intended to internalize and bring attention to embodied carbon in local, state, and federal policy arenas. It outlines existing policies on embodied carbon in the U.S., as well as proposals for future initiatives. Finally, it highlights the forest and climate change implications of these efforts.

State and Local Action

As established by the Climate Leadership Forum, there are several state and local policy mechanisms which may be implemented to limit and reduce embodied carbon emissions.

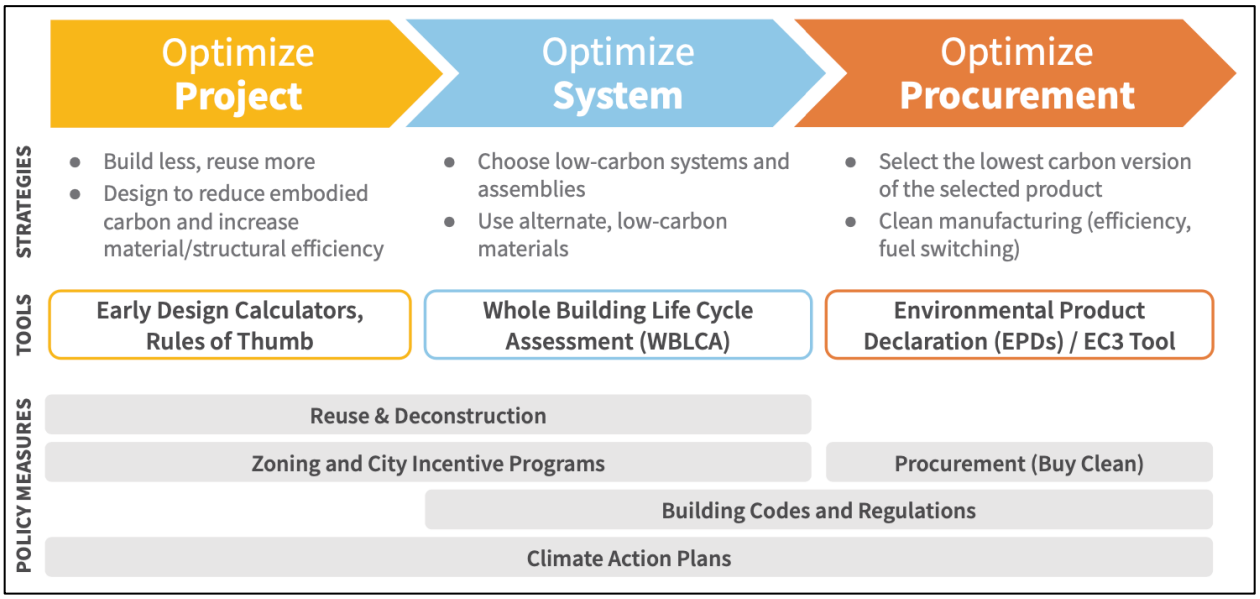
Table 1 lists these mechanisms along with definitions and examples demonstrating the implementation of these frameworks in practice. In **Figure 2,** these policies are outlined in relation to tools, strategies, and the process level they attempt to optimize (e.g., project level, system level, procurement/supply chain level).

Table 1. Embodied Carbon Policies

Mechanism	Definition	Examples
State, regional, and city climate action plans	Strategic framework for measuring, planning, and reducing GHG emissions and related climatic impacts (City of Burlington, n.d.)	• Setting goals related to buildings, materials, and consumption • Establishment of GHG reporting and monitoring systems • Embodied carbon targets and development of complementary policies
Public procurement policies	Establishes materials standards for purchasing certain goods and services (OECD, n.d.)	• Global Warming Potential (GWP) disclosure and limits • Environmental Product Declaration (EPD) requirements for certain materials (e.g., concrete, steel) • Performance incentives for achieved reductions • Financial support for compliance (tax credits or other rewards for developing low carbon products)
Building codes	Rules and regulations which govern the design, construction, and modification of commercial buildings, homes, and other structures in a certain jurisdiction (Ching and Winkel, 2016)	• Limits on carbon from concrete for residential and commercial construction • EPDs and targets • Allowable mass timber projects

Zoning and city incentives	Regulations which control the development of private land through use, density, design, and historic preservation requirements (Calder, 2017)	• Life-cycle equivalent carbon emissions reporting, established targets in rezoning plans • Zoning requirements for bio-based materials (e.g., wood) • Elimination of minimum parking standards • EPD requirements • LEED certification requirements
Reuse and deconstruction practices	Policies which prioritize the reuse, longevity, deconstruction, and salvage of infrastructure sites and materials	• Adaptive reuse ordinances • Building deconstruction laws • Public-sponsored reuse products markets, educational resources

Figure 2. Embodied Carbon Policies, Tools, and Strategies



Note. Image from Carbon Leadership Forum, 2022a. EC3 Tool refers to the free Embodied Carbon in Construction Calculator tool (Building Transparency, n.d.).

Climate Action Plans

Climate action plans (CAPs) provide frameworks for identifying and pursuing activities which lead to reductions in GHG emissions. These are typically implemented at the local level by municipal and county governments (MRSC, 2022). Although approaches are varied, CAPs will usually:

1. Establish GHG-reduction targets, using a community emissions inventory to quantify a baseline

2. Identify emissions policies and strategies by sector (e.g., transportation, land use, buildings, waste reduction, agriculture, and municipal operations)

As of May 2022, eleven local jurisdictions integrate embodied carbon into their CAPs (CFL, 2022b). Embodied carbon strategies present in CAPs include reforming building regulations, creating local markets for reuse materials, and enforcing low-carbon procurement for municipal operations (CFL, 2022b). These strategies are achieved through a combination of education and outreach, incentives programs, and policy development.

Organizations such as the C40 Cities Climate Leadership Group and Architecture 2030 recommend that current embodied carbon emissions be reduced 30% and 45% respectively by 2025, with 50% and 65% by 2030 (CFL, 2022b). However, most existing targets established by municipal governments fall below or barely meet these expectations, as shown in **Table 2**.

Table 2. Embodied Carbon Targets

Jurisdiction	Target
Austin, TX	40% reduction by 2030 from a 2020 baseline
Los Angeles, CA	50% by 2030 (from 2020 baseline, but not confirmed)
Phoenix, AZ	All new buildings within the city should be carbon-neutral equivalent by 2050
San Francisco, CA	Reduce embodied carbon more than 10% from 2021 levels per project by addressing at least three product categories or building assembly types

Public Procurement Policies

Public procurement refers to the purchase of goods and services by a public body, such as a government agency or department (OECD, n.d.). As of this writing, most policies intended to limit embodied carbon emissions statewide involve regulations on materials used in the construction and/or maintenance of public projects. These policies are important, 32% of the embodied carbon resulting from construction in the U.S. between 2008 and 2018 is attributable to public projects (CLF, 2022c).

Public procurement policies might include requirements for:

- Measuring and reducing the carbon intensity of construction by establishing greenhouse warming potential (GWP) limits for eligible materials (e.g., concrete, steel)
- Evaluating and considering embodied carbon when constructing and maintaining projects
- Providing financial incentives for developers utilizing low-carbon materials

According to the Carbon Leadership Forum, it is important to consider the following when creating a public procurement policy (CLF, 2020b):

1. Scope: which materials and types of projects are impacted by the policy?
2. Data: what environmental and project data will be used to demonstrate compliance?
3. Standards (optional): do materials or projects need to be below a GWP?
4. Incentives (optional): is financial and educational support offered to manufactures and developers?

5. Compliance: what is the timeline for submittal and for implementation of each component of the policy?

Table 3 details the current range of public procurement policies in U.S. states, commonly referred to as "Buy Clean" laws, and adjacent pieces of legislation. As indicated in the right column, some states (notably California, Colorado, and New York) utilize EPDs as part of their public procurement frameworks. EPDs disclose the environmental impact of a material and are third-party verified. They are useful for comparing materials between functionally equivalent products (CLF, 2022c). For instance, two concretes of similar strength and performance can be compared against one another, while concrete and wood cannot be compared.

For benchmarking and assessing embodied carbon reductions for different materials within the supply chain, the Embodied Carbon in Construction Calculator (EC3) tool offers a free solution (Building Transparency, n.d.). It allows owners, program administrators, and policymakers to assess supply chain data: allowing them to create EPD requirements and set embodied carbon limits at the construction material and project scale. As the number of EPDs in the U.S. continues to grow at a rapid pace, this tool will become increasingly useful for developers and policymakers alike.

Table 3. State-Level Buy Clean Laws

State	Name	Description	EPD
California	Buy Clean California Act (2017)	GWP limits for structural steel, concrete reinforcing steel, flat glass, and mineral wool board insulation used in public works projects	Type III
California	Senate Bill 596 (2021)	Requires that CARB develop a comprehensive strategy by 2023, focused on the state's cement sector and achieving net-zero emissions no later than 2045	N/A
California	Assembly Bill 1010 (2021)	All licensed architects in the state of California must go through 5 hours of continuing education on net-zero carbon design every 2 years (when renewing a license).	N/A
California	Assembly Bill 2446 (2022)	Bill requires that by 2025, CARB shall develop a framework for measuring and then reducing the average carbon intensity of the materials used in the construction of new buildings, including residential buildings, including a comprehensive strategy for California's building sector to achieve a 40% net reduction in GHG emissions of building materials by 2035.	Type III
Colorado	Buy Clean Colorado Act (2021)	Office of the State Architect and the CDOT are each required to establish policies regarding the GWP for specific categories of eligible materials (e.g., asphalt, cement, steel, wood structural elements) used to construct certain public projects.	Type III

Maryland	Climate Solutions Now Act (2022)	Maryland Green Building Council must evaluate the use of EPDs, performance incentives, expedited product evaluation of low-carbon concrete, and maximum GWP limits for concrete used in state-funded projects.	N/A
Massachusetts	Executive Order 594 (2021)	Executive order requires that all new construction and substantial renovations funded by the state must evaluate and implement strategies to reduce embodied carbon contained in building materials.	N/A
New Jersey	Senate Bill 3091 (2021)	Bill requires builders to offer unit concrete products that utilize carbon footprint-reducing technology as an option in new construction; establishes tax incentives, and state and local purchasing requirements for unit concrete products that utilize carbon footprint-reducing technology.	N/A
New York	Executive Order 4 (2008)	Executive order creates a state procurement and agency sustainability program setting guidelines and specifications for low-carbon concrete utilization.	Type III
New York	Low Embodied Carbon Concrete Leadership Act (2021)	Act requires all New York State authorities and agencies to include climate impact in their selection criteria for concrete procurement, encouraging the use of low-carbon concrete.	N/A
Oregon	House Bill 4139 (2022)	Bill requires ODOT to establish a program which reduces GHG emissions and assesses emissions attributable to certain materials used in construction and maintenance activities (e.g., concrete, asphalt paving mixtures, rebar, steel).	N/A
Washington	Executive Order 18-01 (2018)	Executive order mandates that all newly constructed state-owned (including lease-purchase) buildings shall be designed to be zero energy or zero energy-capable, and include consideration of net embodied carbon.	N/A

Building Codes

Building codes set minimum requirements for how different aspects of residential and commercial buildings (e.g., structural systems, plumbing, heating, ventilation, air conditioning, natural gas systems) should be designed, constructed, repaired, and demolished (NIST, 2022). Usually under the purview of state and local governments, jurisdictions will establish looser or more stringent language based upon a model code. In the U.S., most jurisdictional codes are modeled after those produced by the International Code Council (ICC).

Using building codes, it is possible to establish requirements which reduce the carbon impact of projects. This includes regulating specific building materials as well as the buildings themselves. On the materials side, EPDs and emissions limits for high-carbon materials (e.g., concrete, steel, aluminum, plastic, and glass) can be mandated through code requirements. In some circumstances, high-carbon materials can be prohibited entirely, such as hydrofluorocarbon blowing agents used for insulation (CLF, 2022d). In 2019, Marin County, CA established cement and embodied carbon limits for residential and commercial construction by amending the ICC model code (CFL, 2022d).

Changes in building codes can also be made to regulate whole buildings. Such initiatives focus on the structural and functional elements (e.g., materials used, life-time emissions) involved in the daily operation, maintenance, reuse, and/or demolition of a building. To achieve this, one proposed strategy is requiring that Whole Building Life Cycle Assessments (WBLCAs) be conducted during the design and development stages of the construction process (CLF, 2022d). In this scenario, the environmental impacts of the materials and processes proposed for the building project, as well as the projected energy usage associated with the occupancy and maintenance of a building, would be calculated to determine the building's carbon footprint (SJI, 2019). WBLCA polices either restrict the lifecycle emissions of a building or provide limits on allowable emissions per area (Bowles, 2021). This absolute value approach is in contrast to the alternative "percent-better-than requirement" in which buildings must achieve a specific GWP reduction (e.g., 5% compared to a baseline year). For these "percent-better-than" policies to be successful, methodological and modeling guidance must be produced in order to compare projects to an agreed-upon baseline.

As an additional strategy, building codes may also be used to regulate the "carbon budgets" of buildings. There is already a precedent for establishing "energy budgets" for operational energy, and it is possible that the code could create "carbon budgets" focused on reducing both embodied and operational carbon (CLF, 2022d). This could be achieved through setting a limit based on total GWP for a building, CO_2-e per floor area unit, or a percentage reduction from an established baseline (CFL, 2022d).

Zoning and City Incentives

Zoning refers to a mix of codes, ordinances, and other requirements which dictate the development and usage of land in a given jurisdiction (Transect, n.d.). In the U.S., cities have control over of significant amounts of land, both above- and below-ground. Although control over zoning can differ by county or state, municipal governments are generally tasked with enforcing zoning requirements based on a city's development needs and goals, usually outlined in a master plan. While carrying out enforcement, localities create rules for where residential, commercial, green, and industrial spaces are permitted within their limits thereby dictating the density, function, and relationship between structures.

Zoning requirements offer a way to manage and optimize land use. As such, these policies represent an opportunity to reduce embodied carbon emissions in cities (CLF, 2022e), potentially by using a mix of regulatory and voluntary approaches. For example, to increase the uptake of low-carbon materials and encourage commitment from developers to lower embodied carbon emissions, cities can use expedited permitting processes, fee reductions, and density bonuses to incentivize green buildings (CLF, 2022e). By adopting voluntary mechanisms before regulatory approaches, it is possible to increase market awareness and preparedness before requirements come into effect. In one example, the San Diego County Green Building Incentive Program, reduces plan check and building permit fees for projects meeting program requirements (San Diego County, n.d.)

In terms of zoning regulations, cities can require the use of carbon-storing materials (e.g., mass timber), minimize parking lot sizes, establish size and space efficiency requirements, and zone for

low-carbon building types. For instance, in the district zone of Honkasuo in Helsinki, Finland, all buildings are required to have a wooden frame and facade, increasing the potential for carbon sequestration through the use of carbon-storing wood products (CLF, 2022e).

Deconstruction and Reuse Practices

Deconstruction describes the process of deconstructing a building for the purpose of recovering reusable materials (Build Reuse, n.d.). Unlike conventional demolition (e.g., the use of heavy machinery with limited concern for reusability), deconstruction relies upon the "selective disassembly" of building components (Build Reuse, n.d.). Since the 1990s, this category has gained industry traction and attention from municipal governments, who have implemented a range of policies aimed at fostering more sustainable construction practices. As described in **Table 4**, some of these policies include adaptive reuse ordinances, material reuse ordinances, deconstruction/salvage, design for disassembly, market development, and community investment (CLF, 2022f).

Table 4. Deconstruction and Reuse Practices

Action	Description
Adaptive reuse	Repurposing an existing building for an alternative function, one different from its originally intended use
Material reuse	The reuse of salvaged and/or surplus materials (CLF, 2022f)
Deconstruction/salvage	Prioritizing the preservation of materials during construction and demolition for the purpose of reuse
Design for disassembly	Designing buildings so they are more easily taken apart, making the process of repairing, replacing, and salvaging materials easier
Market development	Government-led efforts to create markets for reused and recycled materials
Community investment	Investing in historical buildings and existing community spaces (CLF, 2022f)

There are several ways local governments can influence this space, from procedures governing the planning, design, and construction phases of a project to regulating deconstruction and enhancing material reuse through market development (CLF, 2022f). Policy mechanisms which may encourage the practices listed above include adaptive reuse ordinances, rezoning requirements, tax penalties for vacant homes, deconstruction ordinances, and government-operated reuse markets.

In the City of Los Angeles, an adaptive reuse ordinance seeks to "encourage mixed commercial and residential uses" to improve air quality, reduce vehicle travel, and support local businesses (City of Los Angeles, 2001). Meanwhile, in the City of Vancouver, British Columbia, Canada, a rezoning mandate requires a percent reduction in life-cycle CO_2-e emissions, as verified by a WBLCA (CLF, 2022f). In this case, reusing material can contribute to meeting the percent reduction requirement.

Federal Action

In 2021, President Biden signed an executive order to leverage the procurement power of the federal government in combatting the climate crisis. One of the goals outlined is to achieve net-

zero emissions associated with federal procurement activities by 2050, as well as to create a "Buy Clean" policy promoting the use of construction materials with lower embodied emissions (The White House, 2021). Federal agencies have already begun to act on this executive order.

By 2022, the General Services Agency (GSA) issued new standards requiring that low-carbon concrete and asphalt be used in nationwide GSA construction, modernization, and paving projects (GSA, 2022). These new standards also mandate that project contractors must provide EPDs when available (GSA, 2022). For transportation initiatives, the U.S. Department of Transportation (DOT) announced a pilot program with the goal of increasing the use and transparency of EPDs and procuring low-carbon materials, while the Federal Highway Administration (FHA) awarded $7.1 million in grants to quantify emissions of sustainable pavements (Kalsman & Lewis, 2022).

Meanwhile, the passage of the Inflation Reduction Act (IRA) in 2022 allocated $4.5 billion to the Environmental Protection Agency (EPA), DOT, and GSA to procure more climate-friendly construction materials for federal infrastructure projects (Kalsman & Lewis, 2022). With this funding, these agencies are encouraged to create a low-embodied carbon labeling system, increase the usage and standardization of EPDs, research emerging technologies, and develop transportation projects using low-embodied carbon materials (Kalsman & Lewis, 2022).

Forest and Climate Change Implications

Influenced by a mix of requirements and incentives, the construction sector is shifting away from using building materials with high embodied carbon (e.g., steel and concrete) to those with low embodied carbon (e.g., mass timber). This has profound effects for forests, carbon, and climate change. In the U.S., as of 2022, there are 738 mass timber projects that have been completed or are under construction, with another 833 projects in the design stage (WoodWorks, 2022).

Compared to conventional building materials like steel and concrete, mass timber and other wood products have low amounts of embodied carbon. This is a result of a combination of factors. First, the extraction, manufacturing, and transportation of timber products emits less GHGs than these same activities do for steel or concrete products (Mantle Developments, 2020). Second, wood products in building and construction can store carbon for long periods of time—keeping carbon out of the atmosphere for the lifetime of a project, and possibly even longer depending on whether wood is reclaimed or reused. The result is a benefit to the climate, as there is a net decrease in GHGs released into the atmosphere.

However, the projected climate benefit of mass timber buildings relies upon the assumption that timber products are sourced and harvested from sustainably managed forests. If this is not the case, it is possible that the emissions associated with unsustainable harvest practices could outpace those involved in the manufacturing and transportation of steel and concrete. Additionally, without independent verification mass timber product origins, it can be difficult to confirm that a harvest was conducted in a sustainable manner (Mantle Developments, 2020). Innovate approaches have been suggested, to solve this issue of transparency and verification, such as utilizing blockchain technology to enhance the trackability of wood products as they move through the supply chain.

Conclusion

Embodied carbon is an area of concern for climate mitigation and adaptation with growing attention from the construction sector and policymakers. If left unaddressed, emissions associated with embodied carbon may exceed 230 gigatons by 2060, more than six times the amount of carbon emissions emitted worldwide in 2022 (CNCA, 2022). To avoid this increase in emissions, local, state, and federal actors must motivate developers to build climate-friendly structures. The

policy mechanisms, tools, and strategies available to achieve this are vast—encompassing the extraction, manufacture, and procurement of construction materials as well as zoning and building code requirements. In considering ways to mitigate the effects of the climate crisis, an understanding of the connection between the built environment and embodied carbon will be essential to policy response in the decades to come.

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