Carbon Leadership Forum

Embodied Carbon Policy Factsheet

Embodied Carbon 101

Embodied carbon refers to the greenhouse gas (GHG) emissions generated by the manufacturing, transportation, installation, maintenance, and disposal of construction materials used in buildings, roads, and other infrastructure. Embodied carbon is a significant percentage of global emissions and requires urgent action to address it.

This factsheet provides a high-level overview of embodied carbon – how it is defined, its significance in the global climate crisis, and why it is an important consideration for policymakers.

Measuring embodied carbon

To quantify embodied carbon, practitioners use a method called ***life cycle assessment (LCA)*** to track the greenhouse gas emissions produced over the full life cycle of a product, building, or infrastructure. These emissions are converted into metrics that reflect their potential effects on the environment. One of these metrics is ***global warming potential (GWP)***, quantified in kilograms of CO_2 equivalent (kg CO_2e). This quantity is also commonly referred to as a carbon footprint.

LCA can be done at multiple scales. The most common scales include:

- Product-level LCAs focus on quantifying the extraction and manufacturing impacts of a specific product. Read more in EPD 101.
- Project-level LCAs that focus on quantifying the impacts of the materials and processes used to construct a building or infrastructure project, across its life cycle. Read more in Building LCA 101 and CLF's Accounting for Embodied Carbon in Roadway Infrastructure.

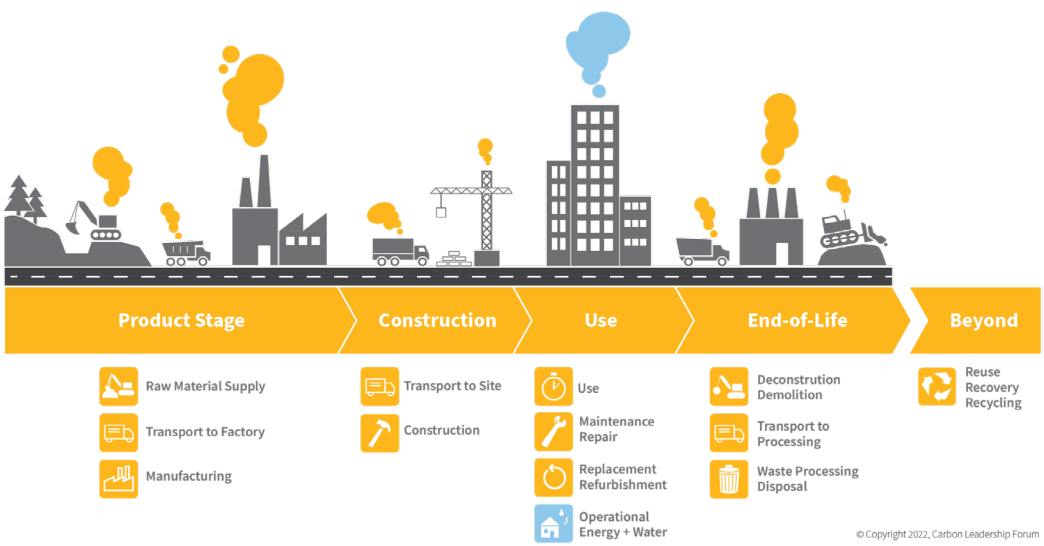

Figure 1. Embodied carbon (yellow) and operational carbon (blue) across the life cycle stage of a building

Embodied carbon is still a gap in climate policy

The majority of a product, building, or infrastructure's embodied emissions are generated before (often referred to as 'upfront' or 'upstream' emissions) the building or infrastructure is constructed and may be spread throughout facilities and supply chains across the globe. Historically, climate policy rarely controls emissions outside of a physical geographic boundary, focusing only on locally generated emissions. This enables one location to outsource its emissions to another, creating a 'carbon loophole'. A 2018 report (by KGM & Associates and Global Efficiency Intelligence) found that approximately 25% of global emissions are embodied in traded goods that pass through this loophole.[1]

KEY TERMS

Life cycle assessment (LCA)

A systematic set of procedures for compiling and evaluating the inputs and outputs of materials and energy, and the associated environmental impacts directly attributable to a product or process throughout its life cycle.

Global warming potential (GWP)

The potential climate change impact of a product or process as measured by an LCA. GWP is reported in units of carbon dioxide equivalent (CO2e) and is the agreed-upon metric for tracking embodied carbon.

REFERENCES

1. Daniel Moran et al. (2018). The Carbon Loophole in Climate Policy: Quantifying the Embodied Carbon in Traded Products.

Embodied carbon is a significant contributor to global emissions

Buildings and infrastructure are top contributors to global climate change. Tackling embodied carbon is key to addressing industrial emissions. The largest contributor to global emissions is the industrial sector, contributing 30% of global emissions (see Figure 2). Building materials are one of the largest sources of industrial emissions and, therefore, are potential solutions for reducing emissions from this sector.

Materials used in the construction of buildings represent about 7% of total global greenhouse gas emissions (see Figure 2). Materials used to construct infrastructure make up another 10%.

Global Greenhouse Gas Emissions Breakdown by Sector (2019)

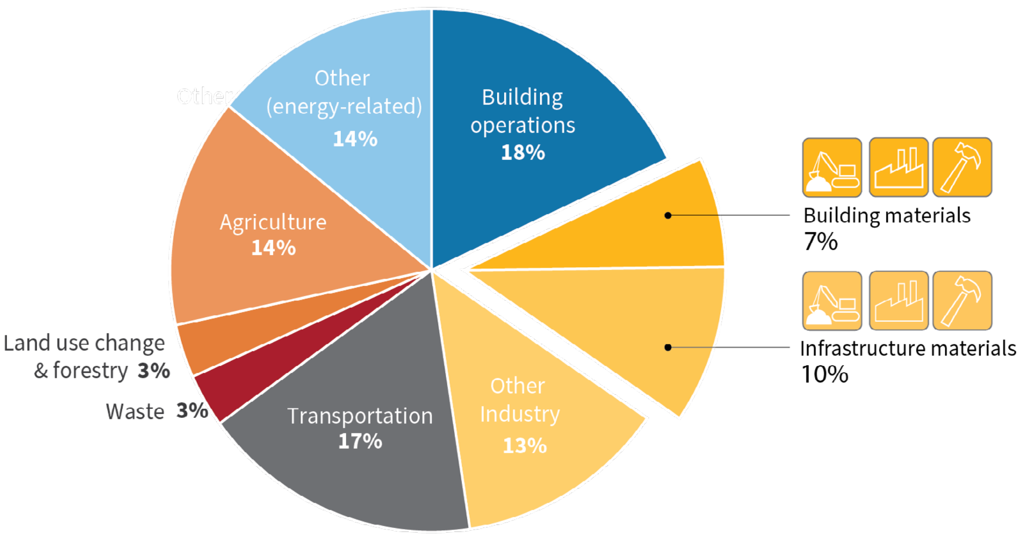

Figure 2. Global end-use greenhouse gas emissions breakdown by sector in 2019. Emissions from building and infrastructure materials comprise 17% of global greenhouse gas emissions.

Sources: CLF analysis based on data from WRI[2] and IEA[3]. Building and infrastructure materials include the share of industrial energy-related and process emissions attributed to buildings and infrastructure (transport, energy, and other) from iron, steel, cement and other non-metallic minerals (ceramics, glass, lime), plastics, aluminum and other non-ferrous metals, wood and wood products, and construction energy use.

When considered over the full life cycle, the impacts of the built environment are spread across:

- **Industry**: The materials used in construction, like concrete and steel, contribute significantly to industrial emissions. The majority of embodied emissions for buildings and infrastructure are from the industrial sector.
- **Agriculture, land use change, and forestry:** The production of bio-based building materials contributes emissions to these sectors.
- **Transport:** Materials are shipped between processing facilities, construction sites, and/or landfills, and these emissions are accounted for as transportation emissions.
- **Waste**: When buildings are demolished, much of the building materials end up in landfills or incinerators, where their decomposition or combustion is tracked as waste emissions. Globally, approximately 100 billion metric tonnes of waste is caused by construction, renovation, and demolition, with about 35% sent to landfills.[4]

REFERENCES

2. World Greenhouse Gas Emissions: 2019, World Resources Institute (WRI), 2022.

3. IEA (2023). Energy Technology Perspectives 2023, see pg 91. “Estimated end-use shares of global consumption for major materials, 2021”.

4. United Nations Environment Programme. (2022). 2022 Global Status Report for Buildings and Construction: Towards a Zero-emissions, Efficient and Resilient Buildings and Construction Sector. Nairobi

Embodied carbon is an urgent problem

Raw material use is predicted to double by 2060 – with steel, concrete, and cement already major contributors to greenhouse gas emissions.[3] To avoid the most catastrophic impacts of climate change, it is essential that we reduce embodied carbon now and develop a pathway to low-carbon construction on every building project. Transforming the building industry cannot wait.

Operational carbon generated from the daily operations of a building can be decreased over time thanks to ongoing energy efficiency efforts, efforts to construct all-electric buildings, and grid decarbonization. In contrast, once ***upfront embodied carbon emissions*** are released into the atmosphere, we can't take them back, and they start affecting the climate immediately.

The Carbon Leadership Forum published a study in 2024 focused on the timing and magnitude of operational and embodied emissions from a set of buildings in California. This study found that for newly constructed buildings in California, embodied emissions would contribute approximately 80% of total emissions between 2024 and 2030 and approximately 70% of total emissions between 2024 and 2045, the deadline year for many of California's emissions reduction targets (see Figure 4 and referenced report).

Emissions released now are more critical than emissions released later because (1) emissions will accumulate in the atmosphere and (2) there is limited time remaining before the tipping point of the climate crisis. This means that in the near term, reducing embodied carbon is as important as—or more important than—operational carbon. The urgency of reducing emissions that will happen in the short term between now and 2030 or 2050 is sometimes referenced as "the time value of carbon."

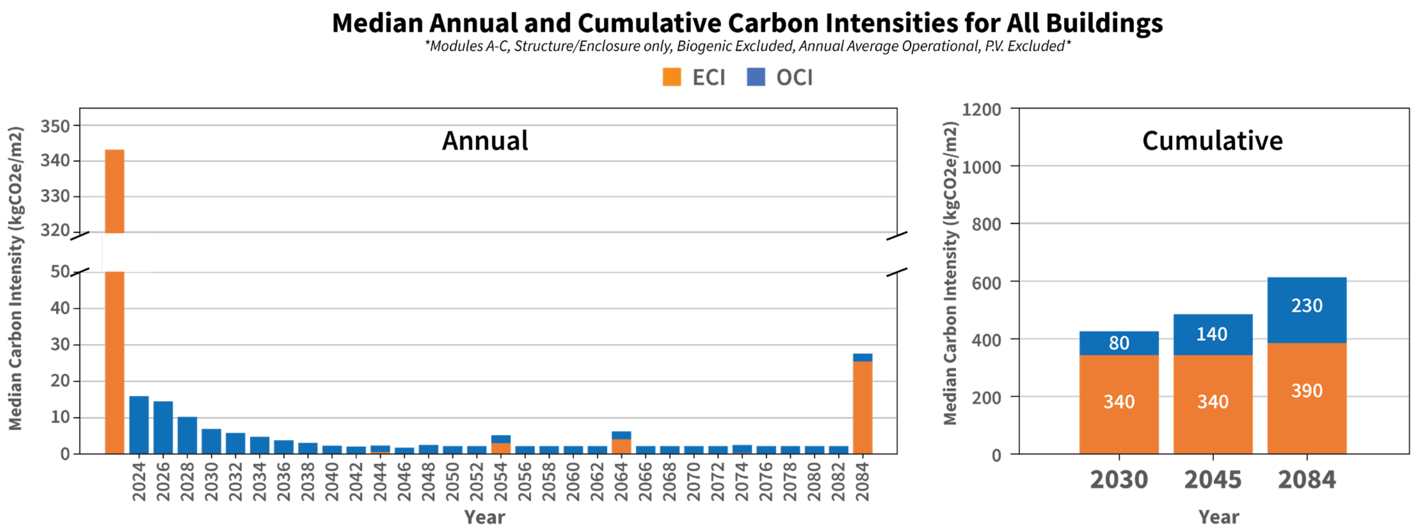

Figure 3. Median annual and cumulative **embodied carbon intensities (ECIs)** and **operational carbon intensities (OCIs)**. Modeling based on the embodied and operational emissions from life cycle modules A-C for the structure and enclosure of buildings in California. Note that the y-axis for annual impacts (above) is shown with a break between 50 and 320 kg CO_2e/m^2).

Adapted from Benke, B., Roberts, M., Lewis, M., Shen, Y., Carlisle, S., Chafart, M., and Simonen, K. (2024). The California Carbon Report: Six Key Takeaways for Policymakers. Carbon Leadership Forum, University of Washington. Seattle, WA.

Embodied carbon is directly linked to public health and equity

The concept of a *just transition* grew out of collaboration between environmental justice groups and labor unions. The IPCC defines a just transition as "a set of principles, processes, and practices that aim to ensure that no people, workers, places, sectors, countries, or regions are left behind in the transition from a high-carbon to a low-carbon economy."[6] A just transition aims to move away from an extractive economy to a sustainable and regenerative economy. The principles of a just transition and the work of the ***climate justice*** movement reinforce the idea that addressing climate change and equity cannot be done in isolation. The transition to a low-carbon future itself must be equitable and create space to focus on new structures of power and accountability.

Embodied carbon is inherently connected to climate justice and issues of public health and equity. Its impact can be seen locally in ***fenceline communities*** – those adjacent to construction supply chains, and globally in ***frontline communities*** – those that experience the impacts of climate change "first and worst."

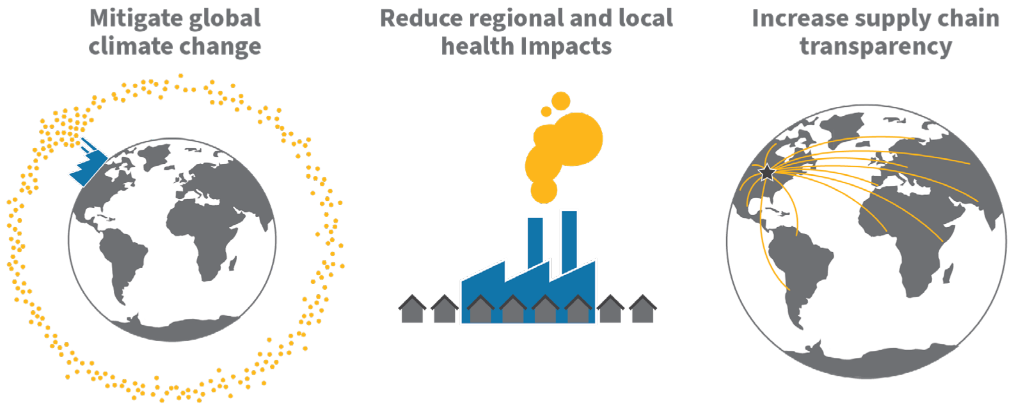

Figure 4. Embodied carbon is inherently connected to climate justice and issues of public health and equity.

Figure 5. Potential Ecological impacts (orange) and human impacts (gray) of embodied carbon across the life cycle stages of a building.

REFERENCES

6. PCC. (2022). Climate Change 2022: Mitigation of Climate Change. Working Group III Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.

KEY TERMS

Climate justice

The moral and ethical principle that seeks to address the disproportionate impact of climate change on vulnerable communities and future generations. Climate justice recognizes that the consequences of climate change are not distributed equally, with marginalized and disadvantaged populations often bearing the brunt of these effects (United Nations Climate Justice Global Alliance).

Fenceline communities

A fenceline community lives immediately adjacent to highly polluting facilities such as fossil fuel infrastructure, industrial parks, or large manufacturing facilities – and is directly affected by the traffic, noise, operations, chemical and fossil fuel emissions of the operation (The Climate Reality Project).

Frontline communities

Frontline communities experience the impacts of climate change "first and worst." They are the communities most vulnerable to and will be the most adversely affected by climate change and inequitable actions because of systemic and historical socioeconomic disparities, environmental injustice, or other forms of injustice (White House Justice40 Initiative).

Embodied carbon can be reduced now with available tools and strategies

Embodied carbon has long been the blind spot of the sustainable design movement and the building industry at large.

Not long ago, it was nearly impossible to find or understand the carbon footprint of some of the most common building materials. But in the past decade, there has been a surge of interest and knowledge-building to address embodied carbon.

Today, we have the tools, data, and strategies necessary for designers and builders to make meaningful carbon reductions on their projects immediately.

The CLF Urban Embodied Carbon Reduction Checklist provides a downloadable Excel worksheet for project teams to ensure they have considered strategies that may be relevant to their projects. The strategies are organized into types, beginning with process and tools and also including:

1. BUILD LESS, REUSE MORE
2. DESIGN LIGHTER AND SMARTER
3. USE LOW-CARBON ALTERNATIVES
4. PROCURE LOW(ER) CARBON PRODUCTS

Learn more about embodied carbon policy opportunities

Policy can be a lever to take project-scale approaches for carbon reductions and scale them up to entire jurisdictions of buildings and infrastructure. There is no one-size-fits-all policy solution for embodied carbon. Many policy levers are complementary, building on the success of related policies.

Learn more in the rest of the **CLF Embodied Carbon Policy Toolkit Factsheet Series**:

Reporting mechanisms used by policy:

- EPD 101: Embodied Carbon Accounting for Materials
- Building LCA 101: Embodied Carbon Accounting for Buildings

Policy pathways:

- Buy Clean Policies: Overview and Implementation
- Building-Scale Embodied Carbon Performance Requirements
- Embodied Carbon and Building Codes
- Deconstruction, Salvage, and Reuse Policies

Also check out CLF's Policy Reports & Case Studies, including:

- Advancing the LCA Ecosystem: A Policy-Focused Roadmap for Reducing Embodied Carbon
- Pacific Coast Collaborative: Embodied Carbon Policy Case Studies
- Northeast U.S. & Canada Embodied Carbon Policy Case Studies

Glossary of Terms

Embodied Carbon

The greenhouse gas (GHG) emissions generated by the manufacturing, transportation, installation, maintenance, and disposal of construction materials used in buildings, roads, and other infrastructure. The terms *"embodied carbon," "embodied carbon emissions,"* and "*embodied emissions*" can be used interchangeably.

Global warming potential (GWP)

The potential climate change impact of a product or process as measured by an LCA. GWP is reported in units of carbon dioxide equivalent (CO_2e) and is the agreed-upon metric for tracking embodied carbon.

Life cycle assessment (LCA)

A systematic set of procedures for compiling and evaluating the inputs and outputs of materials and energy, and the associated environmental impacts directly attributable to a product or process throughout its life cycle.

The results of an LCA can illuminate which parts of a building have particularly high environmental impacts.

What constitutes a "whole building LCA"?

Whole building LCA (WBLCA) is a term that is often used to refer to LCAs of buildings. However, not all "whole" building LCAs truly encompass the "whole building" in terms of scope. Often, these assessments only include certain components, such as structure and enclosure, and exclude other significant components such as MEP, site work, or interiors. CLF encourages the inclusion of these other components into standard practice to realize the full environmental impacts of buildings as data, methods, and tools continue to develop.

Benchmark

A set of environmental impact results that serve as a reference point from which the relative performance of other buildings can be evaluated. For example, benchmarks for operational energy efficiency are measured using energy use intensity (EUI).

The many names of "carbon"

The following is a list of terms that are often used somewhat interchangeably to refer to the emissions associated with climate change or global warming:

Embodied carbon

Carbon footprint

Carbon dioxide (CO_2)

Carbon dioxide equivalent (CO_2e or CO_2eq)

Greenhouse gas (GHG) emissions

Fossil fuel emissions

Global warming potential (GWP)

Climate change (CC) potential

These terms do not share the same meaning. Even though the term "carbon" is commonly associated with climate change, it is technically not elemental carbon that contributes to climate change, but carbon dioxide gas along with many other substances such as nitrous oxide and methane. Nevertheless, "carbon" is often used as an abbreviation to refer to global warming potential.

(Carbon Leadership Forum (2018). Life Cycle Assessment of Buildings: A Practice Guide)

The time value of carbon

Emissions released now are more critical than emissions released later because (1) emissions will accumulate in the atmosphere and (2) there is limited time remaining before the tipping point of the climate crisis. This means that in the near term, reducing embodied carbon is as important as—or more important than—operational carbon. The urgency of reducing emissions that will happen in the short term between now and 2030 or 2050 is sometimes referenced as "the time value of carbon."

Upfront embodied carbon emissions

CO_2e emissions are released during the product and construction stages before the building or infrastructure use begins, also referred to as "cradle to practical completion."

The majority of a building's total embodied carbon is released upfront in the product stage at the beginning of a building's life, in life cycle stages A1-A5.

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EPD 101 Embodied Carbon Accounting for Materials

Industrial policies that target the reduction of emissions from construction products, like "Buy Clean" policies, need data to track and set limits for the emissions of different products.

Environmental product declarations (EPDs) are standardized, third-party-verified documents that report the environmental impacts of a product based on a product ***life cycle assessment (LCA)***. EPDs are the best available mechanism for requiring product embodied carbon reporting and transparency. This document provides an overview of EPDs in the context of policy.

EPDs are the right tool for product embodied carbon reporting in policies

Strategies for reducing the embodied carbon of a product can vary by material and facility. Asking the manufacturer to disclose the footprint of their product via an EPD is a first step to understanding whether or not a product is low carbon.

EPDs are like a mileage rating on a car: they summarize key data to help purchasers compare similar products. Instead of mileage per gallon, EPDs provide the environmental impact per unit of product. They are often also described as nutrition labels for building materials. EPDs can only be used to compare products within the same product category that have the same function.

Many EPDs exist across North America, but some areas have more available than others. To find EPDs, visit Building Transparency's EC3 database or visit the page of a ***program operator***.

EPDs start with a product life cycle assessment

A product LCA is a method for quantifying the environmental impacts of a product over its life cycle. EPDs disclose the results of product LCAs. LCAs can also be done for buildings (read more on Building LCA here) or infrastructure projects (read more here).

Greenhouse gas emissions, including carbon dioxide, are added up over the product's life cycle and reported as ***global warming potential (GWP).*** EPDs also include other environmental impacts, such as acidification, eutrophication, ozone depletion, and smog formation.

Environmental impacts across a product's life cycle are broken into four main stages: Product stage (A1-A3), Construction stage (A4-A5), Use (B), and End-of-life (C), as described in Figure 1. At a minimum, cradle-to-gate emissions (A1-A3) are included in an EPD, which makes them well-suited to capture the benefits of manufacturing and supply chain decarbonization strategies.

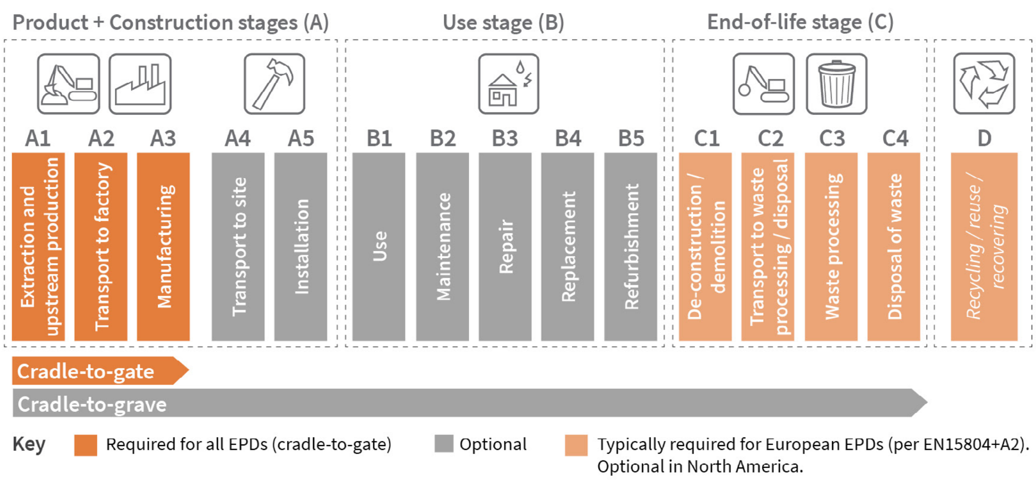

Figure 1. Life cycle stages typically included in North American EPDs. Module names are in accordance with ISO 21930. Product category rules (PCRs) dictate which life cycle stages are required, excluded, or optional.

KEY TERMS

Embodied carbon

GHG emissions are generated by the manufacturing, transportation, installation, maintenance, and disposal of construction materials used in buildings, roads, and other infrastructure.

Life cycle assessment (LCA)

A systematic set of procedures for compiling and evaluating the inputs and outputs of materials and energy, and the associated environmental impacts directly attributable to a product or process throughout its life cycle.

Global warming potential (GWP)

The potential climate change impact of a product or process as measured by an LCA. GWP is reported in units of carbon dioxide equivalent (CO_2e) and is the agreed-upon metric for tracking embodied carbon.

Standards and accounting rules for EPDs

EPDs are third-party verified and based on international standards and agreed-upon rules for how each type of product calculates its footprint. The International Organization for Standardization (ISO) provides the global LCA standards followed in North America.

Each EPD must meet requirements from a family of standards:

- A North American ***product category rule (PCR)***
- ***ISO 21930*** provides core requirements for EPDs of construction products and services and forms the basis for PCRs as the 'core PCR'. In Europe, EN 15804+A2 plays this role instead.
- ***ISO 14025*** defines Type III environmental claims and provides the framework for EPD creation.
- ***ISO 14040*** and ***ISO 14044*** are foundational standards that describe the principles and framework for LCA and lay out basic requirements for all types of LCAs.

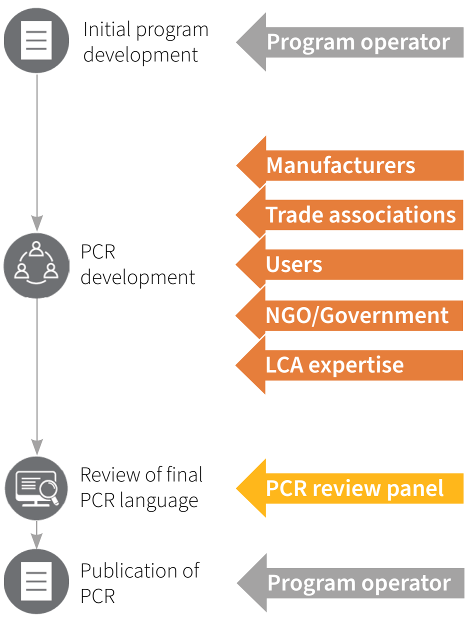

Figure 2. Process and stakeholders for PCR development (adapted from ISO 14025:2006).

ISO standards and PCRs are developed through an open stakeholder development process, where a technical committee comprising experts from industry, academia, NGOs, and government uses a consensus-based approach to create the scope and content of the standard. PCRs are typically updated every 3-5 years, and ISO standards are updated based on industry needs (there is no set interval).

The development of a product category rule is led by a ***program operator***. Examples in North America include NSF International, UL Environment, and Smart EPD.

A PCR can include critical requirements for ensuring data quality and comparability, such as:

- Which life cycle stages and impact categories must be included?
- Which background data can be used?
- Which facilities need to contribute primary data?

Types of EPDs

The most common type of EPDs are those created by a single manufacturer (often called a "***product EPD***" or "product-specific EPD," though this term is used differently in different cases), which report impacts for a narrow range of one manufacturer's products.

Product EPDs can be further classified into "***facility-specific EPDs***" (those that report impacts based on data from a single facility) vs. "manufacturer-average EPDs" (those that report impacts based on averaged data from a manufacturer's multiple facilities).

EPDs may be additionally classified based on the extent of specific data they use from upstream suppliers (i.e., "supply-chain-specific data"). The ACLCA's forthcoming addendum on EPD types and data specificity aims to provide definitions and clarity around these terms.

In contrast, ***industry-average EPDs*** report the impacts of a type of product based on data aggregated from a sample of manufacturers, often published via a manufacturing trade association. These EPDs cannot be used for complying with a policy, because they do not disclose the impacts of an individual manufacturer. However, the data is useful for understanding the industry average, such as in the context of setting policy requirements at the industry average.

KEY TERMS

Product category rule (PCR)

A set of specific rules, requirements, and guidelines for conducting an LCA and developing EPDs for one or more product categories.

Program operator

A company, trade association, public agency, or independent body that manages the development and publication of a PCR and resulting EPDs.

Type III environmental declarations

An EPD is referred to as a "Type III environmental declaration" in ISO 14025: 2006.

Sometimes, the term "Type III EPD" is used to emphasize the third party verification process described in ISO 14025. However, this is redundant, as all EPDs that follow product category rules and meet the required international standards (ISO 14025 and ISO 21930) are third party-verified.

How is an EPD created?

The standards and data all come together during the EPD creation process. EPDs are created by manufacturers. The creation process can be led internally if qualified staff are available, outsourced to an external LCA consultant, and/or supported through the use of EPD generator tools that aim to streamline and simplify this process.

These are the general steps manufacturers must take to create an EPD[1,2]:

- **Step 1 – Manufacturer Data Collection:** Manufacturers must collect data on the quantity and type of materials, energy, and processes used to create the product. Which data is required to be collected varies by the product and what is required by the product category rule (PCR).
- **Step 2 – Product LCA:** Complete an LCA of the product in compliance with the PCR, ISO 14025, and ISO 21930 (as described on the previous page). Where data from the manufacturer is not available or is not required by the PCR, generic or average data sources can be used.
- **Step 3 – Background report:** The background report is a non-public report that accompanies the public EPD and provides further details about the LCA methodology, assumptions, approach, and standards compliance to support the third-party verification review process. This report may include proprietary information, which is why the EPD summarizes the results of the full LCA but does not include the full background report.
- **Step 4 – 3rd party verification:** Every EPD needs to be reviewed by an independent third-party verifier before it can be published. Verifiers are typically experienced LCA professionals approved by the program operator. The verifier checks that the LCA background report adheres to international LCA standards and PCRs.
- **Step 5 – Publication:** Once the EPD has been verified, the manufacturer can submit the EPD document for publication to the program operator, who will process, register, and publish the EPD. Additionally, the EPD can be submitted to a database like EC3.

After publication, EPDs are typically valid for five years from the date of issue. All EPDs state the date of issue and period of validity.

Opportunities to improve data quality and alignment

EPDs use data from a combination of facility data specific to the manufacturer (like facility fuel use, water consumed, or waste generated) and generic or average data sources (like emissions factors for fuel). EPDs will continue to improve over time as the data quality requirements set in standards (and data collection tools) improve, and more robust public data is made available.

Updating PCRs – the rules for how to make EPDs – is the quickest lever for strengthening EPDs as a policy mechanism. As PCRs are updated, they can integrate data quality best practices, create more clarity and transparency around requirements, and increase consistency within and across different product categories. It is important to weigh data specificity requirements against the added time and administrative burden on manufacturers.

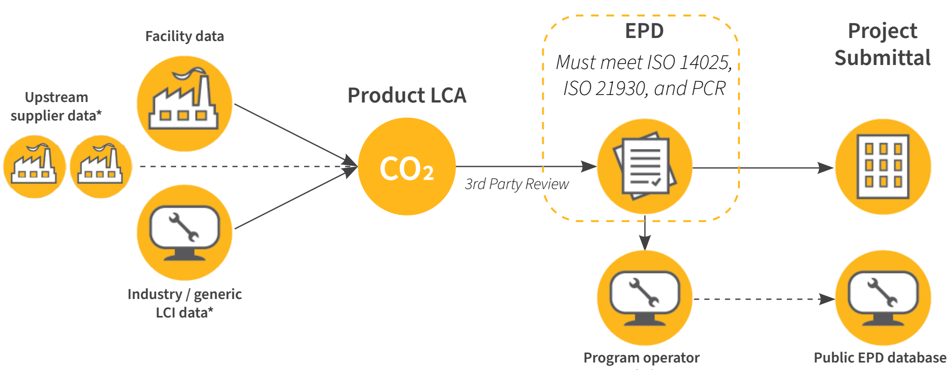

Figure 3. Flow of data to create an EPD. (*) indicates areas where specificity and other minimum data requirements are set by the Product Category Rule. Dashed lines indicate that something is optional. Policies can also add requirements.

REFERENCES

1. OneClick LCA. A simple Guide to EPDs.

2. Building Transparency. How to Get an EPD

Beyond Environmental Impacts: Additional Reporting in EPDs

In addition to environmental impact data, EPDs may also include the location of manufacturing facilities as well as supplementary information about the products or manufacturers that are also of interest to agencies in achieving environmental or social goals.

For example, Washington state requested that manufacturers provide information on working conditions for the facility represented in the EPD and chain of custody data related to the forestry sourcing for engineered wood as part of the Buy Clean Buy Fair pilot study. Buy Clean Buy Fair Minnesota will also include an assessment of employee working conditions at the product's production facilities as part of the pilot study included in the bill.

Guidance on Policy Requirements for EPDs

EPDs are standardized, third-party-verified documents that report the environmental impacts of a product based on a product life cycle assessment. EPDs are the best available tool for requiring reporting of embodied carbon in policies.

	EPD checklist: Minimum requirements
☑	Conforms to international standards (ISO 14025 and ISO 21930) and the applicable product category rule (PCR)
☑	Has a **validity date** that is not expired
☑	Is **product-specific**
	EPD checklist: Best practices
☑	Is **facility-specific**
☑	Reports the **% of supply chain-specific data** used in the LCA
☑	Reports **a data uncertainty range**

Policies that do require embodied carbon disclosure should require valid, product-specific (or facility-specific) EPDs that meet the requirements of ISO 14025, ISO 21930, and the applicable PCR.

Requiring best practice reporting — in addition to the minimum requirements — can help guide future alignment and improvements to standards that guide EPD development.

When possible, government agencies are encouraged to participate in PCRs where they can represent the needs of end-users of EPDs. PCR committees are hosted by the program operator, so applications to join a committee are typically found on their websites.

Read more: carbonleadershipforum.org/clf-policy-toolkit

Learn More

- → Embodied Carbon 101
- → Buy Clean Policies: Overview + Implementation
- → EPD Requirements in Procurement Policies
- → Advancing the LCA Ecosystem

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Embodied Carbon Policy Factsheet

Building LCA 101

Embodied Carbon Accounting for Buildings

Building greenhouse gas (GHG) emissions can be broadly divided into operational carbon – the emissions associated with energy used to operate a building – and embodied carbon – the emissions associated with the materials and construction processes across the building's life cycle.

Life cycle assessment (LCA) is the agreed-upon methodology for measuring embodied carbon. LCA is a systematic approach for evaluating the environmental impacts of a building, product, or process over its full life cycle, from raw material extraction through end-of-life and disposal. By providing a standardized and robust approach to estimating the carbon impacts of construction products and projects, LCA can support more informed decision-making from early design through procurement. In the context of policy, building LCA is required for complying with building embodied carbon reporting requirements or performance standards (read more here).

LCA provides an estimate of greenhouse gas emissions over the building's entire life cycle, reported as ***global warming potential***, as well as other environmental and human health impacts, such as acidification, eutrophication, and smog formation. Life cycle stages (product, construction, use, end-of-life) and modules (A1, A2, etc.) subcategorize the life cycle of a building and help communicate when environmental impacts occur.

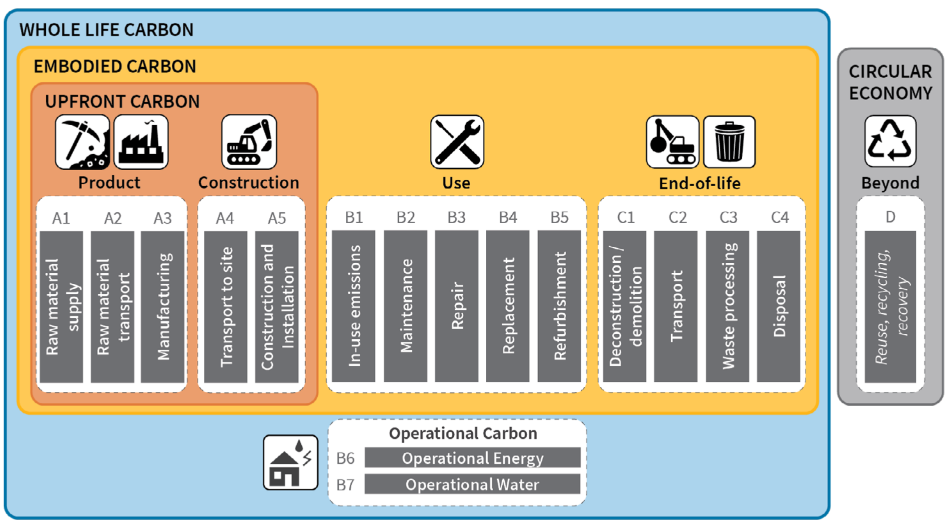

Figure 1. Life cycle stages and modules subcategorize the full life cycle of a building to communicate when environmental impacts occur and help communicate what parts of the life cycle are included in an assessment.

Methodologies for measuring a building's embodied carbon

There are multiple terms used for describing LCAs of buildings. The main differences are which life cycle stages and environmental impacts are included:

- A **whole building LCA (WBLCA)** is a cradle-to-grave (A-C) assessment that evaluates environmental impacts beyond GWP, such as smog formation and eutrophication.
- A **whole-life carbon assessment (WLCA)** is limited to carbon (i.e., GWP) and includes both embodied and operational carbon, accounting for all building-related carbon emissions and allowing for an evaluation of the tradeoffs between operational and embodied reductions.
- An **upfront carbon analysis** focuses on emissions from manufacturing, transportation, and construction activities (A1-A5) occurring before a building is occupied.

When creating a specific LCA policy, policymakers must provide clear requirements and guidance for what is to be included in the assessment and how results should be reported.

KEY TERMS

Embodied carbon

GHG emissions are generated by the manufacturing, transportation, installation, maintenance, and disposal of construction materials used in buildings, roads, and other infrastructure.

Global warming potential (GWP)

The potential climate change impact of a product or process as measured by an LCA. GWP is reported in units of carbon dioxide equivalent (CO2e) and is the agreed-upon metric for tracking embodied carbon.

Building-level accounting is critical for tracking low-carbon designs

There is no one-size-fits-all strategy for reducing the embodied carbon of buildings. Strategies for reducing the embodied carbon of buildings generally fall into four broad categories:

1. **Build less, reuse more** by extending the life of existing buildings through adaptive reuse and reusing materials.
2. **Build lighter and smarter** by using less of a given material (or floor area) to do the same work
3. **Material & assemblies substitution** involves replacing high-carbon materials and assemblies or systems with lower-carbon alternatives.
4. **Procure low-carbon products** by comparing different products or manufacturers with the same function and selecting the lower-carbon option.

Whether these strategies can be used on a specific project varies by building use, geography, height, and other factors, and comparing the impact of different strategies can be difficult due to the complexity of buildings.

What data is used in LCAs?

LCA models draw from a variety of both generic and project-specific data sources. Most of the data below is accessible through building LCA tools, with the exception of material quantities, which must be specific to the project (and therefore provided by the project team).

- **Material quantities** describe the type and quantity of each material used. These are typically collected from BIM software during design (or from contractors after construction).
- **Transportation data** for the distances and vehicles used to deliver materials and along the supply chain can be used to update generic estimates included in LCA tools.
- **Construction data,** such as site electricity use, water use, equipment, and fuel usage for excavation, demolition, and construction can be collected by contractors and used in LCA. Some tools and LCA standards include default estimates for these impacts.
- **Use and end-of-life scenarios** include data about how and when materials will be used and how long they will last, helping calculate landfill emissions and other impacts.
- **Emissions factors** quantify a material or process' life cycle environmental impact per unit (e.g., 262 kg CO_2e per m^3 of 3000 psi concrete or 1730 kg CO_2e per metric ton of fabricated steel plate).[1] These come from other LCA studies, public datasets (like the U.S. Life Cycle Inventory database), private LCA software and databases, or from ***environmental product declarations*** (EPDs).

LCA practitioners select the available data source that best matches their building. As the building is closer to being complete, data can be more specific to the project. During earlier phases, average or regional data is required. As data resolution increases, the potential to make decisions with a large reduction impact decreases, so while 'as-built' estimates are most accurate, they are least likely to facilitate embodied carbon reductions.

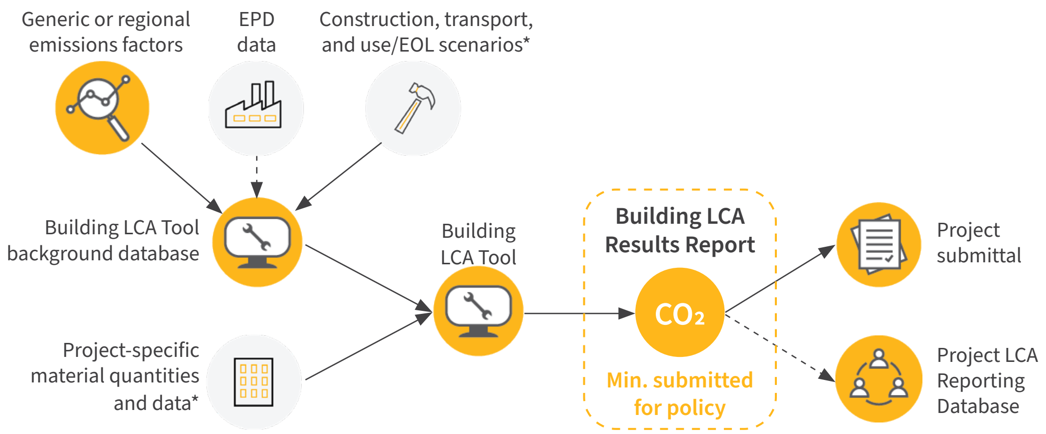

Figure 2. Flow of data to create building LCA results to comply with a policy. (*) indicates areas where scope, minimum data requirements, and other criteria are set by international standards and/or policies. The dashed line indicates "when available / applicable."

KEY TERMS

Environmental product declaration (EPD)

Standardized, independently verified documents that report the environmental impacts of a construction product based on a product LCA. EPDs must conform to international standards and follow the rules for each product category.

In the context of building LCA, EPDs often must be complemented by other more generic data sources to capture impacts for life cycle stages beyond A1-A3, and are most appropriate for assessing projects that have already been built.

REFERENCES

1. Waldman, B., Hyatt, A., Carlisle, S., Palmeri, J., and Simonen, K. (2023). 2023 Carbon Leadership Forum North American Material Baselines (version 2). Carbon Leadership Forum, University of Washington. Seattle, WA. August 2023.

Key Areas for Policy Guidance

Policies should provide clear and explicit guidance, particularly in areas with the greatest differences in existing requirements, such as:

- Which **life cycle stages and modules** (A1-A5, A-C, etc.) are included?
- Which **building elements** (e.g., structure, enclosure, interiors, MEP) are included?
- Which **floor area, definitions, and metrics** are used to calculate the embodied carbon per unit floor area (e.g., kg CO_2e/m^2)? Does the floor area include underground parking?
- What r**eference study period** (RSP) is used? RSP describes the temporal boundary of the LCA in years, and 60 years is the most common RSP
- In which **phase of project design and construction** is the LCA expected to be completed?

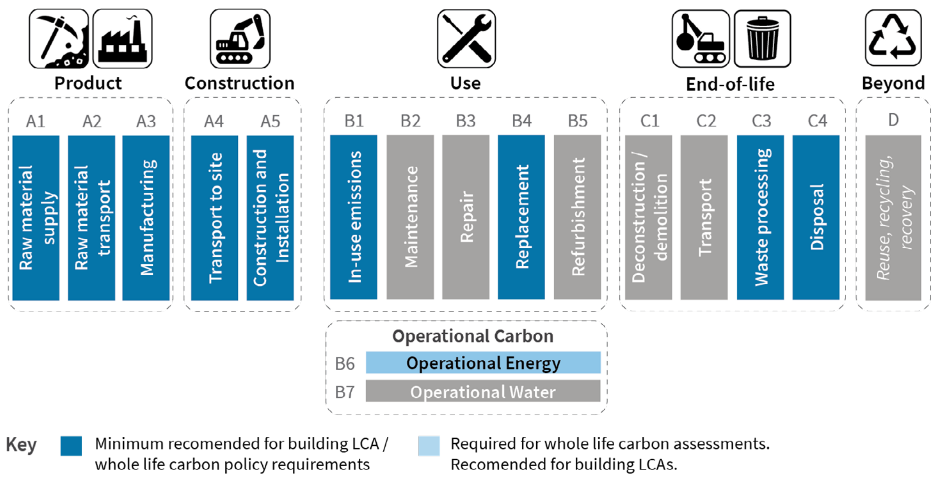

Figure 3. Policies should establish clear requirements around which life cycle stages to include. For policies requiring whole building LCA or whole life carbon assessments, A1-A5, B1, B4, and C3-4 are recommended scope that balance capturing critical impacts with data availability. Of the recommended stages, A5 (construction impacts) and B1 (in-use emissions, including refrigerants) have the largest gaps in current tools.

Standards and guidelines are key to consistency and quality

International standards like EN, ISO, ASHRAE, and ICC standards are developed through an open stakeholder development process, where a technical committee comprising experts from industry, academia, NGOs, and government uses a consensus-based approach to create the scope and content of the standard.

Clear requirements on which international LCA standards and other guidance to follow is critical to consistent assessments and compliance with policy. These requirements also encourage alignment across tools and practitioners. As there is no model code for building LCA, jurisdictions must develop their policy approaches that directly adopt the relevant quantification standard (such as those described below), rather than relying on the adoption of a model code.

As of May 2024, there are two primary international whole-building LCA standards: ***ISO 21931-1*** (globally applicable) and ***EN 15978*** (a European standard). Additional standards include the ***RICS Whole Life Carbon Assessment for the Built Environment***, a more detailed UK standard focused on both buildings and infrastructure. *National Guidelines for WBLCA* is a Canadian guidance document building off EN 15978 that is referenced by Canadian policies.

BSR/ASHRAE/ICC Standard 240P Quantification of Life Cycle GHG (tentative publication date of 2025) will provide a whole-life carbon assessment methodology for evaluating and reporting GHG emissions of both embodied and operational emissions of a building over its full life cycle that policies, codes, and other standards can reference. RESNET Standard 1550 is also in development, intending to provide a methodology for low-rise housing.

Learn More

→ Ramboll. (2023). *Comparing differences in building life cycle assessment methodologies.*

→ Lewis et al. (2023). *Advancing the LCA Ecosystem*

KEY STANDARDS

EN 15978:2011 Sustainability of construction works — Assessment of environmental performance of buildings (to be updated soon)

ISO 21931-1:2022 Sustainability in buildings and civil engineering works — Part 1: Buildings

Royal Institution of Chartered Surveyors (RICS) Whole Life Carbon Assessment for the Built Environment 2nd edition (2023)

Proposed BSR/ASHRAE/ICC Standard 240P — Quantification of Life Cycle Greenhouse Gas Emissions

Results from a whole building LCA, whole life carbon assessment, or upfront carbon analysis may be used to demonstrate compliance with a target (e.g. maximum CO_2e/m^2). To allow for appropriate comparison against a target or baseline, policies must require consistent modeling practices by requiring adherence to an internationally agreed-upon standard, requiring the use of tools that enable compliance with those standards, and adding additional guidance where needed.

For example, Vancouver's Building-by-Laws require practitioners to follow *EN 15978:2011* and the *Natural Research Council Canada Guidelines for Whole-Building LCA version 1.0 (2021)*. In addition, Vancouver provides specific guidance on how to define 'business-as-usual' construction practices for Vancouver, such as standard building material assemblies, concrete mix types, and service lives for materials. The London Plan requires practitioners to follow *EN 15978:2011* and the *RICS Professional Standard: Whole Life Carbon Assessment for the Built Environment.*

Building LCA Policy Guidance Checklist

Note: These relate only to the building LCA itself. To learn more about policy examples and guidance, read the "Building-scale embodied carbon performance requirements" factsheet here.

Minimum requirements:

- Require adherence to agreed-upon standard(s) for calculation and modeling guidance, such as *BSR/ASHRAE/ICC Standard 240P Quantification of Life Cycle GHG* once published.
- Provide a reporting template. At a minimum, biogenic carbon and module D must always be reported separately and GWP should be broken down by systems and life cycle stage.
- Clarify during which design or construction stage the assessment should occur.
- Identify the required life cycle scope, building element scope, reference study period, and floor area definitions to be used in the policy. **Suggestions by type of assessment include:**

	Upfront Carbon Analysis	Whole Life Carbon Assessment	Whole Building LCA
Life cycle scope (minimum)	A1-A5	A1-A5, B1, B4, B6, C3-4	A1-A5, B1, B4, C3-4
Reference study period	N/A	60 years	60 years
Building elements scope	Structure, enclosure, and interiors (minimum). Phase-in MEP and services.		
Environmental impacts	Global warming potential (GWP)	GWP	GWP, acidification, ozone, eutrophication, smog
Floor area definitions	Provide a gross floor area definition specific to the policy and clarify whether or not enclosed parking connected to building should be included.		

Best practices:

☑ Encourage the collection of results in a central reporting database

☑ Require detailed reporting, such as by assembly (see OmniClass Table 21, Level 3) and reporting of material quantities

☑ Require data quality assessment and background dataset disclosure

☑ Provide additional guidance for how to address special topics, such as biogenic carbon and carbonation

☑ Include a list of recommended tools that comply with the referenced standards

☑ Provide recorded training for designers and builders on LCAs and data collection

☑ *If* requiring comparison to a baseline, provide detailed description and calculation guidance for business-as-usual. Read more about different policy examples here.

Read more: carbonleadershipforum.org/clf-policy-toolkit

Learn More

- Embodied Carbon 101
- Building-Scale Embodied Carbon Performance Requirements
- Embodied Carbon and Codes
- Tools for Measuring Embodied Carbon
- AIA-CLF Embodied Carbon Toolkit for Architects

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Embodied Carbon Policy Factsheet

Buy Clean Policies: Overview and Implementation

Buy Clean is a procurement policy approach incorporating low-carbon requirements into government construction materials purchasing. Private-sector building owners can also use a similar approach. Buy Clean policies require ***environmental product declarations (EPDs)*** for reporting the impacts of producing building materials. Many policies also utilize ***global warming potential (GWP)*** limits to reduce the greenhouse gas impacts of their purchases. Others use incentives to provide purchasing preference for the lowest carbon materials on the market.

Buy Clean leverages the significant purchasing power of governments to boost demand and markets for lower-carbon materials. These demand-side policies are important complements to industrial facility regulations, particularly since governments purchase materials from global supply chains beyond the control of a single climate policy. This document provides insight into why ***embodied carbon*** is an urgent problem, how Buy Clean fills a gap to address this problem and an overview of the key policy elements.

Embodied carbon is a big piece of global emissions

The production of construction materials used in buildings and infrastructure accounts for **10-15% of global greenhouse gas emissions**.[1,2] Although embodied carbon emissions as a percent of total global emissions have changed over time due to the relative contributions from other sectors, total global embodied carbon emissions have been rising, which reinforces the importance of decarbonization in this sector.[1,2] Additionally, addressing the embodied carbon of construction materials has the ability to influence the larger scale industrial emissions for similar materials used in other sectors, as shown in Figure 1.

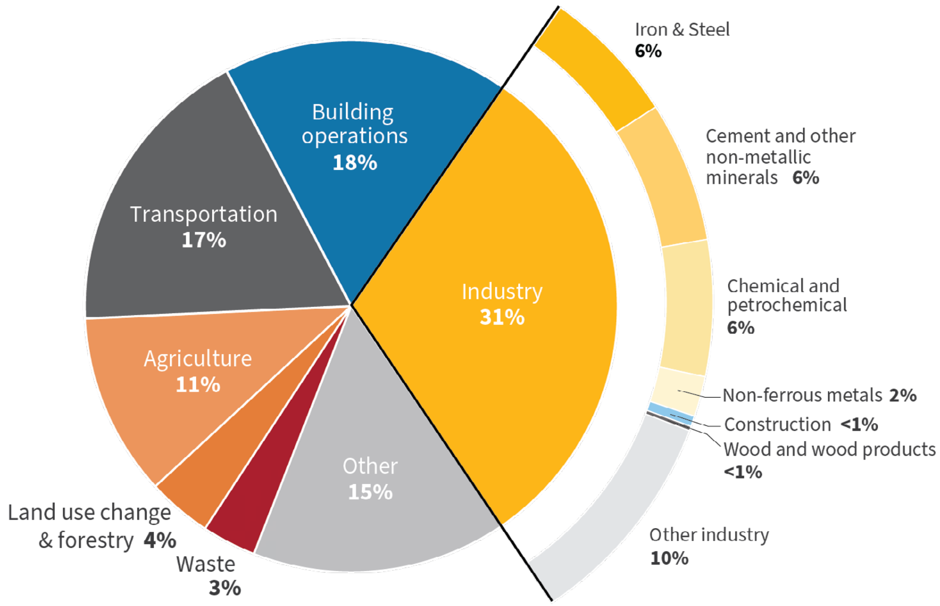

Figure 1. Global end-use greenhouse gas emissions breakdown by sector in 2019. Embodied carbon from manufacturing construction materials is a part of the largest sector of emissions; industry. Data Source: World Greenhouse Gas Emissions: 2019, World Resources Institute (WRI), 2022.

Buy Clean's large potential for impact: direct and indirect

Given the scale of government purchasing, Buy Clean's potential to reduce emissions is significant. Governments can directly reduce emissions on its projects by purchasing low-carbon products.

Public procurement policies like Buy Clean leverage the large purchasing power of governments, which typically makes up 12-30% of a country's gross domestic product.[3]

KEY TERMS

Embodied carbon

Greenhouse gas (GHG) emissions are generated by the manufacturing, transportation, installation, maintenance, and disposal of construction materials used in buildings, roads, and other infrastructure.

Environmental product declarations (EPDs)

Standardized, third-party-verified documents that report the environmental impacts of a product based on a product life cycle assessment (LCA).

Global warming potential (GWP)

The potential climate change impact of a product or process as measured by an LCA. GWP is reported in units of carbon dioxide equivalent (CO_2e) and is the agreed-upon metric for tracking embodied carbon.

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1. United Nations Environment Programme. (2022). *2022 Global Status Report for Buildings and Construction: Towards a Zero-emissions, Efficient and Resilient Buildings and Construction Sector.* Nairobi.

2. United Nations Environment Programme. (2024). *2024 Global Status Report for Buildings and Construction: Beyond foundations: Mainstreaming sustainable solutions to cut emissions from the buildings sector.* Nairobi.

3. United Nations Environment Programme. (2017). *Factsheets on Sustainable Public Procurement in National Governments. Supplement to the 2017 Global Review of Sustainable Public Procurement.*

Green procurement policies, like Buy Clean, are widely recognized as a key strategic lever for driving innovation and increasing public and private sector sustainability.[3, 4]

Approximately 24% of the embodied carbon of construction in the United States between 2013-2023 was attributed to public projects (see Figure 2).

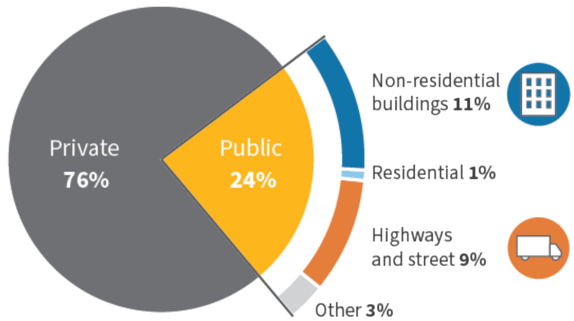

Figure 2. Relative contributions of US private and public project construction GWP. Data sources: US Census Bureau; EPA (USEEIO v1.1)

And Buy Clean has an even larger potential for indirectly reducing emissions in the broader market, by spurring shifts in industry and advancing embodied carbon data and practices. For example:

- Public construction accounts for approximately half of the USA's annual cement consumption and CO_2 emissions. So if Buy Clean incentivizes cement plants to reduce emissions, that would impact all domestic cement—public and private sector consumption.[5]
- Buy Clean can jumpstart innovation by establishing demand certainty for low-carbon materials.5
- Like the ENERGY STAR program, Buy Clean can establish standardized measurement protocols and make those available to the private sector in a format that allows businesses and consumers to distinguish lower-carbon products.[6] As of April 2024, the EPA has already begun developing a labeling program for lower-carbon construction materials.

Buy Clean policies are spreading rapidly in the U.S.

Since California passed the USA's first Buy Clean law in 2017, there has been steady growth in Buy Clean policies at the federal, state, and local levels across the United States.

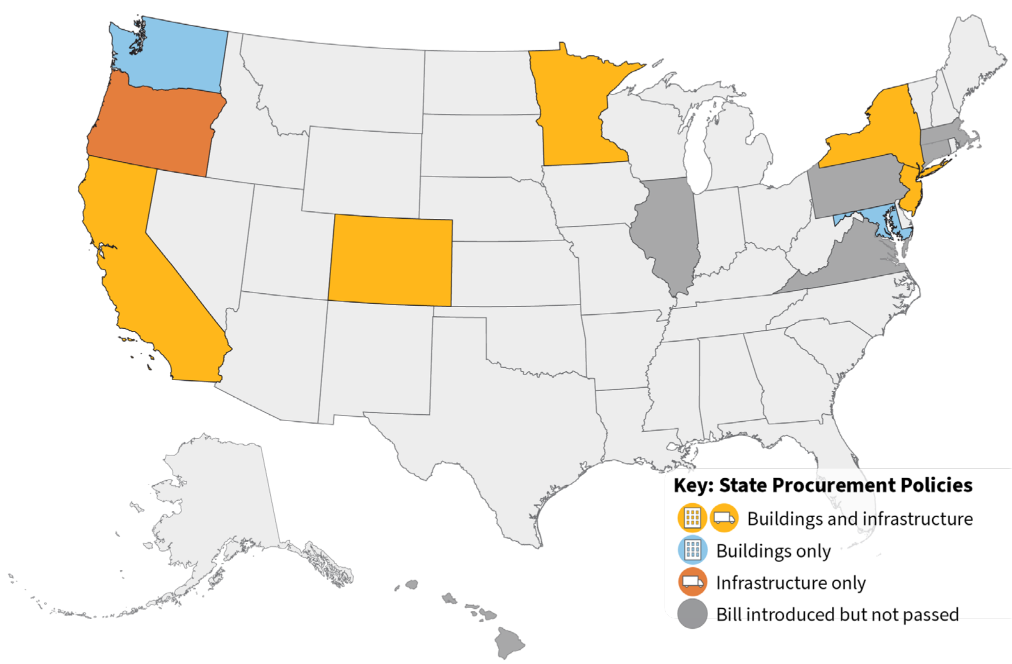

Figure 3. Buy Clean State Policy Map—April 2024 Snapshot. Includes states with unpassed Buy Clean policies; may not be exhaustive.

REFERENCES

4. Hasanbeigi et al. (2019). Curbing Carbon from Consumption: The Role of Green Public Procurement. Global Efficiency Intelligence, LLC. Tampa Bay Area, U.S.

5. Hasanbeigi, Ali; Shi, Dinah; Khutal, Harshvardhan. (2021). Federal Buy Clean for Cement and Steel - Policy Design and Impact on Industrial Emissions and Competitiveness. Global Efficiency Intelligence, LLC. Tampa Bay Area, U.S.

6. Krupnick, Alan. (2020). Green Public Procurement for Natural Gas, Cement, and Steel. Resources for the Future.

Learn More

- → Buy Clean and Beyond: A Guide to Reaching Net-Zero Embodied Carbon in State-Owned Building Projects (RMI, 2023)
- → Build Clean: Industrial Policy for Climate Justice (Dell, 2020)
- → Global Efficiency Intelligence - industrial decarbonization research and resources
- → CLF Embodied Carbon Policy Tracking Map

Key elements of Buy Clean policy

Three core elements make up Buy Clean policies: **reporting**, **limits**, and **incentives**. Reporting of a (disclosure of product GWP) is typically required, whereas the inclusion of GWP limits and/or incentives varies by region and agency.

In addition to these three elements (explained in more detail below), policies must choose which materials and projects are eligible, and when to implement each requirement. Many Buy Clean policies start with structural materials like concrete and steel because they have a significant carbon footprint and a large range of solutions for emissions reductions. Reporting and limit requirements tend to be phased in over two to four years to allow time for adoption.

Reporting

Buy Clean policies require measurement and reporting of production and supply chain emissions in the form of ***environmental product declarations (EPDs)***–documents that contain information about a product's environmental impact and are based on a life cycle assessment (LCA). Reporting requirements increase the quality and quantity of data available, enabling private and public purchasers to identify and select lower-carbon products based on demonstrated carbon reductions.

Possible outcomes of reporting requirements:

- Increased availability of EPDs
- Increased quality, consistency, and breadth of data to support future policies and research
- Procurement teams can select products based on environmental impact data
- Builds capacity of manufacturers to measure and track GHG emissions reductions

Limits

Performance-based standards that set emissions (GWP) limits for eligible products allow for a technology-agnostic, market-based approach to industrial and building sector decarbonization. Emissions limits may be reviewed and lowered at regular intervals to align with climate goals.

Possible outcomes of using GWP limits:

- Encourages domestic low-carbon manufacturing solutions and discourages emissions outsourcing
- Encourages innovation and development of new decarbonization strategies
- Rewards companies that already invested in reducing their carbon footprint and encourage more
- Supports tracking of emissions reductions (unlike prescriptive strategies, which may not necessarily result in emissions reductions)

Incentives

Policies can use incentives to encourage voluntary participation, support broader implementation, or reward high performance.

Examples of incentives include financial support (e.g., tax incentives), technical support and training, preferential purchasing (i.e., bid incentives), and performance bonuses for contractors.

Policies can provide incentives for early implementation through a voluntary trial period or indefinitely.

Possible outcomes of using incentives:

- Rewards innovators and industry leaders to continue pushing low-carbon solutions
- Encourages market-driven solutions for reaching industrial sector climate targets
- May encourage early voluntary participation
- May enable targeted support for small businesses

KEY TERMS

Environmental product declaration (EPD)

A third-party-verified document based on a life cycle assessment (LCA) model, written in conformance with international standards, that reports the environmental impacts of a product.

See EPD 101 for more.

Status of Buy Clean in the United States: April 2024 Snapshot

Figure 4 describes the current implementation status and timelines of federal, state, and local policies in the United States, including:

- 8 state policies in California, Colorado, New York, Oregon, New Jersey, Maryland, Minnesota, and Washington.
- Two local programs in Portland, OR and the Port Authority of New York and New Jersey, and
- Federal requirements set by the GSA, FHWA, and FEMA funded through the Inflation Reduction Act. These are in conjunction with the Federal Buy Clean Task Force's work to develop embodied- carbon-focused policy recommendations and the EPA's interim determination for low-carbon materials.

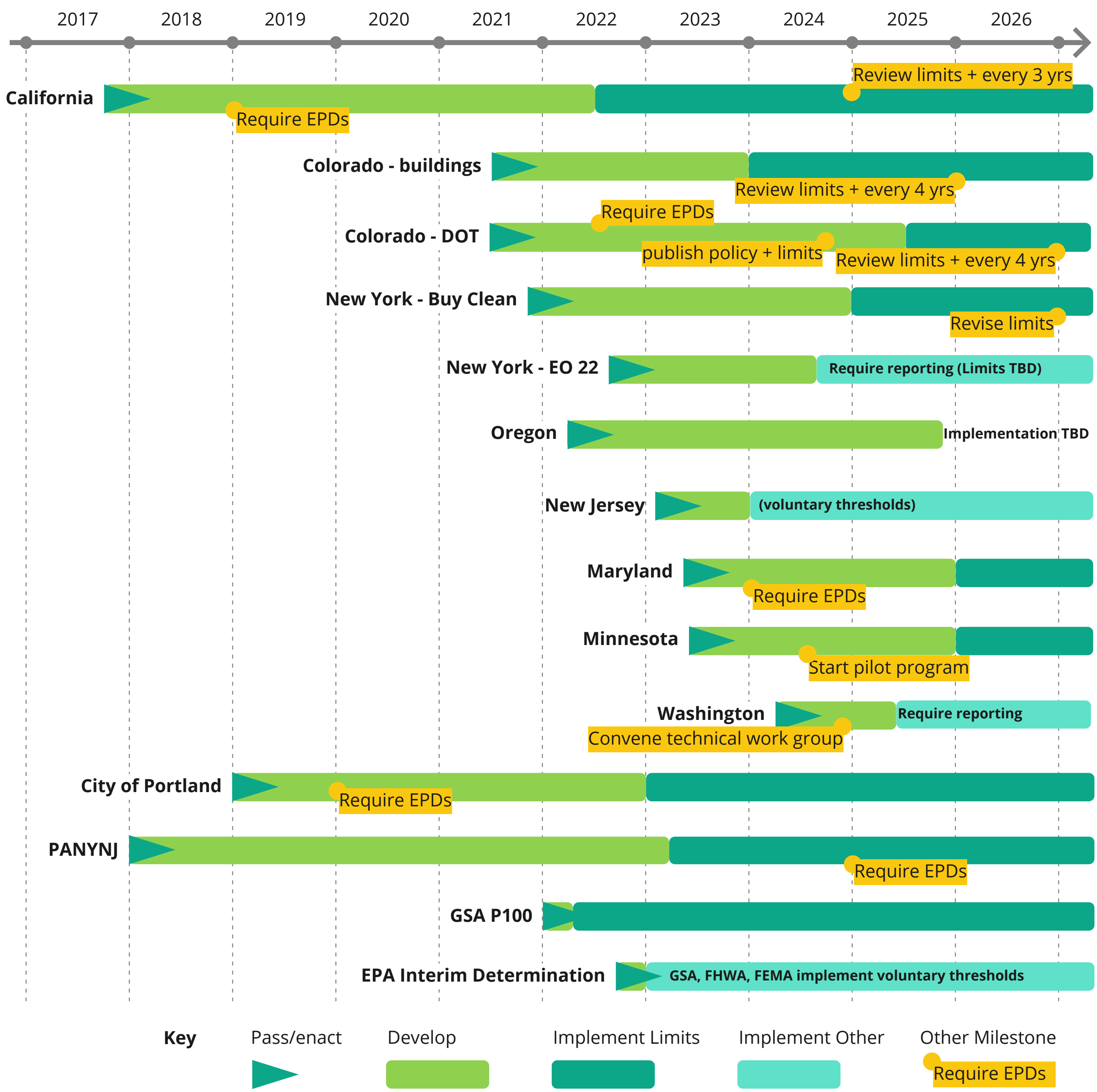

Figure 4. State, local, and federal Buy Clean policy timelines in the United States.

Table 1. Buy Clean policy major elements – April 2024 snapshot. Download "Buy Clean Policy Elements and GWP limits - April 2024" for a more detailed comparison of policy elements and published GWP limits. Policies apply to public construction projects unless noted otherwise.

Policy	Project types	Project eligibility	Material scope	GWP limit calculation
California	buildings, infrastructure	varies by department	steel, flat glass, mineral wool board insulation	industry average
PANYNJ	buildings, infrastructure	all	concrete	based on agency procurement history
Portland, OR	buildings, infrastructure	concrete mixes used on any City project, ≥ 50 yd3	concrete	regional benchmarks (informed by agency procurement history)
Colorado (OSA)	buildings	≥$500,000 project cost	concrete, cement, steel, wood, asphalt, glass	industry average (with added uncertainty in some cases)
Colorado (DOT)	infrastructure	≥$3,000,000 project material costs	concrete, cement, asphalt, steel	TBD
New York - Buy Clean	buildings, infrastructure	>$1,000,000 & >50 yd3; or DOT >$3,000,000 & >200 yd3	ready-mixed concrete	150% of industry average
New York - EO 22	buildings, infrastructure	>$1,000,000	concrete, asphalt, steel, glass	n/a (TBD if policy will include limits)
Oregon	infrastructure	TBD	concrete, steel, asphalt	n/a (TBD if policy will include limits)
New Jersey S278	buildings, infrastructure	any project that uses unit concrete products	unit concrete products (e.g., pavers)	50% reduction compared to conventional
New Jersey S287	buildings, infrastructure	>50 yd3 concrete	concrete	n/a (no mandatory limits)
GSA (P100)	buildings, infrastructure	all projects; ≥ 10 yd3 of concrete or asphalt	concrete, asphalt	20% less than model code language (concrete limits only)
GSA (IRA)	buildings, infrastructure	all	concrete, cement, steel, asphalt, glass, CMU	three tiers: top 20%, top 40%, industry average
FEMA (IRA)	buildings, infrastructure	multiple FEMA programs	concrete, asphalt, glass, steel	industry average
FHWA (IRA)	infrastructure	all	concrete, cement, steel, asphalt, glass	three tiers: top 20%, top 40%, industry average
Maryland	buildings	MD High Performance Green Buildings program projects	concrete, cement	industry average
Minnesota	buildings, infrastructure	buildings >50,000 GSF; trunk highway ≥ 2 lane-miles	concrete, steel, asphalt	TBD
Washington	buildings	2025: buildings >100,000 GSF 2027: buildings >50,000 GSF	concrete, steel, wood	n/a (no limits)

Buy Clean Implementation

A policy can only achieve its goals with effective implementation. The goal of Buy Clean is to reduce the embodied carbon of government building material purchases. Table 1 is adapted from CLF's Implementing Buy Clean report.

Table 2. Summary of implementation recommendations, organized into loosely chronological steps. Guidance will continue to evolve as more policies are implemented.

Development Phase	
Establish agency buy-In	• Dedicate staff time to establish the program • Identify agency policy champions
Start collecting EPDs	• Request EPDs on projects even if not required yet • Plan ahead for EPD and material quantity data management and tracking
Engage stakeholders	• Establish an advisory committee or workgroup • Address equity in committee design • Involve stakeholders early in GWP limit development
Develop draft limits	• Review industry benchmarks and the most recent CLF Baselines report • Establish a baseline by evaluating past public procurement • Leverage regional and private sector data to inform limits • Allow for a project average compliance pathway • Use a two-tiered limits approach • Provide a public notice and comment period
Test limits	• Compare against standard Agency specifications • Conduct pilot projects
Incentivize EPD development	• Incentivize local EPDs through financial, technical, or educational support and drive increased awareness of upcoming policy requirements
Publish limits and methodology	• Publish the initial limits and methodology used to establish the GWP limits
Compliance Phase	
Track compliance	• Establish a central resource for project team requirements • Create a centralized system for tracking EPDs and compliance • Utilize policy exceptions
Incentivize high performance	• Provide high-performance incentives for contractors and/or provide purchasing preferences during the bid evaluation process • Use a two-tiered limits approach (as noted above)
Provide education and training	• Provide both internal and external education and training opportunities • Keep implementing agencies informed • Provide contractor training
Re-evaluate initial limits	• Lower limits at a regular interval over time to continue to drive emissions reductions

Read more: carbonleadershipforum.org/clf-policy-toolkit

Learn More

- Implementing Buy Clean (CLF, 2022)
- Pacific Coast Collaborative: Embodied Carbon Policy Case Studies (CLF, 2023)
- Northeast U.S. & Canada Embodied Carbon Policy Case Studies (CLF, 2024)

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Embodied Carbon Policy Factsheet

Embodied Carbon Policy Factsheet

Building-Scale Embodied Carbon Performance Requirements

Building-scale ***embodied carbon*** performance requirements fill a current gap in building climate policies by targeting greenhouse gas (GHG) emissions from the materials and construction processes across the life cycle of buildings, referred to as embodied carbon. Reducing embodied emissions can also reduce environmental and human health impacts from pollution at manufacturing facilities, highways, construction sites, and landfills. Building policies engage design and construction teams to design more material-efficient and lower-carbon buildings and to specify lower-carbon products.

This document provides an overview of how *performance-based building policy requirements* can help address embodied carbon, why they should be a policy priority, and examples of existing policy paths. To read more about related policy strategies like Buy Clean, check out CLF's other Embodied Carbon Policy Toolkit factsheets.

Embodied carbon is a significant contributor to global emissions

Embodied carbon refers to the GHG emissions from the manufacturing, transportation, installation, maintenance, replacement, and disposal of construction materials used in buildings and infrastructure. In contrast, *operational carbon* refers to emissions from a building's energy consumption, including the burning of fossil fuels to heat, cool, and light the building. Decarbonizing buildings requires eliminating both embodied *and* operational carbon emissions.

The manufacturing impacts of construction materials used in buildings alone are responsible for approximately 10% of global energy-related greenhouse gas emissions.[1] When we look at new buildings, the urgency of embodied carbon is even more clear, as the majority of emissions between now and 2050 will be embodied emissions from manufacturing and building materials. For example, a 2024 CLF study found that for newly constructed buildings in California, embodied emissions would contribute approximately 80% of total emissions from 2024-2030 and 70% of total emissions from 2024-2045.[2]

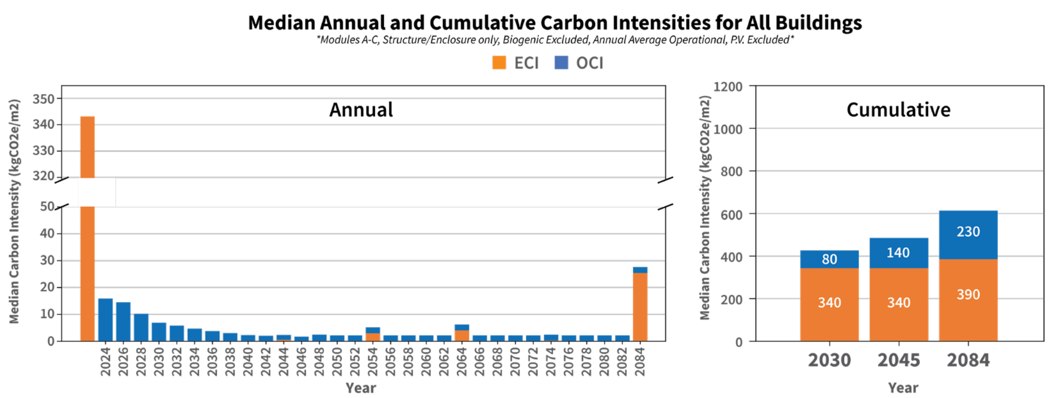

Figure 1. Median annual and cumulative **embodied carbon intensities (ECIs)** and **operational carbon intensities (OCIs)**. Modeling based on the embodied and operational emissions from life cycle modules A-C for the structure and enclosure of buildings in California.

Note that the y-axis for annual impacts (above) is shown with a break between 50 and 320 kg CO_2e/m^2). Adapted from Benke, B., Roberts, M., Lewis, M., Shen, Y., Carlisle, S., Chafart, M., and Simonen, K. (2024). **The California Carbon Report: Six Key Takeaways for Policymakers**. Carbon Leadership Forum, University of Washington. Seattle, WA.

KEY TERMS

Embodied carbon

GHG emissions generated by the manufacturing, transportation, installation, maintenance, and disposal of construction materials used in buildings, roads, and other infrastructure.

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1. IEA. (2021). *Global energy use and energy-related CO2 emissions by sector, 2020.*

2. Benke, B. et al. (2024). *The California Carbon Report: Six Key Takeaways for Policymakers*. Carbon Leadership Forum, University of Washington. Seattle, WA.

Policy opportunities

Low-carbon building requirements or incentives can be integrated into many different policies and programs. Examples of current pathways are:

- Building codes and building owner performance standards
- Government procurement requirements, incentives, and performance standards
- Urban design and zoning requirements or incentive programs
- Climate action plans, executive orders, and private sector commitments

Leading jurisdictions are paving the way

Performance-based low-carbon building policies have been introduced in Europe, Canada, and more recently in the United States. Examples of policies include:

- **International:** The Energy Performance of Buildings Directive Recast updated the overall framework for building energy performance standards in the European Union to now require calculations and targets to reduce embodied carbon, in line with the Level(s) Framework.[3]
- **National:** The Netherlands, Denmark, and France have all set embodied carbon intensity limits for both residential and non-residential buildings.[4] Sweden and Finland require reporting of the results of a building LCA but do not yet set limits.

  The U.S. General Services Administration (GSA) requires federal buildings to target a 20% reduction in the project's embodied carbon as compared to a baseline building of the same project type.[5]
- **State:** California's mandatory green building code, CALGreen, now requires certain new buildings to achieve a 10% reduction in embodied carbon, demonstrated by using results from a building LCA, as one of three pathways. See CLF Codes factsheet for more.
- **City**: Many leading cities now require building embodied carbon reporting and reduction requirements or limits, such as Toronto's Green Standard, Vancouver's Building by-laws, and London Plan 2021. Cities in the U.S. are also working towards the adoption and implementation of requirements, such as New York City (via Executive Order 23) and Cambridge, MA.

Low carbon building policies build on private sector leadership

In addition to policy leadership, the design community has stepped up to address both operational and embodied carbon building emissions. In the absence of regulations, professional organizations have put forward voluntary commitments for design and construction firms, such as:

- SE2050 Commitment Program for structural engineering firms targeting net zero embodied carbon by 2050;
- AIA Materials Pledge and 2030 Commitment for architecture firms, which began tracking embodied carbon alongside operational energy, in 2020;
- MEP2040 Commitment for mechanical, electrical, and plumbing (MEP) engineering and design firms committed to net zero embodied carbon by 2040;
- Climate Positive Design Challenge for landscape architects committed to being climate-positive by 2030;
- Contractor's Commitment to Sustainable Building Practices is a voluntary commitment for contractors started in 2018, focused on carbon, job-site wellness, waste, and more; and
- HomebuildersCAN is a community of practice to measure and reduce embodied carbon in home construction.

Green building certifications have long included embodied carbon-related credits, and they are often a standard part of green building consultants' and professionals' services. Embodied carbon has been a part of the USGBC LEED rating system since 2014, and a growing number of national and international certifications, from BREEAM to DGNB to Passive House and the Living Building Challenge, all now address embodied carbon. Broader policies will speed the process of shifting best practices to everyday norms on projects.

REFERENCES

3. Recast Energy Performance of Buildings Directive, www.eurovent.eu.

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5. GSA. (2022). Facilities Standards for the Public Buildings Service (P100), Section 1.9.2.9. Decarbonization.

Learn More

Find out more about some of these policy case studies in:

→ *Pacific Coast Collaborative: Embodied Carbon Policy Case Studies* (CLF, 2023)

→ *Northeast U.S. & Canada Embodied Carbon Policy Case Studies* (CLF, 2024)

→ CLF Embodied Carbon Policy Tracking Map

Low-carbon building policies are a critical complement to industrial policies

Low-carbon building policies encourage the adoption of strategies that require early design and construction coordination or strategies. These can include things like material efficiency, substitution, and circularity that are not covered by Buy Clean and similar industrial policies that focus on the carbon intensity of specific construction materials. Strategies uniquely influenced by building-focused policies are:

- **Material Efficiency:** Building the same function and strength with less volume of materials, such as using voided slab systems, post-tensioned slabs, or composite design braced frames instead of moment frames.[6] This can also include reducing requirements and incentives for unnecessary parking and underground structures.
- **Circularity:** Minimizing new construction and reusing existing buildings or components, which can include reusing entire foundations or enclosures for individual salvaged materials.
- **Material & Assemblies Substitution**: Evaluating the environmental trade-offs between different components of a building, such as carbon-storing materials (climate-smart wood, hempcrete, bio-based insulation, etc.) or other alternatives in place of conventional materials.
- **Engaging designers**: Architects and engineers lead compliance with building LCA and performance standards and are key to maximizing reduction potential by coordinating early in the design and construction process, ensuring that changes make it into the specifications, and educating clients and contractors on potential changes.

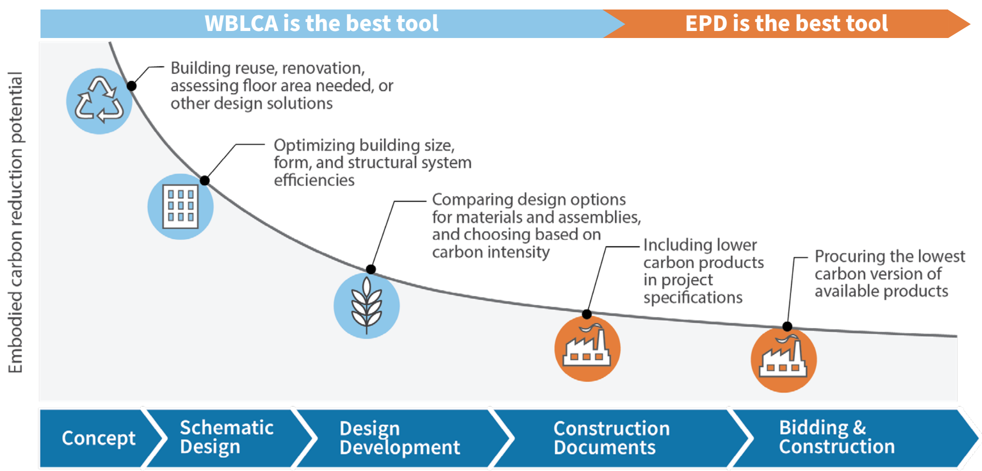

Figure 1. The availability of carbon reduction strategies changes across the design and construction timeline. Strategies like building reuse and material efficiency are only available earlier in the design process. Early coordination can unlock greater reductions in selecting and procuring the lowest carbon versions of products available.

Low embodied carbon building policies have the potential to result in large emissions reductions. Strategies to optimize buildings holistically may have a larger carbon reduction potential in the short term, whereas strategies to optimize procurement have a greater long-term potential when technological developments unlock greater industrial decarbonization.[7,8] In the long run, we need *both industrial and building* policies to reach global climate targets.

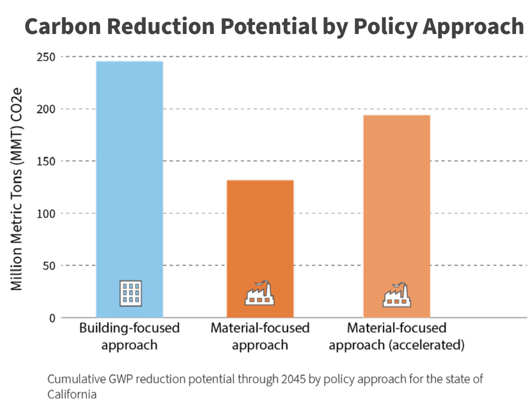

Figure 2. Cumulative global warming potential (GWP) reduction potential through 2045 in California, by policy approach. Source: Arup, NRDC. (2023). **Embodied Carbon Reduction Roadmap: Strategies and Policies for the State of California**.

REFERENCES

6. Webster, M. et al. (2020). *Achieving Net Zero Embodied Carbon in Structural Materials by 2050*. Structural Engineering Institute's Sustainability Committee Carbon Working Group. 10.13140/RG.2.2.28440.14085.

7. Arup, NRDC. (2023). *Embodied Carbon Reduction Roadmap: Strategies and Policies for the State of California*.

8. Benke, B., Lewis, M., Carlisle, S., Huang, M. & Simonen, K. (2022). *Developing an Embodied Carbon Policy Reduction Calculator.*

Basic elements of a low carbon building policy

Performance-based low-carbon building policies require two to three basic elements: (1) reporting (minimum), (2) limits/targets, and/or (3) incentives. Policies must also choose which projects are eligible, and when to implement each requirement. Requirements for limits are often phased in over several years to allow time for adoption.

Reporting

Policies *must* require reporting to verify compliance.

Measurement and reporting of embodied carbon for a building requires a building life cycle assessment (LCA), a methodology for accounting for GHG emissions and other impacts across the entire life cycle.

Possible outcomes:

- Availability of more building LCA results for informing targets and prescriptive approaches
- Increased capacity of the building sector to understand and track reductions in greenhouse gas emissions

Targets

Policies may require projects to meet performance targets *(read more on pg. 5)*. Embodied carbon intensity targets are flexible and technology-agnostic, enabling teams to select the decarbonization strategies that work best for their projects. Targets must be lowered or reviewed at regular intervals to result in reductions.

Possible outcomes:

- Encourage the use of available strategies for material efficiency and material substitutions
- Encourage building and material salvage and reuse strategies
- Use of available lower carbon product choices, especially in combination with Buy Clean requirements

Incentives

Policies can use incentives to encourage voluntary participation, support broader implementation, or reward high performance.

Examples of incentives include owner bid preferences, zoning incentives (e.g., expedited permitting, density bonuses), tax incentives, free technical assistance, and contract performance incentives.

Possible outcomes:

- Continued innovation
- Piloting cutting-edge solutions required to reach building and industrial sector climate targets
- Increased early, voluntary participation

Embodied Carbon Performance Requirements: Policy Variations

Policies typically use a combination of reduction targets and/or building carbon budgets to set building embodied carbon performance requirements. The variations described below can be used for either regulatory or incentive requirements.

Policy Variation A **% Reduction Targets**	Policy Variation B **Building Carbon Budgets**	Policy Variation C **Combined Approach**
Projects must reduce the building's embodied carbon by a certain percentage compared to a building-specific baseline. This is typically user-modeled.	The embodied carbon intensity per floor area (kg CO_2e/m^2) must be below a maximum value.	Projects can comply with either variation A or B. Another option is to require a % reduction target (A) but *coupled with* a high maximum kg CO_2e/m^2 (B).
Example: The U.S. General Services Administration (GSA) requires certain federal buildings to achieve a 20% embodied carbon reduction compared to a baseline.[5]	**Example:** France's RE2020 requires new buildings to be below 640 - 740 kg CO_2e/m^2, depending on the type of building (single-family house, multi-family house, etc.) and climate zone.	**Example:** Beginning in 2025, the City of Vancouver will require projects (based on building type and height) to reduce 10-20% from either (a) 400 kg CO_2e/m^2 limit or (b) a baseline building modeled according to Vancouver's requirements.
Pros:		
+ **Flexible.** Reduction targets can be applied across building types and geographies. + **Familiar.** This approach has been implemented for multiple years in rating systems (e.g. LEED v4.1)	+ **Familiar.** A similar approach to requiring energy use intensity (EUI) targets for buildings. + **Lower administrative and compliance burdens.** Agencies do not have to create baseline building guidelines or review submissions in detail to identify whether requirements are being 'gamed'. Teams only have to model one building.	+ **Most flexible.** Teams can select the approach that is best for their project, and agencies do not have to establish limits for every type of building.
Cons:		
– **Administrative burden** on government agencies to provide adequate definition of a baseline building and review work of project teams. – **Compliance burden**. Requires design teams to define and model a baseline building in addition to the actual design, which can be a challenge if not enough guidance is provided by the jurisdiction.	– **Requires limit development**. Efforts to develop North American building-level benchmarks are advancing rapidly, but policy makers may need to lead data collection in the short-term, and/or have a phase-in period. – **Requires consistent tools and modeling requirements** to compare a building effectively to a kgCO_2e/m^2 target	– **High administrative burden**. The combined approach requires government agencies to both (1) provide additional guidance to define the baseline building and also (2) develop limits.

Building policies with embodied carbon performance requirements are important, are possible with existing tools and standards, and are growing rapidly in Europe and North America. To find more examples and learn about related policy approaches, check out the other CLF Embodied Carbon Policy Toolkit factsheets and resources.

Learn More

- → Embodied Carbon 101
- → EPD 101
- → Building LCA 101
- → Buy Clean: Overview and Implementation
- → Embodied Carbon and Building Codes
- → Deconstruction, Salvage, and Reuse Policies

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Embodied Carbon Policy Factsheet

Embodied Carbon and Building Codes

Building codes are a comprehensive set of interconnected regulations that are designed to govern new construction, renovations, repairs, and demolitions. In the U.S. and Canada, they are adopted by state/province or local jurisdictions, are enforceable by law, and provide minimum requirements for the design and construction of buildings to protect public health and safety. There are separate codes for commercial and residential buildings and codes that address many different topics of building performance. Some of these include building codes, energy codes, or fire codes, and cover everything from structural design to energy use.

Decades of research on reducing operational energy consumption and the related greenhouse gas (GHG) emissions have raised awareness of the important role that buildings play in addressing climate change, leading to more energy-efficient codes. In contrast, ***embodied carbon*** has been largely excluded from building code conversations until the last few years.

Building Code as a lever for reducing embodied carbon

Public sector green procurement policies and building requirements have been adopted across the country (see CLF Embodied Carbon Policy Map). While other policies can be faster to adopt, building codes impact the largest number of projects compared to other policy types. The International Building Code (IBC) is in use or has been adopted for commercial buildings in all 50 U.S. states, and the International Residential Code (IRC) has been adopted in 49 states.[1] Therefore, nearly all construction in the U.S. is regulated by codes. Even relatively small embodied carbon reduction requirements in the building code can result in big reductions due to the code's widespread reach while sending a clear market signal to designers, builders, and manufacturers to meet future market demands.

Building energy codes have been critical in reducing operational carbon in the United States, reinforcing codes as a critical mechanism for embodied carbon reductions. The Department of Energy estimates that model energy codes have resulted in a nearly 60% reduction in commercial building operational energy use since 1975.[2]

Addressing embodied carbon through building codes has the potential to impact nearly all construction in the U.S., including public and all types of private construction. As shown in Figure 1, 76% of the estimated embodied carbon in the United States is attributed to private, non-residential, and residential buildings that are impacted by local and state codes.

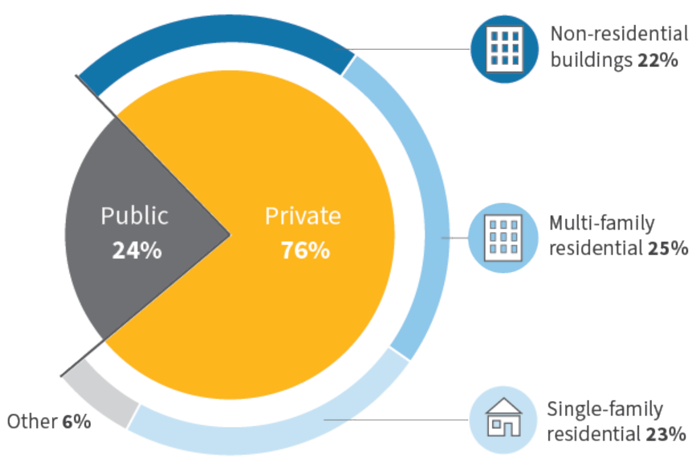

Figure 1. Relative contributions of the global warming potential (GWP) of US construction for private and public projects. Data sources: **US Census Bureau** ("Annual Value of Construction Spending Put in Place" for 2013–2023); and US EPA (**USEEIO v1.1 data**).

KEY TERMS

Embodied carbon

The greenhouse gas (GHG) emissions are generated by the manufacturing, transportation, installation, maintenance, and disposal of construction materials used in buildings, roads, and other infrastructure.

REFERENCES

1. International Code Council (ICC). (2020). Code Adoption Maps.

2. DOE Building Energy Codes Program Infographics. https://www.energycodes.gov/infographics

Approaches to reducing embodied carbon in building codes

Many pathways exist for integrating embodied carbon reduction into building codes. These can be combined to provide multiple compliance pathways, phased in over time, or used in isolation.

Material-Scale Approach

Building codes are organized around product and material categories and offer opportunities for different forms of material requirements to be integrated. Some use an approach similar to 'Buy Clean,' requiring reporting of the ***global warming potential (GWP)*** for certain products using a ***Type III environmental declaration or EPD***. The EPD can then be compared against a maximum CO_2e limit set by material type per unit of material.

GWP limits can also be set for refrigerants in performance-based codes. California, Washington, Vermont, and New Jersey mandate that refrigerants used in new air conditioning equipment must have a GWP no higher than 750, and refrigerants used in new refrigeration systems with more than 50 lb (20.68 kg) of refrigerant must have a GWP no more than 150.[1]

Codes can also prohibit the use of specific materials with high GHG emissions, such as banning spray foams with hydrofluorocarbon-blowing agents. Codes can adapt over time to allow the use of materials previously excluded (directly or indirectly) by codes, like mass timber, agricultural fiber products, or reused materials.

Precedents:

- Marin County's Low-Carbon Concrete Code amends the California Building Standards Code to require that all new residential and commercial construction use low embodied carbon concrete. The code provides two pathways for compliance: a total cement limit (via cement per cubic yard limits) or a maximum CO_2e limit assigned by the compressive strength category and verified by a product-specific EPD.
- Denver's Green Code requires certain concrete and steel products to have EPDs and meet maximum CO_2e limits. Alternatively, steel products can qualify by proving they are manufactured in a facility that is an EPA Green Power Partner or that uses at least 50% renewable energy for production. Currently, commercial projects must choose to follow about 10% of the Green Code, which may include these embodied carbon requirements.
- Oregon Residential Code allows for the use of reused timber (Oregon Residential Specialty Code, Chapter 1, Section R104.9.1).
- Vermont's Energy Code, starting in July 2024, allows projects to earn optional credits if they report the GWP of the insulation materials used for the foundation, walls, and roof.

Building-Scale Approach

With a building-scale approach, projects must report a building's GWP (CO_2e) using a ***whole building life cycle assessment (WBLCA)*** or ***whole life carbon assessment***. Similar to an energy model, WBLCA can be used to compare a proposed design to a maximum CO_2e limit per floor area (like an energy use intensity (EUI) target used for operational energy) or a GWP percentage reduction requirement from a modeled baseline. Codes could also be updated to encourage material efficiency by allowing advanced framing methods or other materially efficient design techniques.

Precedents:

Vancouver Building By-laws require all new Part 3 buildings to achieve % reductions from a baseline building or be below maximum embodied carbon limits (measured in $CO2e/m^2$).

KEY TERMS

Global warming potential (GWP)

The potential climate change impact of a product or process as measured by an LCA. GWP is reported in units of carbon dioxide equivalent (CO2e) and is the agreed-upon metric for tracking embodied carbon.

Type III environmental declaration

An EPD is referred to as a "Type III environmental declaration" in ISO 14025: 2006. An EPD is a third-party-verified document based on an LCA model, written in conformance with international standards, that reports the environmental impacts of a product. Read more in CLF's EPD 101 Factsheet.

Life cycle assessment (WBLCA)

A methodology for measuring the environmental impacts of a building, product, or process over its full life cycle, from raw material extraction through end-of-life and disposal. When LCA is performed on a building or part of a building, it is called ***a whole building LCA (WBLCA)***. Read more in CLF's Building LCA 101 Factsheet.

A ***whole-life carbon assessment*** evaluates *both* embodied and operational carbon simultaneously, with the goal of fully accounting for all building-related carbon emissions. Read more in CLF's Building LCA 101 Factsheet.

REFERENCES

1. ASHRAE. (2021). ASHRAE Task Force for Building Decarbonization, *Embodied Carbon Codes and Policies Summary*, October 1, 2021.

Combined Approach

A combined approach leverages material, building, and other pathways.

Precedents:

California Green Building Standards Code (CALGreen) requires all nonresidential building projects over 100,000 square feet and public K-12 school building projects over 50,000 square feet to comply with one of three pathways: (1) reuse at least 45% of an existing structure; (2) complete a WBLCA that demonstrates 10% lower embodied emissions than a baseline project; or (3) provide EPDs and meet maximum CO_2e limits for certain materials. The CA Building Code Commission voted unanimously to approve these requirements, which go into effect in July 2024. Learn more by checking out AIA California's FAQ and the CA official supplemental guidebook.

Overcoming perceived challenges

Perceived challenges	Mitigation strategies
Cost concerns	• Costs for embodied carbon reporting (EPDs and WBLCA) can be minimal, particularly for larger projects when compared to a total project budget. EPD generation will continue to decrease in cost as EPA's Inflation Reduction Act (IRA) program launches and EPD generation tools continue to drive down the cost and time for manufacturers to develop EPDs. Free building LCA tools are available. • Existing research indicates that lower carbon buildings can be achieved with minimal to no cost impact. RMI (2021) found that embodied carbon reductions of 19-46% could be achieved with less than a 1% cost premium.[1] California Energy Codes & Standards (2023) found that the cost premium for concrete, rebar, insulation, and finishes was minimal or non-existent, and structural steel and glazing premiums were 1% and 10%, respectively.[2]
Need for standardized methods and tools	• Many international standards and tools for EPDs and building LCA are already available.[3] • Developing standards like the proposed BSR/ASHRAE/ICC Standard 240p, ACI 323, and RESNET 1550 (see sidebar) aim to fill gaps in existing standards.
Code enforcement concerns	• An authority having jurisdiction (AHJ) determines compliance requirements. Field verification by a building department is not a requirement. • New Buildings Institute (NBI) (2023) highlights how existing plan and submittal review processes can easily integrate embodied carbon requirements.[4] If a project's documentation isn't compliant, most AHJs have non-compliance fee structures in place already for non-life safety code violations. • Applicants can bear the burden of showing compliance. For example, for CALGreen, when the design professional of record (e.g., architect) stamps and signs project drawings, they are also self-certifying compliance with the embodied carbon requirements. Building officials still have the discretion to invoke special inspection.
Industry readiness/ capacity to comply	• Embodied carbon credit requirements have been included in the LEED Rating System since 2014, and green procurement policies for materials, or 'Buy Clean,' are already required federally and passed in 8 states across the country. Design teams are increasingly familiar with these requirements. Codes can start with larger buildings that are most likely to have design teams already familiar with embodied carbon requirements. • Using an approach with alternative compliance pathways (similar to CALGreen) can allow design teams to pick what works for their level of knowledge. • Codes can start with a small number of eligible buildings and conservative (i.e., easy to meet) GWP limits, and phase in stronger requirements over time.

DEVELOPING STANDARDS

*Proposed **BSR/ASHRAE/ICC Standard 240P** — Evaluating Greenhouse Gas (GHG) and Carbon Emissions in Building Design, Construction, and Operation* - will provide a calculation and reporting methodology for both the operational and embodied emissions associated with buildings.

ACI 323 *- Low-Carbon Concrete Code* - aims to provide consistent code language to aid practitioners in reducing embodied carbon levels in finished slabs and structures. ACI is targeting publication within the International Code Council 2025 cycle.

RESNET Standard 1550 - will provide a consistent methodology for calculating and reporting the embodied carbon of dwelling and sleeping units that uses the same modeling data, processes, and reporting employed by standard ANSI/RESNET/ICC 301.

REFERENCES

1. RMI. (2021). Reducing Embodied Carbon in Buildings: Low-Cost, High-Value Opportunities.

2. California Energy Codes & Standards. (2023). Embodied Carbon and CALGreen Embodied Carbon Requirements.

3. Lewis, M., Waldman, B., Carlisle, S., Benke, B., and Simonen, K. (2023). Advancing the LCA Ecosystem: A Policy-Focused Roadmap for Reducing Embodied Carbon. Carbon Leadership Forum, University of Washington. Seattle, WA.

4. NBI. (2023). Addressing Embodied Carbon in Building Codes.

Code cycles are slow: Action is urgent

Each code has a unique amendment and adoption cycle at the national level and the state or jurisdiction level. Each cycle typically takes three years to complete, allowing for a lengthy public comment period, hearings, and education for the broader public before new amendments come into effect. If embodied carbon is integrated into model codes and standards provided by organizations like the ICC and ASHRAE, jurisdictions won't need to develop their codes.

As with any change in standard practice, there may be resistance from the building industry no matter what code changes are adopted. Incorporating embodied carbon requirements for large buildings into the code today may impact fewer projects, but it sends a message to the industry to broaden awareness, shift practices, and prepare for future codes. Large projects typically have larger design teams from firms that are already familiar with the concepts, tools, and issues related to embodied carbon and other sustainability requirements.

Over time, eligibility for requirements can be strengthened to (1) apply to more projects and/or more materials and (2) lower maximum GWP limits. This will only be made possible by introducing conservative requirements that can expand over time as industry capacity increases. This phased approach works particularly well in jurisdictions that already have government lead-by-example policies (like 'Buy Clean').

From Green Code to Building Code

The International Green Construction Code (IgCC) provides adaptable code language for communities to go beyond the requirements contained in other model codes and standards to create green, sustainable buildings. The 2024 IgCC, which integrates the ASHRAE 189.1-2023 standard, will require the submittal of environmental product declarations (EPDs) for products meeting specific criteria, and the reporting of total global warming potential (GWP) from those products. It also includes provisions for salvaged material content, biobased products, and life-cycle assessment. A version of the IgCC is currently adopted or in use in 13 states and Washington D.C., as well as several federal agencies.

Over time, embodied carbon requirements can move from green codes into the International Building Code (IBC), further expanding the IBC's ability to safeguard the public from the hazards associated with the creation of building products. The materials chapters of the IBC (e.g., concrete, steel, wood, glass and glazing, and aluminum) are already used by the design and construction industry to ensure that the materials that make up our built environment preserve public health and safety, and are well-suited to also integrate embodied carbon.

Future opportunities for embodied carbon and codes

As the research and practice of reducing embodied carbon continue to advance in response to growing codes and policy requirements, additional pathways for codes to reduce embodied carbon will become available.

Many building industry advocates would like to see a list of evidence-based prescriptive strategies as a complement to the performance-based building pathways described earlier in this document. While high-level strategies (like material efficiency in designing structural systems or using lower-carbon building materials and assemblies) are clear, available research does not tie these strategies to reliable percentage reductions across buildings.

Once building LCA has been more broadly adopted and more LCA results are available, analysis of the pool of LCA results should be able to fill this research gap. However, even as prescriptive design strategies become available, WBLCA will always have a role in assessing novel materials and design solutions.

Read more: carbonleadershipforum.org/clf-policy-toolkit

Learn More

- NBI Embodied Carbon Building Code Overlay (2023)
- NBI Addressing Embodied Carbon in Building Codes Factsheet (2023)
- Stop Waste Low Carbon Concrete Code Amendment Toolkit
- California Energy Codes & Standards Embodied Carbon and CALGreen Requirements
- NBI LifeCycle GHG Impacts in Building Codes (2022)
- ASHRAE Embodied Carbon Codes and Policies Summary (2021)
- Arup Embodied Carbon Reduction Roadmap (2023)
- The Role of Reach Codes in Addressing Embodied Carbon (2023)
- CLF Pacific Coast Collaborative Embodied Carbon Policy Case Studies (2023)
- CLF Northeast U.S. and Canada Embodied Carbon Policy Case Studies (2024)

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Embodied Carbon Policy Factsheet

Carbon Leadership Forum

Deconstruction, Salvage and Reuse Policies

Reusing buildings and materials reduces ***embodied carbon*** and waste while promoting environmental and human health. ***Deconstruction*** is the process of disassembling buildings to allow for the salvage of building materials for reuse. ***Building reuse***, also called adaptive reuse or renovation, describes a process wherein the structure, envelope, or other portions of an existing building are retained and utilized during a renovation project. If the existing building hadn't been reused, it would have been fully demolished and replaced with a newly constructed building on the same site.

This factsheet provides an overview of reuse concepts and how government policies and programs can contribute to a circular building and material reuse ecosystem.

Shifting towards a Reuse Economy

Current disposal practices of construction and demolition debris contribute to the loss of valuable resources, which leads to an increased demand for virgin raw materials and the subsequent greenhouse gas emissions associated with manufacturing new products. Reuse helps keep material resources in circulation and has a wide range of potential benefits depending on how that material is processed and its final end use. Reuse has even larger benefits than material recycling by extending the life of a material or building with fewer resource inputs, which can have environmental, health, and community benefits. These include but are not limited to:

- Largely avoids the cradle-to-gate embodied carbon from the process of extracting and manufacturing new materials.
- Avoids materials ending up in landfills. According to the EPA, an estimated 600 million tons of construction and demolition (C&D) waste are generated in the U.S. each year. C&D waste is the largest single-stream source of refuse in the United States - more than double the amount thrown into household trash bins (EPA, 2018).
- Contributes to investment in existing communities, historic and culturally significant buildings, and high-priority development areas.

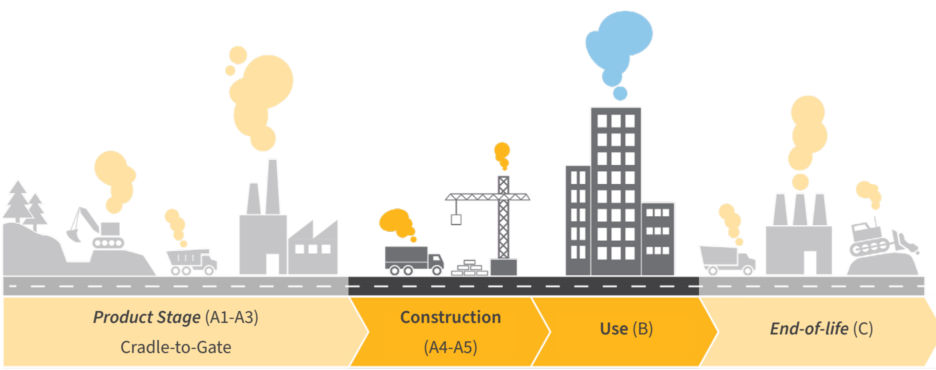

Figure 1. Reusing buildings and products reduces product extraction and manufacturing emissions (due to producing fewer new materials) and results in fewer end-of-life emissions (through avoiding landfill or downcycling emissions).

Reuse reinvests local resources into local economies

Reuse and ***deconstruction*** have many co-benefits such as creating jobs and adding new regional markets for the removal, sale, and distribution of salvaged materials. Deconstruction requires more skilled contractors than demolition, thereby creating new training opportunities and jobs.

The storage, refurbishment, and resale of salvaged materials require the development of new markets, reuse warehouses, and local community hubs. Many of these organizations prioritize community as a part of their mission. For example, the ReUse Center in Cincinnati has a youth training program targeted towards at-risk youth to teach basic work and life skills that will set them on a successful path.

KEY TERMS

Embodied carbon

The greenhouse gas (GHG) emissions are generated by the manufacturing, transportation, installation, maintenance, and disposal of construction materials used in buildings, roads, and other infrastructure.

C&D Waste

Construction and Demolition (C&D) debris is a type of waste that is typically not included in municipal solid waste. Materials included in the C&D debris generation estimates are steel, wood products, drywall and plaster, brick and clay tile, asphalt shingles, concrete, and asphalt (EPA).

Cradle-to-Gate

Environmental impacts of the product life cycle stages from resource extraction (cradle) to manufacturing (gate).

See Product Stages A1-A3 in Figure 1.

Opportunities for Policy and Government-led Programs

There are a variety of opportunities for policy and government-led programs across the design, construction, use, and end-of-life of a project to contribute to the circular economy.

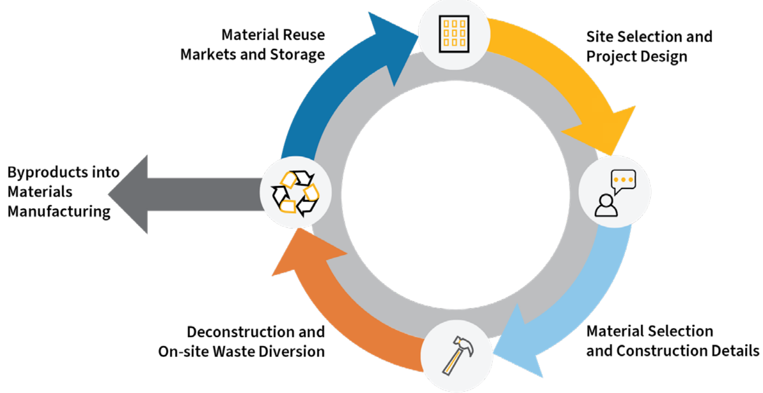

Figure 2. Key intervention points for promoting reuse across the design, construction, and eventual end-of-life of a building

Site Selection & Project Design : **Policies that Incentivize Building Reuse**

Building reuse has the most significant opportunity for carbon reductions and co-benefits. Zoning, land use policies, and historic preservation policies can influence owners towards building reuse. Policies that limit the embodied carbon on a project can also directly or indirectly encourage reuse over demolition and new construction because reusing an existing building preserves the embodied carbon in those materials.

Precedents:

- Los Angeles Adaptive Reuse Ordinance provides developers with density and other bonuses for adaptive reuse in a specific region.
- Pittsburgh's Zoning Performance Points provide density bonuses for building reuse.
- LEED v4.1 awards points for teams that maintain existing building structure, envelope, and interior nonstructural elements.
- California Green Building Standards Code (CALGreen) requirement allows eligible projects to comply with one of three pathways, including the reuse of at least 45% of an existing structure.

Material Selection & Construction Details : **Policies that Include Salvaged Materials in Design and Procurement**

Procurement policies like 'Buy Clean' can include salvaged materials as additional compliance pathways and support creating *demand* for salvaged materials. This complements the creation of *supply*, referenced under deconstruction policies below. During design, projects can specify salvaged materials (from on-site or off-site, like a reuse warehouse) and use design for disassembly principles to increase the future supply.

Precedents:

- LEED v4.1 Sourcing of Raw Materials awards points for material reuse.
- Inflation Reduction Act: EPA determined that salvaged and reused materials from onsite and/or within the project region qualify as having substantially lower levels of embodied GHG emissions under the requirements of the Inflation Reduction Act.

KEY TERMS

Building Reuse

Repurposing an existing building (or portion, such as structure or envelope) rather than demolition and new construction. When a building is reused in a different capacity, this is referred to as *adaptive reuse*.

Material Reuse

Installation of a previously used material or product that requires limited to no processing for reinstallation and use on a different project. (EPA)

This category of materials does *not* refer to recycled content in manufactured materials/products. Some level of processing (e.g., resawing salvaged lumber) would still be considered a minimally processed salvaged and reused material. (EPA)

Salvage

The deliberate reclamation of reusable materials from the disassembly, deconstruction, or demolition of buildings or structures. (EPA)

Design for disassembly

The design of buildings to facilitate future change and the eventual dismantlement (in part or whole) for recovery of systems, components, and materials.

Deconstruction

The systematic dismantling of a structure, typically in the opposite order it was constructed, to maximize the salvage of materials for reuse, in preference over salvaging materials for recycling, energy recovery, or sending the materials to the landfill. (City of Portland (OR) City Code 17.106.020)

Deconstruction & On-site Waste Diversion : **Deconstruction Policies**

Requiring or incentivizing deconstruction (rather than demolition) is critical for creating a supply of quality salvaged materials for reuse on projects. Deconstruction policy examples include ordinances/requirements, and incentives, including financial, technical assistance or permitting.

Precedents:

- Portland, OR Deconstruction of Buildings Law
- Palo Alto, CA Deconstruction Ordinance
- Boston, MA Zero Waste Deconstruction Initiative
- Seattle, WA Deconstruction Incentive Pilot
- Hennepin County, MN Building Reuse Grants
- Victoria, BC offers reimbursement for demolition permits if you ensure deconstruction
- Case study: Deconstruction vs. Demolition: An evaluation of carbon and energy impacts from deconstructed homes in the City of Portland (Nunes, Palmeri, and Love 2019)

Material Reuse Markets & Storage : **Government-supported material reuse markets** and storage

Once materials are salvaged from a project site (rather than being landfilled), they must be transported and stored until they are used by the current building owners or on a new project. Many reuse warehouses today are run by nonprofit organizations or funded by local governments, and serve a relatively small number of projects. Nonprofits like All for Reuse and Build Reuse have directories of local organizations to connect demand for salvaged materials to supply.

In order for material reuse to scale, online platforms are needed to easily connect design teams and contractors with available materials, while also reducing the need for physical space in expensive real estate markets. The technology for building databases and software systems to catalog and advertise salvaged materials to potential owners and buyers for projects is a critical piece of the circularity ecosystem. Tools are available that support the tracking of materials from deconstruction to storage to procurement for new projects. In one example, the City of San Francisco is working with Rheaply intending to connect suppliers to receivers before materials are removed from building sites.

Precedents and Resources:

- City of Houston Reuse Warehouse
- Pennsylvania Recycling Markets Center Incubator
- MassDEP RecyclingWorks C&D Materials Guidance
- City of Seattle EPA SWIFR grant to develop a salvaged wood warehouse
- Washington Materials Marketplace
- Boston Deconstruction and Material Reuse Roadmap

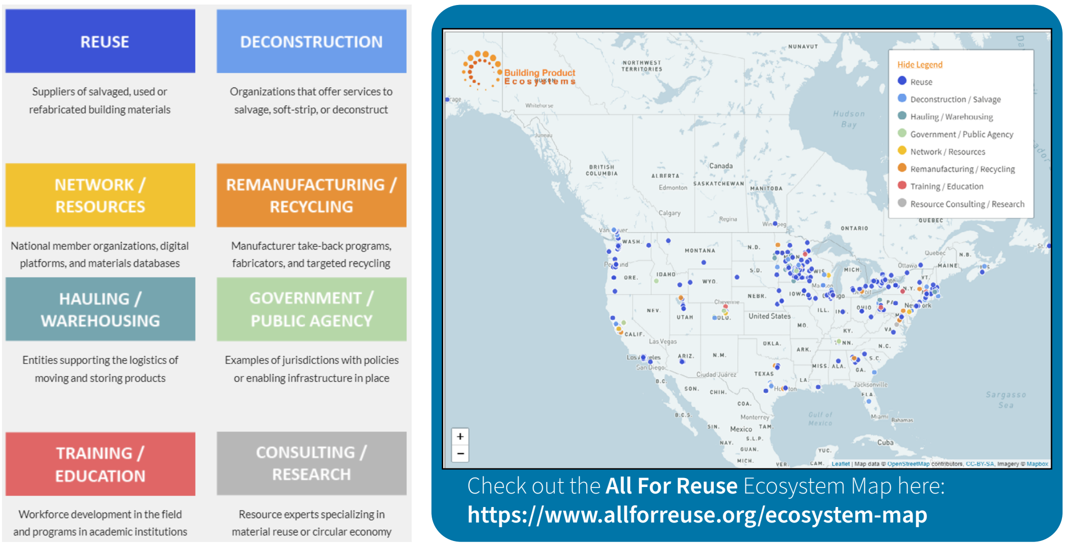

Figure 3. All for Reuse's [Reuse Ecosystem Map] is connecting the dots across the design and construction industry toward an inclusive circular economy.

Tools exist to measure the benefits of reuse

Even before design begins, there are tools that can help communicate the benefits of building reuse to the building owners, community members, and other stakeholders, by comparing the carbon impacts of an existing building retrofit vs. demolition and new construction. **The CARE Tool** (**Carbon Avoided Retrofit Estimator**) and the **EPIC Tool** (**Early Phase Integrated Carbon**) can run early building reuse scenarios that assess embodied and operational carbon.

Later in the design process, whole building life cycle assessment tools can help users calculate the avoided carbon from reusing building systems or components. Often, this is calculated by excluding A1-A3 emissions for reused materials— while still accounting for transportation, installation, use, and end-of-life emissions.

Additional data on the emissions associated with deconstruction and re-processing or storage of materials will help advance the data on the emissions impact of reused materials.

Case Studies:

- Sustainable reuse of post-war architecture through life cycle assessment. Ferriss, L. (2021). Journal of Architectural Conservation.
- The Total Carbon Study: Case Study of DPR Construction San Francisco Office Building – Net Positive Existing Building Reuse. (EBNet, 2015).

The future of deconstruction and reuse policies

Policies that encourage building reuse, deconstruction, and material salvage and reuse are evolving quickly in many forms. They are often coupled with historic and cultural preservation, the prioritization of a circular economy, or social and workforce benefits. Some emerging policy approaches include:

- **Design for disassembly (DfD)** is the process of designing buildings with their eventual disassembly in mind allowing for ease of recovering and reusing the materials and products. The EPA published a series of Fact Sheets on Designing for the Disassembly and Deconstruction of Buildings.

- **EPDs for salvaged materials -** The EPA conducted stakeholder engagement related to the IRA funding for reducing the embodied carbon of construction materials, and one theme that emerged was interest in EPDs for salvaged and reused materials.
- **A digital product passport (DPP)** is a tool to create product transparency that shares product information across the entire value chain – including data on raw material extraction, production, recyclability, and more.[1] The European Commission is drafting a regulation on DPP's with an expected approval date in 2024 and implementation starting in 2026.
  - The Palats tool allows for picture tagging and a digital product passport to be created with material data.
- Improved modeling of what happens to building materials at the end of their life is an important component for policies that require WBLCA. In a recent CLF Report: End of Life (EOL) Modeling and Data in North American WBLCA Tools, the researchers conducted interviews, surveys, and a workshop which resulted in a list of challenges faced by projects considering deconstruction and reuse, as well as proposed recommendations. The report recommended that WLBCA tools better incorporate reuse scenarios at the assembly and building scale to aid design decisions. More broadly, the report recommended filling data gaps in the transport and processing of salvaged materials and establishing regional default waste management rates to harmonize modeling for projects and policies.

Circular Buildings: Policy Checklist

- ☐ Establish land use, zoning, and/or building policies that incentivize building reuse through setting building embodied carbon limits and allowing building reuse as a compliance pathway
- ☐ Include salvaged materials as a compliance option in 'Buy Clean' and other material procurement policies
- ☐ Provide developer incentives for building reuse (over new construction)
- ☐ Establish a local deconstruction requirement or grant/incentive program
- ☐ Provide training for contractors on deconstruction and for architects on how to specify salvaged materials and design for disassembly.
- ☐ Integrate these actions and policies into a regional Climate Action Plan
- ☐ Fund local reuse warehouses and markets
- ☐ Support online platforms to connect designers and salvageable materials
- ☐ Use tools like the CARE Tool or the EPIC Tool to educate and advocate for building retrofit over new construction to building owners, municipalities, community members, and other stakeholders.

REFERENCES

1. World Business Council for Sustainable Development. (2022). The EU Digital Product Passport shapes the future of value chains: What it is and how to prepare.

Learn More

- → Zero Net Carbon Collaboration
- → CR0WD, supported by Cornell's circular construction lab, has deconstruction fact sheets and more.
- → Build Reuse Wiki- a website that displays key information and resources produced by the building material reuse community
- → Northeast Recycling Council (NERC) Webinars
- → Build Change 'Saving Embodied Carbon Through Strengthening Existing Housing'

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