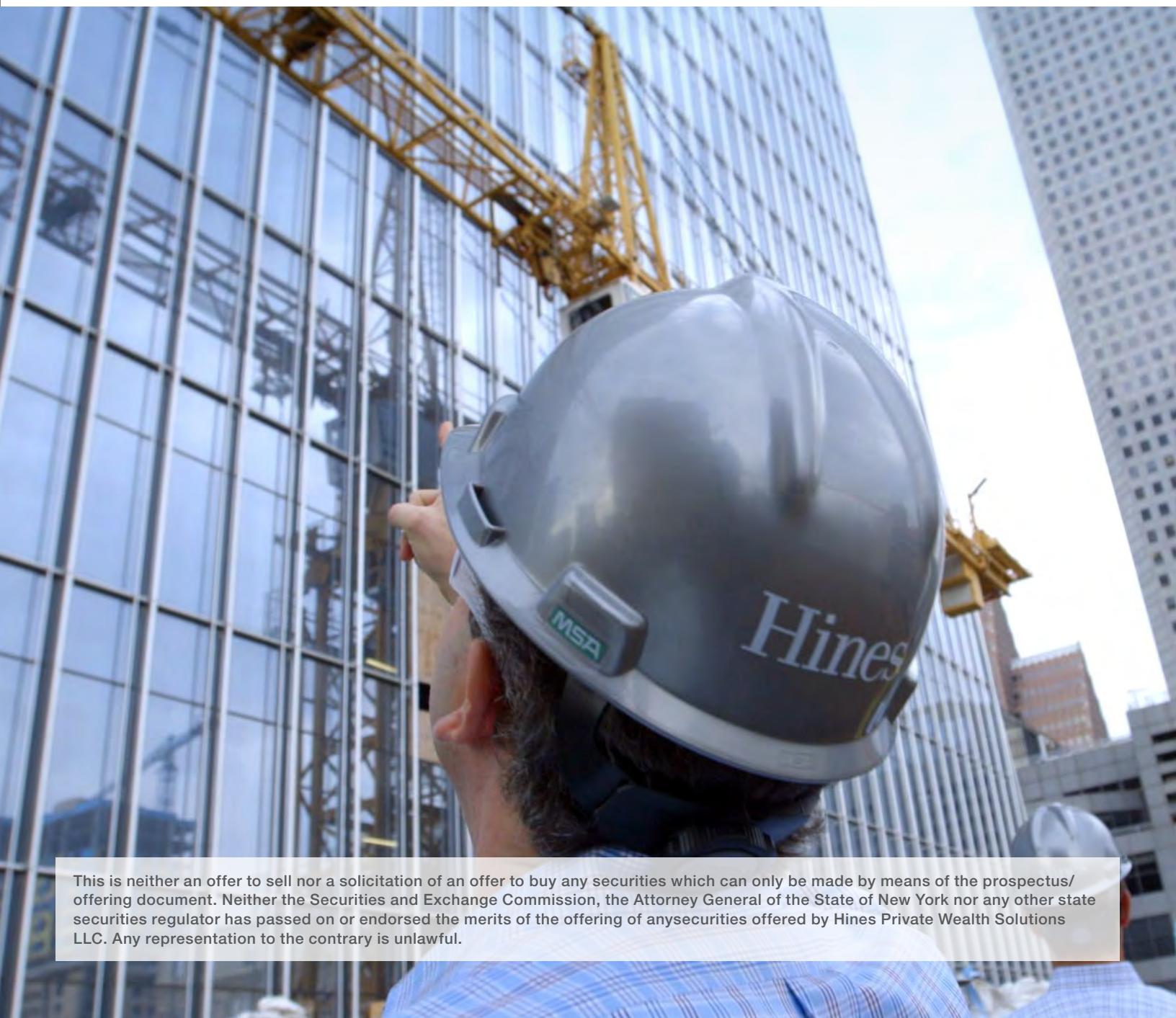
Hines

Embodied Carbon Reduction Guide

April 2022



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MESSAGE FROM THE CHAIRMAN

Jeffrey C. Hines
Chairman and Co-Chief Executive Officer

OUR MISSION

To be the most trusted real estate investment and execution partner across all major property types and geographies—and be the leader in real estate carbon reduction.

My dad, Gerald D. Hines, came into real estate with a no-waste ethic, endless curiosity and a desire to innovate—continuously setting higher standards on each new project and effectively 'raising the bar' on himself and his firm, as well as the industry at large. As a mechanical engineer, his drive to build quality projects more efficiently and to employ premium design and placemaking has continued to prove itself out economically over more than six decades.

From day one, there was a significant focus on designing to reduce energy consumption and the resulting operating costs. Early on, Hines adopted and became leaders in programs such as the United States Environmental Protection Agency's ENERGY STAR®. When the U.S. Green Building Council developed LEED®, we were asked to help design the program and rating systems and, once again, became a leader among peers in the program. We are very proud of our history of designing and managing to reduce **operational carbon** over the years.

Today, we are taking an even stronger stand to support more-significant carbon reduction and combat the climate crisis by admitting we have been part of the problem and innovating a new way to be a part of the solution. The built environment is responsible for 38% of all energy-related emissions generated across the globe and that is a sobering statistic. One of our major focuses is on reducing **embodied carbon**—the CO_2 generated during the product creation.

Working with MKA, an award-winning structural and civil engineering firm, we are spearheading a groundbreaking new program starting with this guide to educate our employees around the world, as well as the architects, designers, contractors and subcontractors with whom we work. We are mandating that all new Hines projects going forward use this framework to quantify, track and ultimately reduce embodied carbon footprints of real estate. We believe over time this approach will become an industry standard, driving material suppliers to do better and rewarding those that do.

By bringing focus to significantly reducing embodied carbon, while continuing to decrease operational carbon, we are addressing the impact real estate has on carbon, and in doing so, will move closer to a net-zero carbon portfolio.

Please join us in this pursuit as we pilot and develop this program, led by our Conceptual Construction Group and our global ESG team. Over the years, the group has analyzed and refined the pre-construction phases of concept, design and contracting, striving to manage every aspect to cut costs, reduce risk and deliver greater long-term value.

As we begin to carefully collect data to quantify progress, we plan to share our work, research and programs with our clients and investors, as well as our competitors and the industry at-large. Thank you for taking a look at this guide and joining us in the march for a more sustainable planet.

Hines + MKA

About Hines

Our founder, Gerald D. Hines, believed in creating long-term value for the people and communities we touch, and that ethos and commitment has driven us to become one of the largest and most respected real estate organizations in the world.

Hines believes that what makes buildings successful and sustainable in the long term is the ability to provide a healthy, productive environment that supports businesses, employees, and residents. Now more than ever, creating value means providing safe, healthy places for people to live, work and play.

Carrying on our founder's legacy, we continue to explore innovative ways of advancing new technologies to reduce our carbon footprint, including embracing the use of new materials to reduce the environmental impact. From construction to the operations and management of the building, our focus is to harness the latest technologies to work with our partners towards net zero carbon and net zero energy.

Our focus on environmental, social and governance (ESG) drives innovation at Hines, provides a platform for us to engage and collaborate with like-minded partners, and challenges us to stay on the leading edge of our industry. To create this Embodied Carbon Guide, we partnered with Magnusson Klemencic Associates (MKA), who share our views and are pioneering research and engaging with low-carbon construction advocacy.

About MKA

For over 100 years, Magnusson Klemencic Associates (MKA) has provided enduring, creative, and innovative structural and civil engineering solutions for projects worldwide from their Seattle and Chicago offices. With designs totaling over $100 billion in 49 states and 61 countries, MKA is in an industry-leading firm offering clients highly targeted expertise and technical skill.

Carbon-conscious engineering has the power to combat climate change. In pursuit of this goal, MKA targets carbon construction with guidance and leadership from the early design stages through construction. MKA's engineers are advocates and pioneers in the research and development of technologies that advance our understanding, create more reliable outcomes, and improve our built environment for a better planet. The firm's recent collaborations include the development of the Embodied Carbon in Construction Calculator (EC3) Tool hosted at buildingtransparency.org—just the latest chapter in MKA's history of collaborative engagement for more sustainable design.

Pillars of MKA's work are reliability, responsible stewardship of resources, and collaboration to create materially efficient structures, striving to improve the industry's processes with every new opportunity. Innovation and growth never come from maintaining the status quo, and MKA believes "if you cannot measure it, you cannot manage it." Success for a lower carbon-built environment requires a collective industry effort, which is why Hines and MKA are partnered in this journey to lower-carbon construction. Together we can build better.

555 Greenwich | New York

The Built Environment's Carbon Impact

Hines is committed to improving the built environment for people and the planet. Through the years, our firm has endeavored to bring responsible, sustainable practices to Hines projects, and we will continue to lead our industry by creating sustainability guides that set and raise the bar as we build for the future.

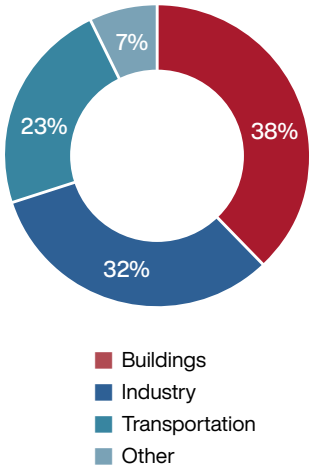
With this mindset of bettering our firm and our industry, we are pursuing more sustainable design and construction practices through the introduction of the Hines Embodied Carbon Reduction Guide. The primary goal of this effort is to reduce the embodied carbon of our vast and diverse portfolio. We also recognize the unique opportunity Hines has as leader in our industry and we are committed to collaboration and education of our development partners, staff, general contractors, and design consultants. This Guide is a guide intended to provide the background to understand embodied carbon, and the tools and processes to achieve our goals for reduction.

The impact of climate change is visible today. Communities and habitats across the globe have experienced extreme weather damage, sea-level rise, and natural disasters leading to billions of dollars of lost value.

Worldwide, researchers agree that if our planet experiences more than 2°C rise in global temperatures above preindustrial levels, irreparable global damage to ecosystems is expected. Recently, the Intergovernmental Panel on Climate Change (IPCC) has endorsed targeting 1.5°C as the maximum rise to limit the lasting effects on ecosystems.

Within this global climate context, the urban built environment plays a large role, with buildings alone responsible for at least 38% of global energy-related Greenhouse Gas (GHG) emissions. Reducing these emissions has become the goal of many worldwide organizations and understanding how Hines can provide leadership in this shared mission is the focus of this Guide.

GLOBAL CO_2 ENERGY-RELATED EMISSIONS BY SECTOR



Source: United Nations Environment Programme 2020 Global Status Report for Buildings and Construction

CHAPTER 1

River Point | Chicago

CHAPTER 1

Understanding Carbon

The term “carbon” is commonly associated with climate change. Greenhouse gases include a variety of substances, such as carbon dioxide, nitrous oxide, and methane; however, carbon dioxide is the most commonly referenced among them and therefore “carbon” has become the shorthand vernacular used worldwide. The metric used to measure these gases and their effect on climate change is called Global Warming Potential (GWP), reported in kilograms of carbon dioxide equivalent, or “kgCO_2eq.”

Buildings have a significant impact on global carbon emissions. To reduce that impact, we must understand the cumulative impact of the processes, materials, and products that go into constructing a building by identifying the individual carbon impact of each component.

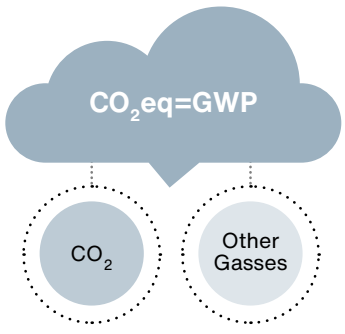
Building Emissions

The life of a building includes many components, phases, renovations, and eventual decommissioning. All of these use energy and create carbon emissions.

Embodied Carbon and Operational Carbon

The classification of carbon emissions is often divided into two primary categories—embodied carbon and operational carbon. Embodied carbon accounts for the carbon emissions from all aspects of the building’s life cycle (material production, transportation, etc.) unrelated to its operations. Operational carbon is the carbon emissions resulting from the energy used to operate a building (lights, air conditioning, elevators, etc.).

CARBON



Greenhouse Gases

The building industry's ability to track operational carbon is fairly sophisticated. Consider, for example, a public utilities meter on a building measuring and tracking energy use. With this information, a building's operational impact can begin to be understood and managed. By comparison, embodied carbon does not have a meter and is more difficult to measure.

While operational carbon accrues over the life of a building, its impact varies and is most often influenced by the local energy grid. As grids become less fossil-fuel dependent, the impact of operational carbon will lower over time. Therefore, in locations where the local grid efficiency leads to lower operational emissions, the embodied carbon impact can be relatively significant in comparison. Because of this, the industry has recently turned its attention to the understanding and quantification of embodied carbon.

Although its study is an emerging topic and less understood, estimating and reducing embodied carbon is an important next step to lowering the overall carbon impact of our built environment.

TOTAL CARBON EMISSIONS OVER TIME

Scenario A

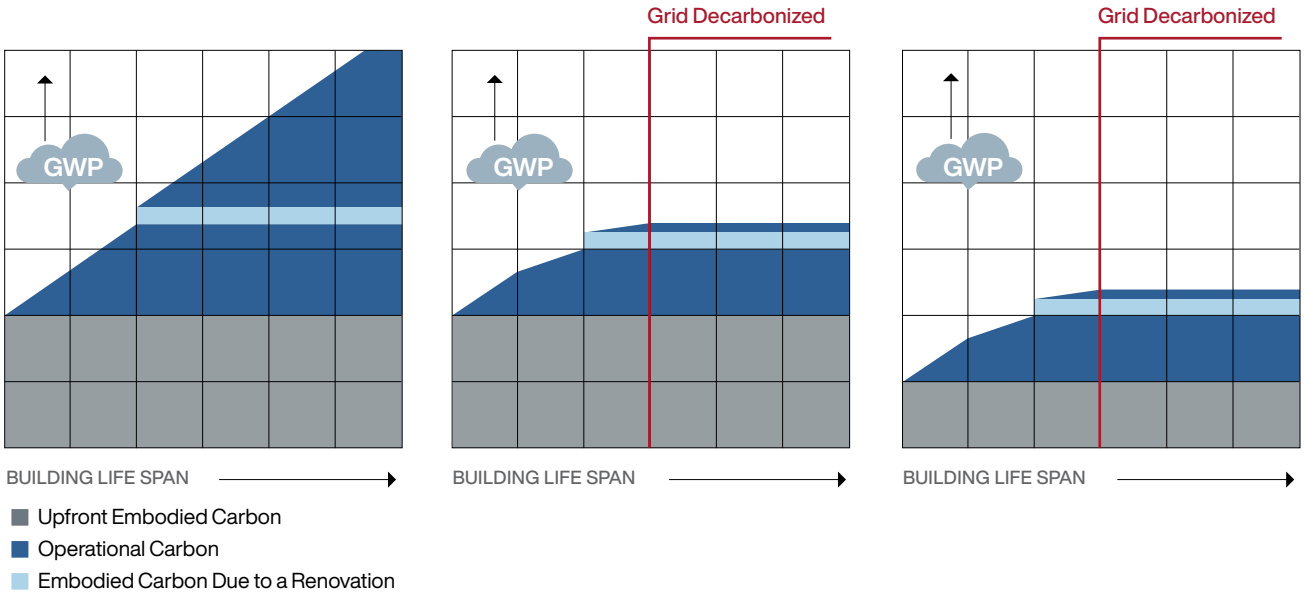
- Upfront embodied carbon remains as is
- Energy grid remains as is

Scenario B

- Upfront embodied carbon remains as is
- Energy grid increases in efficiency until it switches to renewable energy (is "decarbonized")

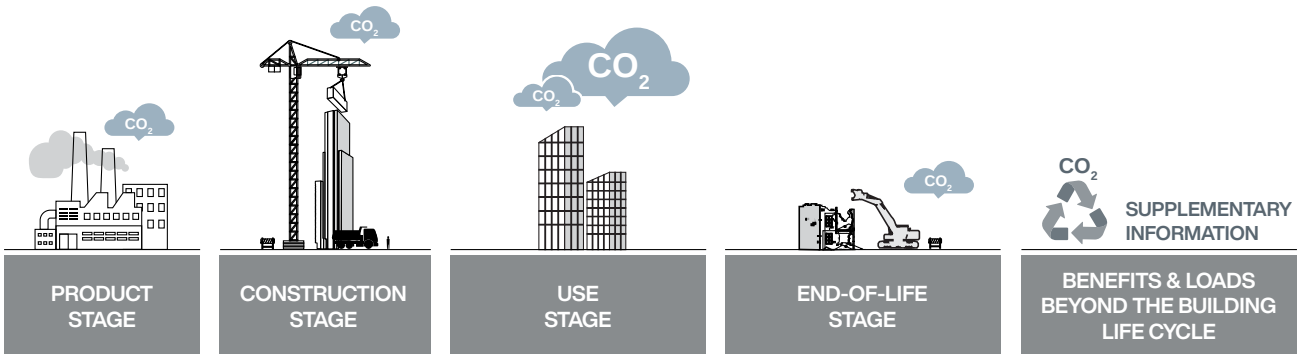
Scenario C

- Upfront embodied carbon is reduced
- Energy grid increases in efficiency until it is decarbonized




As local
energy grids
shift towards
decarbonization,
the significance of
embodied carbon
emissions grows.

For many buildings, the initial Product Stage is the largest contributor to its total embodied carbon emissions.



Building Life-Cycle

To organize and track a building's carbon impact, its life span can be broken out into different stages. Each stage represents a different timeframe in a building's life-cycle, from beginning to end, and is associated with varying levels of carbon emissions. These stages, identified below, are described in detail in **European Standards (EN)** 15978 and **International Organization for Standardization (ISO)** standard 14040:

» Product Stage: raw material extraction, transportation, and manufacture into building materials or products

» Construction Stage: transportation of building components and their construction or installation

» Embodied Use Stage: upkeep of building components, including maintenance and replacement, along with renovations

» Operational Use Stage: energy and water consumption due to building operations

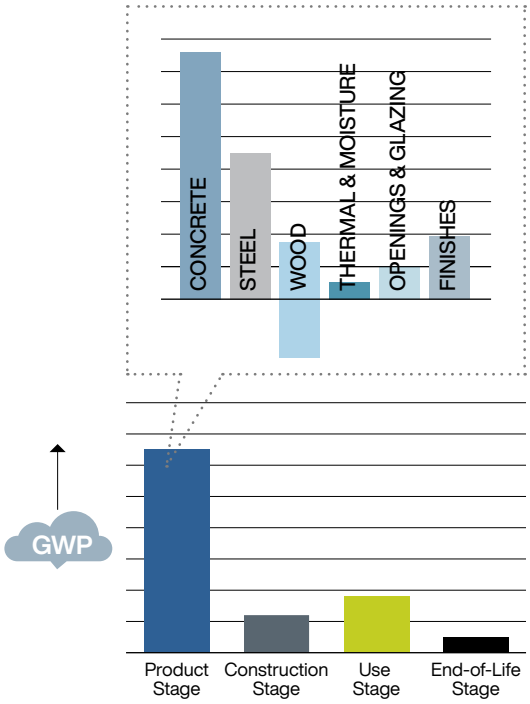
» End-of-Life Stage: demolition of building and disposal of waste

» Considerations Outside System Boundary: recovery of building components and their reuse or recycle along with **sequestration**

All of these stages, with the exception of the Operational Use Stage, contribute to the total embodied carbon impact of a building. For many buildings, the initial Product Stage is the largest contributor to its total embodied carbon emissions. In some instances, this stage can make up to three quarters or more of the embodied carbon impact.

When examining the Product Stage for typical buildings, the structural materials used to support a building tend to be the biggest contributors to embodied carbon emissions, followed by non-structural items such as architectural finishes.

EMBODIED CARBON CONTRIBUTIONS EXAMPLE



Source: MKA Mixed-use Project WBLCA study, 2020

Building Components

Each building material and product has its own unique characteristics and life cycle, and therefore, its own unique considerations that inform its carbon emissions. Explored in more detail below, these materials and products can be generally broken into the categories of Structure, Envelope, Finishes, and Other.

Structure

A building's structure is often the largest contributor to its embodied carbon impact. Typically, the structure consists of concrete, steel, and timber.

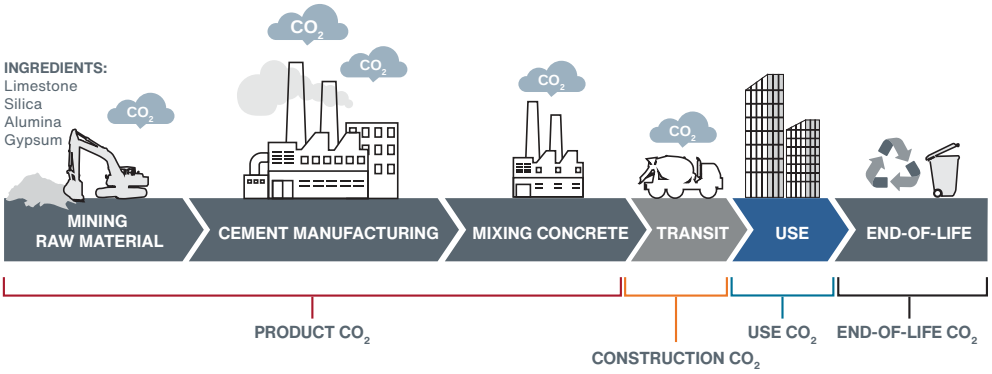
CONCRETE | Concrete is the world's most widely used building material. It also has a relatively large carbon impact. These two factors result in this single material making up approximately 10% of global carbon emissions alone. The primary contributor is its cement, and thus reducing cement content within concrete mix designs is a key carbon reduction strategy.

STEEL | The steel manufacturing process at a mill is the largest determinator of this material's carbon impact—mainly, the difference between a mill using a Basic Oxygen Furnace (BOF) or an Electric Arc Furnace (EAF). BOFs generally consume raw materials and burn coal or natural gas to melt these materials to create first-generation steel. This means the recycled content for BOFs is relatively low, about 25%. In comparison, EAFs use scrap material to create steel, making their recycled content often greater than 90%. Within the U.S. and Europe, most steel mills use an EAF, whereas other internationally produced steel uses both processes.

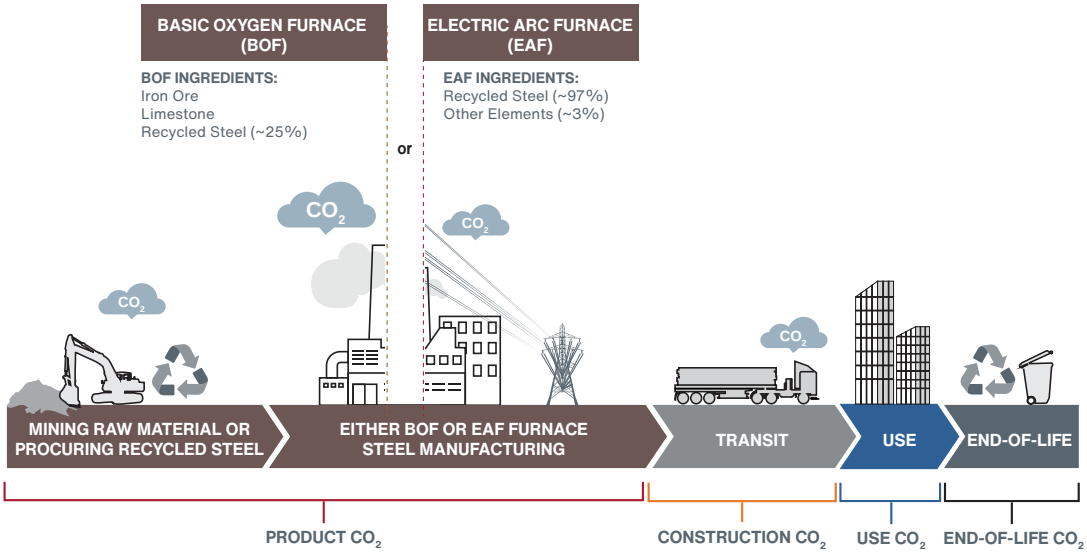
TIMBER | Unlike concrete and steel, wood is grown. While a tree grows, it sequesters (or pulls out) carbon from the atmosphere—a negative emission to the carbon life cycle. However, if a timber product is burned or left to decompose after a building is decommissioned, the carbon that had been sequestered is released back into the atmosphere.

How to account for the carbon sequestration of timber is a debated topic, made more complicated by variables not reported within forest management practices. It is generally accepted, however, that better managed forests lead to greater sequestration, resulting in a lower carbon product.

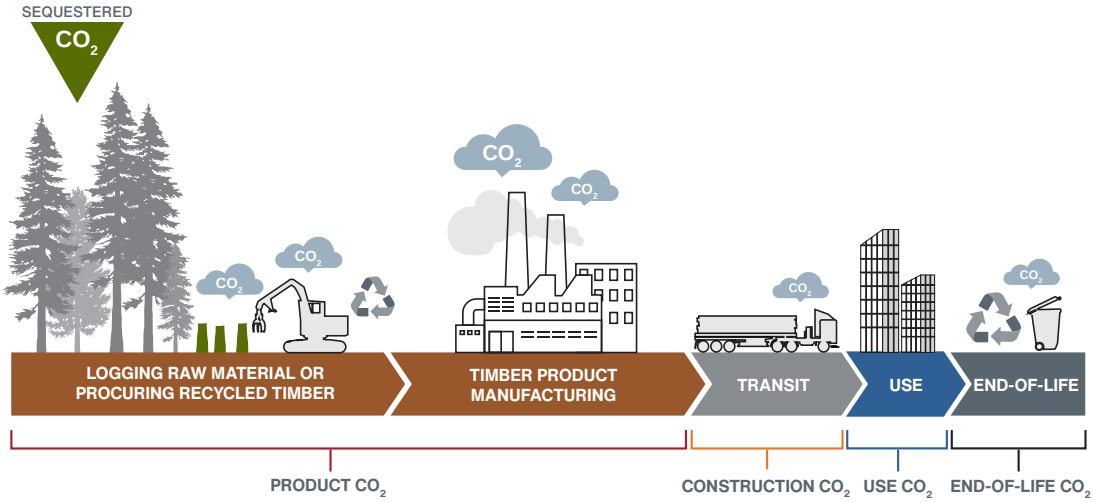
CONCRETE



STEEL



TIMBER



Envelope

Elements that make up the building envelope, such as cladding and insulation, present an interesting dichotomy between embodied carbon and operational carbon. Since the envelope directly affects a building's energy performance, a poorly insulated envelope will cause greater operational cost over the building's life span. Better insulated envelopes, however, may require more material, leading to an increase in the embodied carbon impact. Because of the interplay between these two types of carbon, it is important to weigh both impacts simultaneously to make informed decisions.

CLADDING | A cladding system can be made up of many materials—aluminum, glass, concrete, etc.—and the carbon impact of each needs to be considered. This leads to complicated carbon accounting. Adding to the complexity, cladding is often a custom design to achieve a specific architectural vision and energy performance. Together, these aspects make it difficult to quantify the overall carbon impact of cladding.

INSULATION | Similar to cladding, insulation encompasses a broad range of products, manufactured from a variety of materials. Depending on which material is selected, a large variance in GWP can be realized. In general, the most carbon intensive option for insulation is extruded polystyrene, or XPS. Less intensive options are those created from natural materials, such as mineral wool batting.

Finishes

Architectural finishes encompass a wide array of products with a wide selection of materials for various purposes. The following are some examples and their considerations. In general, the carbon impact of a finish correlates to its material makeup—natural versus synthetic—and the processes used to create them, with synthetic materials requiring more manufacturing than natural alternatives.

DRYWALL | Drywall, also known as gypsum board, can be made from both natural and recycled materials. Both options are energy-intensive to manufacture. Its use also results in a large amount of waste from over-ordering, damage, and off-cuts during construction.

METAL STUDS | Metal-stud framing typically consists of sheet metal. Due to stringent dimensional tolerances, sheet metal often requires virgin material and uses less recycled steel, resulting in a much higher carbon impact than that of rolled steel shapes.

Wolf Point East | Chicago

CARPET | Carpet can be a large contributor to carbon, especially for renovation projects such as tenant fit-out. Like other architectural elements, carpet has a wide variability in its GWP depending on the type and manufacturer. It is also often highly processed, involving production from crude oil and components made of petrochemicals and plastics.

CEILING TILES | Ceiling tiles are composed of a wide variety of materials, some of which are highly processed. Like other architectural components, these materials present a large range in GWP data.

Other

Other items such as mechanical/electrical/plumbing (MEP) equipment and components, elevators, and building maintenance units (BMUs) also play a role in the embodied and operational carbon impacts. Research suggests that the embodied carbon impact from MEP systems may be significant, often due to its heavy use of sheet metal. However, the data to quantify this is relatively non-existent today. For this reason, these "other" building components remain a future consideration for embodied carbon accounting as more data becomes available. Operational carbon, however, is heavily impacted by the chosen MEP systems and this can be considered today as a target for a building's overall carbon reduction.

GWP DATA AVAILABILITY

MOST DATA AVAILABLE	LIMITED DATA AVAILABLE	LEAST DATA AVAILABLE
Concrete	Timber	BMUs
Steel	Ceiling Tiles	Elevators
Carpet	Cladding	MEP Equipment
Drywall	PT Tendons	Piping
Insulation		Ductwork

Environmental Product Declarations

To measure the embodied carbon of a material or product, the standard reporting mechanism is an **Environmental Product Declaration (EPD)**. An EPD is a report that describes a material or product's environmental impact. An EPD is analogous to a nutrition label, reporting a variety of health information. In this case, one of the important tracked "nutrients" is the product's GWP.

EPDs are governed by industry-established **Product Category Rules (PCRs)** that document the reporting requirements and guidelines for a specific material or product type. They are typically updated every five years following a series of ISO guidelines.

EPDs are commissioned by manufacturers or vendors to report their environmental impacts. The most credible EPDs are third-party verified, with a number of organizations providing this service to the industry. For vendors that have not yet created EPDs for their products, several trade organizations have created industry-average EPDs based on the average national data for those materials.

TYPES OF EPDs

	PCR IS THIRD-PARTY REVIEWED?	EPD IS THIRD-PARTY REVIEWED?	SPECIFIC TO A SINGLE PRODUCT FROM A SINGLE SUPPLIER	STANDARD FOLLOWED
Product-Specific Declaration (Self-Declared)	—	—	✔	ISO 14044
Product-Specific Type III PREFERRED	✔	✔	✔	ISO 14025 ISO 14040 ISO 14044 ISO 21930 / EN 15804
Industry-Wide	✔	✔	—	ISO 14025 ISO 14040 ISO 14044 ISO 21930 / EN 15804

Nutrition Facts

Serving Size 1/2 cup (130 g)

Amount Per Serving

Calories 120

	%Daily Value*
Total Fat 2g	3%
Saturated Fat 0g	0%
Trans Fat 0g	
Cholesterol 0mg	0%
Sodium 130mg	6%
Total Carbohydrate 20g	7%
Dietary Fiber 4g	14%
Sugars 3g	
Protein 7g	
Vitamin A	2%
Vitamin B	0%
Vitamin C	0%
Vitamin D	0%

* Percent Daily Values are based on a 2,000-calorie diet. Your daily values may be higher or lower depending on your calorie needs.

An EPD is analogous to a nutrition label.

T3 | Minneapolis

Understanding an EPD

EPDs can be lengthy and complicated reports, with a large breadth of information to digest. For this Guide, the most important piece of information provided in an EPD is the product's GWP, reported in $kgCO_2eq$. Again, Global Warming Potential (GWP) is the metric used to measure the effect of carbon emissions of a material or product.

PARTS OF AN EPD

Availability and Comparability

Since embodied carbon is an emerging topic, only recently gaining mainstream attention, the majority of U.S. vendors or manufacturers have not commissioned EPDs. The more the AEC industry and building owners request and require EPDs, though, the greater the availability and accuracy of the data. This drives the market in a positive direction towards increased transparency, allowing stakeholders the opportunity of more informed decision-making.

EPDs are not equally available across the U.S., nor across materials or products. Suppliers on the West Coast, for example, have commissioned many more EPDs than in the Midwest region. And, while each material supply chain is expanding their production of EPDs, concrete EPDs are becoming available the fastest. As EPDs are requested, the project team should ask supply chain questions and be aware of local market conditions impacting the availability of EPDs.

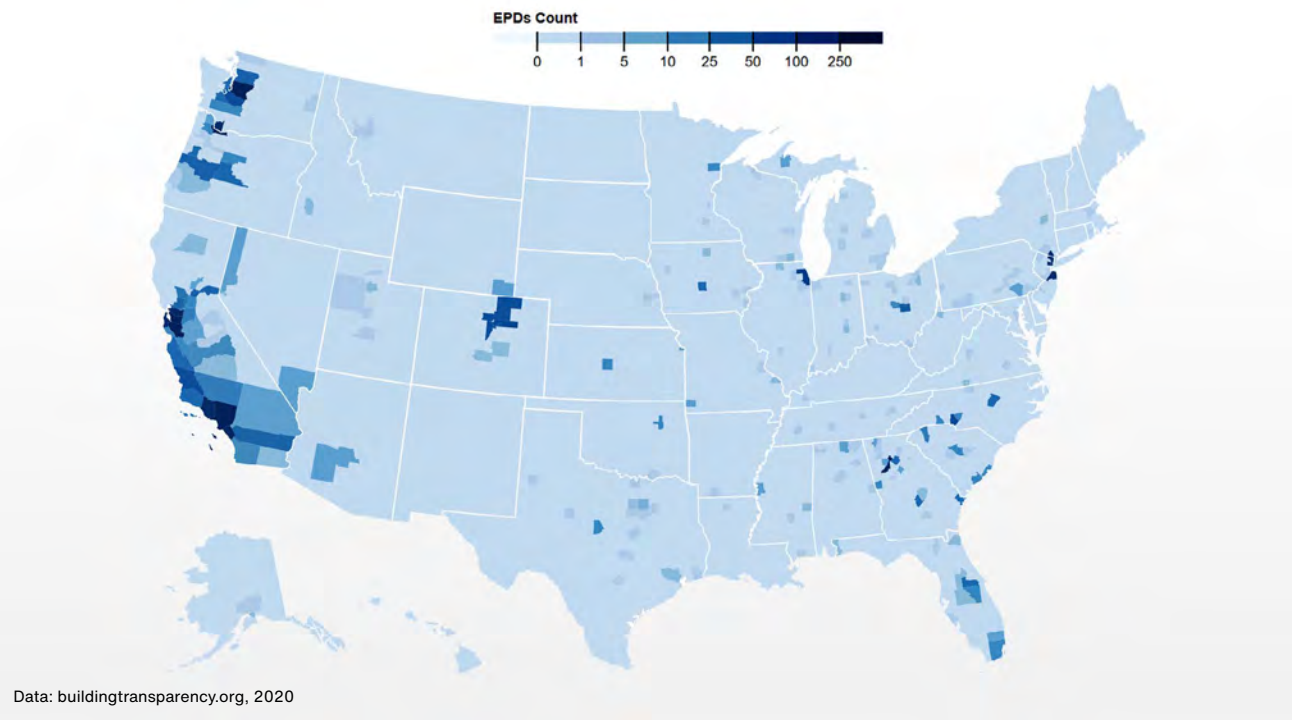
Comparability of EPDs

Currently, EPD comparisons are not straightforward between different materials and products (e.g. concrete to steel to timber) because EPDs for specific materials are governed by different PCRs or rules. While PCRs primarily focus on the product life-cycle stage, they each make different assumptions, and in turn make it difficult to compare the data. Today it is like comparing "apples to oranges to bananas" when trying to directly compare the GWP of different materials reported by EPDs.

EPDs of the same material or product, however, are generally comparable when following the same PCR. It is these "apples-to-apples" conditions that result in the most accurate comparison of carbon emissions.

Overall, while inconsistency and uncertainty exist with EPD data, it is the best information at our disposal for measuring carbon emissions of materials and products. This data will be refined and improved over time with industry adoption.

DIGITIZED EPDs BY U.S. COUNTY



Data: buildingtransparency.org, 2020

CHAPTER 1

Summary

- Carbon emissions are categorized into **Embodied and Operational**
- Embodied carbon includes emissions from product creation, construction, remodeling, and deconstruction
- Operational carbon includes energy emissions from daily building operations
- **The Product Stage** is typically the largest contributor to embodied carbon
- **Structural materials** are often the largest contributor to embodied carbon
- Embodied carbon is reported with **Environmental Product Declarations (EPDs)** in terms of Global Warming Potential (GWP), measured in $kgCO_2eq$
- Today, availability of EPDs varies widely across the U.S. and for different building products, but information is **rapidly expanding**
- Dissimilar materials **cannot** be easily compared

Operational Carbon

What about operational carbon considerations? Although the focus of this Guide is on embodied carbon, Chapter 3 provides guidance for how to combine operational carbon with embodied carbon. Future stages of the guide will provide more in-depth guidance around the measuring and reporting of operational carbon.

Aqualuna at Bayside Toronto | Toronto

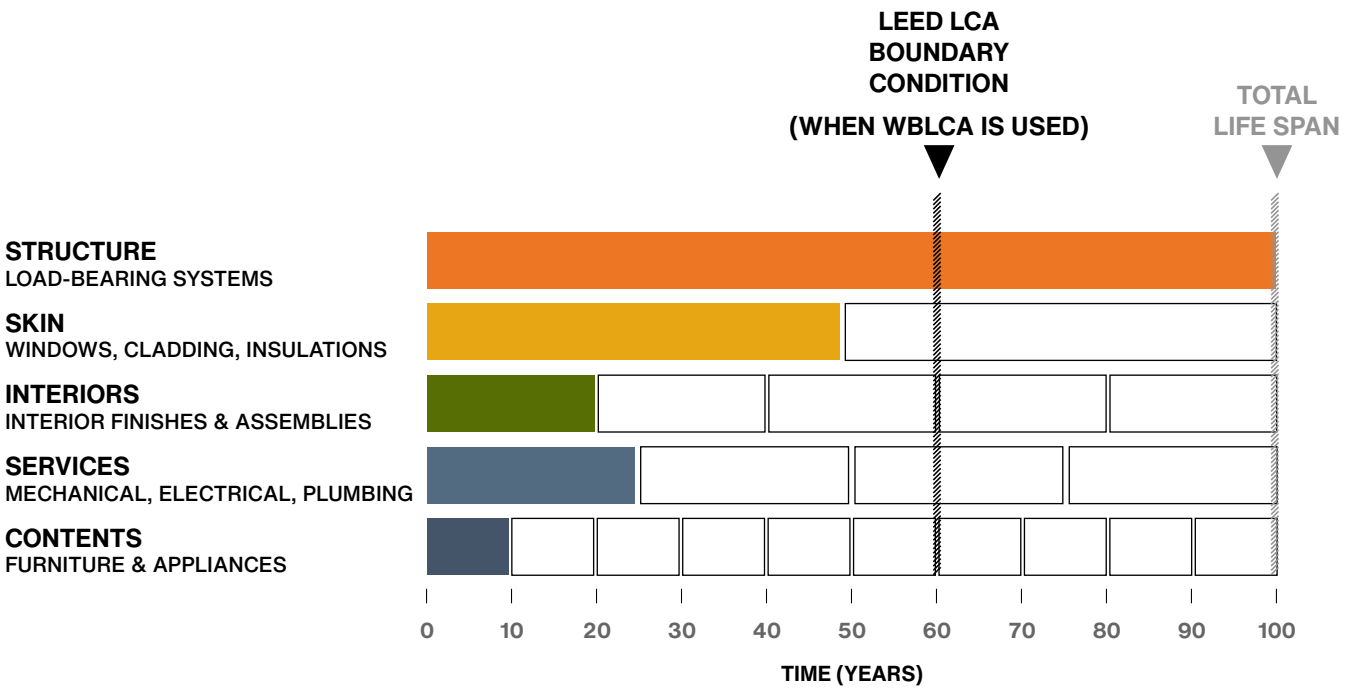
CHAPTER 2

Measuring Carbon: Product and Construction Stages

There are a variety of ways to measure the embodied carbon of a building. Common practices include the Product Stage Method (which is sometimes expanded to include the Construction Stage) and through a Whole-Building Life-Cycle Assessment (WBLCA).

The WBLCA method accounts for all carbon emissions through the duration of a building's life-cycle and relies on data from many life-cycle stages. This process involves estimation and some speculation and becomes complex when performed accurately; thus, it requires careful judgment and a thoughtful consideration of the variables involved.

PRODUCT STAGE AND CONSTRUCTION STAGE $kgCO_2eq$ REPORTING



The Product Stage Method focuses on the up-front carbon emissions emitted during the A1-A3 Product Stage of the Whole-Building Life-Cycle, and can be utilized for any building material or specific product.

Reporting during the A4-A5 Construction Stage is similar to the Product Stage as it captures carbon emissions that occur as a result of the initial construction. Construction Stage emissions become an extension of the data collected within the Product Stage, and together can create a full up-front carbon accounting of a building's creation, or it's Cradle-to-Construction carbon emissions.

Neither Product or Construction Stage carbon reporting considers replacement timelines, or the time-value of carbon topics that need to be addressed when there is a pre-set Life-Cycle Assessment (LCA) boundary condition. These upfront emission stage evaluations are still very meaningful as they often represent the largest carbon emissions over the life of a project; however, they are not representative of a WBLCA as they do not consider "life-cycle" topics holistically. That process is described in greater detail within Chapter 3.

Product Stage Method

The first of five life-cycle stages, the Product Stage Method focuses solely on A1-A3 reporting and captures the highest embodied carbon contributors within a WBLCA. This stage requires less speculation and fewer variables than other stages, making it a meaningful way to focus on the biggest impacts with the least uncertainty and variability.

In this approach, the determination of embodied carbon is distilled to a single equation: the amount of material within a building multiplied by each material's Global Warming Potential (GWP). Once these numbers are determined for individual materials, the totals can be added together to compute the total embodied carbon for the building components.

Material Quantities

The first part of the Product Stage Method equation involves computing the quantities of building materials.

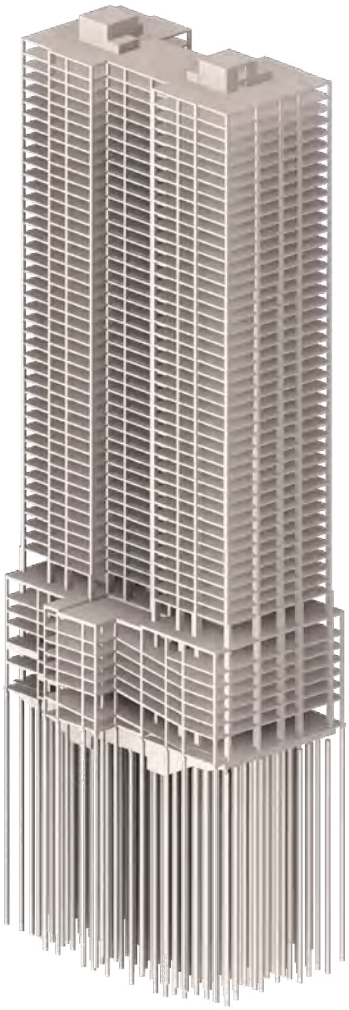
CALCULATING EMBODIED CARBON

Material Quantity	X	Global Warming Potential	=	Embodied Carbon

Pursuing a WBLCA

If it is determined that a WBLCA is appropriate for a project, refer to Chapter 3 which includes information on the following:

» Who should perform a WBLCA
» Description of life-cycle stages
» WBLCA considerations
» Comparison of WBLCA tools



WHAT TO MEASURE | Quantities can be gathered for any building component. Because a large portion of a building's impact comes from its structural system, the primary structural elements should be the minimum consideration. These include the concrete, reinforcement, steel, and timber that make up a building's foundations, vertical framing, and horizontal framing.

The quantification effort should focus on primary elements that account for most of the material as opposed to miscellaneous elements (e.g., nails, curbs, housekeeping pads, etc.), which have less of an overall impact. Miscellaneous elements can be quantified using estimation. Additionally, for items that are difficult to quantify, such as material overruns and component connections, allowances or contingencies should be included.

MINIMUM CONSIDERATIONS

At minimum, consider the primary structural elements:

VERTICAL FRAMING:
Columns, Walls, Bracing

HORIZONTAL FRAMING:
Slabs, Beams

FOUNDATIONS:
Piles, Mat Foundation, Spread Footings

Risk Management

If quantities are measured and reconciled consistently and accurately throughout the design and construction phases, this effort can simultaneously serve as a quantity control method and a cost control method—the added benefit being risk management for Hines' budget. This helps ensure that material estimates are achieved, or that discrepancies are exposed for further investigation.

345 Hudson | New York

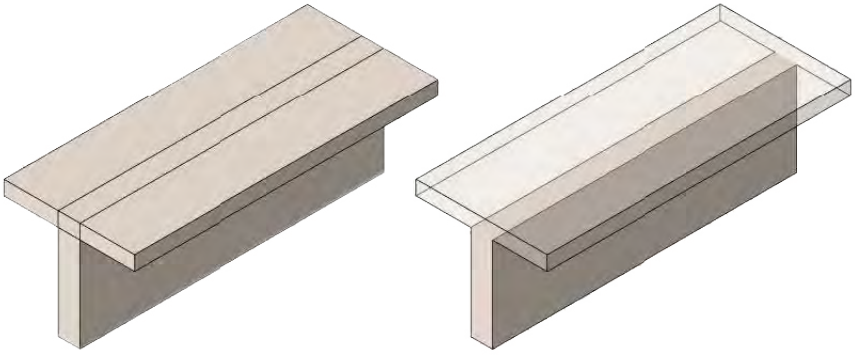
HOW TO MEASURE | The process of measuring quantities is critical to accurately ascertain a building's embodied carbon. The best sources to track material quantities are Building Information Models (BIM) that have been established to measure quantities, which are supplemented with hand calculations that account for what is not within the BIM model and ultimately with bills of materials delivered to site. The material quantities often start as estimates in early design, are refined throughout the design process, and become finalized in construction.

As quantities are summarized, they should be broken out by specification—reinforcement and steel grades or glass type, for instance—so that the GWP can be calculated for individual materials. BIM software, such as Revit, can be leveraged to calculate quantities, though caution should be taken. The BIM model must be created thoughtfully to ensure accurate modeling of the elements. Strict modeling standards are required to ensure this accuracy.

It is necessary to understand what is included and excluded in a BIM model. For example, items such as concrete reinforcement, wall paint, and component connections are typically excluded from the model. These items should still, however, be included in the overall material quantities using manual take-offs or allowances.

REVIT MODELING STANDARD EXAMPLE

Needed for Accurate Material Quantification



DEFAULT

By default in Revit, walls do not automatically join to floors and the overlapping region may be double counted.

JOINED

When joined to floors, the concrete volume is removed from the overlapping region and only floor volume is counted.

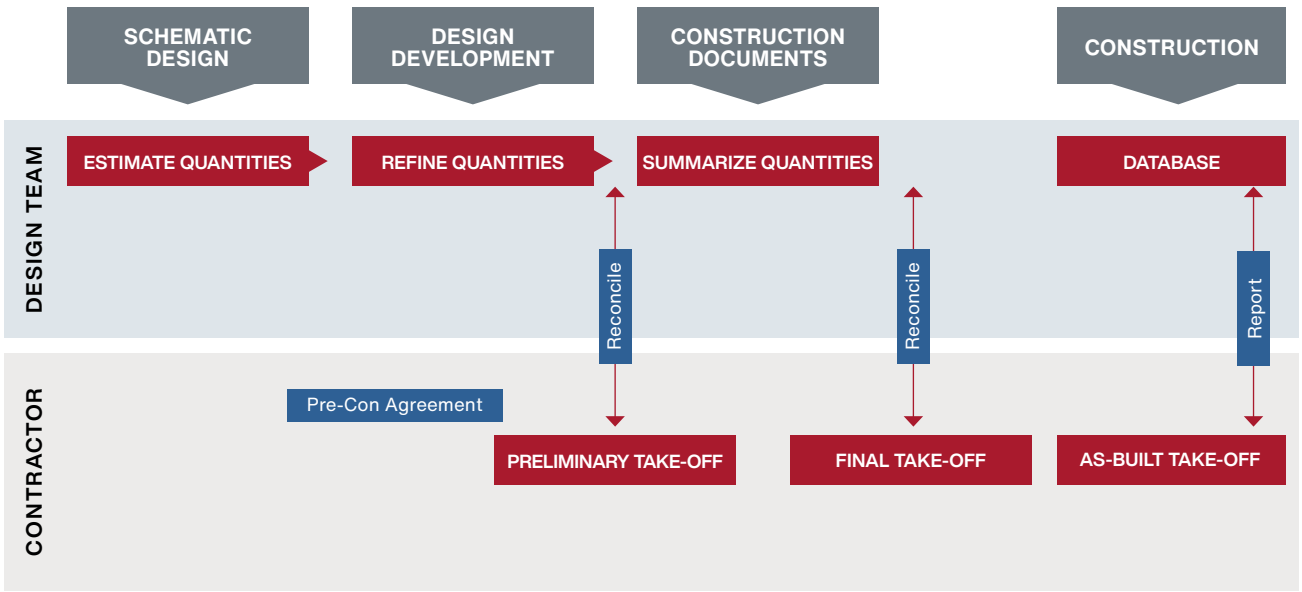
WHEN TO MEASURE | Tracking of material quantities should start no later than the Schematic Design phase. Design team members, such as the Architect and Structural Engineer, should be totaling project quantities using Schematic Design assumptions. These vary by material or component, but some examples include estimating square footage of cladding, sizing members preliminarily, and estimating concrete reinforcement ratios.

In Design Development, further design analysis is completed, leading to quantity refinement. Depending on the project's delivery method, the General Contractor may be on board by the end of this phase and should also be completing material quantity take-offs. It is recommended to reconcile quantities between the design team and the Contractor to ensure an aligned understanding of the design.

As construction documents are finalized, final material quantities should be summarized by the design team and compiled into an "As-Designed" quantity summary. The Contractor's quantity take-offs should be reconciled again with the design team's numbers to ensure that material information is properly communicated by the designer and understood by the Contractor.

When construction reaches completion, the final "As-Built" quantities should be compiled by the Contractor and reported back to the design team and Hines.

CALCULATING QUANTITIES THROUGH DESIGN AND CONSTRUCTION



Consultant Scope of Work

To ensure the process of determining material quantities is considered by the Structural Engineer and Contractor, scope language has been added to the Hines Structural Engineers Request for Proposal and General Contractors Request for Proposal documents, available from Hines Conceptual Construction Group.

Global Warming Potential (GWP)

Once the material quantities have been tallied, the remaining variable is the material or product's GWP.

INDUSTRY-AVERAGE VS. PRODUCT-SPECIFIC | Industry-average Environmental Product Declarations (EPDs) are created to describe an average product's impact, considering multiple suppliers throughout the country. They are not specific to one product or supplier.

Product-specific EPDs, on the other hand, are specific to a single product from a single manufacturing source. The highest level and most accurate type of EPD is Type III, which means it has been

third-party verified. Because product-specific EPDs are unique to a supplier and therefore to a project when a supplier is selected, they are preferred over industry-average EPDs.

DURING DESIGN: INDUSTRY-AVERAGE DATA | Industry-average EPDs can be used to estimate embodied carbon during this phase since the exact products and material suppliers are typically unknown.

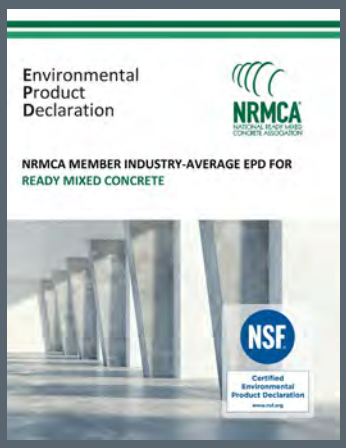
DURING PROCUREMENT/CONSTRUCTION: PRODUCT-SPECIFIC DATA | Once a project has transitioned into the procurement or construction stages and a Contractor is selected, carbon estimates can be determined using product-specific data. The benefit of product-specific data is the ability to quantify materials specific to a project. Subsequently, the amount of uncertainty in the data reduces.

Embodied Carbon

Regardless of whether a project is in the design or construction stage, the quantities of materials can be multiplied by their GWP to provide a cumulative embodied carbon estimate for the project.

Industry-Average Data for Primary Structural Materials

CONCRETE



The National Ready Mixed Concrete Association (NRMCA) produces an industry-average EPD that provides data by concrete strength and amount of cementitious material. The result is a significant amount of data—over 70 different GWP values.

When using this EPD, consider the following:

» Select the appropriate value based on strength and cement replacement ratio, depending on the application

» The maximum concrete strength considered is 8,000 psi, which may not be high enough for certain building types (for example, a high-rise tower with a concrete core)

STEEL

The American Institute of Steel Construction (AISC) produces three industry-average EPDs. These representative EPDs capture three different steel products: hot-rolled sections, steel plate, and HSS.

TIMBER

The American Wood Council (AWC) produces 12 different EPDs representing 12 different timber products. Not refined by species or forestry practice, EPDs exist for:

- » Softwood lumber
- » Redwood lumber
- » Glue laminated timber
- » Softwood plywood
- » Oriented strand board
- » Laminated veneer lumber
- » Laminated strand lumber
- » Wood I-Joists
- » Particleboard
- » North American hardboard
- » Medium density fiberboard
- » Cellulosic fiberboard

Last updated: September 2020

How are EPDs Created?

For suppliers that do not have EPDs readily available, see the How to Create an EPD Appendix (page 96).

Product Stage Method: Strengths and Weaknesses

As with any analysis tool, there are strengths and weaknesses to using the Product Stage Method on a project.

STRENGTHS

» Avoids Complexity | This method is simple, can be performed by various members of the project team, and does not require the use of proprietary software or complex tools to calculate the data.

» Considers Largest Contributors | This method focuses attention on the phase with the most significant source of emissions in a project, the Product Stage.

» Leverages Most Accurate Data | By focusing on the stage that currently has the most amount of data, this method requires the least speculation.

WEAKNESSES

» Excludes Portions of Life-Cycle | By only focusing on the Product Stage, this method does not account for a building's entire life span.

» Requires EPDs | Calculating carbon impact with this method depends on the availability of EPDs, which varies significantly by building component and market sector.

» Compares Only Similar Materials | Due to the nature of EPDs, comparison between different materials is not possible.

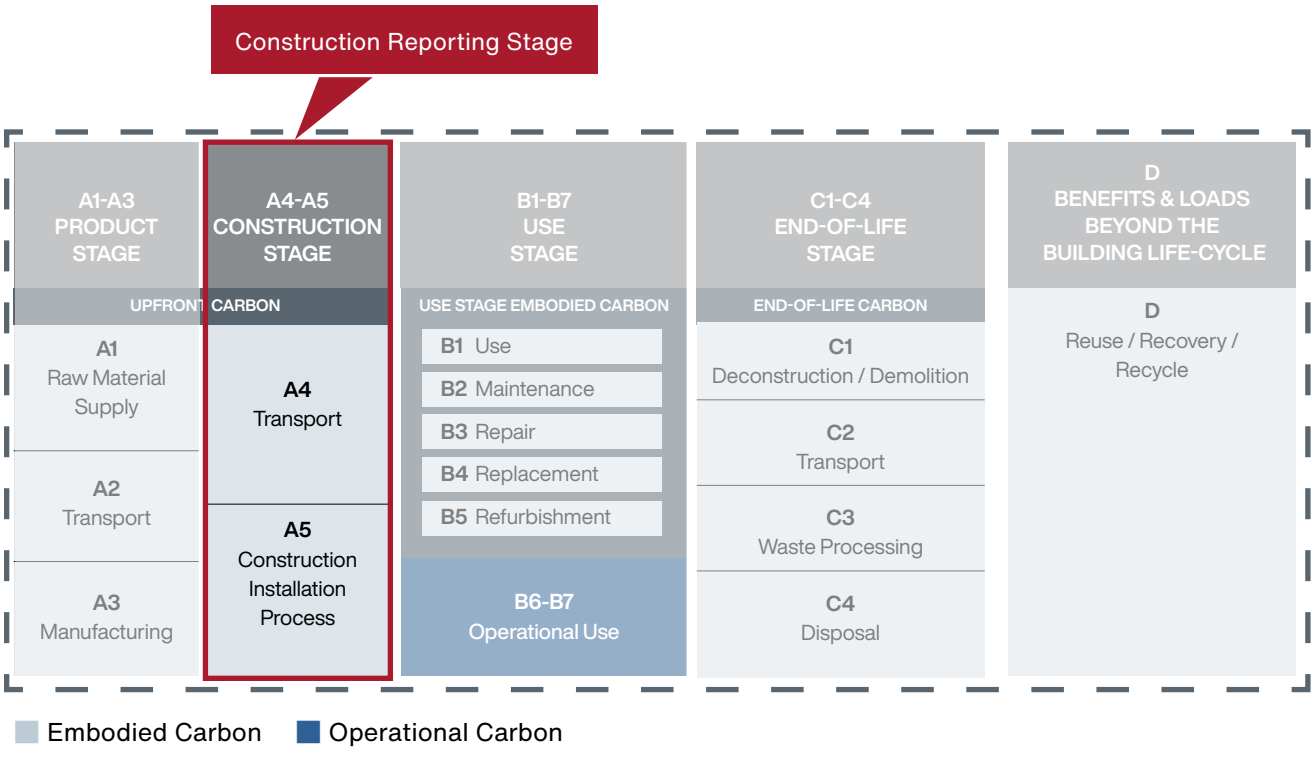
Project Closeout Reporting to Hines Conceptual

Regardless of which method is used, project embodied carbon information should be collected and recorded with Hines Conceptual at project close-out. This data should clearly report three things: the materials incorporated into the design, the method used to quantify the embodied carbon for those materials, and systems integrated into the project. The purpose of this reporting is to allow for internal benchmarking based on real project data, to then better inform future project estimating.

Construction Stage Reporting

For the building life-cycle stages of A4 (transport to the building site) and A5 (construction activity), the procedures for how to measure these emissions are in the early stages of development for most contractors. Transportation fuel use and temporary electrical power consumption are perhaps the easiest to quantify. The $kgCO_2eq$ from other construction-related activities—site demolition and clearing, excavation, temporary works construction (shoring systems crane footings, etc.), material handling, and material waste—all need to be accounted for, but historically have not been regularly tracked. To help facilitate this reporting, when construction activity is to be included in a $kgCO_2eq$ report for a project, the General Contractor should develop a project specific Construction Carbon Plan (CCP), to track embodied and operational carbon emissions. While the General Contractor should direct this process, they should work in partnership with the subcontractors and suppliers. A key purpose of the CCP is to identify key emission sources, have an action plan, and to organize roles and responsibilities for those involved. This tracking will support and expand on information being collected within the Product Stage Method reporting, or for any WBLCA.

WHOLE-BUILDING LIFE-CYCLE



Salesforce Tower | Chicago

"You can't manage what you don't measure."

Construction Carbon Plan (CCP)

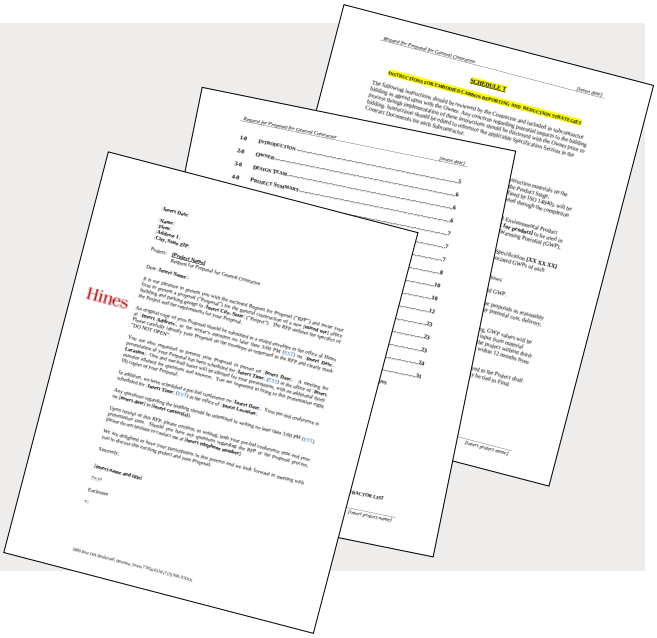
The CCP should begin as soon as a General Contractor is mobilized on the project and it should continue until the certificate of occupancy turn-over of the site. A CCP should emphasize its importance as a "measuring and management tool" that promotes lean construction, material re-use, and waste reduction management throughout the duration of the project. Construction-related embodied and operational carbon reporting for the CCP should be in the units of $kgCO_2eq$ and be reported monthly throughout the duration of project's construction, with a final summary document provided at the end of construction. Tying the monthly reporting of information from subcontractors and suppliers to their pay applications has been shown to be an effective way to ensure the requested information is provided.

Means and Methods Materials Reporting

The CCP should include the carbon emissions estimates for any temporary works materials and equipment consumed through the construction process, following the guidelines outlined within the Product Stage Method, unless such systems are already integrated into the final building design and have been accounted for within the primary building WBLCA modeling.

GENERAL CONTRACTOR REQUEST FOR PROPOSAL

The RFP document for the General Contractor by Hines Conceptual Construction Group has been updated to request voluntary alternates from the Contractor that address transportation to the site and installation processes. This language has specifically been added to address the Construction Stage.



These include:

- Temporary site shoring walls, dewatering systems, and excavation equipment that is not re-used
- Man-lift, tower crane, temporary generators, and similar means and methods temporary works foundation elements, steel bracing, support structures, and connection materials
- Blinding slabs below primary frame structural foundations
- Jobsite trailer supports and frames for all materials that are not re-used
- Formwork and shoring materials consumed over the course of the project
- Material waste due to activities on the jobsite

The CCP should not have to account for the carbon emissions from creation and manufacturing of materials (A1-A3 stages) that are specified within the architectural, primary frame structural, or MEP drawings, which become the final project. However, the design team and contractor should coordinate who is measuring what elements to eliminate double counting and omissions. Temporary works material measuring should target 90% or more of the consumed materials, with up to a 10% allowance added for materials consumed through construction but not explicitly tracked. Managers of the CCP should exercise judgment in the application of any allowances, including documenting where they occur and the allowance values being used.

Anti-Idling Recommendation

The CCP should include language that reduces non-productive engine idling. Automated electronic anti-idling devices to shut down and restart combustion engines are not required, but are encouraged where they do not impede the safe operations of the equipment or vehicle

Fossil Fuel Use Reporting

The CCP should include a consistent monthly reporting of fossil fuel use, which can be broken down between transportation emissions, and fuel emissions on the site. Transportation emissions can be estimated by directly tracking gallons consumed, or the vehicle miles traveled then multiplied by an averaged fuel consumption per mile, for that vehicle.

Reporting should itemize the type of fuel (diesel, gasoline, propane, etc.) for each month and should include the following:

- Delivery vehicles for building materials, tracking from the factory gate to the jobsite (for delivery vehicles associated with multiple project deliveries at a time, only account for the mileage from the last supply house to the job site)
- Each month's fuel use of shuttle buses from parking lots to the job site (if provided by the General Contractor, they should be reported)
- Vehicles and equipment used within the job site that have emissions
- Information collected from the subcontractors and suppliers
- Do not include commuting miles using personal vehicles to the job site
- Include off-site earthwork debris and waste removal from the site to location of final disposal

The General Contractor should provide subcontractors and suppliers with a common reporting spreadsheet that is submitted each month, showing, at a minimum, the following:

- Total round trip miles for each type of vehicle being driven in a month
- The type of vehicle (light-duty truck, medium- or heavy-duty truck, car, barge, rail, etc.)
- Optional/preferred: provide the miles per gallon for each vehicle, if known

Non-transportation fossil fuel use should also be reported monthly and will often include:

- Fossil fuels used during the testing/commission phase, typically through natural gas and diesel to test generators
- Acetylene for on-site steel welding
- Temporary heating by natural gas and propane
- Gallons consumed and/or GPS/run time data for on-site equipment (can often be used for estimating the fossil fuels consumed)

Electrical Use Reporting

The CCP should include a consistent reporting of electrical power meter readings for all on-site activities. This should be tracked and reported on a monthly basis matching the fossil fuel reporting time steps. Keep in mind that when switching from temporary to permanent power, meter locations and data sources will change. It is important to capture the data from both. Translating electricity meter readings to $kgCO_2eq$ can be done by identifying the power grid supplying the project, and using that utilities report of their yearly average $kgCO_2eq$/kwh.

Within the United States, this reporting can be found at:
https://www.epa.gov/egrid

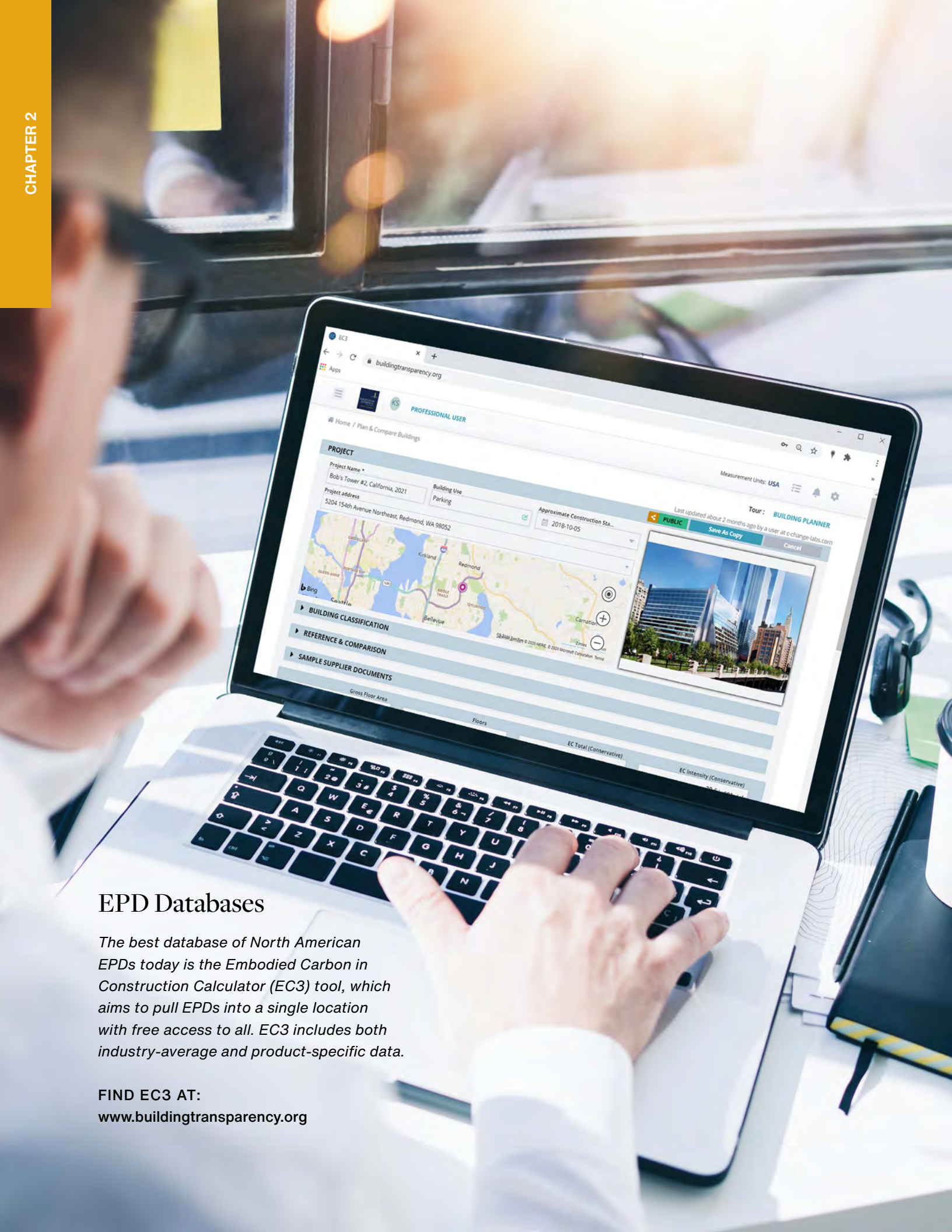
As an alternative to tracking meter readings, the collection and reporting of electrical bills for the project can also be used. Both sources can report a summary of total electricity consumed per month.

Overall, the act of tracking waste and carbon emissions during the Construction Stage emphasizes the importance of conservation and can yield project cost savings and reduced emissions—as once the information if measured it can be managed.

The construction A4-A5 carbon reporting as outlined above is from a combination of inputs from contractor's who's leadership efforts are helping to advance the industry within this space. This has included inputs from Sellen Construction, Skanska, Turner Construction Company, and Webcor Construction.

Power Reduction Recommendation

Where temporary power is available, contractors should connect to that power source instead of generator-supplied power. Temporary Power Units (TPUs) should also have a timed shut-off with manual overrides. Where safety is not compromised, crews should establish shut-off schedules to automatically turn off the lighting 30 minutes after typical working hours end.



EPD Databases

The best database of North American EPDs today is the Embodied Carbon in Construction Calculator (EC3) tool, which aims to pull EPDs into a single location with free access to all. EC3 includes both industry-average and product-specific data.

FIND EC3 AT:
www.buildingtransparency.org

CHAPTER 2

Summary

- There are five stages in a building's life-cycle: Product Stage, Construction Stage, Embodied Use Stage, Operational Use Stage, and End-of-Life Stage
- Whole-Building Life-Cycle Assessments (WBLCAs) or partial assessments that focus on the Product Stage and sometimes the Construction Stage, are common ways to measure embodied carbon
- The Product Stage Method is a simplified alternative to a WBLCA that requires less speculation, but only considers a portion of a building's carbon impact
- Material Quantity x GWP = Product Stage Embodied Carbon
- All primary structural elements should be quantified, including foundations, vertical framing, and horizontal framing, as these often have the largest carbon impact
- There are two types of Environmental Project Declarations (EPDs)—Industry-Average and Product-Specific
- Construction Stage Reporting should track the materials used for means and methods of construction, fossil fuels, and electricity consumed, including the transportation of materials from the factory gate to the job-site

Levit Green | Houston

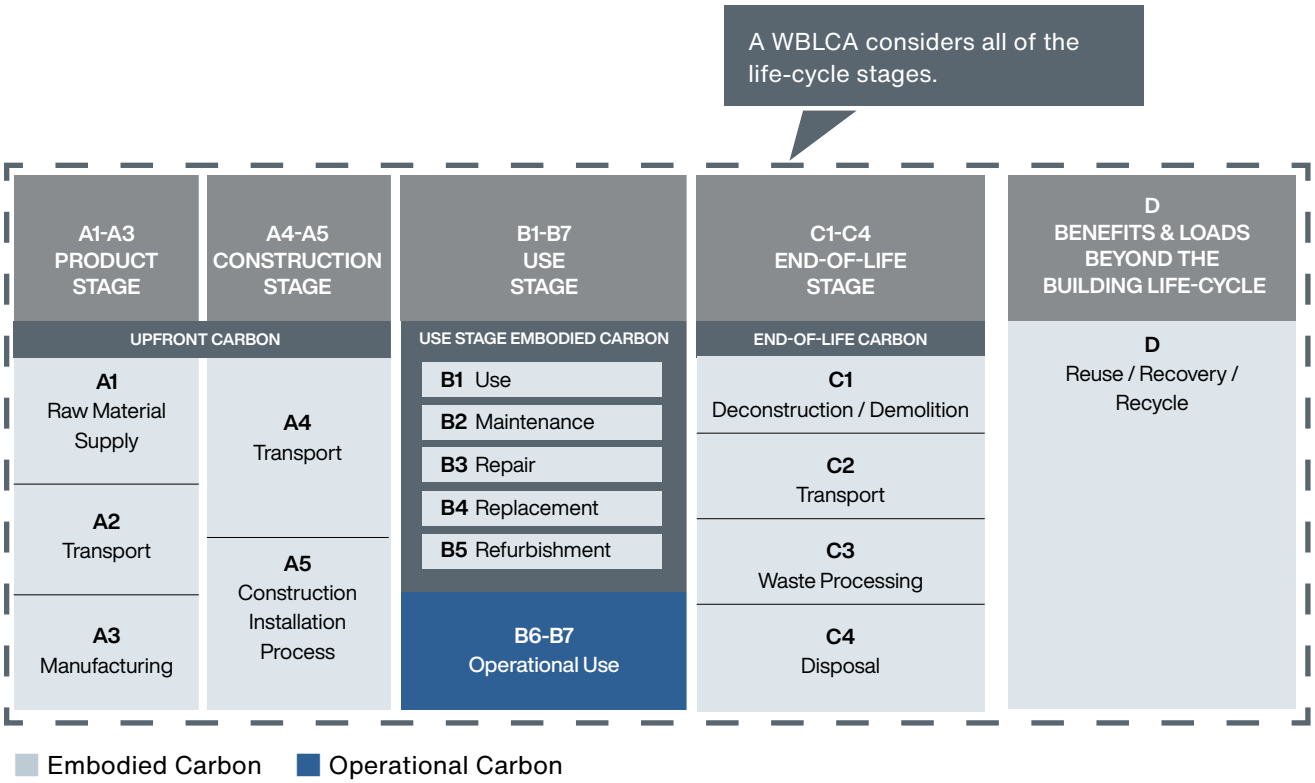
CHAPTER 3

Measuring Carbon: Whole-Building Life-Cycle Assessment

Building off the the Product Stage Method and Construction Stage Reporting discussed in Chapter 2, this chapter expands to carbon accounting for a building's entire life-cycle. A Whole-Building Life-Cycle Assessment (WBLCA) can be used when a project wants to consider more than just upfront carbon.

This chapter explains how to work with the data from the other stages of a WBLCA, providing clarity on when and where it is appropriate to use this information for project decision making.

WHOLE-BUILDING LIFE-CYCLE



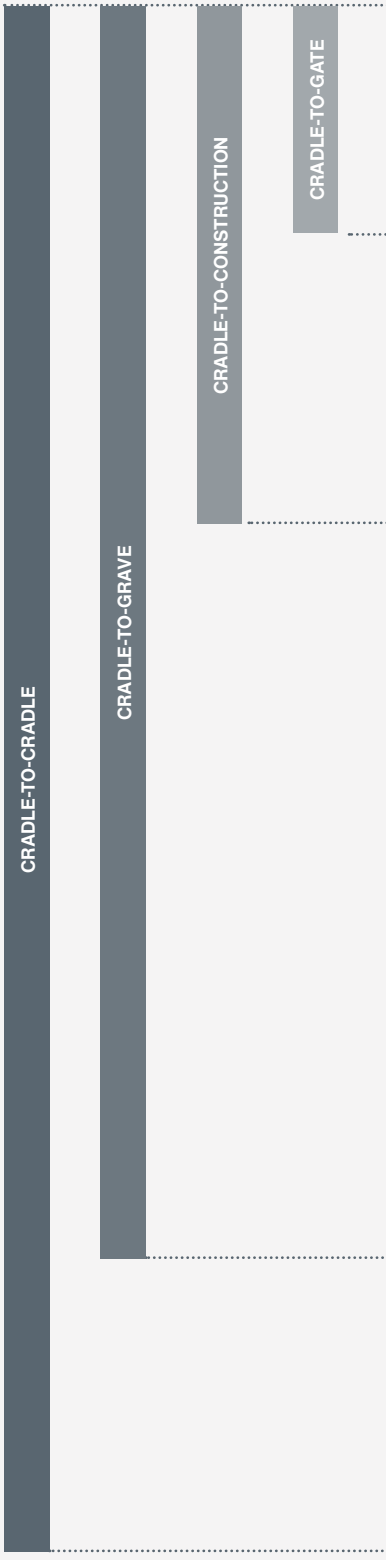
A WBLCA is necessary when combining Embodied and Operational Carbon into decision making, considering the time value of carbon, attempting to compare the carbon implications of a renovation or building new, comparing the carbon implications of dissimilar materials, or attempting to account for the long term carbon impacts of durability and resiliency choices.

A WBLCA attempts to account for all carbon sources present throughout a building's life. While the Product Stage Method boundary considers "**Cradle-to-Gate**" information, and Construction Stage Reporting adds in upfront carbon that extends the boundary to account for **Cradle-to-Construction** information, a WBLCA typically extends to either a **Cradle-to-Grave** (typical) evaluation, or **Cradle-to-Cradle** (less frequent) evaluation. This process quickly becomes complex if it is going to be reliably accurate; so a meaningful WBCLA requires clear and early project definition of its questions and goals.

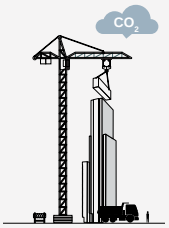
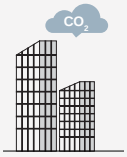
The WBLCA was first used in Europe and standardized by the International Organization for Standardization (ISO) in ISO standards 14040 and 14044.

A project may choose to perform a WBLCA for various reasons. One of the most common is to achieve points for green rating certification. Perhaps the most ubiquitous of these, Leadership in Energy and Environmental Design (LEED) now awards points for performing a WBLCA for a building's structure and enclosure. A point is awarded for performing the WBLCA. Further points are awarded if it can be demonstrated that the building achieved a reduction of 5% or more when compared to a baseline building.

If considering a WBLCA for a project, have a discussion first with Hines Conceptual and then with the design team and sustainability consultant. To make the conversation productive, start by clearly identifying the questions or comparisons that a WBLCA should answer. With this group, assess the cost and schedule implications of the WBLCA, the timing of information becoming available, and the quality of the data needed for credible decision making.



Building Life-Cycle Stages

STAGE (MODULE)	DESCRIPTION	QUANTIFICATION	EXAMPLE
PRODUCT (A1-A3) 	Emissions result from raw material extraction, transportation of these materials, and their manufacture into building components; occurs prior to start of construction	A1-A3: Environmental Product Declarations (EPDs)	Mining of stone from quarry, crushing stone into aggregate, transportation of aggregate to ready-mixed plant, combination with other products to create concrete
CONSTRUCTION (A4-A5) 	Emissions result from transportation from manufacturing plant to construction site and construction-related processes; occurs prior to start of building operations	A4: Measuring miles driven and associated fuel source A5: Difficult to quantify due to multifaceted nature; monitoring utility consumption at construction site is one example	Transportation from elevator assembly factory to construction site and the installation of the elevator unit Account for basement shoring and excavation means and methods
EMBODIED USE (B1-B5) 	Emissions result from building operations, unrelated to water and energy consumption; occurs over operational span of the building	B1-B3: Difficult to quantify, assumptions required B4-B5: Similar to Product Stage, with assumptions for frequency of replacement required	Replacement of a curtainwall panel after damage from adjacent construction site
OPERATIONAL USE (B6-B7) 	Emissions result from building operations related to energy and water consumption, including both direct and indirect fuel sources; occurs over operational span of the building	B6: Energy modeling B7: Water use modeling	Energy consumed to heat an apartment unit
END-OF-LIFE (C1-C4) 	Emissions result from building decommissioning, including demolition and transportation of waste; occurs at end of building life span	C1-C4: Difficult to quantify due to multifaceted nature, assumptions required	Demolition of the shell and core of a building to allow for future construction, transportation of demolition waste to a waste facility, processing of this waste, and its ultimate disposal
CONSIDERATIONS OUTSIDE OF THE SYSTEM BOUNDARY (D) 	Emissions result from processes beyond the building scope, such as recycling or timber sequestration; typically of building life span	D: Difficult to quantify due to multifaceted nature, assumptions required; quantification is still debated and data compatibility can be a challenge	Processing of demolished concrete to create recycled aggregate for reuse in concrete occurs at beginning or end Consideration of biogenic carbon from wood and other bio-based materials

CHAPTER 3

WBLCA: Strengths and Weaknesses

Consider these strengths and weaknesses when deciding if a WBLCA is appropriate for a project:

Strengths

» Informs Early Decision-Making | Designers may use a WBLCA to evaluate the embodied and operational carbon trade-offs between one type of product or system against another that serves the same function.

» Allows for Dislike-Material Comparisons | To holistically compare building systems, a WBLCA can be used to consider all materials associated with each option and their impacts to the various life-cycle stages.

» Considers All Components of a Building | WBLCA allows decision-makers to view the "whole picture" across multiple disciplines, focusing on the building in its entirety rather than any single component.

Weaknesses

» Utilizes More Complex Modeling Tools | To create an accurate and detailed WBLCA, a more detailed process is involved that can require the use of multiple tools, which may not always be compatible, and input from multiple disciplines.

» Includes Speculation | Since a WBLCA incorporates future stages, data collected outside of the Product and Operational Use stages requires speculation, which affects the confidence of the results.

» Relies on Uncertainty | The WBLCA should quantify the uncertainty within its findings and make clear where credible conclusions can or cannot be drawn

» Requires Understanding of Current Limitations | A comprehensive WBLCA is not a trivial effort. Today's WBLCA tools are works in progress, data that is not regularly tracked, and uncertanties that are rarely reported for assessing data quality. Current reports are often only partial WBLCAs, which are still very useful, but require an understanding of the data quality and what is and is not within the findings presented.

WBLCAs are a quickly evolving science. Pursuing a WBLCA will get easier with time, especially as more reliable data becomes available and analysis tools improve. It is a Hines goal to help lead the building industry forward in the evolution of WBLCA, making them easier, more timely, and more actionable. However, this aspiration needs to be thoughtfully considered on a project-by-project basis especially regarding the local industry practices and the material supply chain's ability to provide responses to the questions that WBLCAs raise.

Questions Answered with a WBLCA

When working with a designer or consultant to perform the WBLCA, consider the following questions:

» Has the goal of performing the WBLCA been clearly identified?

Examples:

- LEED certification
- Deciding between renovation or new build construction options
- Deciding between exterior wall systems and comparing the embodied and operational carbon impacts of each choice over the life of the project
- Tracking whole building embodied carbon from Schematic Design through construction

» Has the consultant performing the WBLCA coordinated with the design team to verify WBLCA assumptions and inputs?

Examples:

- Architectural verification of insulation thickness or R-value
- Structural verification of concrete reinforcement density per application
- MEP verification of HVAC equipment energy consumption

» Has the appropriate life spans for different building systems been selected for analysis?

Example:

- Typical WBLCA evaluation durations per green building rating systems is 60 years

» Have the appropriate building components, based on project goals, been included in the WBLCA analysis?

Example:

- Building structure and enclosure for LEED certification

Further questions will be appropriate based on project-specific needs. To ensure validity of the results, it is suggested that a WBLCA kick-off meeting is held prior to performing the WBLCA with all pertinent stakeholders to allow for project team collaboration and alignment.

Comparison of WBLCA Tools

Which WBLCA Tool Should Be Used?

Various tools are available to assist designers in performing WBLCAs. The below table compares the two most commonly used WBLCA tools in North America. Determining which tool to use is often based on preference of the consultant performing the WBLCA. Once a tool is selected for the first WBLCA model run, stay with the same tool for the duration of WBLCA evaluations on the project.

	TALLY (choosetally.com)	ONE CLICK LCA (oneclicklca.com)
SOFTWARE TYPE	Revit plug-in	Stand-alone or Revit plug in
APPLICABLE REGION	North America	North America, Europe, Middle East, Pacific Asia, and South America
SOURCE OF QUANTITY INFORMATION	Revit model (manual entry not possible), with descriptive data applied to Revit components (ex: concrete reinforcement)	BIM model (including Revit and SketchUp), Excel, or manual entry
EASE OF MANIPULATION	Changes must be made through Revit and re-imported into Tally, or data must be adjusted in an excel file, after findings are exported out of Tally	Data may be modified within software, without re-importing from BIM
ABILITY TO COMPARE DESIGNS	With Revit Design Options only	Within software
SOURCE OF GWP DATA	GaBi Life-Cycle Inventory (LCI) database developed by thinkstep	OneClick database, augmented with custom database, product-specific EPDs
CERTIFICATION ELIGIBILITY	LEED, ILFI, Green Globes	LEED, ILFI, BREEAM

Basis of Analysis

One of the most important parts of a WBLCA is to identify the goals and boundary conditions of the assessment as early as possible, confirming the questions the WBLCA is trying to answer. This is done by writing a Basis of Analysis (BOA), which establishes assumptions and WBLCA boundary conditions. This is an opportunity to educate both the ownership stakeholders and the design and construction teams, to ensure all members understand what a WBLCA is trying to accomplish.

A mistake often seen in a WBLCA is that the consultant performing the study will make assumptions on behalf of the owner based upon defaults within the WBLCA tool, or based upon their limited understanding of the full building they are modeling. It is important that ownership be engaged to set the default assumptions and the implications of those assumptions. The BOA is an opportunity for the ownership to ask questions and discuss and document assumptions, and their implications, prior to the WBLCA moving forward. Every Hines WBLCA should start with a BOA.

BOA assumptions not defined in detail within this chapter, but important to Hines should include B1-B7 Use Phase reporting. C1-C4 End of Life phase recycling, and D Beyond System Boundary considerations, such as up-stream forest and biogenic carbon reporting from wood. These phases are evolving topics and the ability to collect data for each should be considered on a project by project basis. The key to the BOA is that assumptions be documented with ownership input before the WBLCA occurs.

Details of a Basis of Analysis

Project Description

Every BOA should start with a project rendering, a site location definition, and a program and area description. This is to make it clear what building is being considered within the WBLCA. For multi-phase projects, it allows for clarity around what parts of the development are in or out of the analysis.

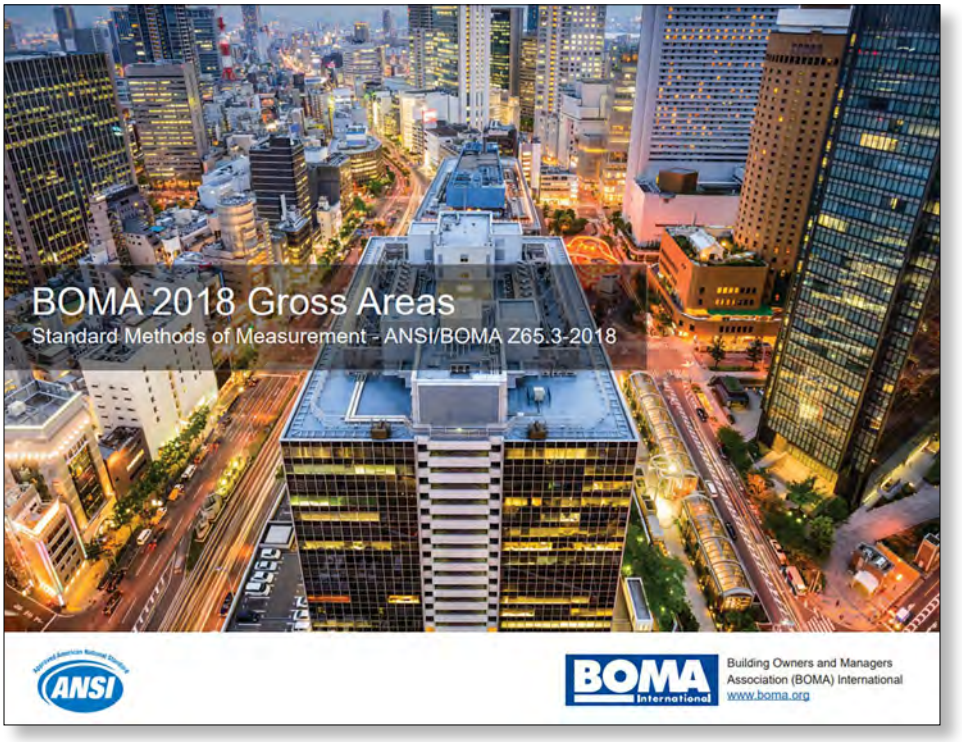
Units of Measure

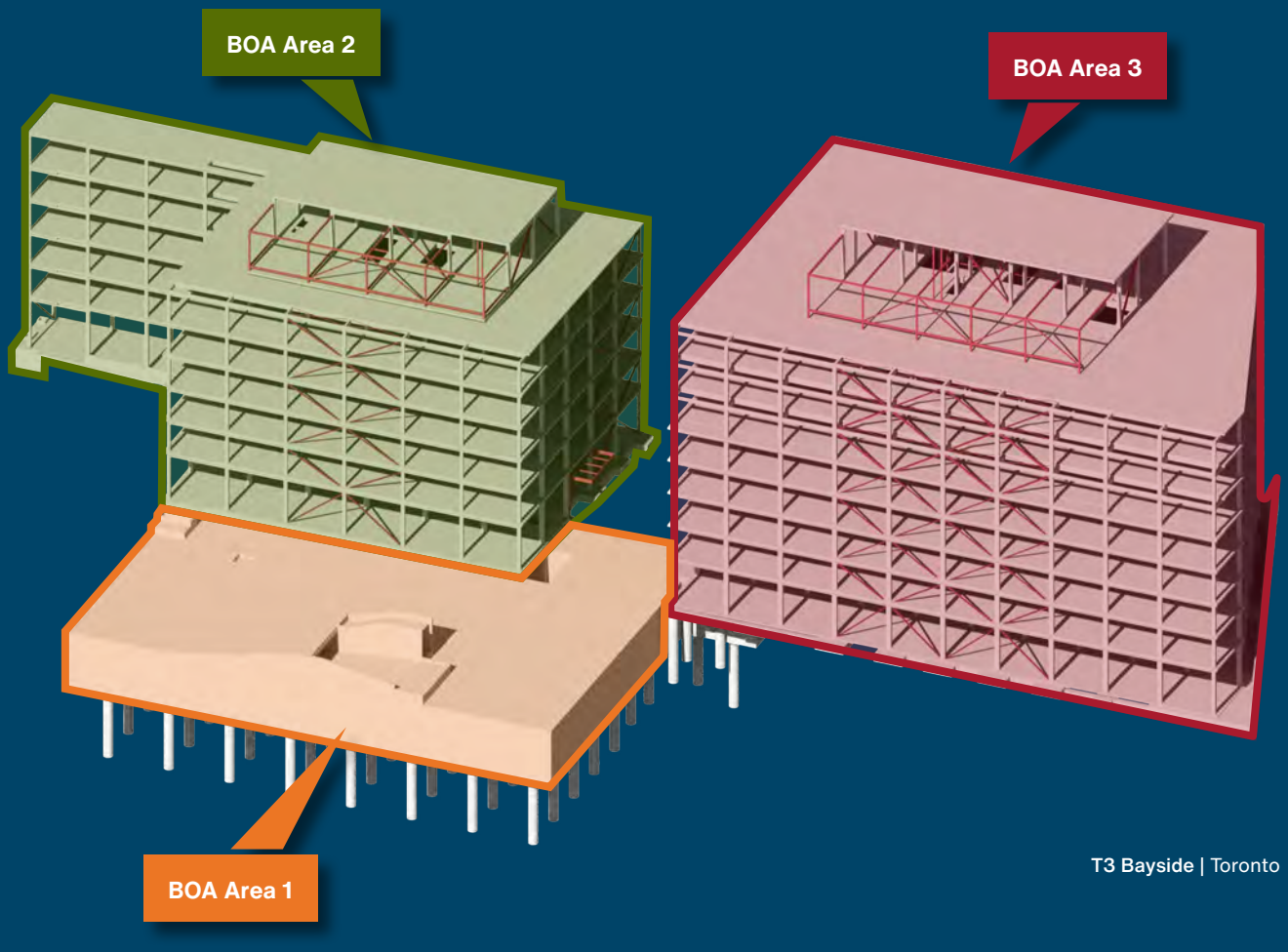
As a Hines standard for all WBLCAs performed, all GWP data reporting should be in the metric units of $kgCO_2eq$, and final WBLCA reporting should be in $kgCO_2eq/m^2$. The assumed areas within a summary calculation should be the total gross built floor area, including roofs, decks, parking, columns, and walls, but excluding shafts. The 2018 BOMA Standard for Gross Area 4 (Construction Method) provides further details for this area definition.

Each Hines platform will have a different breakout of how parking and amenity areas are tracked. Final reported data should follow each platform's standard for the detailed breakout of area summaries and groupings of sub-data sets, with full summary reporting as noted here.

CONSISTENT FOR ALL WBLCAS

$kgCO_2eq/m^2$





T3 Bayside | Toronto

Timeline: Residual Value and End of Life

Estimating Until and After WBLCA Boundary Condition

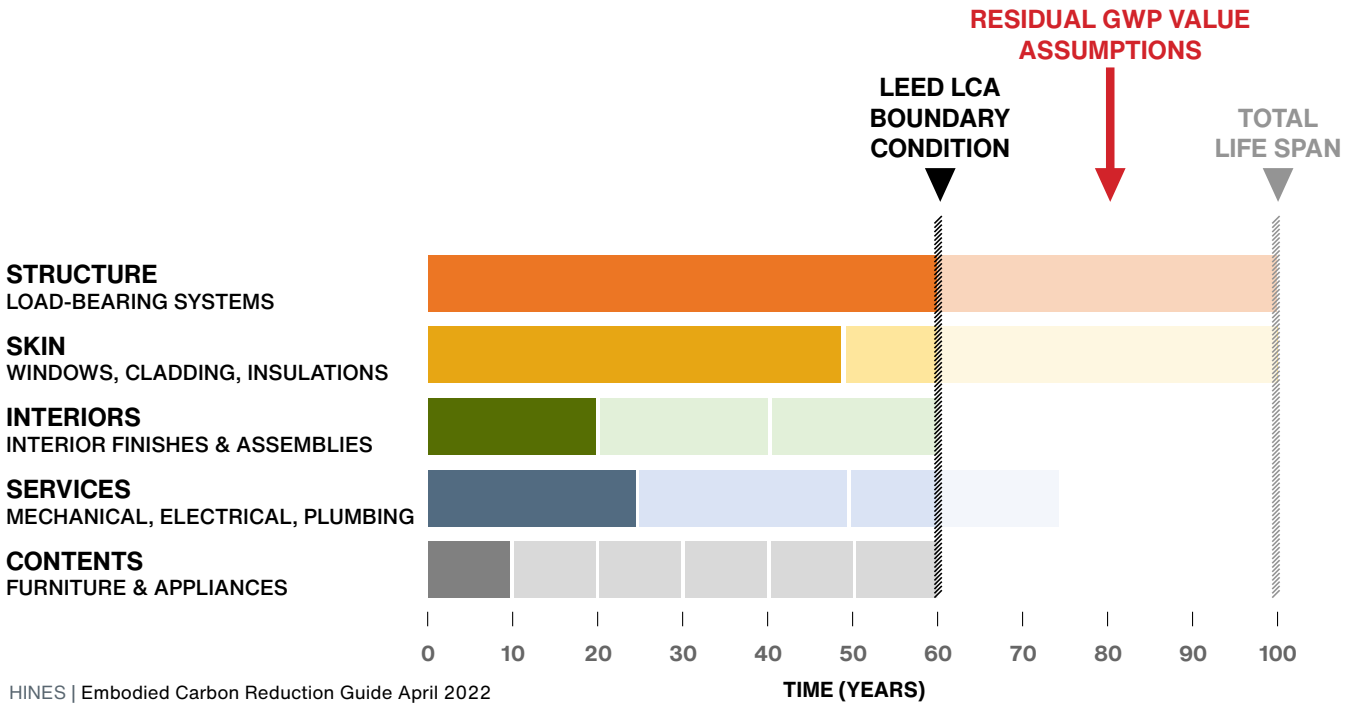
Documenting the longevity of different building components before expected replacement is important. Having the WBLCA accurately reflect these longevity assumptions reveals where higher quality and longer lasting systems are the lower carbon alternative.

Residual value and end-of-life assumptions that may extend beyond the boundary condition of the WBLCA are also important. For LEED points, most WBLCAs consider a 60-year duration; however, the structure and other building components, depending upon their replacement rate, may have a life span that continues past 60 years.

To calculate the GWP for any one system, as well as any remaining residual value and end-of-life assumptions, for inclusion within the WBLCA, the guide recommends component service life and a linear depreciation approach by taking the building component calculated GWP, dividing it by the number of years determined for that component's service end of life, then multiplying by the duration of the WBLCA. In this way, component GWPs can be normalized and comparatively evaluated. This also helps establish a rational end of life assumption that accounts for those systems that may stay in service past the WBLCA boundary condition.

This approach to WBLCA modeling is consistent with the 2021 published work by Joensuu for assessing the carbon footprint of reusable building components (see reference #8 in the appendix).

RESIDUAL VALUE AT WBLCA BOUNDARY CONDITION



There is a valid argument that carbon expended today is more important than carbon later in a buildings life. But the calculations to account for an exponential decline of carbon over time are not agreed upon or consistently applied within WBLCA's today. Until there is better industry agreement on how to address this topic. Use the linear depreciation simplification unless a more detailed time value of carbon calculation is brought forth by the project's WBLCA consultant, and is agreed to within the BOA.

Residual GWP Value Calculation:

CALCULATION:
(Building Component GWP / Component Service Life) x LCA Boundary Condition

Structure Example:

Assume 300 $kgCO_2eq$ (A1-A5 reported) GWP, with a 100-year structural frame life and a 60-year WBLCA

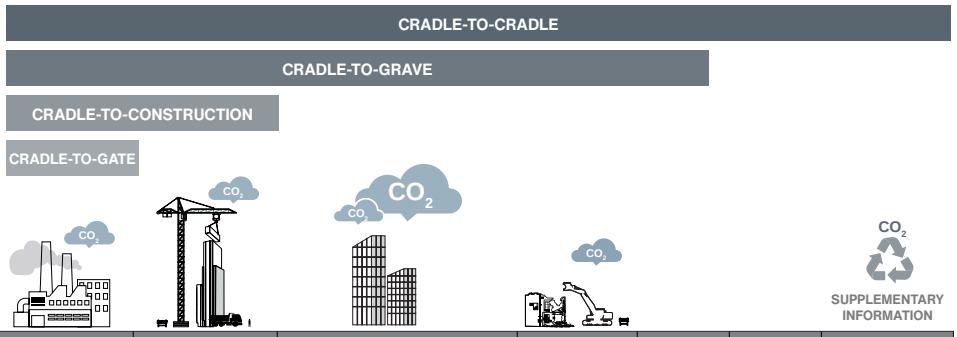
CALCULATION:	NOTES:
(300 $kgCO_2eq$ / 100 years) x 60 years = 180 $kgCO_2eq$	GWP within WBLCA calculation
300 - 180 $kgCO_2eq$ = 120 $kgCO_2eq$	GWP outside of WBLCA boundary, residual value remaining

Services Example:

Assume 20 $kgCO_2eq$ (A1-A5 reported) GWP, with a 25-year MEP services life and a 60-year WBLCA

CALCULATION:	NOTES:
(20 $kgCO_2eq$ / 25 years) x 60 years = 48 $kgCO_2eq$	GWP within WBLCA calculation
(3 x 20 $kgCO_2eq$) - 48 $kgCO_2eq$ = 12 $kgCO_2eq$	GWP outside of WBLCA boundary, residual value remaining

WBLCA — MEASURE AND ASSUMPTIONS SUMMARY REPORTING STANDARD



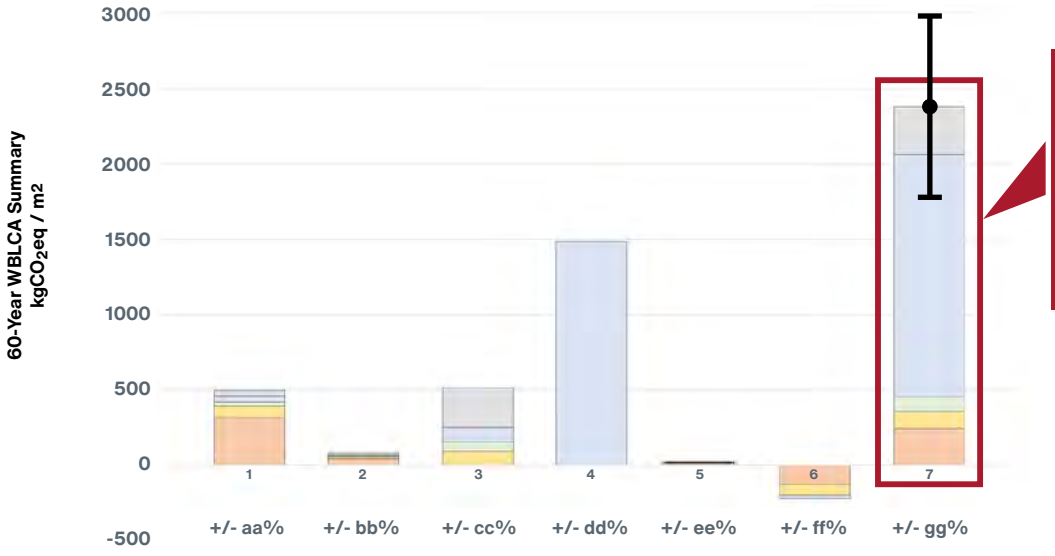
WBLCA BOUNDARY = 60 YEARS	SERVICE LIFE	PRODUCT STAGE	CONSTRUCTION STAGE	USE STAGE		END-OF-LIFE STAGE	RESIDUAL VALUE ADJUST-MENT	WBLCA BOUNDARY SUMMARY	BENEFITS & LOADS BEYOND THE BUILDING LIFE CYCLE
LCA Phase:		A1-A3	A4-A5	B1-B5	B6-B7	C	(After 60 Years)	Emissions	Beyond Life
Carbon Type:	Years	Embodied	Embodied	Embodied	Operational	Embodied	Total	Total	—
STRUCTURE LOAD-BEARING SYSTEMS	100	315	43.2	1.2		10.9	-126	244.3	
SKIN WINDOWS, CLADDING, INSULATIONS	50	77.2	13	90.2		4.1	-72.16	112.34	
INTERIORS INTERIOR FINISHES & ASSEMBLIES	20	27.3	4.5	63.6		1.8	0	97.2	
SERVICES MECHANICAL, ELECTRICAL, PLUMBING	25	39.2	8.5	95.4	1484	4.3	-23.52	1607.88	
CONTENTS FURNITURE & APPLIANCES	10	39.6	13	263		2.6	0	318.2	
BUILDING CARBON EMISSIONS		498.3	82.2	513.4	1484	23.7	-221.68	2379.92	

LEGEND

(TYPICAL FOR ALL COLORS):

- **MEASURED** (DARKER CELL)
- **INDUSTRY AVERAGE ESTIMATE**
- **PROJECT ESTIMATED**
- **NOT MEASURED**

Clearly identify and report within each WBLCA evaluation what is Measured / Estimated / Not Measured.



Totaled WBLCA findings from each model run should be tracked and recorded over time within a **WBLCA Summary.**

Summary of findings from WBLCA evaluation above, showing both data within the WBLCA table and within a bar chart, with the range of possible outcomes (uncertainty + variability) being estimated at each bar. These +/- values should be SRSS combined considering their weighted value, totaled, and reported within the whisker bars added to the bar chart.

WBLCA

Measure and Assumptions

This color-coded WBLCA table creates a visual cue to the quality of the data provided with in a specific WBLCA model evaluation. Color density should change at each stage of analysis to make it easy to understand what is being measured, what is being estimated, and what is not being included within that analysis.

End-of-life assumptions should be handled on a project-by-project basis and documented within the BOA. These may include:

» Cradle-to-cradle thinking (WBLCAs that consider Module D: “Beyond Life”)

» System re-use

» Designing for deconstruction

» Intentional consideration of what materials go to the landfill vs. what materials are recycled or upcycled

Cradle-to-cradle thinking, (Module D: Beyond Life assumptions) may be included within any project WBLCA, provided these ideals are fully thought through and considered within a baseline design.

The WBLCA data within the table should also be summarized and shown within a bar chart below the table, to visually highlight the relative impacts of the different WBLCA stages. The range of possible outcomes (uncertainty + variability) within the data should also be reported at each project stage, and within the total summaries, shown with whisker bars.

When a WBLCA is performed, this table and bar chart graph should be included as the summary of every evaluation. This table clearly and visually identifies what is and is not included within the WBLCA. Directly measured information will have the least uncertainty, compared to project-specific assumptions, industry place holders, or information not considered.

Estimating – Uncertainty and Variability

Understanding and assessing the range of potential outcomes within the data presented in a WBLCA is important to making reliable project decisions. Sources of imprecision come from the "unknowns" in the underlying data (e.g., the actual emissions from a manufacturing process or the material quantity estimates before a design is complete) in addition to the known variability (e.g. use of average data that represents a range of possible manufacturing processes).

Ideally, the 20% to 80% range of the data under consideration should be reported. Extreme outlier data points within a material's reporting can be ignored, but the goal is for data evaluations to estimate this range of potential outcomes, and to then show this range within the final findings at any WBLCA evaluation time step.

At present, the range of potential outcomes within WBLCAs is often under reported or omitted from report summaries. This is due to the difficulty in assessing data quality, and an often reluctance to highlight information that might undermine the perceived quality or conclusions of a report. However, reporting the range of potential outcomes is key to interpreting the finding of a WBLCA to make best-value decisions—excluding this information undermines the integrity of the process.

Reducing uncertainty is best done through alignment and improvement of Life Cycle Inventory (LCI) datasets that are behind WBLCA reporting, a consistent use of the same LCI datasets when industry average data is being used, and from refinements in the material quantity estimates that happen over the course of a design.

Variability and uncertainty will typically reduce significantly when the material supply chain of the project becomes known, material quantities are finalized and vendors are selected. This is when moving from industry average data during design to vendor-specific, third party-verified EPDs should also happen.

ISO 21970:2017: provides some guidance on how the range of potential outcomes should be addressed within WBLCAs and EPD data reporting, including a requirement stating that "the information provided for any comparison shall be transparent to allow a clear understanding of the limitations of comparability."

How to Measure The Range of Potential Outcomes

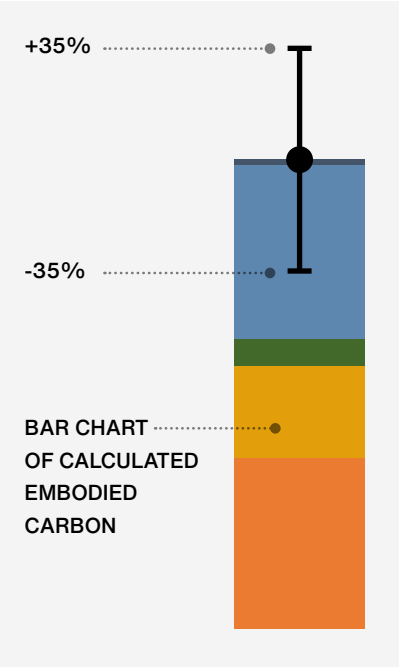
Many embodied carbon modeling tools provide a measure of uncertainty reporting for the carbon data within them, for example:

» OneClick - Reports a "meta-data" uncertainty factor for each material $kgCO_2eq$ used.

» EC3 Tool - Reports an uncertainty for each EPD embedded within its open-access database, including both industry average and vendor-specific EPD uncertainty reporting.

» CLF's Materials Baseline Report v2 - Provides a low, median, and high value for each reported material for North American industry average material $kgCO_2eq$ values. The difference between their reported low and high values represents a +/- range of potential outcomes, based upon a 20% and 80% range. (See Appendix B: Hines Standard GWP Values for North America.)

REPORTING DATA RANGES



Calculating data uncertainty can be a complex topic. When higher-level LCA expertise is available within a WBLCA effort, a more refined consideration of data uncertainty leading to better estimating and data understanding should be encouraged. At a minimum, for all Hines WBLCAs, consultant reports should estimate and disclose two levels of data uncertainty and variability, as extracted from within the WBLCA tool being utilized, as estimated within the Hines Appendix for industry average data sets, and as estimated by the consultant team or contractor for material quantity estimates.

1) Material Quantity Estimating: +/- %
2) Material $kgCO_2eq$ Estimating: +/- %

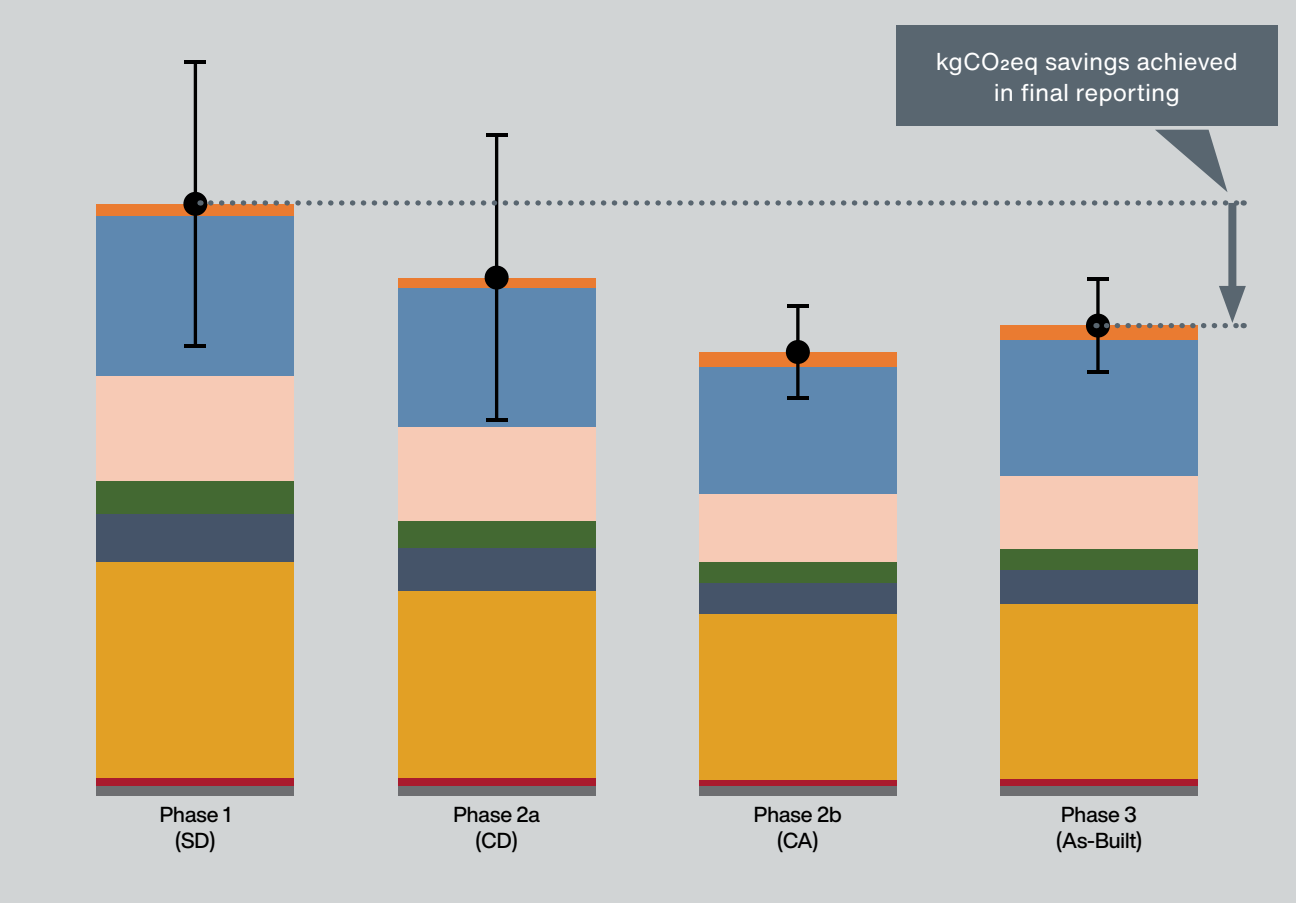
The reported data ranges per material should be combined utilizing a square root sum of squares (SRSS) method, producing ± overall ranges for that dataset.

$$\textbf{Data Range} = +/-\sqrt{(\text{quantity range})^2 + (kgCO_2eq\ \text{range})^2}$$

Once a material's range of potential outcomes is assessed = +X%/–Y%," the bounds of reasonable confidence for that range can be shown. This is ideally communicated with a whisker bar reporting on a bar chart for the $kgCO_2eq$ summary from the WBLCA.

CALCULATION:
Calculated embodied carbon is = 100 $kgCO_2eq$, and $kgCO_2eq$ 20% to 80% data range = +35%/–35%,
Bottom of Whisker Bar = 100 – (0.35*100) = 65 $kgCO_2eq$
Top of Whisker Bar = 100 + (0.35*100) = 135 $kgCO_2eq$

CONCEPT DESIGN THROUGH AS-BUILT REPORTING CHART



Concept Design Through As-Built Reporting

Idealized Reporting with Time During a Project

When a WBLCA is performed at each of the project milestone phases described, a summary of each of those evaluations can be created to show the impact of project choices over time.

This allows for a clear reporting of total project GWP savings against the Schematic Design project baseline. It also shows how the data range of possible outcomes are improved.

Note that design quantity estimates typically will not include or allow for a waste factor that occurs during construction for consumed materials. For example, it's not uncommon for the amount of drywall ordered to be 30% more than what is measured on the architectural drawings. This is one of the reasons the Phase 3 (As-Built) GWP values will often be higher than the Phase 2b (CA) measurements.

As-built findings should be reported to Hines Conceptual, and that is maintained for each Hines Platform, similar to project quantity and cost data.

When To Measure

When a WBLCA is used over the course of a project, a minimum of the four phases of reviews below should be considered. Additional milestone reviews may also happen, such as an additional review at a Design Development stage to monitor progress. That should be considered on a project-by-project basis.

Phase 1: Schematic Design

A comprehensive Schematic Design WBLCA model, using project estimates and assumptions, should be created to establish a baseline model. Later stage analysis will be referenced against this model to track changes. The BOA is most critical to capture the details that establish this baseline model.

Phase 2a: Construction Documents

At Construction Documents, update the WBLCA model from Phase 1 to include value engineering and refined material quantities and system evolution. This WBLCA may include BIM model estimating, where the Phase 1 WBLCA will often occur prior to a BIM model being available. In either scenario, consistency is important. Carefully account for all materials, not just those modeled within a BIM model, for later stage evaluations to be comparable. This evaluation should be when the majority of the building shell and core design can be measured, but it precedes availability of vendor-specific EPDs for the majority of the building materials and systems; therefore, evaluations should still use industry-average GWP data.

Phase 2b: Construction

At the start of Construction Administration, after suppliers are known and vendor-specific EPDs are available, update the WBLCA model to show the savings achieved through double-bottom-line-procurement decision making.

Phase 3: As-Built

At the end of Construction Administration, as-built documentation of quantities and vendor-specific EPDs should be reported. The Contractor should collect all final quantity and EPD information and make them available for a final documentation within the WBLCA model.

Limited WBLCA Studies

Early Phase 1 limited WBLCA modeling can also be used to assess project options. These comparative models may be less refined than the Phase 1 baseline model, but only when the baseline model has not yet been established. The best available information should always be used when performing any WBLCA.

Phase 1 limited WBLCA needs to include only the information needed to make them reliable. Evaluation uncertainties should be estimated and noted and only similar variables should be considered. Consultants may have difficulty including a range of possible outcome estimates since not all WBLCA software easily identifies this information. Early and partial WBLCA efforts also include limited data. Despite these limitations, requiring the range of possible outcomes to be estimated helps assess uncertainty and is a good way determine the confidence of the findings being provided.

EARLY PHASE 1 LIMITED WBLCA EVALUATION
EXISTING BUILDING VS RETROFIT VS BUILDING NEW GWP EVALUATION

Example 1 (shown above):

https://carbonleadershipforum.org/care-estimator (Carbon Avoided Retrofit Estimator)

Example 2:

https://epic-documentation.gitbook.io/epic/

PG&E Headquarters Redevelopment and Seismic Retrofit | San Francisco

WBLCA Findings

A WBLCA model will include more speculation than a Product Stage Method analysis, but it also allows the design and construction team to account for full GWP impacts of decisions made throughout a project's life-cycle.

A comprehensive WBLCA continues to be an evolving process. Much of the data sought is not regularly tracked, and the data uncertainty is rarely reported. Although comprehensive information is limited, it is still useful information but a critical evaluation of the findings is important. When reviewing a WBLCA report, assessing what is, and is not being reported, and the quality of the data that is informing a project's decision making is critical.

Most WBLCAs today will not directly measure all of the areas of the WBLCA tables and graphics shown within this chapter. They will often either report partial information, or they will rely on WBLCA tool default settings, which may not be reflective of the targeted project or location. Best quality information will typically come from the WBLCA stages of A1-A3 Product Stage and possibly from the A4-A5 Transportation and Construction stages. Asking for a reporting of data as presented within the graphics shown within this chapter will help ensure meaningful and understandable findings.

When the range of possible outcomes whisker bars within a bar chart reporting of GWP information are provided, overlap between comparative choices is an indication of when that WBLCA may not be an appropriate analysis to justify a decision. However, it can be very useful in identifying probable outcomes, pinpointing where for better data clarity is needed, and if it is worth the financial and time expenditures to do so. It also informs where to push future WBLCA efforts.

Bringing rigor, clarity to this process, and advancing the quality and frequency of a WBLCA Tools is a Hines leadership goal. As WBLCA tools evolve, many of the ideas presented within this chapter will be reported directly. Until that time, it is likely a WBLCA consultant will need to post-process data findings in order to put them into the formats shown. This is encouraged for both an easier understanding of what is being reported, and for consistency for Hines internal tracking efforts and future comparisons.

As the WBLCA process evolves and as specific project challenges come up, reaching out to Hines Conceptual for clarifications and input on questions is encouraged.

CHAPTER 3

Summary

- Whole Building Life Cycle Analysis (WBLCA) should start with a Basis of Analysis, documenting variables and assumptions
- One Click and Tally are two of the most prominently used WBLCA tools today
- Cradle to Gate, Cradle to Construction, Cradle to Grave, and Cradle to Cradle evaluations all happen today — only the second two of these are a WBLCA
- WBLCA involves a different approach to the time value of carbon
- Residual carbon value calculations should be included in any WBLCA for addressing system service lifes past the WBLCA time boundary condition
- WBLCA is how embodied and operational carbon can be combined
- Range of Possible Outcomes should be reported within WBLCA summary findings
- Concept Design through As-Built reporting should include a minimum of (4) WBLCA model runs, to document both the project baseline, and $kgCO_2eq$ adjustments with time
- Limited WBLCA evaluations are good for early comparative project decision making

HEKLA | Paris-La Défense

CHAPTER 4

Reducing Embodied Carbon

Reducing embodied carbon requires input and effort from various project team members throughout all phases of design and construction. There is no universal method for reduction, but rather a combination of potential options unique to each project.

Chapters 2 and 3 outline measuring processes that can be utilized on all projects across all building components. This chapter focuses on carbon reduction strategies in the A1-A3 module, given that the material decisions made within these stages can have large impacts on carbon reduction with the fewest variables. Further valuable building phase reductions, will be advanced in future editions of this guide.

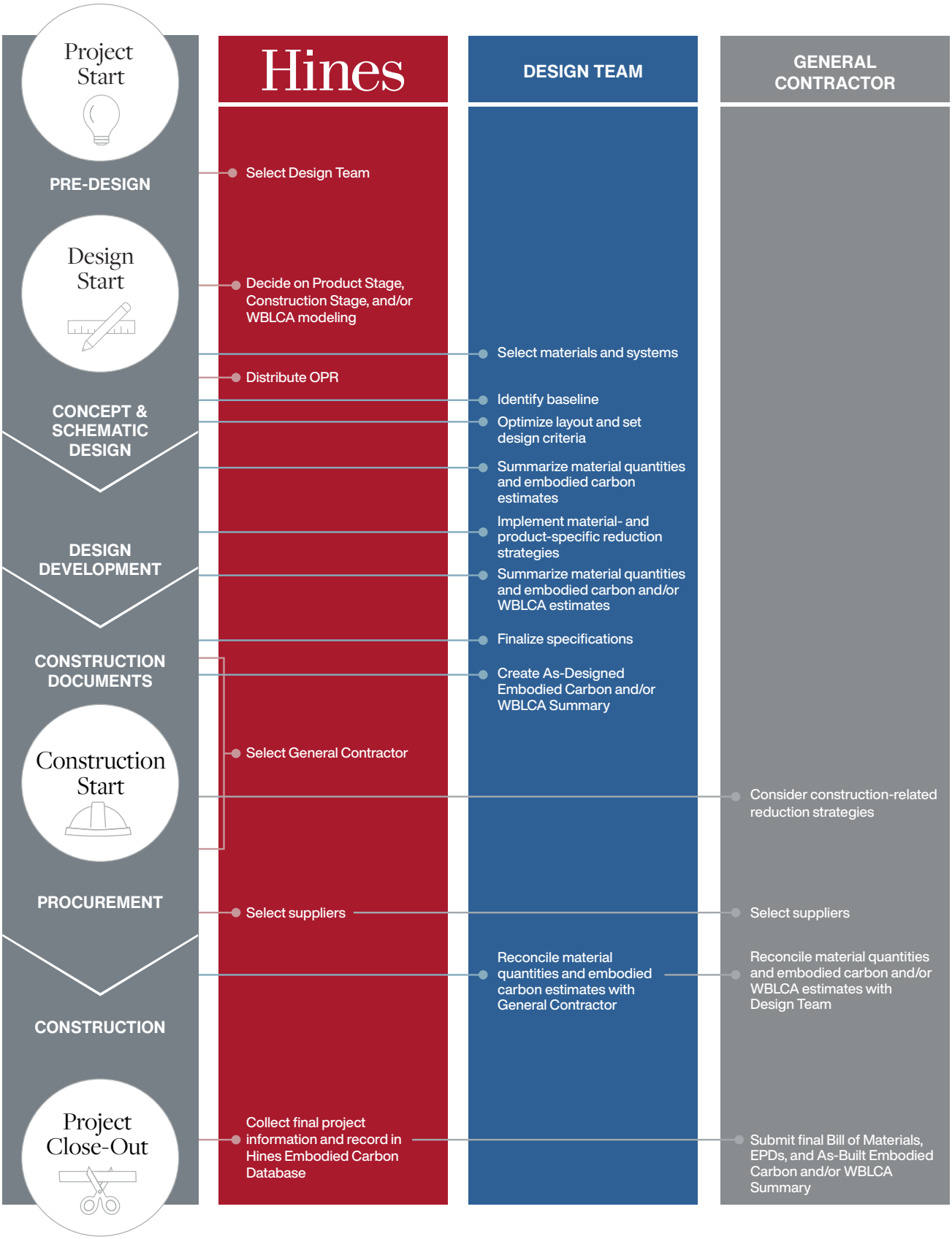
Pre-Design

A critical first step for Hines is the selection of the design team. At minimum, chosen consultants should show a willingness to participate in carbon reduction strategies. Ideally, design team members show enthusiasm for the topic and have past leadership experience.

The primary consultants that can most effectively contribute to reducing embodied carbon are the Architect and the Structural Engineer. Additionally, a Sustainability Consultant may be engaged to assist designers with holistic strategies. Given the lack of available embodied carbon data for mechanical/electrical/plumbing systems today, MEP Consultants should be challenged to consider embodied carbon impacts within their designs, but may have a bigger effect on reducing operational carbon at this time.

As discussed in Chapter 2, quantities can be gathered for any building component that Hines wishes to assess for embodied carbon. Since the primary structural system is often the largest portion of a building's impact, Hines should consider structural elements at a minimum for carbon reduction.

Embodied Carbon Reduction Responsibilities



Ideally, non-structural components, such as enclosure and finishes, are also considered for a project. This will become increasingly possible as Global Warming Potential (GWP) data becomes more readily available from these industries. When considering these components, the Architect's scope of work should be revisited to reflect carbon-related services.

Design

As the general progression of a design will vary from project to project, so too will the opportunities for embodied carbon reduction and the timing for when to consider these strategies. The following process is a guide that can be applied to all building components throughout the different phases of design.

Concept and Schematic Design Phase

The early stages of a project present the most opportunity to initiate embodied carbon reduction. In the early stages, materials and systems are selected, layout and design criteria are determined, and embodied carbon baselines are established.

Structural Engineer Scope of Services

The carbon impact of a building's structure is often large. For this reason, the Structural Engineer scope of work should include investigating reduction strategies, summarizing and consistently tracking structural material quantities as the design evolves, and creating embodied carbon estimates. Hines Conceptual Construction Group's Consultant Scope of Services for the structural engineer includes these items.

As Hines selects the design team, it is essential to choose consultants who are open to pursuing embodied carbon reduction strategies. Learning about past experience with carbon reporting and reduction is valuable and should be considered during the consultant selection process.

SELECT MATERIALS AND SYSTEMS | Material selection—such as concrete versus steel, and curtain wall versus precast panels—should be primarily based on best project value. Cost, schedule, and labor conditions should drive these decisions over embodied carbon at this early stage.

When a material has been selected, but the system is still in question, embodied carbon can be considered in the decision-making process. Since half the carbon equation is material quantities, design teams should create a material quantity summary for each system considered. Industry-average GWP factors can then be applied to create a preliminary carbon estimate of each option. In general, optimized use of material schemes will result in less carbon, which can mean less cost—a win-win scenario.

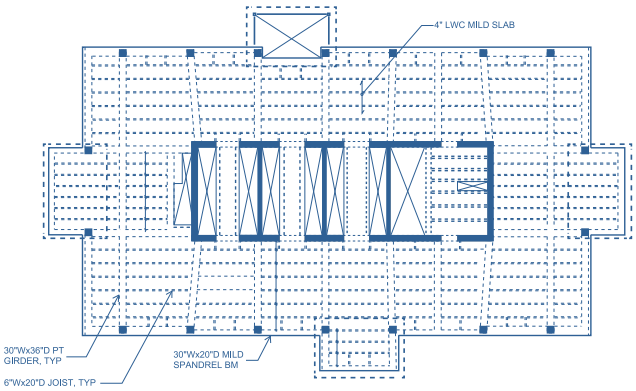
OPTIMIZE LAYOUT AND SET DESIGN CRITERIA | Once the materials and systems have been selected, optimization of design is key—taking materials out of the building is the most direct way to reduce embodied carbon. Design optimization entails reviewing spatial requirements and assessing them for inefficiencies. For example, consider relocating columns to reduce large spans and transfers, reshaping façade geometry to minimize surface area, and revisiting landscape assemblies to reduce materials and loading.

Throughout this chapter, examples with a green check mark indicate where embodied carbon reduction methods are considered for the structure. The same methods can be applied to all materials and products considered.

COMPARISON OF ALTERNATE STRUCTURAL SYSTEMS EXAMPLE

Concrete Option 1

Pan Joist System

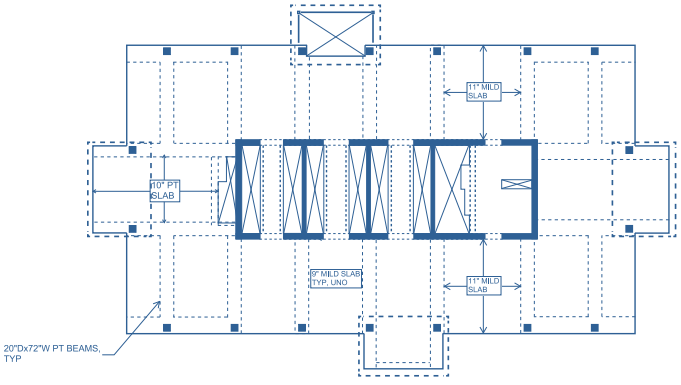


OPTION 1 MATERIAL QUANTITY SUMMARY

POST-TENSIONING	0.5 PSF
MILD REINFORCING	5.5 PSF
CONCRETE VOLUME RATIO	0.73 ft³/ft²
INDUSTRY-AVERAGE GLOBAL WARMING POTENTIAL	**15 kg CO_2eq/ft²**

Concrete Option 2

Post-tensioned Wide-shallow Beam System



OPTION 2 MATERIAL QUANTITY SUMMARY

POST-TENSIONING	0.75 PSF
MILD REINFORCING	5.0 PSF
CONCRETE VOLUME RATIO	0.93 ft³/ft²
INDUSTRY-AVERAGE GLOBAL WARMING POTENTIAL	**19 kg CO_2eq/ft²**

The design criteria should also be created and evaluated. Consider reviews for the following examples:

» Programming criteria, including design loads

» Finish tolerance criteria, including secondary coverings and exposed structure

» Daylighting criteria, including envelope assembly and geometry

» Serviceability criteria, including deflections and vibrations

» Site-specific lateral and resiliency criteria

Both the layout and design criteria establish the guiding rules for the remainder of the design phases and are important to confirm early on. At this time, a project-specific Hines Owner Project Requirements (OPR) Template should be distributed to the design team to relay project expectations and encourage carbon-reduction considerations.

IDENTIFY BASELINE | For comparison throughout the design phases and eventually at project close-out, an embodied carbon **baseline** or starting place should be identified near the beginning of the project. A common baseline metric is **carbon intensity**, or the GWP per area, in units of $kgCO_2eq/m^2$ (see Chapter 3 Basis of Analysis).

Today, due to lack of nation-wide data, there is no consensus on a set baseline. Various options for Hines to consider include:

» **Schematic Design Baseline (Current Preference) |** This method is created at the end of Schematic Design by taking schematic material quantities and applying GWP factors found in the Hines Standard GWP Values Appendix for the Product Stage estimating. The WBLCA SD Baseline estimating is similar, but with different assumptions around time and system replacements, as defined within the WBLCA Basis of Analysis.

» **Carbon Leadership Forum (CLF) Baseline |** A “per-material” baseline, this conservative estimate represents an 80th percentile, upper-bound estimate for that material's carbon footprint. For the product stage, it can be used as a comparative reference point, but it does not represent “business as usual.” That reference point should be the Schematic Design Baseline (with industry average data), compared to the project-specific data.

» **SE 2050 Baseline |** This is a structural baseline that is yet to be finalized and determined from nation-wide voluntary reporting from structural engineering firms. Data is not yet available for this baseline and it only considers a building’s structural system.

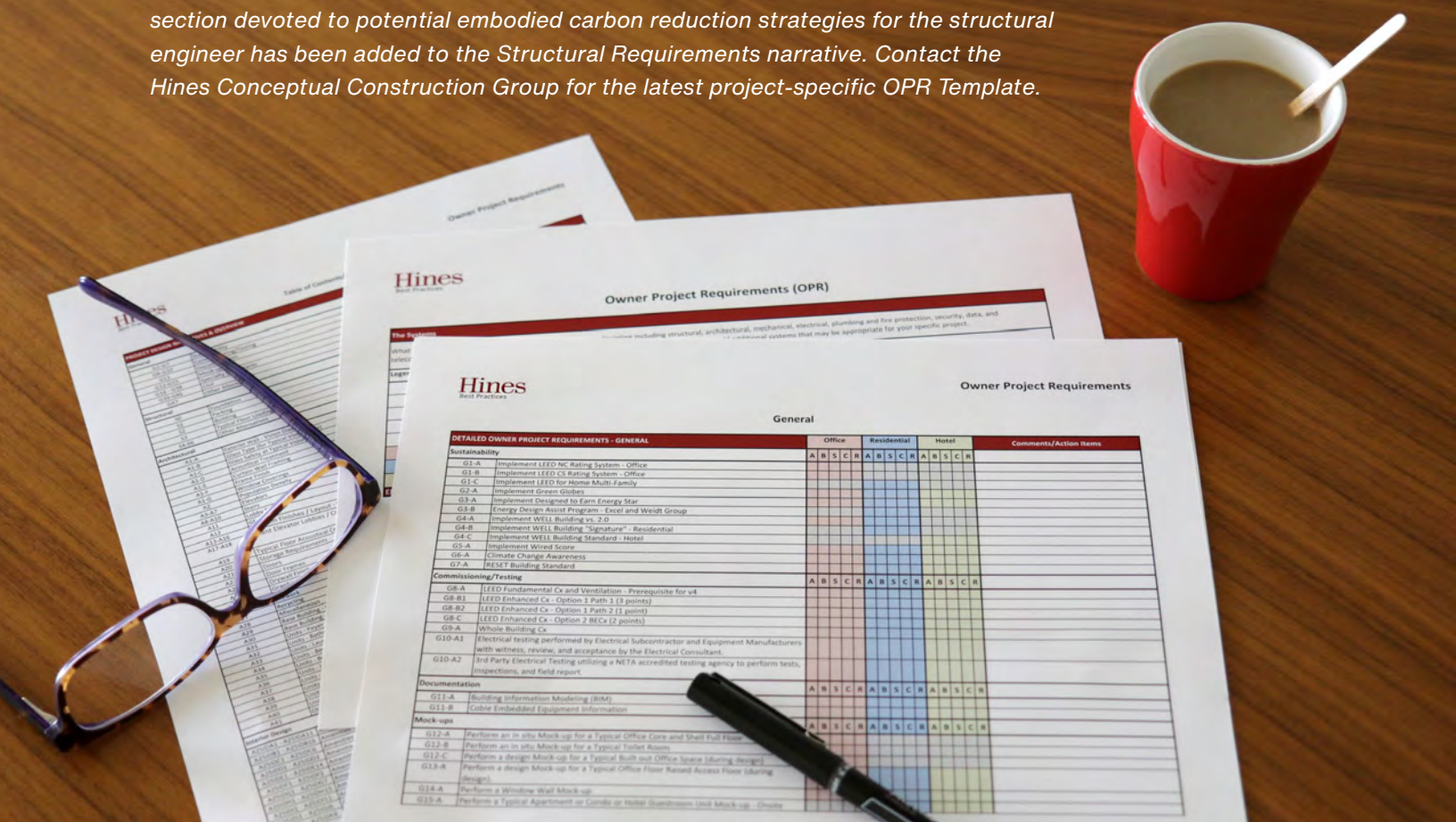
» **International Living Futures Institute Net Zero Carbon (ILFI - NZC) |** This building shell and core, upfront carbon limit is 500 $kgCO_2eq/m^2$. It is based on the A1-A5 LCA stages, excluding site work, shoring, and excavation. This value is gaining industry traction, but it is likely to adjust with time as construction carbon starts to be measured (especially for shoring and excavation).

Although many options exist, the preferred option is the Schematic Design Baseline. This sets the building as the point of comparison from its inception, evaluating the "business as usual" condition. Because this is specifically based on the original project's intent, it is a strong point of reference as it relies on project-specific metrics. By measuring a project against itself in this way, credible findings on embodied carbon reductions after Schematic Design are established.

After Schematic Design, an embodied carbon estimate should be performed to summarize the Schematic Design phase. This serves two purposes—for use as the Schematic Design Baseline, if this option is selected, or as the beginning of carbon reporting for the remaining design phases.

Owner Project Requirements

The Hines Owner Project Requirements (OPR) is a powerful tool to ensure the design team has reviewed the design criteria and considered reduction options. A section devoted to potential embodied carbon reduction strategies for the structural engineer has been added to the Structural Requirements narrative. Contact the Hines Conceptual Construction Group for the latest project-specific OPR Template.



For Schematic Design and all future design milestones, design team members should apply the GWP values listed in the Hines Standard GWP Values Appendix to the component quantities to create the embodied carbon summary at any given milestone. These GWP values are predominantly determined from U.S. industry-average data, from the National Ready Mix Association (NRMCA) for concrete, and from the CLF Materials Baseline Report. As more data becomes available, through wider adoption of Environmental Product Declarations (EPDs), more components can be added to this Appendix.

Applying values standardized by Hines, rather than alternate sources, ensures consistency for all Hines projects and across differing design firms. On a project-by-project basis, Hines may choose to apply alternate GWP factors to better align with regional standards for comparative purposes. For this reason, it is important that GWP assumptions are accurately cataloged throughout all phases of design. This will allow informed comparisons to be made in later design phases and to other projects.

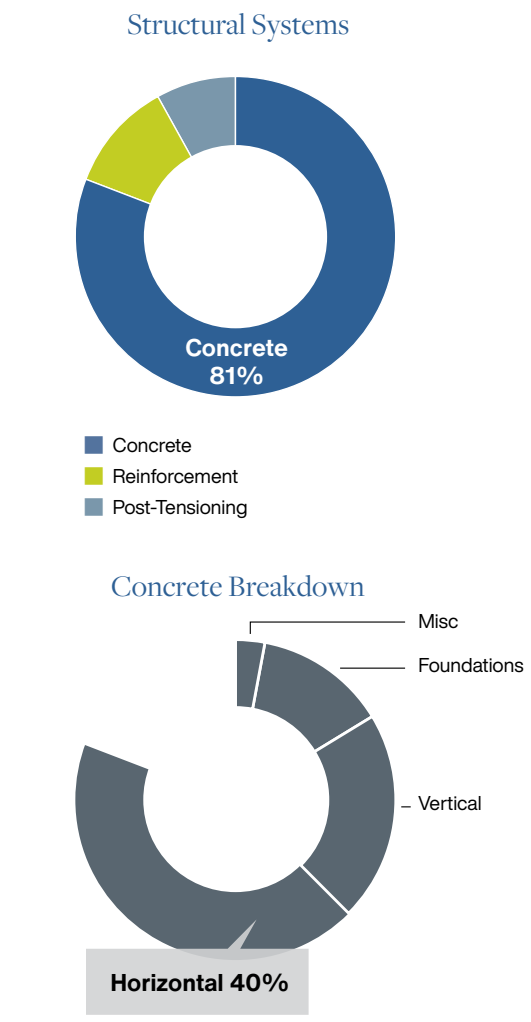
DESIGN DEVELOPMENT PHASE | Once materials and systems have been selected and the layout and design criteria determined, the Design Development stage allows for optimization and implementation of the chosen material- or product-specific carbon reduction strategies. Initial strategy suggestions can be found in the Material-Specific and Product-Specific Embodied Carbon Reduction Strategies guides on the following pages. As the industry progresses on this topic, more strategies will become available.

Using the embodied carbon estimate performed at the end of Schematic Design, the largest contributors of the project's carbon impact can be identified. The design team should target these areas for optimization and continue to track progress throughout design.

An updated embodied carbon estimate can be performed again at the end of Design Development, for continued monitoring as the design develops.

If the Contractor is already engaged and completing take-offs, the design team material quantities and the Contractor take-offs should be reconciled at this stage to confirm alignment.

IDENTIFICATION OF LARGEST CARBON CONTRIBUTORS TO STRUCTURAL SYSTEM EXAMPLE



Material-Specific Embodied Carbon Reduction Strategies

CONCRETE

» Utilize Performance-Based Concrete Specifications to allow for supplier flexibility in mix designs
» Use columns with high-strength concrete at lower levels to minimize area
» Reduce concrete strength where possible to lower cement content in mix designs
» Relax concrete day-of-strength requirements as much as construction schedule will allow to lower cement content in mix designs
» Use round columns where architecturally acceptable to reduce concrete volume and reinforcement density
» Consider formwork systems and sequencing that limit early strength-gain requirements to critical locations to lower cement content in mix designs
» Compare EPDs from material suppliers to inform supplier selection

STEEL

» Utilize high-grade steel where most effective (columns, transfers, trusses, etc.) to reduce steel tonnage
» Consider shape optimization (asymmetrical built-up shapes, castellated beams, etc.) where economically feasible to reduce steel tonnage
» Optimize steel detailing practices (camber, size variation, column splicing, etc.) to reduce steel tonnage
» Compare EPDs from material suppliers to inform supplier selection

TIMBER

» Specify sawn lumber for elements up to 2"x10" and glued laminated timber (glulam) for larger members to reduce timber volume
» Utilize a “Forest Sourcing Disclosure Questionnaire” to ensure material traceability and validity
» Design mass-timber slabs as composite systems for spans greater than 25 feet to reduce timber volume
» Conduct a material optimization study that compares cross-laminated timber (CLT), glue-laminated timber (glulam), dowel-laminated timber (DLT), and nail-laminated timber (NLT) to determine least material option
» Consider using alternate materials (steel or concrete) to create an optimized timber-hybrid structure
» Specify timber sourcing from responsibly managed forests to reduce embodied carbon impact
» Optimize timber detailing practices to reduce material volume
» Compare EPDs from material suppliers to inform supplier selection

REINFORCEMENT

» Utilize high-grade rebar where most effective (columns, walls, foundations, etc.) to reduce steel tonnage
» Optimize reinforcement detailing practices (lap splices, development lengths, curtailment, etc.) to reduce steel tonnage
» Compare EPDs from material suppliers to inform supplier selection

Product-Specific Embodied Carbon Reduction Strategies

ENVELOPE

CLADDING

- Use low-carbon materials to reduce embodied carbon impact
- Incorporate recycled aluminum and metals when available
- Implement wind tunnel testing to reduce system weight and minimize applied wind pressures
- Compare EPDs from product suppliers to inform supplier selection

INSULATION

- Avoid petroleum-based products (XPS, EPS, and foam, etc.) where climate appropriate
- Substitute natural materials that sequester carbon (wood, straw, and wool) to reduce embodied carbon impact
- Use blown-in insulation, where possible, to reduce both embodied and operational carbon impacts
- Compare EPDs from product suppliers to inform supplier selection

Product-Specific Embodied Carbon Reduction Strategies

DRYWALL

» Purchase boards at dimensional sizes to limit construction waste
» Use lightweight options or minimum thickness required to reduce embodied carbon impact
» Use low-carbon alternatives, such as CAF, where allowed by code
» Recycle construction waste at appropriate recycling locations to reduce overall waste impact
» Compare EPDs from product suppliers to inform supplier selection

METAL STUDS

» Increase stud spacing to reduce metal tonnage
» Use minimum thickness required for application to reduce metal tonnage
» Utilize prefabricated panels, where possible, to reduce metal waste
» Consider HSS or rolled shapes at high load applications
» Consider wood framing where allowed by code and durability requirements to reduce embodied carbon impact
» Compare EPDs from product suppliers to inform supplier selection

CARPET

» Use products with a high recycled content to reduce embodied carbon impact
» Use products with solution-dyed yarn to reduce embodied carbon impact
» Utilize carpet tiles, where applicable, to reduce construction waste
» Compare EPDs from product suppliers to inform supplier selection

CEILING TILES

» Avoid ceiling tiles and use exposed structure, where possible, to eliminate embodied carbon impact
» Incorporate natural materials, such as wood, to reduce embodied carbon impact
» Use products with a high-recycled content
» Compare EPDs from product suppliers to inform supplier selection

Construction Documents Phase

As the project design nears completion, the design team should finalize project Specifications and create an **As-Designed Embodied Carbon Summary.**

SPECIFICATIONS | Project Specifications should include language that requires the General Contractor to submit EPDs for all components considered and tracked for embodied carbon reduction. EPDs should be product-specific Type III EPDs conforming to ISO standards. The EPDs should cover, at a minimum, the life-cycle Product Stage, or Modules A1-A3.

Specifications should also call for the Contractor to submit a Bill of Materials that provides building quantities itemized by application and type. The GWP for each item, based on EPDs, should also be included. Refer to Hines Conceptual Construction Group for material specifications with language calling for these items.

AS-DESIGNED EMBODIED CARBON SUMMARY | When the project design is complete, the design team should compile a final As-Designed Embodied Carbon Summary in a format approved by Hines that will be collected and documented in the Hines Embodied Carbon Database.

PROJECT MASTER SPEC AND EXAMPLE BILL OF MATERIALS

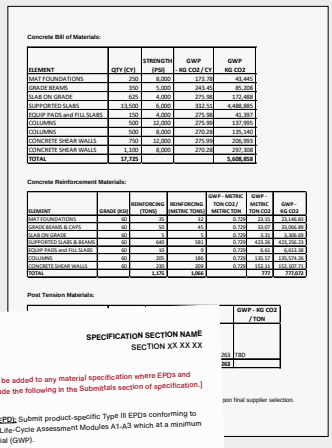
The following language can be added to any material specification where EPDs and total GWP are to be considered. Include the following in the Submittals section of specification.

ENVIRONMENTAL PRODUCT DECLARATION (EPD):

Submit product-specific Type III EPDs conforming to ISO 14025 and ISO 21930 including Life-Cycle Assessment Modules A1-A3 which at a minimum must include Global Warming Potential (GWP).

BILL OF MATERIALS:

Submit amount of each product type and specification, prior to start of construction and at completion of construction. Report any assumptions and allowances included in amounts.



Concrete Bill of Materials:

ELEMENT	QTY (CY)	STRENGTH (PSI)	GWP KG CO2 / CY	GWP KG CO2
MAT FOUNDATIONS	250	8,000	173.78	43,445
GRADE BEAMS	350	5,000	243.45	85,208
SLAB ON GRADE	625	4,000	275.98	172,488
SUPPORTED SLABS	13,500	6,000	332.35	4,488,885
EQUIP PADS and FILL SLABS	150	4,000	275.98	41,397
COLUMNS	500	12,000	275.99	137,995
COLUMNS	500	8,000	270.28	135,140
CONCRETE SHEAR WALLS	750	12,000	275.99	206,993
CONCRETE SHEAR WALLS	1,100	8,000	270.24	297,308
TOTAL	17,725			5,608,859

Concrete Reinforcement Materials:

ELEMENT	GRADE (KSI)	REINFORCING (TONS)	REINFORCING (METRIC TONS)	GWP - METRIC TON CO2 / METRIC TON	GWP - METRIC TON CO2	GWP - KG CO2
MAT FOUNDATIONS	60	82	73	0.729	53.15	53,146.83
GRADE BEAMS & CAPS	60	50	45	0.729	33.03	33,066.85
SLAB ON GRADE	60	5	5	0.729	3.33	3,306.68
SUPPORTED SLABS & BEAMS	60	640	581	0.729	423.26	423,256.23
EQUIP PADS and FILL SLABS	60	10	9	0.729	6.61	6,613.38
COLUMNS	80	205	186	0.729	135.57	135,574.26
CONCRETE SHEAR WALLS	60	230	209	0.729	152.31	152,307.72
TOTAL		1,171	1,064		777	777,072

Post Tension Materials:

	GWP - KG CO2 / TON
	TBD

PROJECT – MASTER SPEC
LOCATION

SPECIFICATION SECTION NAME
SECTION XX XX XX

[NOTES: The following language can be added to any material specification where EPDs and total GWP are to be considered. Include the following in the Submittals section of specification.]

Environmental Product Declaration (EPD): Submit product-specific Type III EPDs conforming to ISO 14025 and ISO 21930 including Life-Cycle Assessment Modules A1-A3 which at a minimum must include Global Warming Potential (GWP).

Bill of Materials: Submit amount of each product type and specification, prior to start of construction and at completion of construction. Report any assumptions and allowances included in amounts.

Wolf Point | Chicago

Construction and Procurement

As the project moves from design to construction, the General Contractor and component suppliers are typically selected. The final supplier selection can present an important opportunity to reduce embodied carbon.

General Contractor Selection

The Request for Proposal (RFP) for the General Contractor should include language indicating the Contractor's embodied carbon responsibilities, including:

- Performing quantity take-offs prior to construction, including collection and verification from Subcontractors
- Determining availability of product-specific EPDs prior to supplier selection
- Considering GWP, price, and schedule during supplier selection
- Collecting EPDs throughout construction
- Creating a summary of GWP throughout construction

» Submitting a final Bill of Materials that states the actual quantities used and a final **As-Built Embodied Carbon Summary** at project completion

The Contractor's proposal should identify capabilities, experience, and strategies related to embodied carbon reporting and reduction. It should also include considerations for the Construction Stage (as outlined in Chapter 2) regarding emissions related to transportation and construction. The Contractor's bid should disclose the cost of embodied carbon reporting and any carbon reduction strategies. If these strategies require additional cost beyond "business as usual," they should be broken out as alternate costs for Hines to consider.

Hines Conceptual Construction Group's RFP for the General Contractor includes language for this embodied carbon scope of work.

Material Bidder Selection

Similar to the Contractor RFP, Subcontractor bid documents should also include language regarding embodied carbon, most importantly the requirements to provide product-specific Type III EPDs and a table of quantities for each product with its associated GWP.

CONCRETE BASE BID VS. ALTERNATE BID EXAMPLE

			Design Team Estimate		Supplier BASE Bid		Supplier ALTERNATE Bid	
			$kgCO_2eq/cy$	$kgCO_2$	$kgCO_2eq/cy$	$kgCO_2$	$kgCO_2eq/cy$	$kgCO_2$
USEAGE	SPECIFIED PSI	VOLUME cy	INDUSTRY-AVERAGE EPD		PRODUCT-SPECIFIC EPD		PRODUCT-SPECIFIC EPD	
Slab on Steel Deck	4,000 NWC	5,000	253	1,265,000	251	1,255,000	251	1,255,000
	4,000 LWC	20,000	446	8,920,000	385	7,700,000	385	7,700,000
Shear Walls	10,000 NWC	10,000	450	4,500,000	276	2,760,000	229	2,290,000
	12,000 NWC	15,000	540	8,100,000	327	4,905,000	242	3,630,000
Other Concrete (7 Other Mixes)		7,200		2,306,200		1,997,563		788,613
TOTAL		**57,200**		**25,091,200**		**18,617,563**		**15,478,860**
GWP REDUCTION				**—**		**-26%**		**-38%**

Collect Base Bids and Alternate Bids to weigh options for embodied carbon reduction. Alternate Bids may boast larger reductions, but this needs to be considered alongside any cost premium.

CHAPTER 4

A Schedule attached to the Contractor RFP will identify bidder instructions to submit a **Base Bid** and **Alternate Voluntary Bids**. The Base Bid should reflect the lowest-cost bid while reporting GWP. Alternate Voluntary Bids should reflect an embodied carbon reduction from the Base Bid, while identifying potential cost and schedule impacts. By collecting both sets of information from suppliers, Hines and the Contractor may make informed decisions balancing carbon, cost, and schedule.

An alternate bid approach helps the team target best-value alternatives. Asking questions about embodied carbon and reviewing a variety of bids often leads to significant carbon reduction at little to no additional cost, simply from researching and presenting alternative options.

For *Instructions for Embodied Carbon Reporting and Reduction Strategies*, refer to the Hines Conceptual Construction Group's General Contractor RFP document.

Design Team and Contractor Embodied Carbon Reconciliation

As the Contractor creates embodied carbon summaries, it is important that these are reconciled with the design team's As-Designed summary. This entails review and comparison of design team material quantities and Contractor Bill of Materials, along with applied GWP factors to each. This will provide opportunities to identify discrepancies between design intent and Contractor interpretation.

After reconciliation is complete, the difference between using industry-average and project-specific GWP results can be assessed.

Project Close-Out

Throughout construction, the Contractor should report the project's embodied carbon summary to Hines. Through this, Hines will be able to monitor progress and determine if carbon reduction goals are being met.

At substantial completion of construction, the Contractor should report the following to Hines:

» Final Bill of Materials

» Product-specific EPDs

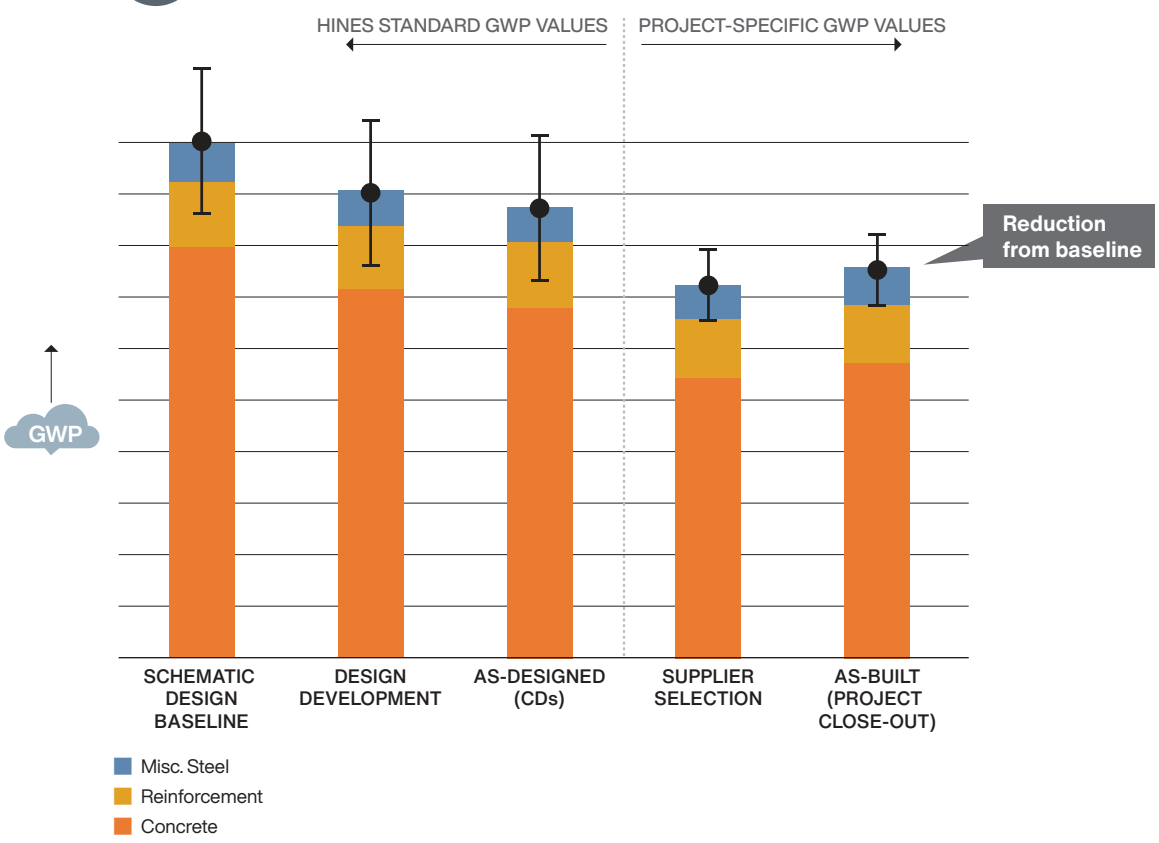
» As-Built Embodied Carbon Summary

The As-Built Embodied Carbon Summary can be compared to the As-Designed summary. Both of these, along with the final Bill of Materials, will be recorded within the Hines Embodied Carbon Database.

After the project has been completed, Hines will have multiple points of data describing the project's embodied carbon throughout design and construction. This can be charted to observe the general trend of carbon over time.

Embodied carbon may increase or decrease throughout the project, depending on many factors. A decrease may be observed, for example, when an alternate bid is selected to reduce carbon. Inversely, an increase may be observed during construction if a higher strength concrete mix is utilized due to availability. Through monitoring of these impacts, Hines can make informed decisions throughout design and construction—allowing the opportunity for a general downward trend in embodied carbon. By reviewing these impacts at project close-out and cataloging lessons learned, Hines can perpetuate reduction on future projects.

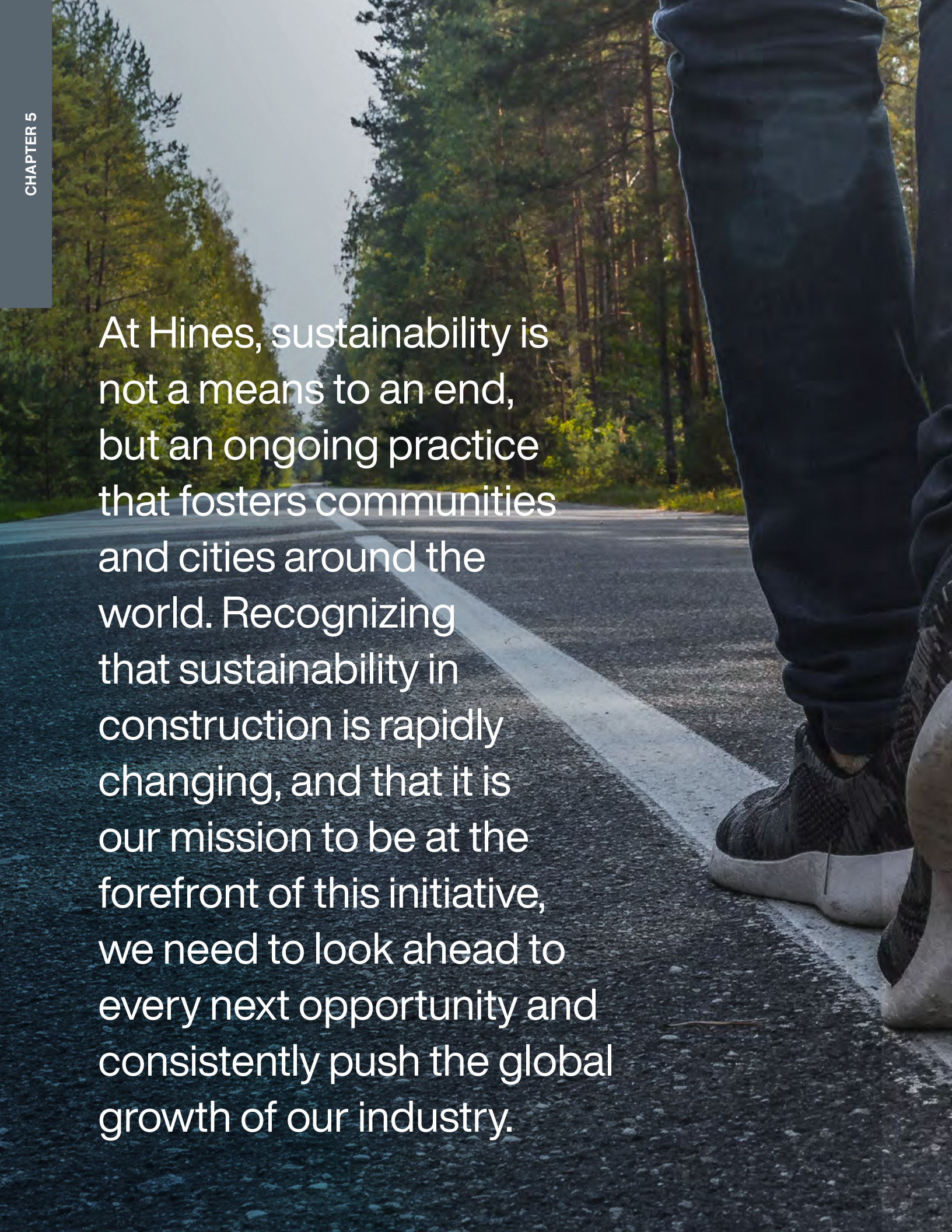
MONITORING STRUCTURAL EMBODIED CARBON THROUGHOUT DESIGN & CONSTRUCTION EXAMPLE



CHAPTER 4

Summary

- Selected consultants should ideally have **experience** in and a **willingness and enthusiasm** to pursue embodied carbon reduction
- Opportunities for embodied carbon reduction are present throughout **all phases of design**
- The design team should create a material quantity **summary** and embodied carbon **estimate** at project milestones
- Design team specifications should **require** the submission of EPDs and Bill of Materials
- The design team should compile an As-Designed Embodied Carbon Summary and **submit** to Hines at the **end of design**
- General Contractor selection should consider embodied carbon **responsibilities**, including collection of **EPDs and GWP reporting**
- Supplier Base Bids and Alternate Voluntary Bids should be solicited to determine the **best carbon option** based on cost and schedule
- Contractor embodied carbon estimates should be **reconciled** with the design team's As-Designed summary to identify discrepancies
- The General Contractor should compile a final Bill of Materials, product-specific EPDs, and an As-Built Embodied Carbon Summary and **submit** to Hines at **project close-out**
- Hines will record all embodied carbon project information in the **Hines Embodied Carbon Database**



At Hines, sustainability is not a means to an end, but an ongoing practice that fosters communities and cities around the world. Recognizing that sustainability in construction is rapidly changing, and that it is our mission to be at the forefront of this initiative, we need to look ahead to every next opportunity and consistently push the global growth of our industry.

CHAPTER 5

Further Considerations

There are a vast number of topics related to sustainability within the built environment. While today's focus may be limited by the information that is readily available, Hines should consider adjacent topics that may become imperative in the near future. Chapter 4 presents a "just-around-the-corner" look at the industry, and the areas that Hines will likely want to evaluate as the next step in carbon reduction practices.

Additional Building Components

In Chapters 1 and 2 of the guide, the focus has been on the embodied carbon of structure, envelope, finishes, transportation, and construction activities during the Product and Construction Stages. As more industries expand their literacy with embodied carbon, carbon accounting and reduction will be possible among an expanded list of building components and processes.

Chapter 3 of this guide outlines the process of Whole-Building Life-Cycle Assessment, and how that differs from the upfront embodied carbon accounting of Chapter 2. One of the major evolutions happening today with WBLCAs is a move toward Cradle-to-Cradle thinking, and discussions of a circular economy for all buildings and systems. Further evolution on this topic, as well as more integration with embodied and operational carbon, will evolve with next generations of this guide.

For any new components being considered, the process outlined in Chapter 4—reducing measuring embodied carbon throughout design, requiring the submission of Environmental Product Declarations (EPDs) through specification, and using bid alternates in procurement—should be followed. Although EPDs may not be widely available for all products, requesting them from suppliers signals the importance to the market, encourages evolution by setting new standards, and will lead to future availability.

Certification and Legislation

Beyond Hines' instinct for leadership, there are external factors driving the focus on embodied carbon—certification and legislation. Both are changing rapidly.

Certification

Many certification programs address operational carbon, with a heavy emphasis on energy savings. In recent years, certification programs have begun to add embodied carbon requirements as well.

LEED | Perhaps the best-known green rating system in the United States, the U.S. Green Building Council's LEED has amended its program language for embodied carbon. The following points relate to embodied carbon in LEED v4.1:

- MR Credit: Building Product Disclosure & Optimization-Environmental Product Declarations
- MR Credit: Building Life-Cycle Impact Reduction
- MR Credit: Building Product Disclosure & Optimization-Sourcing of Raw Materials
- Pilot Credit: Procurement of Low Carbon Construction Materials

Of these credits, the MR Credit regarding EPDs and the pilot credit are of note.

The first point of the EPD MR Credit can be achieved by adding EPD language to the design specifications, as outlined in Chapter 3. The point calls for projects to collect at least 20 different EPDs from five different manufacturers. This is easily achieved by adding EPD submission requirements to the project specifications. Refer to Hines Conceptual Construction Group for material specifications that include requirements for EPD submission.

The Pilot Credit calls for carbon accounting of specific building materials, all of which are covered in Chapter 3. It directs projects to determine an embodied carbon baseline for these materials, and compare this baseline against the final project results. The baseline is determined by multiplying material quantities by Global Warming Potential (GWP) factors set by the Carbon Leadership Forum (CLF). The project results are determined by multiplying these same quantities by the GWP factors determined from collected product-specific EPDs. One point is awarded for showing no or minimal reduction, while two points are awarded for reduction greater than 30%. One way to achieve this point is through use of the Embodied Carbon in Construction Calculator (EC3) Tool.

OTHERS | Within the U.S., other rating systems that address embodied carbon are the Green Building Initiative (GBI) Green Globes Certification, the International Living Future Institute (ILFI) Living Building Challenge and Zero Carbon Certification, and BRE Group's Building Research Establishment Environmental Assessment Method (BREEAM). All of these require projects to perform a WBLCA to compare its embodied carbon against a baseline and show various levels of reduction. Because of this, these certifications may not be relevant to the Hines portfolio, except on specific projects.

Legislation

Legislation that pertains to embodied carbon is limited in the U.S. today, but it is quickly expanding. Buy Clean is an example of legislation that is gaining traction throughout the country, with enactment in California and interest elsewhere. States that are considering legislation soon are:

» Colorado

» Minnesota

» Oregon

» Hawaii

» New York

» Washington

BUY CLEAN | Buy Clean is a movement aimed at implementing low-carbon policy nationwide. Its first enactment in California calls for collection of third-party verified EPDs on all public projects. In 2022, this legislation will shift to also setting maximum allowable GWP factors for the selected materials.

BUY CLEAN

OTHERS | Legislation is being considered at the federal, state, and local levels. For example, New York State passed a progressive climate bill in 2019 that may not explicitly include embodied carbon goals but outlines goals that have future implications. Minnesota recently updated their public works guidelines to include WBLCAs.

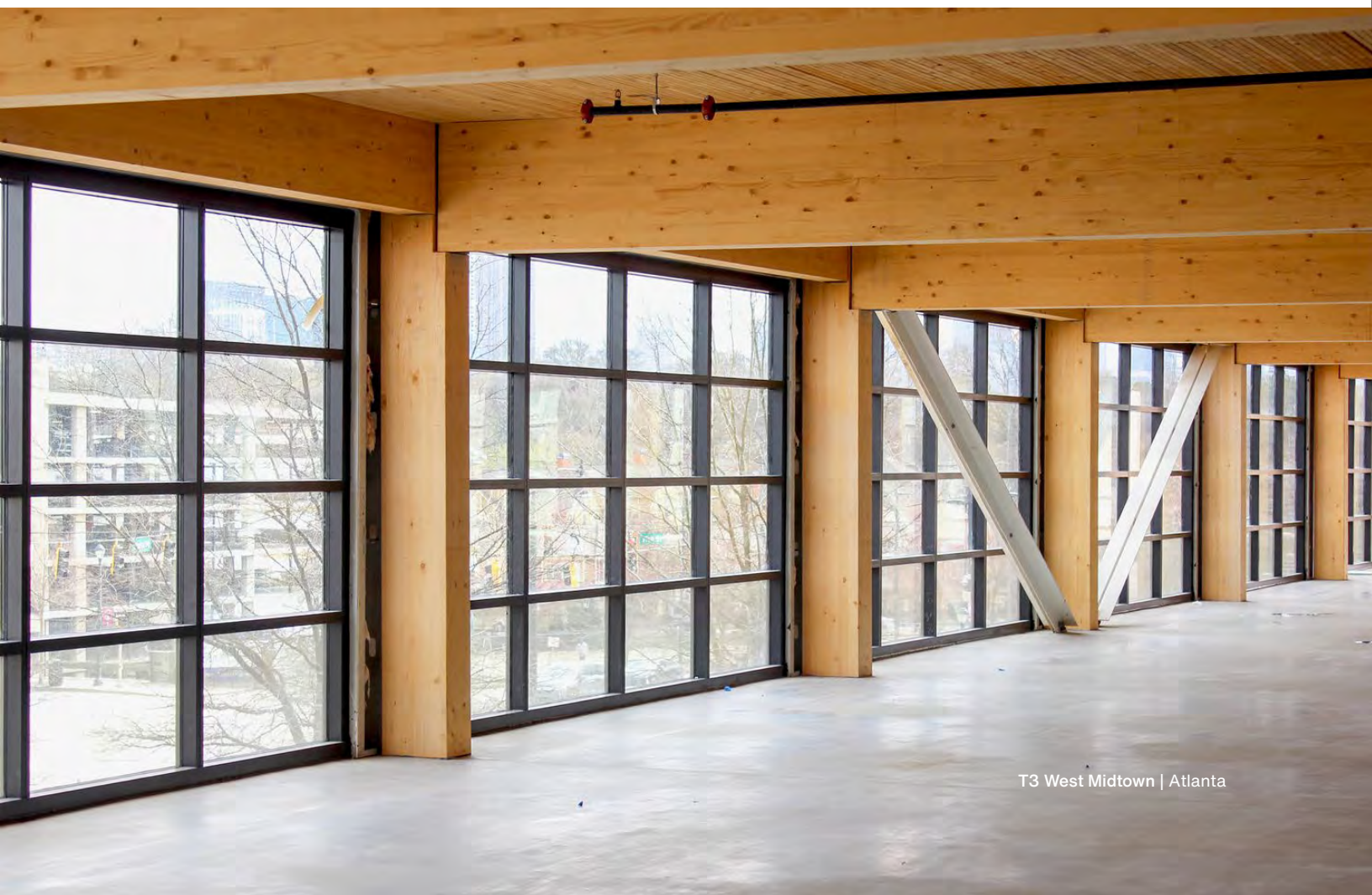
An example at the local level, Marin County of California adopted a Low-Carbon Concrete Code in 2019. Solely aimed at reducing the embodied carbon impact of concrete, this standard sets maximum allowable cement and embodied carbon limits for concrete mix designs. Although the effectiveness of an approach that entails setting a GWP maximum is debated (while that code was well researched for Marin County specifics, concrete varies by location due to regional materials, and by application as multiple variables exist beyond material strength), Marin County's standard has become model language for other jurisdictions.

By beginning to address embodied carbon today, Hines is positioning itself well to address future policy decisions. Since the legislative landscape is continuously evolving, local assessment should be done at the start of new projects to determine appropriate embodied carbon goals.

Evolution is the Expectation

As with any emerging science or new building technology, evolution is the expectation, and the same is true for carbon reduction within the building industry. Progression of information in the coming years as these processes are adopted by firms and manufacturers around the country and the world will significantly increase the reliability and accuracy of reduction methods. It is vital that Hines, as an industry leader, takes initiative to set standards for carbon reduction to encourage the evolution of these methods, promote the tools available, and contribute to the overall reduction of carbon emissions in the built environment.

Through this Guide, Hines is moving forward in support of this mission. By subsequent revisits and updates to this Guide, Hines is committing to continued leadership and innovation within the design and construction industry in the future.



T3 West Midtown | Atlanta

CHAPTER 5

Summary

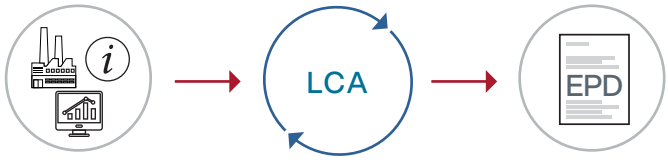
- Hines should consider “just-around-the-corner” topics as the **next step** in carbon reduction practices
- Requesting EPDs from suppliers will lead to **future availability** by **encouraging change** and **setting a new standard** for production requirements
- Refer to the Construction Stage Embodied Carbon Reduction Strategies panel for **starting-point approaches** for reduction at this stage
- General Contractor familiarity with carbon reduction **will grow** as requests from clients increase
- Certification and legislation are additional, **rapidly changing drivers** that **encourage a focus** on embodied carbon

Appendices

Appendix A: How to Create an EPD

What Is an EPD?

An EPD is an Environmental Product Declaration. Through performing a life-cycle assessment, an EPD quantifies and reports a material or product's environmental impact. The most frequently tracked of these impacts is greenhouse gas emissions, known as Global Warming Potential (GWP), reported in kilograms of CO_2 equivalent ($kgCO_2eq$).



What Does Type III Mean?

Type III EPDs are third-party, independently verified according to ISO standards 14025 and 21930. Because they are audited, they are the preferred type of EPD.

PREFERRED

Who Writes the Rules for an EPD?

Product Category Rules (PCRs) are a set of specific guidelines for developing EPDs, defined by ISO standards 14025 and 21930. For North America, PCRs are written by a Program Operator, typically in association with the national trade organization for that material.

Who Do I Contact to Get an EPD?

There are multiple EPD providers, with a variety of offerings to create an EPD. When selecting an EPD provider, consider the following:

» What is their understanding and experience with the issues associated with the material or product?

» Do they have associations with third-party verifiers who can provide the verification as a single, joint service, or does that verification need to be contracted separately?

See the following page for an abbreviated list of EPD developers in North America, along with their expertise and contact information.

Where Can I Get More Information?

These online resources are additional trusted sources of information regarding EPDs and embodied carbon:

» **Carbon Leadership Forum (CLF)** an independent and non-profit organization that is the leading entity in North America on embodied carbon and life-cycle assessment
https://carbonleadershipforum.org/

» **Embodied Carbon in Construction Calculator (EC3)** a free and open-access database of North American EPDs
https://www.buildingtransparency.org/

EPD Providers in North America

ORGANIZATION	NUMBER OF EPDs in EC3	MATERIAL OR PRODUCT COVERED: CONCRETE	STEEL	REBAR	TIMBER	MASONRY	COLD-FORMED STEEL	OTHER	WEBSITE
Climate Earth	25,000+	✓	✓	✓	✓	✓	✓	✓	www.climateearth.com/
ASTM International	15,000+	✓	✓	✓	✓	✓	✓	✓	www.astm.org/CERTIFICATION/
NRMCA	1,000+	✓							www.nrmca.org/association-resources/sustainability/
Athena	1,000+	✓	✓	✓	✓	✓	✓	✓	www.athenasmi.org/what-we-do/epd-and-ebd-services/
UL Environment	1,000+	✓	✓	✓	✓	✓	✓	✓	www.ul.com/resources/environmental-product-declarations-program
SCS Global Services	100+		✓	✓	✓		✓	✓	www.scsglobalservices.com/services/environmental-product-declarations
International EPD System	100+	✓	✓	✓	✓	✓	✓	✓	www.environdec.com/
NSF International	100+	✓	✓	✓	✓			✓	www.nsf.org/knowledge-library/sustainable-product-certification-services
BRE Global	100+	✓				✓	✓	✓	www.bregroup.com/services/certification-and-listings/en-15804-environmental-product-declarations/
thinkstep	100+	✓	✓	✓	✓	✓	✓	✓	epd.thinkstep.com/epd-knowledge
Institut Bauen und Umwelt	< 100		✓				✓	✓	ibu-epd.com/en/epd-programme/
FPInnovations	< 100				✓			✓	web.fpinnovations.ca/

LAST UPDATED: August 2020

Appendix B: Hines Standard GWP Values for North America

Purpose

To create standardization across all U.S. Hines projects, designers should use these Hines Standard GWP Values to estimate embodied carbon during design. The As-Designed Embodied Carbon Summary is determined using these values and should be created at the end of Construction Documents and recorded in the Hines Embodied Carbon Database.

See the Design section of Chapter 4 for more details.

Limits of Use

The Global Warming Potential (GWP) values presented here describe the life-cycle Product Stage, or Modules A1-A3, only. Therefore, these values can be used to measure embodied carbon following the Product Stage Focus Method, but not to complete a Whole-Building Life-Cycle Assessment (WBLCA) without further data being added to these values. See Chapter 2 and 3 for more details.

Using these values to compare dislike materials or products is not advised. See the Availability and Comparability section of Chapter 1 for more details.

What if My Material or Product is Not Listed?

The GWP values listed here generally represent North American industry-average information that is available today. As more trades create industry-average Environmental Product Declarations (EPDs), this Appendix should be updated.

The following resources can be used to determine GWP data for products and materials not available in this Appendix:

» **Embodied Carbon in Construction Calculator (EC3) Tool** | A free, open-source database of North American EPDs, which includes both industry-average and product-specific EPDs
https://www.buildingtransparency.org/

» **GaBi** | Carbon Leadership Forum Material Baselines Report v2, July 2021
https://carbonleadershipforum.org/2021-material-baselines/

» **One Click LCA** | Proprietary database of global EPDs, including both industry-average and product-specific, and a WBLCA tool
https://www.oneclicklca.com/

» **NRMCA Member Industry-Average EPD for Ready Mixed Concrete, January 2022**
https://www.nrmca.org/wp-content/uploads/2022/03/NRMCA_EPDV3-2_20220301.pdf

Caution should be taken when reviewing EPDs to confirm consistent units are utilized.

LAST UPDATED: April 2022

Structure

CONCRETE

Apply +/- 26% uncertainty to GWP values listed below, based on EC3 estimated uncertainty for NRMCA industry-average EPD.

STRENGTH (PSI)	WEIGHT	GWP FACTOR BY % CEMENT REPLACEMENT ($kgCO_2eq / m^2$) 0-19%	20-29%	30-39%	40-49%	≥50%	SOURCE*
0-2,500	NORMAL	280	242	221	200	179	NRMCA Member Industry-Average EPD for Ready Mixed Concrete, Jan 2022
2,501-3,000		311	268	245	221	197	NRMCA Member Industry-Average EPD for Ready Mixed Concrete, Jan 2022
3,001-4,000		384	329	300	269	239	NRMCA Member Industry-Average EPD for Ready Mixed Concrete, Jan 2022
4,001-5,000		469	401	364	326	288	NRMCA Member Industry-Average EPD for Ready Mixed Concrete, Jan 2022
5,001-6,000		494	422	383	342	303	NRMCA Member Industry-Average EPD for Ready Mixed Concrete, Jan 2022
6,001-8,000		575	490	444	396	349	NRMCA Member Industry-Average EPD for Ready Mixed Concrete, Jan 2022
8,001-9,000		654	558	505	449	395	Extrapolated from NRMCA Member Industry-Average EPD for Ready Mixed Concrete, Jan 2022
9,001-10,000		707	603	546	484	426	Extrapolated from NRMCA Member Industry-Average EPD for Ready Mixed Concrete, Jan 2022
10,001-12,000		787	671	607	537	472	NRMCA Member Industry-Average EPD for Ready Mixed Concrete, Jan 2022
0-3,000	LIGHT	558	480	438	471	421	NRMCA Member Industry-Average EPD for Ready Mixed Concrete, Jan 2022
3,001-4,000		643	555	504	542	474	NRMCA Member Industry-Average EPD for Ready Mixed Concrete, Jan 2022
4,001-5,000		716	613	553	596	516	NRMCA Member Industry-Average EPD for Ready Mixed Concrete, Jan 2022

*Title of EPD unless noted otherwise

SUGGESTED % CEMENT REPLACEMENT BY APPLICATION

Since the percent of cement replacement is not typically specified by designers, consider using these default values when they are unknown.

APPLICATION	% CEMENT REPLACEMENT
Foundation	30-39%
Horizontal	0-19%
Vertical	20-29%

Additional GWP Values

For the following materials, use the Carbon Leadership baseline values from the Material Baselines Report v2, July 2021.

https://carbonleadershipforum.org/2021-material-baselines/

» Reinforcement

» Steel

» Aluminum

» Wood & Composites

» Masonry

» Insulation

» Cladding

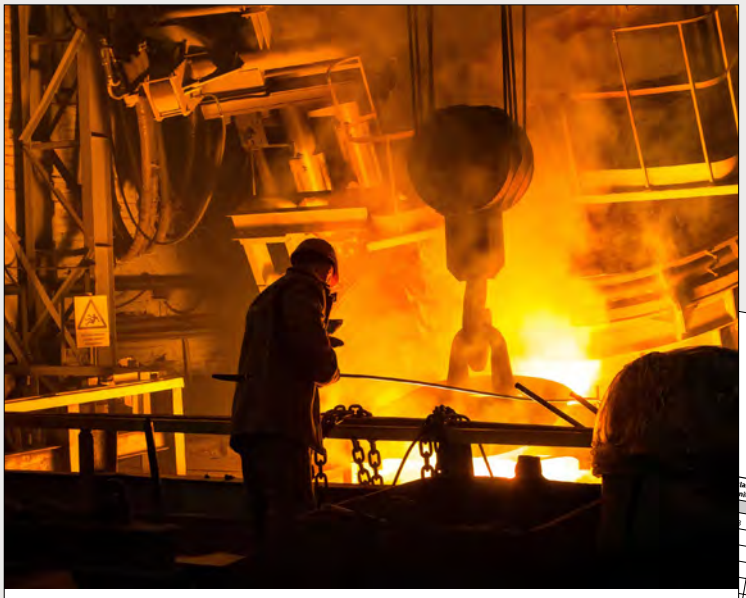
» Finishes

» Communications

» Bulk Materials

		2021 CLF BASELINES v2 kg CO2e per declared unit					
Category	**Subtype**	**Achievable (Low)**	**Typical (Median)**	**Baseline (High)**	**Declared unit**	**Method**	**Data Source & Notes**
Cold Formed Steel	Framing	1.5	2.28	**3.0**	kg	3	Typical = IW-EPD Cold-Formed Steel Studs and Track Manufactured in U.S. and Canada (SRI, 2016); Due to low number of EPDs, Low = point between IW-EPD value and estimated global low based on ICE database (Circular Ecology, 2019); High = point between IW-EPD value and estimated global high based on ICE database (Circular Ecology, 2019).These numbers match the 20% and 80% figures in EC3 as of Jan 2021, drawn from IW-EPD and 4 product-specific EPDs.
Open-web steel joists	Open-web steel joists	0.7	1.38	**2.5**	kg	3	Typical = IW-EPD Open-web steel joists (SJI, 2015); Due to low number of EPDs, Low = CLF 2019 beta value = IW-EPD value minus estimated uncertainty factor; High = CLF 2019 beta high value = IW-EPD value plus estimated uncertainty factor.

Use median values listed and include the range between Achievable and Baseline, which represents +/-range of possible outcomes in the data.



2021 Carbon Leadership Forum

Material Baselines

BASELINE REPORT v2 | July 2021

Carbon Leadership Forum

Glossary of Terms

A

Alternate Voluntary Bids
Alternate, voluntary bids submitted by the Subcontractor or Supplier that reflect embodied carbon reduction compared to the Base Bid and identify potential cost and schedule impacts.

As-Built Embodied Carbon Summary
A summary of the project's final embodied carbon produced by the Contractor and calculated using actual material quantities and GWP factors as determined from project-specific EPDs, to be submitted to Hines at project close-out.

As-Designed Embodied Carbon Summary
A summary of the project's embodied carbon compiled by the design team and calculated using estimated material quantities and GWP factors per the Hines Standard GWP Values Appendix, to be submitted to Hines at design completion.

B

Base Bid
The lowest-cost bid submitted by the Subcontractor or Supplier that reflects "business-as-usual" and reports GWP values.

Baseline
A starting point identified at the beginning of a project to be used as a point of reference for embodied carbon comparison throughout design and project close-out. If embodied carbon reduction targets are set for a project, this baseline becomes the comparison point from which to evaluate achieved reductions.

C

Carbon Leadership Forum (CLF) Baseline
A conservative academic baseline built into the Embodied Carbon in Construction Calculator (EC3) Tool. Due to its conservative nature, it should not be used to illustrate carbon reductions when compared against project-specific data as it does not accurately reflect achievement.

Carbon Leadership Forum (CLF)
An independent and non-profit organization that is the leading entity in North America on embodied carbon and life-cycle assessment. www.carbonleadershipforum.org

Carbon Intensity
A metric used to describe embodied carbon impact that is determined by dividing the GWP over project area and expressed in units of $kgCO_2eq/m^2$.

Cradle-to-Construction
The life-cycle stages from the Product through the Construction Modules, or A1-A5, which begins with the raw material's extraction and ends at the completion of construction.

Cradle-to-Cradle
The life-cycle stages from the Product through the Considerations Outside of the System Boundary Modules, or A1-D, which includes a closed loop system that begins with the raw material's extraction and ends with recycling, system reuse, or return to the earth for future use.

Cradle-to-Gate
The Product Module life-cycle stages A1-A3, which begin with the raw material's extraction and ends at the factory "gate" ready for transportation to a construction site.

Cradle-to-Grave
The life-cycle stages from the Product through the End-of-Life Modules, or A1-C4, which begins with the raw material's extraction and ends at disposal of materials after the building's demolition.

E

Embodied Carbon
The greenhouse gas emissions that result from constructing, renovating, and demolishing a building.

Embodied Carbon in Construction Calculator (EC3)
A free and open-access database of North American EPDs, including both industry-average and product-specific.
www.buildingtransparency.org

Environmental Product Declaration (EPD)
A report that describes a component's environmental impact, including GWP; analogous to a food item's nutrition label. It is determined by performing a life-cycle assessment of the component under consideration, following ISO standards 14025, 14040, and 14044, and can be representative of an average component from multiple suppliers (industry-average) or a single component from a single supplier (product-specific). Varying types of EPDs exist but Type III product-specific are the most desirable.

European Standards (EN)
Document standards that have been ratified by one of the three European Standardization Organizations.

G

Greenhouse Gas (GHG)
Gas that absorbs and emits radiant energy into the atmosphere, causing the greenhouse effect or the warming of the earth. The primary greenhouse gases in Earth's atmosphere are water vapor, carbon dioxide, methane, nitrous oxide, and ozone.

Global Warming Potential (GWP)
The metric used to measure greenhouse gases and their effect on climate change, expressed in kilograms of carbon dioxide equivalent ($kgCO_2eq$). "Carbon" is the generic, easy to understand, term commonly used in place of GWP.

H

Hines Embodied Carbon Database
An anticipated database created and maintained by Hines where embodied carbon data collected by region and project type is recorded.

Hines Regional Baseline
An anticipated baseline determined from the Hines Embodied Carbon Database, based on project location and type.

Hines Standard GWP Values
A list of GWP values predominantly determined from industry-average EPD data. Consistent application of these values to material quantities throughout design allows comparison across Hines' projects by creating standardization in determining embodied carbon estimates.

I

International Organization of Standardization (ISO)
The international, non-government organization that develops and publishes standards.

L

Leadership in Energy and Environmental Design (LEED)
A green building certification program developed by the U.S. Green Building Council and utilized worldwide.

M

Materials
Construction elements made up of unprocessed or processed substances, such as concrete, steel, and timber.

Modules
A term used to describe different points in time throughout a building's life-cycle, for the purpose of carbon impact calculations and WBLCA.

O

Operational Carbon
The greenhouse gas emissions that result from the energy and water consumed by a building during its operation.

P

Products
Processed, finished items that are offered for sale, typically created with manufactured combinations of a variety of materials.

Product Category Rules (PCRs)
Industry-established standards determined by trade associations that document the environmental reporting requirements and guidelines for a specific material or product type and govern the creation of EPDs.

Product Stage Focus Method
The process used to account for the embodied carbon emissions from the Product Stage of a building's life span.

R

Residual Value
The estimated value of an asset, or building, at the end of its life, defined by the amount of value which the owner of that particular asset will obtain or expect to get eventually when the asset is dispositioned.

S

Schematic Design Baseline
A baseline established at the end of a project's Schematic Design that calculates the materials quantities at that phase and applies Hines Standard GWP factors to generate an embodied carbon estimate. Today, this is the preferred baseline for Hines' projects.

SE 2050 Baseline
A structural, elements-only baseline determined from voluntary reporting by structural engineering firms. Due to its launch in 2020, data is not yet available.

Sequestration
To pull carbon dioxide out of the atmosphere through natural processes, an example of a "negative" source of carbon emissions.

W

Whole-Building Life-Cycle Assessment (WBLCA)
The process used to account for all carbon emissions from all emitters throughout a building's full life span.

Endnotes

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5 Rodriguez, B.X., Lee, H.W., Simonen, K., Huang, M. (2018) Life Cycle Assessment (LCA) for Low Carbon Construction: MEP Systems in Commercial Office Buildings

6 https://www.boma.org/BOMA/BOMA-Standards/BOMA_Floor_Measurement_Standards/Gross_Areas.aspx

7 Waldman, B., Huang, M., & Simonen, K. (2020). Embodied carbon in construction materials: a framework for quantifying data quality in EPDs. Buildings and Cities, 1(1), 625–636. DOI: http://doi.org/10.5334/bc.31

8 Tuomo Joensuu, Roosa Leino, Jukka Heinonen, Arto Saari, (2021) Developing Buildings' Life Cycle Assessment in Circular Economy-Comparing methods for assessing carbon footprint of reusable components, Sustainable Cities and Society, https://doi.org/10.1016/j.scs.2021.103499

9 Ganesh Balakrishnan, Reducing Embodied Carbon in Construction-Microsoft Campus Refresh White Paper, July 2021, https://query.prod.cms.rt.microsoft.com/cms/api/am/binary/RWGtgl

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