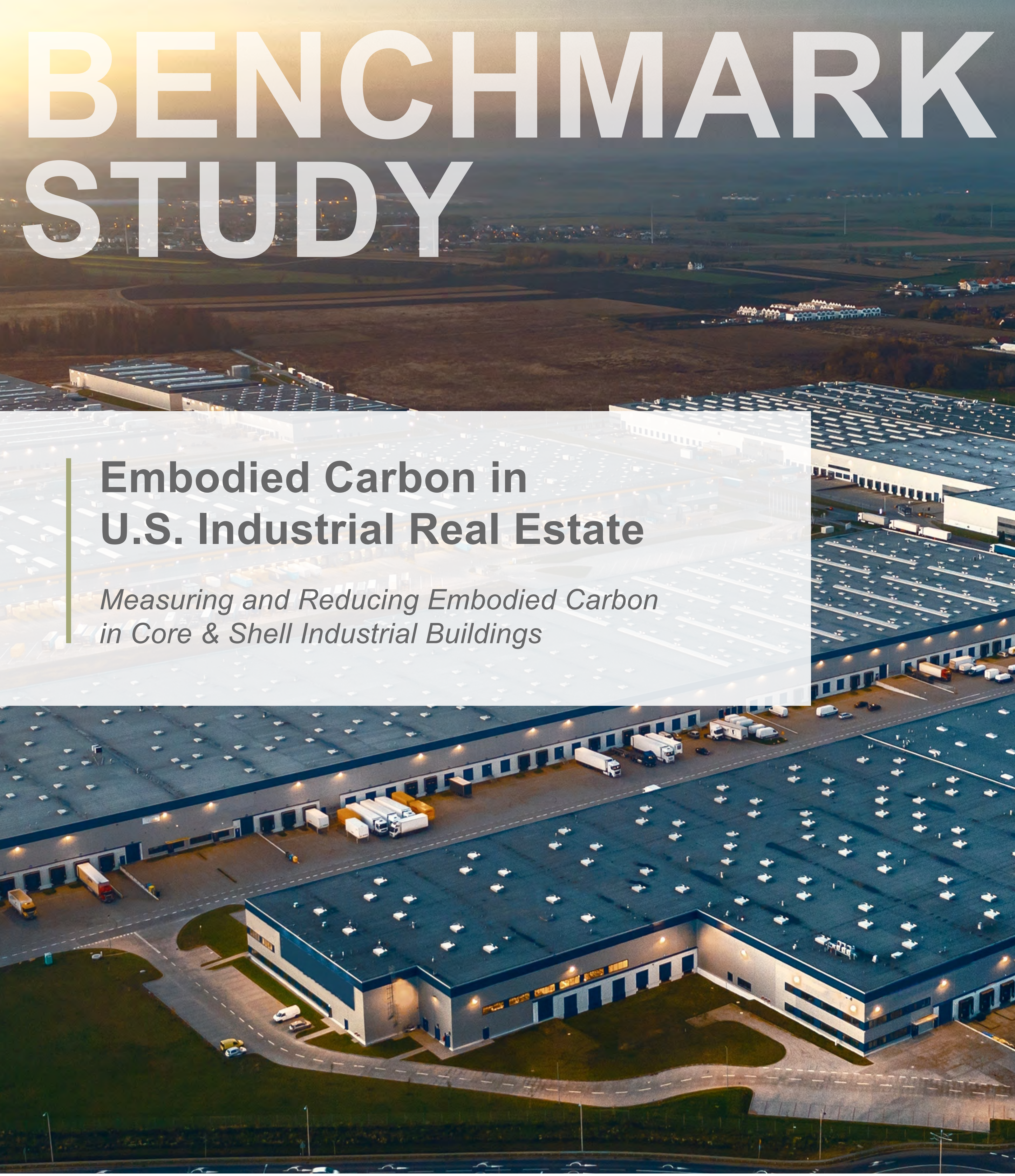

BENCHMARK STUDY

Embodied Carbon in U.S. Industrial Real Estate

Measuring and Reducing Embodied Carbon in Core & Shell Industrial Buildings

MAY 2023

Version 1

Welcome

ABOUT THIS REPORT

Leaders in commercial industrial real estate seeking to ensure a resilient and sustainable logistics model are working to reduce greenhouse gas emissions associated with the construction of new buildings. This effort is relatively new and this report seeks to provide a better understanding of the emissions associated with constructing industrial buildings. This report is limited to assessing emissions related to the construction of the structure and enclosure of a core & shell industrial building only and is not intended to represent a standard for the industry. We are hopeful that the industrial real estate and construction sectors will continue to improve their methods for quantifying GHG emissions and employ reduction strategies. This report is intended to engage these industries to promote increased competency and transparency related to embodied carbon emissions.

ACKNOWLEDGEMENTS

We extend our gratitude to our partner organizations who provided valuable insight, feedback and support throughout the study process. The support and advocacy of these organizations has been instrumental in forming this report and creating urgency for embodied carbon reduction in the industrial sector. We recognize that our understanding and ability to measure and reduce embodied carbon in industrial buildings will evolve significantly over the coming years.

PARTNERS

Affinius Capital
Bridge Industrial
Brookfield Properties
IDI Logistics
Prologis

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ABOUT BRANCHPATTERN

BranchPattern is a building consultancy dedicated to creating ***Better Built Environments***®. Our team consists of Professional Engineers, Registered Architects and Building Scientists that focus on implementing programs and solutions to optimize human experience and environmental stewardship. The firm provides broad expertise to support the sustainability goals of the Commercial Real Estate Industry throughout North America, South America and Europe.

FROM OUR STUDY PARTNERS

AFFINIUS CAPITAL

To help ensure our sustainability efforts have quantifiable impacts, Affinius Capital has committed to conduct embodied carbon accounting for all new industrial developments in 2023 and going forward. This accounting effort will include all A1-A3 emissions associated with each new development and will establish an emissions baseline that we will not only report against, but strive to improve as we implement innovative technologies and construction methodologies.

Josh Hullum
Executive Director of Construction

BRIDGE

As a leading industrial real estate developer, Bridge has a critical role to play in reducing the ~40% of global carbon emissions attributable to the built environment. With the help of BranchPattern, Bridge is conducting whole-building life cycle assessments to better understand the embodied carbon impact of different materials and construction technologies so we can begin incorporating innovative techniques to reduce the embodied carbon of our projects.

Francesca De Amicis
Vice President, Sustainability

Brookfield Properties

Brookfield Properties is committed to advancing the development GHG emissions-free assets and minimizing embodied carbon within building materials and systems.

Devin Barnwell
Managing Partner, Global Head of Portfolio Management, Logistics, Brookfield Asset Management

As a leader in logistics development, prioritizing the reduction of embodied carbon in our developments- even beyond contemplated government mandates- is a first and vital step in reaching our global emissions reduction targets.

Nicole Ivers
Vice President, Global Head of Environmental, Health and Safety, Logistics

IDI Logistics

We are at a pivotal moment for owners and developers of real estate to look beyond the greenhouse gases emitted during building operations. As industrial developers, the emissions embodied within large, concrete and steel buildings have an outsized role in the assets' total carbon footprint. Working with industry peers, key partners and suppliers to create pathways to lower carbon materials, design and construction techniques is an integral part of reducing the impact buildings have in climate change

Chris Brown
Solar Development and ESG Director

PROLOGIS®

Improved accounting and disclosure on embodied carbon will help identify and promote the lowest carbon construction materials and practices across the industry. Given our company's global scale and leadership in sustainable development, we welcome opportunities to collaborate with partners like BranchPattern in this effort and in pursuit of our net zero goal.

Suzanne Fallender
Vice President, Global ESG

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Environmental, Social and Governance	ESG
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Greenhouse Gas Emissions	GHGs
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International Living Future Institute	ILFI
Kilograms of Carbon Dioxide Equivalent	kg CO_2e
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Ordinary Portland Cement	OPC
Portland Limestone Cement	PLC
Recycled Asphalt Pavement	RAP
Square Foot	ft^2 or SF
Square Meter	m^2
Supplementary Cementitious Material	SCM
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World Green Building Council	WGBC

GRAPHICS

1. Abstract

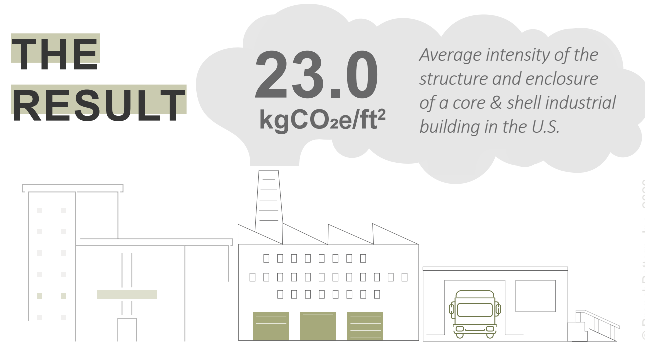
Under the Paris Agreement in 2015, 195 countries committed to reduce global greenhouse gas emissions (GHGs) with the goal of preventing the temperature of the Earth from rising 2 degrees Celsius by 2100 compared to 1990. As of today, the construction and operation of buildings represents 40% of GHG emissions, including indirect emissions, annually.

> **Emissions related to building operations and building construction account for 28% and 11%, respectively, of global greenhouse gas emissions.[1]**

As buildings become more energy efficient and fuel sources become cleaner, operational carbon is reduced. As such, addressing embodied carbon (EC) emissions will become increasingly critical to meet climate goals.

Whole Building Life Cycle Assessment (WBLCA) is a comprehensive method to measure embodied carbon in buildings, amongst other environmental impact categories. Many developers and building owners seek out WBLCAs to measure embodied carbon for the purposes of Environmental, Social and Governance (ESG) reporting and achievement of 3rd party green building certifications, such as U.S. Green Building Council's LEED® program.

BranchPattern performed a meta-analysis of 26 WBLCAs completed by the consultancy in 2022 with the goal of better understanding the average embodied carbon intensity of core & shell industrial buildings in the United States (U.S.).



GRAPHIC 1 Average Embodied Carbon Intensity of Core & Shell Industrial Building

BranchPattern is hopeful the industrial sector will adopt WBLCAs to quantify GHG emissions and employ proven reduction strategies. BranchPattern will work with industry partners to increase transparency related to embodied carbon emissions. Greater access to embodied carbon measurement tools and comparative data can help the industrial sector make informed decisions when designing and constructing commercial buildings. A strategic, transparent and shared approach to measuring and reducing GHG emissions can support global commitments to reduce GHGs. This study summarizes benchmark calculation methodology, innovation and reduction strategies and how the U.S. and global community might consider embodied carbon in the future.

2. Introduction to Carbon in U.S. Industrial Real Estate

2.1 What Do We Mean When We Say Carbon?

Global Warming Potential (GWP) is a measure of radiative forcing of various Greenhouse Gases (GHGs) over the course of 100 years. GHGs include carbon dioxide (CO_2), methane, fluorinated gases, nitrous oxide and others. Each GHG has various emission sources, different residence time in the atmosphere and a specific GWP. Following industry standards, BranchPattern utilizes the unit “carbon dioxide equivalent (CO_2e)” to factor the impact of GHG and report GWP in each WBLCA.

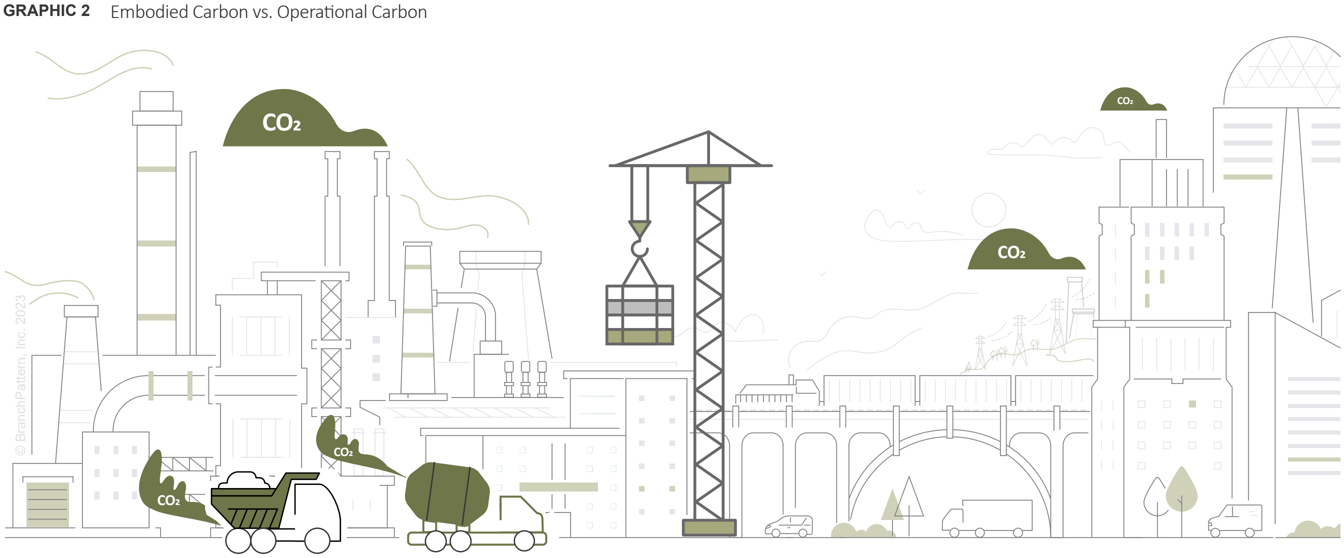
In this paper, the term “carbon” is used in reference to the carbon equivalent impact from the GHG emissions of a given material or design strategy.

2.2 Defining Operational and Embodied Carbon

When people think of a "sustainable" building, they may think of one that uses less energy to operate or that sources renewable energy. However, decreasing energy consumption is only one step in a building’s carbon emission story. Research, policies, and investor and tenant market demand have driven innovation in building envelope and systems design to produce more energy efficient buildings. To realize lower carbon emissions, the building fuel source and energy grid need to be considered. Incorporating renewables on site and into our energy grids will result in lower operational carbon emissions.

> **We must also consider embodied carbon to help complete the emissions story and build better buildings.**

GRAPHIC 2 Embodied Carbon vs. Operational Carbon



EMBODIED CARBON

GHG’s generated from the entire life cycle of a building, including its manufacturing, transportation, installation, maintenance and disposal.

OPERATIONAL CARBON

GHGs emitted to the atmosphere from the building’s use of energy from the utility company, whether it’s electricity, natural gas, diesel fuel or even chilled water, steam, or heating hot water from a central utility plant.

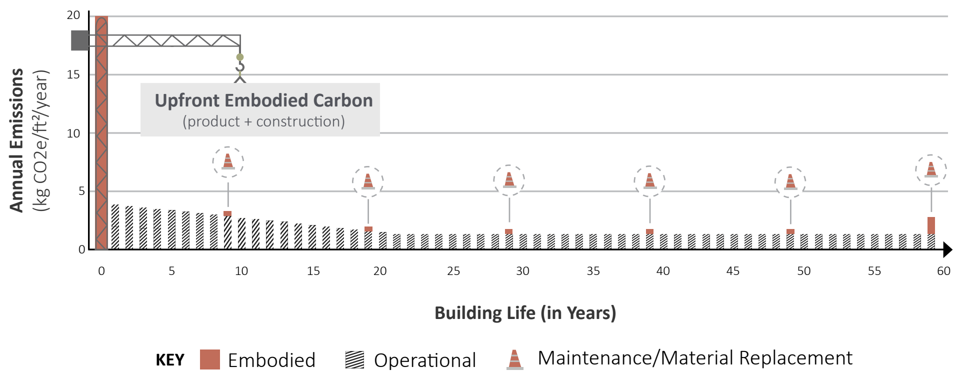
Embodied carbon refers to the GHG emissions generated from the entire life cycle of a building, including the extraction of raw materials, manufacturing of building materials, transportation, installation, maintenance and disposal. The future deconstruction, demolition and waste processing at the end of a building's lifetime also contribute to the embodied carbon emissions of a building. Assuming a 60 year reference period, BranchPattern's data shows that 17.4% of a commercial industrial building's lifetime emissions are embodied carbon. **Graphic 3** visualizes the embodied and operational carbon emissions over the course of a building's lifetime and operational carbon notably decreases over time.

This graph considers that the emissions profile of a building is anticipated to change dramatically in the near future as the electricity providers incorporate more renewable energy as well as carbon capture and storage.

According to the 2019 Global Status Report for Buildings and Construction from the International Energy Agency, 28% of annual global emissions come from building operations, while 11% are emitted in the construction of buildings.[1] Global building area is projected to double by 2050, meaning reducing both operational and embodied carbon is imperative to reach climate goals.

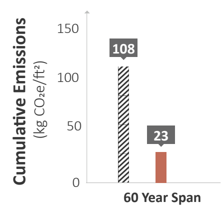
GRAPHIC 3

Total Emissions Over Industrial Building Lifetime*



EMBODIED VS. OPERATIONAL

Over 60 years, embodied carbon from an industrial commercial building will account for 17.4% of its total emissions. This is based on conservative assumptions for grid renewable energy.

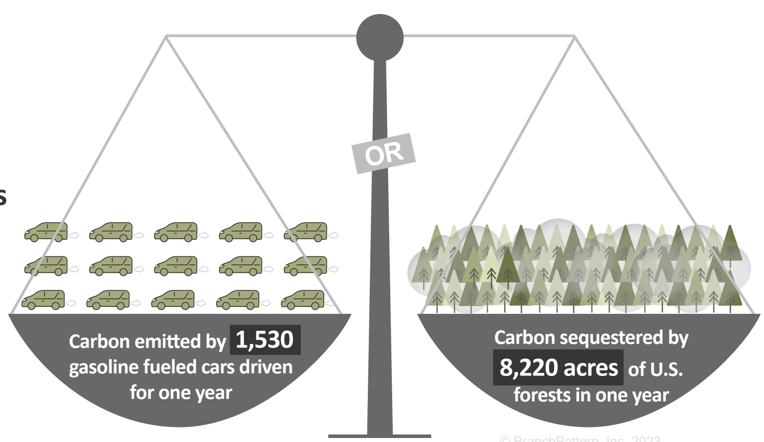


**Graphic 3 assumes an energy mix of 20% natural gas and 80% electricity, according to the energy use intensity for a warehouse result within the 2018 Commercial Building Energy Consumption Survey. (superscript 2) The electricity emissions are reduced over 20 years based on the U.S. National Renewable Energy Lab cambium-middle-scenario for grid renewable mix adoption curve.[3] After 20 years, the grid emissions factor is assumed to be constant.*

TRANSLATING CARBON INTENSITY

An average embodied carbon intensity of 23.0 kg CO2e/SF means the construction of a 300,000 SF core & shell warehouse results in 6,890 MT of lifetime CO_2e emissions.

These emissions are equal to...



GRAPHIC 4 Equivalencies of Total Embodied Emissions Over Building Lifetime*

**Emission equivalency figures derived from the assumption of a 300,000 SF building over 60 years and input into the EPA Greenhouse Gas Equivalencies Calculator.*

2.3 Core & Shell Industrial Buildings

The stakeholders within an industrial building project have varying responsibilities and financial interests in reducing a building's carbon emissions. The uses of industrial buildings also vary drastically and may include multiple space types, such as bulk storage, fulfillment, manufacturing and office. It is common for core & shell industrial buildings to be constructed in a manner that can serve these varying uses. The scope of this study considers the building structure and enclosure only and excludes site and tenant improvement scope. Developers and tenants have differing roles during the design, construction and use stage of a building and, as a result, differing impact on a building's embodied and operational carbon.

GRAPHIC 5

Developer and Tenant Roles in Embodied and Operational Carbon Emissions

DEVELOPER	VS	TENANT
Keep costs low while delivering a product that is comparable in efficiency and sustainability norms relative to the development location	GOAL	Utilizes a functional space and optimizes operational costs
Constructs and designs the core & shell of a building. These decisions can have a significant impact on reducing embodied carbon.	EMBODIED CARBON	Participate in tenant improvement scopes which often include MEP systems in addition to interior finishes
Considers base building design elements, such as orientation, windows and insulation, and solar-readiness which significantly determine energy efficiency	OPERATIONAL CARBON	Can reduce the operational carbon of a building by making decisions about space usage, hours of operation, design temperatures, equipment efficiency and process loads

LOOKING AHEAD

A VESTED INTEREST IN SUSTAINABLE BUILDINGS

The real estate market is helping to align stakeholders around shared ESG goals. Increasingly, industrial commercial developers are responding to the GHG targets of prospective tenants. For example, roof structures are often designed for the weight of photovoltaic panels that may be installed by tenants in the future. Higher levels of insulation and material substitutions may be evaluated for ecological impact. Addressing embodied carbon is in line with the goals and demands of both developers and tenants as ESG performance becomes central to business strategy.

3. Average Embodied Carbon in U.S. Industrial Buildings

A Meta-Analysis of WBLCAs Performed by BranchPattern

3.1 Analysis Approach

BranchPattern conducted 46 WBLCAs globally within the 2022 calendar year and 26 are included within this study. WBLCAs contribute to earning points within green building certifications, inform clients about their building practices and provide direction on optimization strategies to reduce embodied carbon. BranchPattern has found that the most asked question is:

> ***How do we compare to the national average?***

In 2017, the *Carbon Leadership Forum* performed a benchmark study on embodied carbon; however, the scope of the Life Cycle Assessments within the study was primarily limited to residential and office buildings. The study notes, “Further research is needed to develop larger samples that represent the actual commercial and residential building stock."[4]

There are many variables within the commercial sector (i.e., floor area ratio, height, program, design requirements, typical assemblies, etc.), making it necessary to have a distinct benchmark for commercial offices and for commercial industrial buildings. Currently, there are no significant data available for an embodied carbon industry standard in the industrial building sector.

BranchPattern performed a meta-analysis of the results from WBLCAs completed by BranchPattern with the intent to establish a reference point for future comparison within the sector. This benchmark will help the industry move forward strategically to optimize design and reduce embodied carbon impact. Further information on the methodology used to perform the WBLCAs can be found in **Appendix A**.

The meta-analysis includes 26 new building projects for nine separate industrial real estate developers and/or owners in the U.S. in 2022. The WBLCAs included in this study were completed either during the project design or construction phase. This study/meta-analysis is limited to Class A Core & Shell Industrial Warehouses of similar scope.

The meta-analysis includes projects from six different regions in the U.S.: Eastern, Great Lakes, Southeastern, Pacific Southwest, Pacific Northwest and South Central. The regions referenced in the report are based on the regions set by the National Ready Mix Concrete Association.

BranchPattern's analysis of embodied carbon for the selected projects was limited to the structure and enclosure of each building. The reference period for the lifetime of the buildings is 60 years. This scope and building life match the LEED® v4.1 MRc "Building Life Cycle Impact Reduction" requirements. The only environmental impact category compared in this analysis is GWP, measured in kg CO_2e. Operational carbon is excluded.

Embodied carbon results are aggregated nationally and normalized by building area, i.e., embodied carbon intensity. Intensity is expressed as the total kilograms of carbon dioxide equivalent (kg CO_2e) per square foot (ft^2).

GRAPHIC 6

U.S. National Embodied Carbon Benchmark Results*

	# of Projects Within Study	Standard Deviation (kg CO_2e/ft^2)	Range (kg CO_2e/ft^2)	Avg. Intensity (kg CO_2e/ft^2)
BranchPattern 2023 Benchmark	26	4.27	14.9 to 32.0 kg	23.0
CLF v. 2017 Benchmark[4]	2	N/A	18.5 to 22.0 kg	20.2

**includes the results of comparable projects within the CLF study for comparison purposes.*

3.2 Results

The average national results of the buildings included in the BranchPattern Embodied Carbon in U.S. Industrial Real Estate Study are represented in **Graphic 6**.

Two WBLCA studies of new, Northern American, Industrial Commercial Warehouses with a reference period of 60 years are referenced from the 2017 CLF Embodied Carbon Benchmark Study and are included in **Graphic 6**. The interpreted embodied carbon intensity results from the CLF study assume a 150,000 SF warehouse.

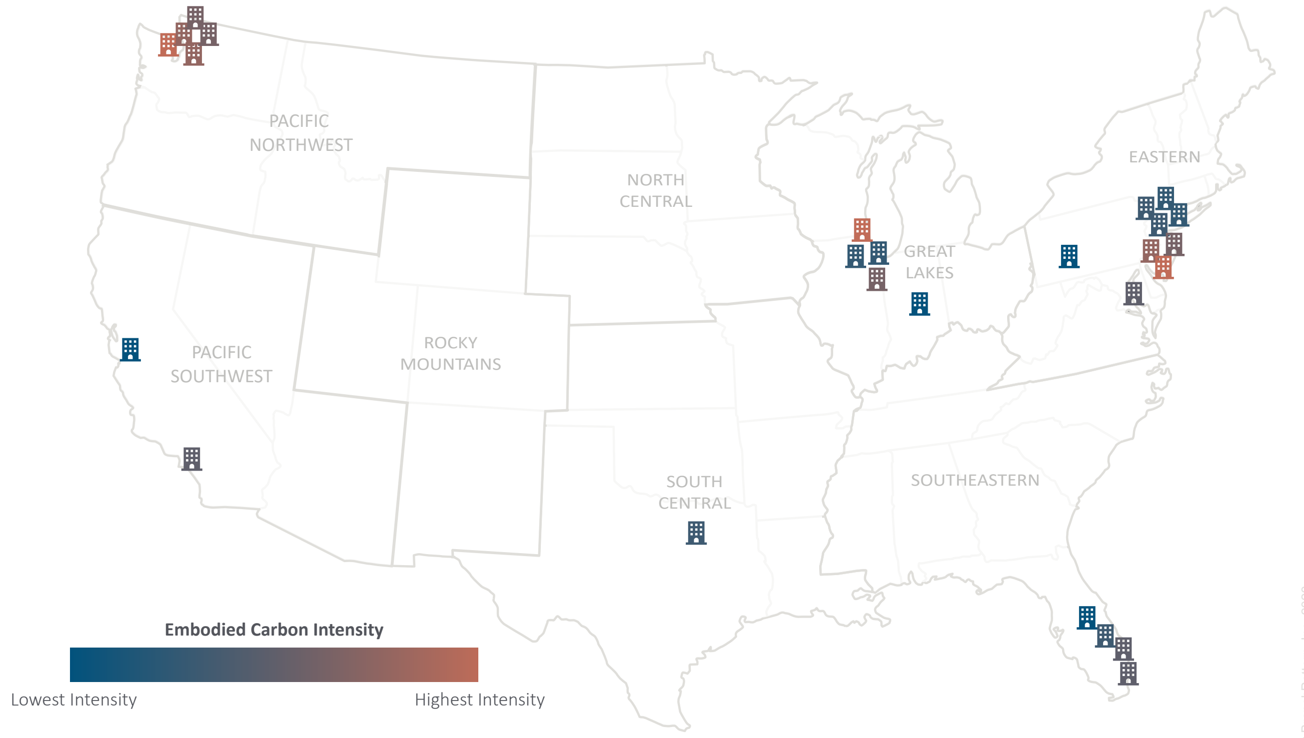
3.3 Discussion

Embodied carbon may vary between regions of the U.S. due to local material availability and transportation method, as well as construction methods and materials appropriate to the region's environmental conditions. Region was not a moderate overall predictor of embodied carbon emissions.

A larger, more robust dataset is required to determine regional variation with statistical significance. **Graphic 7** visualizes the results of each individual WBLCA project within the study.

GRAPHIC 7

Plotted Embodied Carbon Results on Map of U.S.

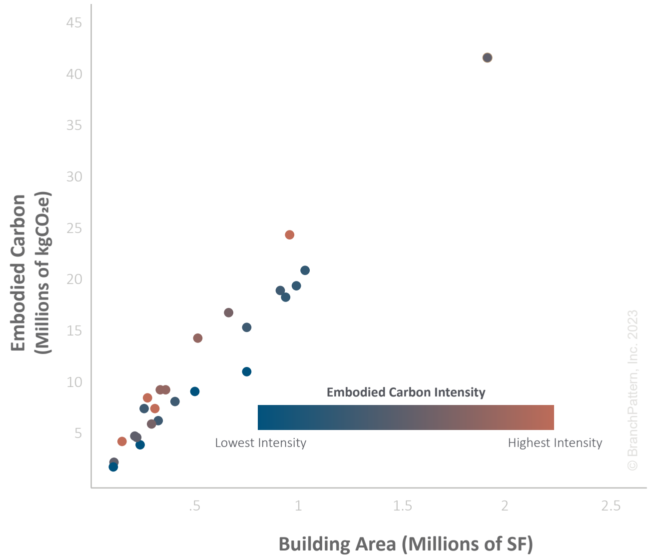


BranchPattern's study shows that embodied carbon displays a strong, positive, linear correlation with building square footage and embodied carbon emissions. These results offer insights for developers and owners, providing a tool to evaluate embodied carbon performance. See **Graphic 8** for a scatterplot of the analyzed data.

Comparison between the 2023 BranchPattern Study and 2017 CLF Embodied Carbon Benchmark Studies cannot be adequately performed due to the limited number of data points available for comparison. However, it is worth noting that the CLF benchmark falls within the range of data observed in the BranchPattern dataset, indicating that the study's findings may serve as a valuable reference for evaluating embodied carbon performance on construction projects. Further research with larger sample sizes is needed to thoroughly assess and compare the two benchmarks and to evaluate the significance of additional factors regarding embodied carbon intensity outcomes.

GRAPHIC 8

Scatterplot of Building Area vs. Embodied Carbon

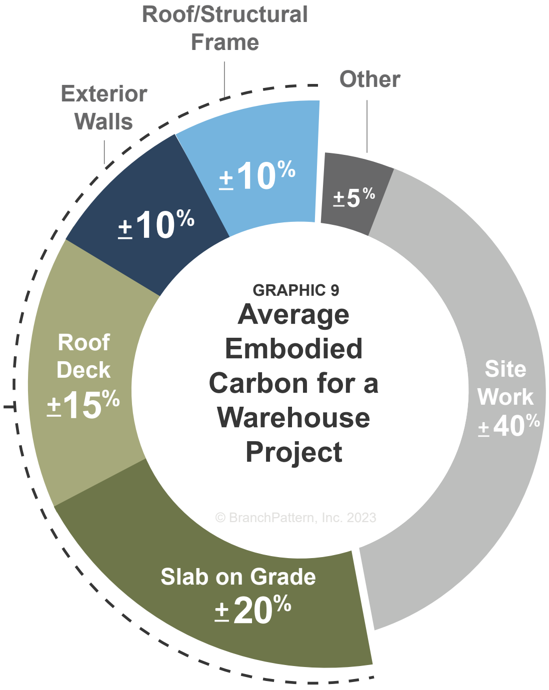


4. Innovation and Reduction Strategies

4.1 Global Warming Potential Contributions by Assembly Type

There are multiple elements that may be assessed within a WBLCA: Site Work, Structure, Enclosure, Mechanical, Electrical and Plumbing (MEP), and Finishes. Based off of results from WBLCAs performed by BranchPattern, **Graphic 9** demonstrates the average carbon emissions associated with each assembly type in an industrial building. The structure and enclosure of a commercial industrial warehouse include the foundation, slab on grade, roof assembly, framing system and exterior walls. Site work also significantly contributes to embodied carbon emissions, mainly due to it involving the utilization of large amounts of earthwork, concrete, asphalt pavement, cement soil stabilization and other concrete elements.

> **Approximately 55% of a commercial industrial warehouse's embodied carbon comes from its structure and enclosure.**



EC LIMITATIONS WITHIN CERTIFICATIONS

BranchPattern's goal is to understand, quantify and reduce embodied carbon emissions as efficiently as possible and the structure and enclosure systems are assembly types with high reduction potential. Mitigation of emissions associated with site work would be enhanced if site work were included in the WBLCA requirements within green building certification programs such as LEED® and Living Building Challenge℠.

BranchPattern is committed to including site work in all carbon accounting work in 2023 to accurately account for full project development impact. For comparison purposes of 2022 studies, the scope of BranchPattern's benchmark study was limited to the emissions associated with the structure and enclosure systems.

4.2 Reduction Strategies

High carbon materials are ubiquitous in the built environment and lower-impact substitutions are increasingly evaluated. Concrete, other cement-based materials and steel are all major contributors to GHG emissions. While the embodied carbon in buildings accounts for at least 11% of global GHG emissions annually, concrete and steel alone account for 11% and 10% of global GHG emissions annually (respectively) due to the ubiquitous use of these materials in other sectors beyond the building sector.[1] As such, chiefly addressing concrete and steel emissions is critical to the global effort to reduce construction impact on climate change. The optimal reduction strategies will be different for each project. However, some of the most common replacement materials, their reduction potential and their limitations are presented below.

4.2.1 Reduce Cement Content

Concrete is made of aggregate, water, binder and admixture. For a traditional concrete mix, cement production accounts for approximately 80% of the carbon emissions.[5] The percentage varies based on the cement per cubic yard, the transportation of materials and the production methods used. Ordinary Portland Cement (OPC) is the most commonly used type of cement in the U.S. A lower carbon alternative, Portland Limestone Cement (PLC), is quickly growing in use. This product category allows a higher percentage of limestone to be incorporated, with little or no impact on performance and workability.

> **Emissions can be reduced by 10% or more by utilizing PLC.[6]**

Traditional concrete mixes can be modified to replace OPC with supplementary cementitious materials (SCMS) such as fly ash, slag, pozzolan and limestone calcined clay. According to the National Ready Mixed Concrete Association:

GRAPHIC 10 Cement Mix Embodied Carbon Reductions[4]

GOING FURTHER

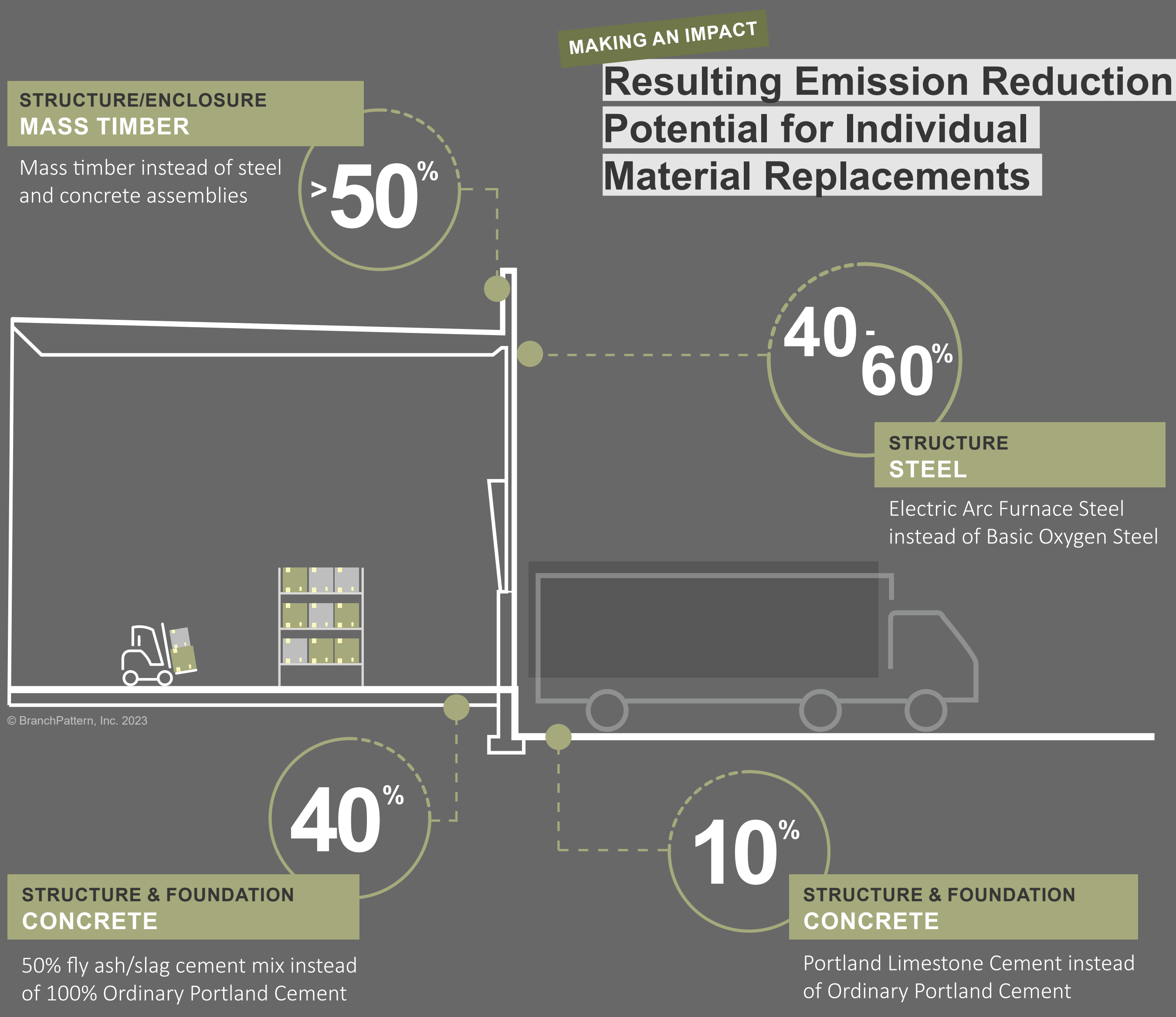
The effective implementation of alternative SCMs depends on understanding each mix's performance for a given end use and region. Often, the addition of SCMs can impact the workability of concrete and its ultimate strength and cure time. Some SCMs, including fly ash and slag, are waste byproducts of coal-fired electricity plants and basic oxygen furnace steel production. These value chains are also subject to pressure to reduce carbon emissions. Research into lower-carbon and even carbon-neutral binders for concrete is a focus in the industry. Innovative design can help reduce the volume of concrete in structures while still meeting performance requirements. Embedded monitors and specifying longer strength development times are strategies for achieving performance with less cement.

4.2.2
Reduce Concrete Volume

Expertise in mix design, base preparation and reinforcing and joint design allows thinner slabs to achieve the same performance as traditional slabs that are 1 or 2 inches thicker. Large format or jointless slabs utilize steel or synthetic fiber to create efficient, low-maintenance surfaces.

Alternative wall assemblies may significantly reduce the carbon intensity of concrete walls or completely replace concrete with other materials. Traditional precast or tilt-up concrete panels may be replaced with insulated composite wall panels, where rigid insulation is sandwiched between two concrete wythes. Alternatively, insulated concrete forms inverse this assembly and can also reduce concrete volume. Another alternative is insulated metal panels or other proprietary composite panels. Reduction potential for alternative wall assemblies varies depending on the structural framing system required to support the panels. Insulated wall panels may also decrease operational carbon emissions by providing a better-performing envelope.

GRAPHIC 11 Material Replacements: Impact on EC Emission Reduction[6, 8, 12]



4.2.3

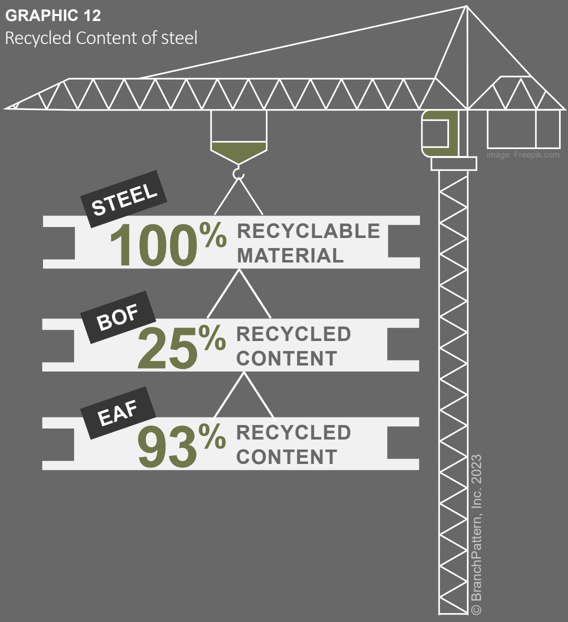
Electric Arc Furnace Steel

Steel is a widely used and necessary material to ensure the strength and durability of buildings and it is a 100% recyclable material.

> **11.1% of annual global GHGs are related to steel production.[1]**

Steel is primarily manufactured in two types of factories: basic oxygen furnaces (BOF) and electric arc furnaces (EAF). BOFs have the capacity to process virgin iron ore to create steel, resulting in a steel mix with an average of 25% recycled content.[7] EAF factories typically only have the capacity to melt scrap iron and steel, resulting in a steel mix with an average of 93% recycled content and a 40-60% reduction in related emissions.[8]

GRAPHIC 12
Recycled Content of steel



Electric Arc Furnace Steel Production

Purchasing EAF steel as opposed to BOF steel assures significant reduction in embodied carbon emissions in a building with no sacrifice in performance.

40-60%
RELATED EMISSIONS REDUCTION[6]

4.2.4 Reuse and Design for Disassembly

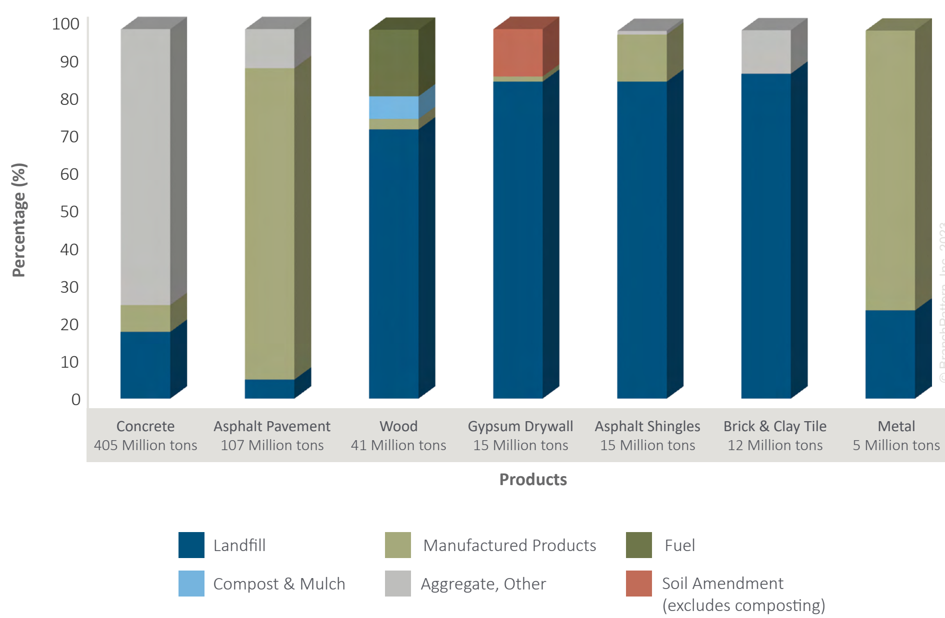
At the end of a building's life cycle, materials may be reused, recycled, waste-to-energy, composted or sent to the landfill. The reuse of buildings has the greatest impact on lowering embodied carbon emissions. Emissions are significantly lower when high-impact materials are reused and incorporated into new project designs. This reduction is largely because the "Product" stage (A1-A3), shown in **Graphic 17**, is eliminated, since the materials already exist in the built environment.

Recycled materials typically have lower embodied carbon than virgin material counterparts because they reduce production emissions and reduce the demand for material extraction. Lumber, steel and asphalt are common, high-impact reuse materials. Over the years, the U.S. has significantly increased the amount of recovered construction and demolition (C&D) materials. In 2009, the Environmental Protection Agency (EPA) reported that 40% of C&D materials were diverted from landfills.[9] In 2018, the EPA estimated that 76% of C&D material was recovered, while 24% was sent to landfills.[10] **Graphic 13** shows the end-of-life destination of various C&D materials in the U.S. in 2018. In 2018, landfills were the primary destination for wood, gypsum drywall, asphalt shingles, brick and clay tile. A major challenge with recovering construction materials today, especially wood-based materials, is that conventional demolition is often much cheaper than selling scrap materials through intentional deconstruction. However, a building that is designed for disassembly may have greater residual value, as the integrity of more materials is preserved.

Design for disassembly incorporates the deconstruction planning of a building into the design phase. This practice increases the feasibility of reusing materials at the end of the building's life cycle and contributes to a circular economy. Design for disassembly is most useful for reducing the embodied carbon of materials in future projects, though it does not necessarily reduce the embodied carbon of a present-day project. The design method sets a standard for all developers to commit to ease of disassembly for the construction industry to reap the benefits of recycled, low-embodied carbon material going into the future. As demand increases for building materials in the coming decades, reuse will remain a critical low-carbon strategy.

GRAPHIC 13

Construction & Demolition Debris Management by Destination[10]



4.2.5 Alternative Pavement

While site work is not included within the parameters of the 2023 BranchPattern Benchmark Study on Embodied Carbon in U.S. Industrial Real Estate, site work does make up approximately 40% of the total embodied carbon of a warehouse development. Pavement is a major contributor to site work emissions.

Two primary alternatives to baseline pavement usage are optimized concrete paving systems and the use of Recycled Asphalt Pavement (RAP).

Mix design, joint spacing and sub-base preparation can be used to directly reduce the volume of concrete used for site work. Proprietary, vertically integrated paving and slab companies have accelerated innovation in the sector.

Industry Partners to Achieve Net Zero

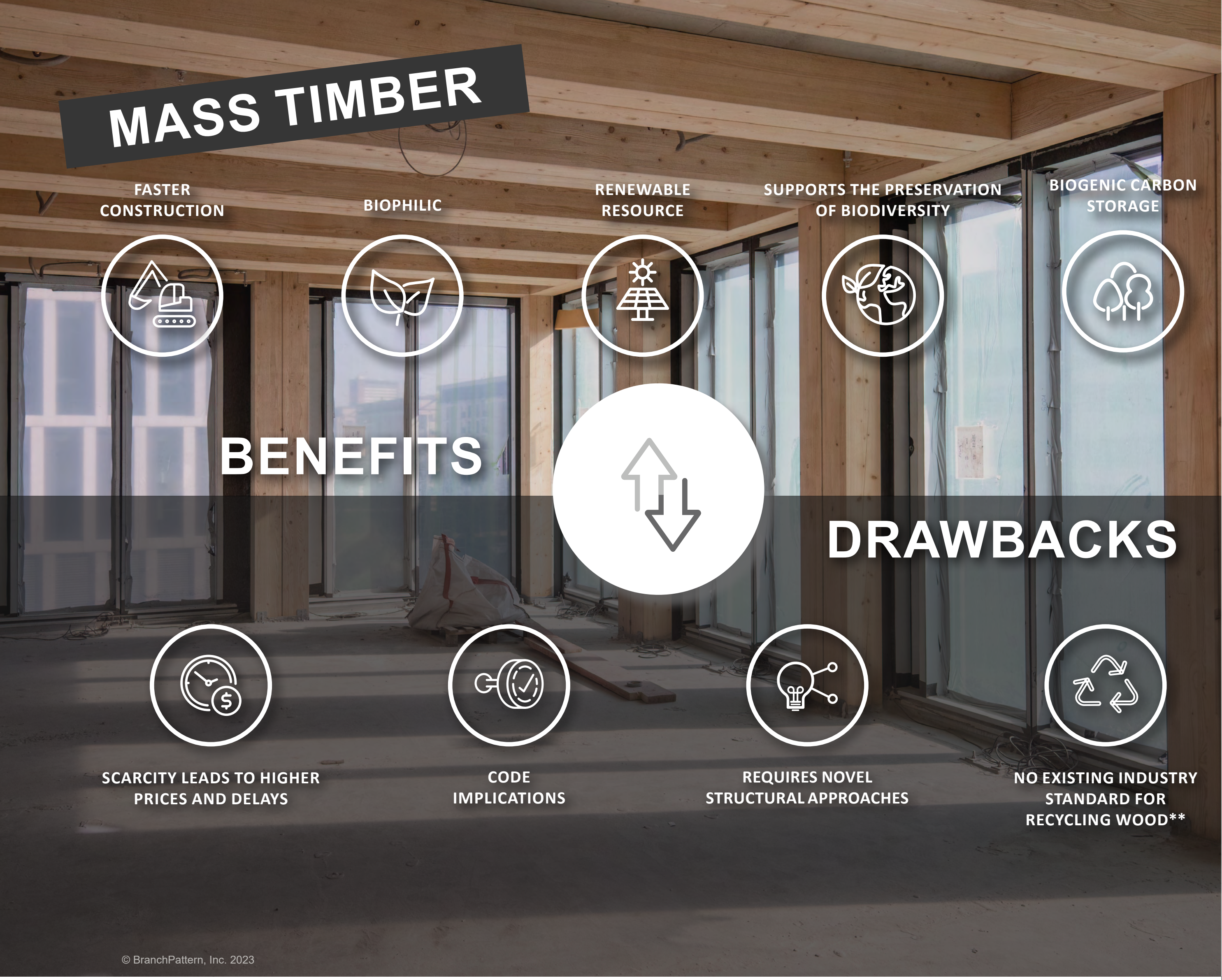
In collaboration with MIT's Climate and Sustainability Consortium, commercial real estate leader, Prologis, has committed to a net zero value chain by 2040. The use of low-carbon materials will be essential to meeting this goal.

For more information, **click here.**

Not included in this study is site work, which typically makes up 40% of the total embodied carbon of an industrial development.

Hot mix asphalt (HMA), or asphalt concrete, is a flexible paving incorporating bitumen binders and aggregate. Typically, a wearing course is installed over a binder course, on a prepared aggregate base. Resurfacing of the top-wearing course is required every 8-15 years. Therefore, strategies that prolong the life of the wearing course are fundamental to life cycle embodied carbon reduction. Innovations such as synthetic fibers and polymer-modified admixtures may extend the service life of the wearing course.

HMA is a 100% recyclable material. Using RAP in creating new HMA mixes reduces the virgin asphalt binder required. The binders in HMA are responsible for over 90% of its total emissions.[11] The raw material acquisition phase of asphalt binders includes the mining and processing of bitumen, typically from oil sands or as a byproduct from oil refining. About 30% of the virgin asphalt binder in a mix can be substituted with RAP. Substitution rates vary depending on individual asphalt plant procedures. When considering the use of asphalt on site, it is vital to consider the other sustainability impacts beyond carbon, such as an increase in VOCs and heat island effect.



GRAPHIC 14 Benefits and Drawbacks of Mass Timber
***see Graphic 13*

4.2.6 Mass Timber

Using Mass Timber for exterior wall assemblies, floor and roof decking, and structural framing can reduce a project's carbon footprint, as compared to steel and concrete assemblies. According to a publication in the Journal of Building Engineering, in buildings where Cross Laminated Timber (CLT) has replaced conventional reinforced concrete, the embodied carbon of an entire building can be reduced by over 50%.[12] Biogenic storage is a significant reason mass timber has a comparatively low embodied carbon. Biogenic carbon is the carbon stored or emitted from a bio-based material through natural sequestration during growth or decomposition. This can be accounted for in the life cycle product stage, modules A1-A3 and D, shown in **Graphic 17**.

PILOTING CLT CONSTRUCTION TECHNOLOGIES + METHODS

Developers are piloting the use of CLT for industrial buildings. Affinius Capital recently completed a 161,200 SF Class A Industrial/ Logistics Warehouse with CLT, resulting in a 60% reduction in embodied carbon compared to a concrete build.

For more information, **click here**.

5. Embodied Carbon in the Future

The Paris Climate Accords set a goal of reducing GHGs by 40% by 2030 compared to 1990 emissions.[13] The World Green Building Council (WGBC) aims to achieve net zero buildings by 2050.[14] Operational carbon standards have been studied and enacted for years and to meet the rigorous, international emission reduction goals, we must now focus on embodied carbon as well. Meeting these goals will require top-down and bottom-up demand to evolve industry standards of embodied carbon disclosure, measurement and reduction.

The demands from consumers to policymakers must be well informed.

Transparent and clear carbon accounting methods support stakeholder engagement. To reduce, we must measure.

WHAT YOU SHOULD KNOW

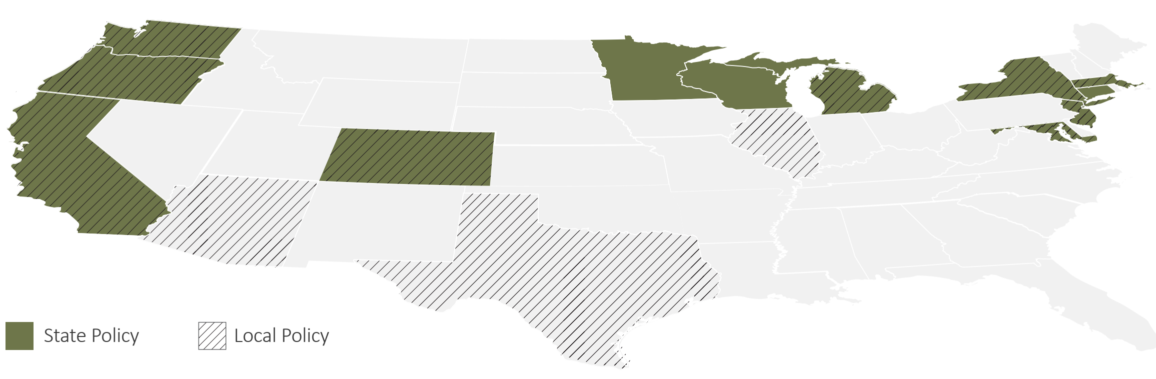
AN INDUSTRY OUTLOOK

1 Increased Policies on Embodied Carbon

Government funding and policy changes will increase the feasibility of developing and implementing low-carbon emission construction solutions while simultaneously requiring changes in the construction industry. On a national scale, the Inflation Reduction Act (IRA) of 2022 sets aside five billion dollars in funding to incentivize the development of construction projects with low embodied carbon. Specifically, the IRA allocates funding to support the development of Environmental Product Disclosures (EPDs) for construction materials. Through the Buy Clean Task Force within the 2021 Executive Order 'Catalyzing Clean Energy Industries and Jobs,' an avenue is created to identify and utilize low embodied carbon materials for federal construction projects.

Multiple jurisdictions have passed requirements for environmental product declarations, introduced low-carbon procurement policies, and placed limits on GWP for various materials. **Graphic 15** displays the U.S. state and local jurisdictions that have passed or proposed policies related to embodied carbon in the construction industry.[15]

GRAPHIC 15 Map of U.S. Jurisdictions with Embodied Carbon Policies



2 Sustainable Building Certifications

Green building certification programs will continue to play a significant role mainstreaming embodied carbon knowledge within various building sectors.The International Living Future Institute's (ILFI) Net Zero Carbon Certification and the ILFI Living Building Challenge's Energy + Carbon Reduction Petal both include prescriptive requirements for embodied carbon reductions and LEED® Building Design and Construction (BD+C) version 4.1 offers credit opportunities for performing WBLCAs and reducing embodied carbon. Full embodied carbon accounting is also necessary for measuring and reporting Scope 3 emissions.

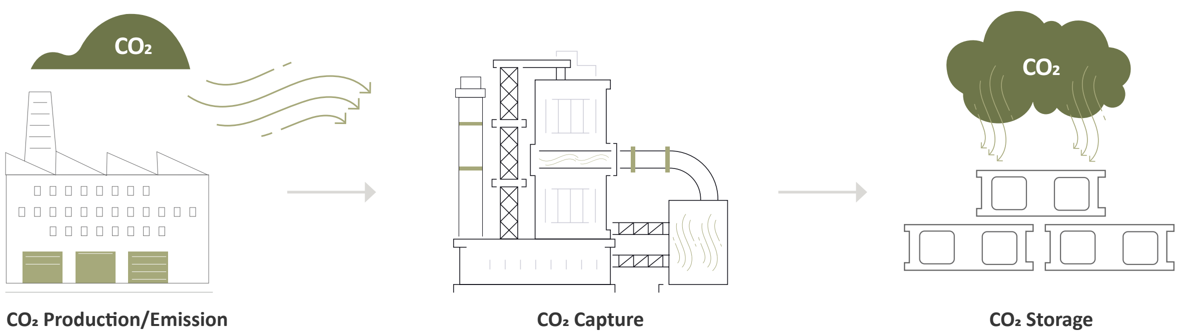
3 Low-Carbon Building Materials

The materials industry is making significant progress in making low carbon materials available. As of 2023, many materials such as SCMs, EAF low carbon steel and mass timber are increasingly cost competitive and widely available. Exciting and creative materials such as algae-derived cement and fossil free steel are being developed for future use.

4 Innovative Technology

Engineering solutions are increasing the viability of capturing and storing CO_2 within the built environment as well. Some current examples of carbon capture, utilization and storage include injecting CO_2 into concrete during the mixing process or curing concrete in a CO_2-rich environment.

GRAPHIC 16 Depiction of Carbon Capture and Storage



CALL TO ACTION

BranchPattern's 2023 Benchmark Study on Embodied Carbon in U.S. Industrial Real Estate is a starting point.

> **The industrial development sector must continue to track and report embodied carbon transparently to promote practices that reduce emissions. The construction sector must continue to innovate materials and methods that reduce emissions.**

BranchPattern is excited to see increased conscientiousness of embodied carbon in buildings, to share impactful emission reduction strategies and support the evolving low-carbon material landscape. Embodied carbon related emission reductions are possible, necessary and promising.

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APPENDIX A

Methodology

Methodology

Purpose

A WBLCA is used to quantify the environmental life cycle impacts of a building. Impact categories include GWP, acidification, eutrophication and ozone depletion. The outcome of the WBLCA can be used to determine the most effective optimization strategies to reduce a building's impact on the environment. Optimization efforts can earn necessary credits for various 3rd party green certification programs, including LEED® BD+C, IFLI Net Zero Carbon, Living Building Challenge and more. The outcomes can also be used for ESG reporting.

Functional Equivalent

There are multiple assembly types that may be assessed within a WBLCA: Structure, MEP, Enclosure, and Finishes. Site work is another major contributor to embodied carbon but is not included in a typical WBLCA. BranchPattern has performed WBCLAs including various combinations of assembly types, depending on the goals of the client. Comparison of the intensity of projects including various assembly types would produce false and inaccurate averages. For the purpose of studying projects with similar scopes, BranchPattern's benchmark study is limited to the projects including only the structure and enclosure of the buildings.

Reference Study Period

The Reference Study Period and the Required Service Life are both 60 years for all buildings in the meta-analysis.

Boundary

In the results of the benchmark analysis, there is minor variance in the stages assessed in each sample project's WBLCA due to varying scopes, reporting requirements and software databases. The WBCLA results exclude Operational Carbon data (Modules B6 and B7). Each WBLCA includes Modules A1-A4 and C2-C4 at a minimum. All projects include some use stages within Module B.* Due to the typical program area and the materials used in Industrial Commercial Real Estate developments, approximately 85% of the projects' embodied carbon is attributed to the Product Stage. This is largely due to the amount of concrete and steel used in the building's structure and enclosure. Though many of the WBLCAs reported all environmental impact categories as required by LEED®, the only category assessed for this benchmark analysis is GWP.

Several software programs were utilized in this assessment. Athena Impact Estimator relies on internal Life Cycle Inventory (LCI), with variations based on project location, for all life cycle stages. One Click LCA relies on its generic data or EPD for Modules A1-A3. Scenarios for A4 through B5 are based on site geography, standard maintenance and replacement periods. End-of-Life scenarios C1-C4 assume demolition, transport, recycling and disposal based on the material input. Reference **Graphic 17** for guidance on the life stage of each module.

Impact Reduction

The baseline design represents standard practices in the construction of similar facilities. Similar facilities are buildings of the same use type, located in the same region and have the same gross square footage. Industry-wide EPDs and generic product data are employed for building products, including concrete for foundations, slabs and wall panels. Industry-wide EPDs and generic product data are also employed for the windows, doors, structural steel, steel decking and roofing systems.

GWP intensity is measured in kg CO_2e per ft^2. The intensity of a proposed building using standard practices can be compared to a proposed design model to assess total GWP reduction for a proposed design and additional optimization strategies.

38% of projects report on Module B1. 77% report on Module B2. 50% report on module B3. 86% report on Module B4. 77% report on Module B5.

GRAPHIC 17

Building Life Cycle Information