BuildingGreen

SPOTLIGHT REPORT

The Urgency of Embodied Carbon and What You Can Do About It

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About BuildingGreen

BuildingGreen, Inc is an independent consultancy committed to providing accurate, unbiased, and timely guidance to help building industry professionals and policy makers improve the environmental performance of buildings and reduce their adverse impacts.

We offer consulting, training, facilitation, and online resources to help our customers design and build from a whole-systems perspective. Our integrated design approach minimizes ecological impact and maximizes economic performance.

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The Urgency of Embodied Carbon and What You Can Do About It

Building materials emit massive amounts of carbon long before the lights go on. Here's how thoughtful design can reduce global warming impact.

By Paula Melton

Editorial Director

Climate change is a rapidly escalating emergency, and we have a lot of hard work to do in order to mitigate its effects. For building professionals, that has typically meant increasing energy efficiency and pushing for renewable energy production, thus reducing the amount of carbon generated by the fossil fuels we burn in order to operate our buildings.

But as crucial as that is, it's not enough: we also need to think about the greenhouse gases that are emitted to construct our buildings in the first place—the *embodied carbon*. The manufacture of building materials makes up 11% of total global greenhouse gas emissions, according to the latest data from the United Nations Environment Programme.

That 11% might sound small compared with the impact of operational energy (28%), but for new construction, embodied carbon matters just as much as energy efficiency and renewables. That's because the emissions we produce between now and 2050 will determine whether we meet the goals of the 2015 Paris climate accord and prevent the worst effects of climate change.

"We are making global progress in reducing operating emissions," said Erin McDade, program manager at Architecture 2030. "According to the best scientific data and consensus, we have to phase out all fossil fuel emissions by 2050. … Without embodied carbon, we will not meet our climate targets."

Image: Foster+Partners

Arup used whole-building life-cycle assessment to help reduce the embodied carbon of the new Mexico City Airport.

So where do building professionals come in?

Design teams have a huge role to play. This report focuses on how architects and designers, working with other key members of the project team, can find low-cost and no-cost ways to reduce the embodied carbon of new construction projects.

Does It Need to Be New?

The very first question to ask for any project is whether new construction is needed. By avoiding the use of new materials, we avoid their impacts altogether. Building reuse and incorporation of salvaged building materials can greatly reduce the embodied carbon of construction.

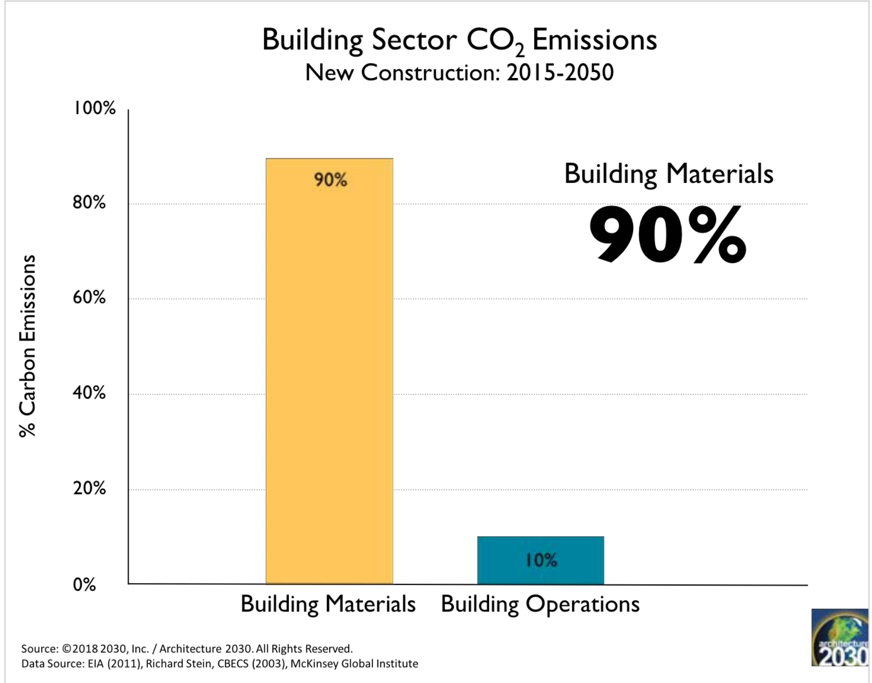

Image: Architecture 2030

If things don't change with how we treat embodied carbon, impacts will total 90% of the carbon released from newly constructed buildings between 2015 and 2050.

And while we're at it, it's also vital to think about the end of life of new buildings before they're even built. It doesn't make sense to emit carbon twice or three times when the same building could serve two or three different uses over its lifetime. Consider design for future uses of whole buildings and design for deconstruction of systems so that materials can have a second life in another building.

Assessing Embodied Carbon

Once you've identified embodied carbon as a problem to be solved, what happens next?

The first step is to identify carbon "hot spots"—materials or systems that contribute the most to a building's embodied greenhouse gas emissions. That way, project teams can prioritize the materials that make the most difference and can start finding solutions that have the biggest impact.

The most widely accepted method for assessing embodied carbon is whole-building life-cycle assessment (WBLCA), but other tools can supplement this as a first step.

Getting started: free databases

To get a general sense of proportion and start getting a feel for the carbon footprint of common materials, there are a few free resources available. One is the Bath Inventory of Carbon and Energy (ICE), which has the advantage of being a long-respected source of embodied carbon data. The main drawback of ICE is that it's not updated frequently; data are also specific to the U.K. BEES (Building for Environmental and Economic Sustainability) is a similar tool offering North American data.

A newer resource is the Quartz database, which has basic environmental-impact and health-related data on 102 common building materials. Carbon data come from thinkstep, an internationally respected life-cycle analysis firm, and are specific to the U.S.

Keep in mind, though, that these resources are a first step: they can give you a sense of the baseline embodied carbon of brick or aluminum or foam insulation, but they don't tell you a lot more than that. (The carbon footprint is listed under "global warming potential" and is expressed in kilograms of carbon dioxide equivalent.) It's not even really appropriate to compare materials because their embodied carbon is listed here by weight. You wouldn't want to compare a kilogram of brick to a kilogram of aluminum; that makes no sense in the context of a building project.

Digging deeper: EPDs

Some of these problems are solved when you look at environmental product declarations (EPDs) for the carbon footprint of specific products. EPDs are usually based on "functional units" rather than weight, and many will provide the carbon footprint of a specific product or set of products rather than a generic

Defining Embodied Carbon

Definitions of embodied carbon differ. Some view the embodied carbon of a building as including the entire life cycle of the materials, even the operational phase of the building—for example, taking into account multiple replacement cycles of finishes over time. A full life-cycle view of embodied carbon would account for impacts of landfilling or recycling materials as well.

For simplicity in this report, we are focusing on initial embodied carbon—the impacts associated with extracting, manufacturing, and transporting materials to the jobsite. "Carbon" is used to indicate all greenhouse gas emissions, not just carbon dioxide.

baseline. (The exception is a so-called industry-wide EPD, whose job is to set a baseline to compare with product-specific EPDs.)

An EPD consists of life-cycle assessment (LCA) information summarized in an easier-to-read format. It looks at a number of impact categories beyond global warming potential (like smog and eutrophication), but it's the go-to place to learn about the carbon footprint of a specific product.

But EPDs have drawbacks as well, the biggest one being that laypeople are not in a good position to compare their results. You definitely can't compare steel to concrete, for example, and it's a tricky business even to compare one concrete mix to another. For more on (not) comparing EPDs, see Apples to Pineapples: Four Reasons You Can't Compare EPDs and Wood, Concrete, and Steel and Their Incomparable EPDs.

The gold standard: whole-building life-cycle assessment

The only way to get a really clear picture of how one material or system compares to another in the context of a building project is to use whole-building life-cycle assessment, or WBLCA. This process looks at multiple impacts of building materials, including global warming potential, over their entire life cycle—from extraction and manufacturing through the landfill or recycling plant.

Although WBLCA requires specialized software and training, the good news is that this software is designed to be used by building professionals. The software can also be used to conduct more limited studies, like comparisons of different structural systems or enclosure scenarios. Studies like these can be key to reducing the embodied carbon of a building because they allow designers to view multiple ways of accomplishing the same goals. Two major tools dominate the WBLCA market in North America—Athena Impact Estimator and Tally.

The Carbon Leadership Forum, a network of experts on the carbon impacts of the building industry, has developed an LCA practice guide aimed at building professionals. Makers of WBLCA software tools also offer trainings to help users navigate the software and interpret results.

INSIGHT

New: Embodied Carbon Guidance for Designers

Architecture 2030 is introducing the Carbon Smart Materials Palette, a tool laypeople like architects and designers can use to identify and take action on embodied carbon "hot spots" in building materials.

Working with a network of life-cycle assessment experts, Architecture 2030 developed the tool to provide "high-level and easy-to-digest information" about specific building materials like steel, concrete, finishes, and insulation, according to Erin McDade, program manager at Architecture 2030. Each "swatch" in the palette includes a material's basic attributes, information about how the material is produced and where its embodied carbon footprint comes from, and design guidance for reducing its footprint.

Users can learn more about the Carbon Smart Materials Palette on the Architecture 2030 website.

Photo: Mithun (Photography by Michael Fiegenschuh)

Architecture firm Mithun used life-cycle assessment tools to assess the benefits of cement replacement and the use of wood instead of concrete piers for the Louisiana Children's Museum in New Orleans.

Optimizing Structural Systems

Not every project has a budget for a full-scale whole-building life-cycle assessment (although many firms are doing more limited LCA work on projects on their own time). Luckily, there are takeaways from this process that project teams can apply to their everyday work without additional expense or, in some cases, even without client buy-in or knowledge needed.

One of the most important takeaways from whole-building LCA is that structural systems almost always comprise the largest source of embodied carbon in the building—up to 80%, depending on the building type. So the first goal when looking to reduce the embodied carbon of a project is to target the structural system. Concrete, steel, and wood can all be optimized in different ways to reduce impacts.

In all this, it's important to get the structural engineer involved early. "The form of the building often takes shape even before we get into schematic design," noted Mark Webster, P.E., a structural engineer with Simpson Gumpertz & Heger. "It would be great if architects would reach out earlier to us [structural engineers] to help them make decisions related to building form and structural materials." He added, "It's increasingly obvious, the role that we have to play in terms of embodied impacts with respect to climate change."

Concrete and cement

Concrete has a large footprint because of the carbon-emitting process used to make one of its most important ingredients—the binder portland cement (see Reducing Environmental Impacts of Cement and Concrete). By some estimates, production of portland cement is responsible for 5% of total global CO_2 emissions. Replacing some cement with supplemental cementitious materials (SCMs) like fly ash or blast-furnace slag is a go-to way for project teams to reduce the embodied carbon of the concrete in their projects.

But that's not always as simple as it might sound, and structural engineers have some advice about how to do it right.

Engineering firm Walter P Moore has conducted about 20 whole-building LCAs in pursuit of the Building Life-Cycle Impact Reduction credit under LEED version 4, according to Dirk Kestner, P.E., director of sustainable design. Kestner's takeaway? Every project—even those with wood structural systems—contains substantial amounts of concrete, and cement content is one of the largest contributors to embodied carbon on a project.

"One thing that people … need to start doing is thinking about how they specify their concrete and stop talking about it as 'percent fly ash,'" said Kestner. "It's about getting cement content down and using only what you need."

Reducing cement content can take many forms, he said, including simply using less by specifying higher-quality aggregate or reducing water content. Kestner says successful lower-impact concrete specifications can be performance-based—stating the structural requirements (how much strength is needed when) and environmental requirements (like global warming potential per yard of concrete) rather than specifying a percentage of cement and SCMs. In other words, you might be able to reduce impacts further by asking for exactly what you want. Getting the structural engineer in direct dialogue with the ready-mix supplier is essential to this approach, he said.

Cure times and subtle color differences can be a barrier when using SCMs, according to Meghan Lewis, associate at

TAKEAWAYS

Concrete and Cement

- Cement is responsible for concrete's **large carbon footprint**; a ton of cement represents about a ton of greenhouse gas emissions.
- Fly ash and blast-furnace slag can improve certain properties of the concrete but can also **take longer to cure** and can affect the final color.
- All buildings—even wood buildings—contain a **significant amount of concrete**.
- Avoid over-engineering without good reason: work with the structural engineer to ensure you're **using only as much concrete as you really need**.
- Consider working with the structural engineer on a **performance-based concrete specification** that sets environmental requirements.
- When calculating carbon reductions from using supplemental cementitious materials, **choose an honest baseline**—not a 100% cement mix, which is rare.

Mithun, but "concrete in the foundation is not as time sensitive," and you don't have to worry about color there, either. "You can have a huge impact just focusing on the foundation," she suggested. That includes working with the structural engineer to ensure the foundation isn't unnecessarily overdesigned—using less concrete in the first place. All this can be done without added costs.

For the new Mexico City Airport project, Arup conducted extensive life-cycle assessment studies to reduce embodied carbon (the project is pursuing LEED v4 certification). Although the team spent most of the analysis time on modeling the enclosure correctly, in the end, according to Arup's Frances Yang, S.E., it was the concrete mixes as well as the efficiency of the unique structural steel design that helped cut the total embodied carbon of the planned building by 10% compared with a benchmark building. Embodied carbon reductions totaled 130 million kilograms of CO_2 equivalent, she said—which is like taking 28,000 cars off the road for a year.

Yang emphasized the importance of using reasonable regional benchmarks for concrete, since it's already commonplace to replace some cement content with SCMs. (The team also studied the structural systems of several other airports with similar spans to establish a baseline tonnage of steel, she said.) The National Ready Mix Concrete Association publishes benchmark data that can be used for this purpose. "I don't think it's right to choose an all-cement mix" as a baseline for all mixes, Yang said. "Go with what you have experience seeing."

Arup also worked with the Athena Sustainable Materials Institute, developer of Athena Impact Estimator tool, to ensure that all data were specific to the region—an important detail since the software's default data don't extend beyond regions in the U.S. and Canada.

Steel

By weight, steel has a much higher embodied carbon footprint than concrete does—with one ton of steel representing approximately a ton of greenhouse gas emissions. According to the World Steel Association, steel production is responsible for 6.6% of greenhouse gas emissions globally—more than portland

TAKEAWAYS

Steel

- A ton of steel represents about **a ton of greenhouse gas emissions**.
- North American steel generally has a **lower carbon footprint** than steel from overseas.
- Concrete buildings use a lot steel for reinforcement; this can be **90%–100% recycled steel** if choosing North American products.
- Avoid over-engineering without good reason: consider a **braced frame rather than a moment frame**, and work with the structural engineer to manage the architectural impacts.

Image: Foster+Partners

By replacing portland cement and using other carbon-reducing strategies, the team was able to cut the embodied carbon of the new Mexico City Airport project by 130 million kilograms cement (see Better Steel, Lower Impacts). Those global numbers reflect use of dirtier technology in much of the world, which is still using basic oxygen furnaces (BOF) rather than electric arc furnaces (EAF). In North America, the industry has mostly switched over to EAF technology—the process used to recycled steel. This, along with a cleaner electrical grid, has resulted in a 36% reduction in the industry's carbon footprint since 1990, according to Mark Thimons, P.E., vice president, sustainability, at the Steel Market Development Institute.

So that's the first rule of thumb for reducing the embodied carbon of steel on a project: specify steel produced in North America—or, if that's not possible, at least specify recycled steel, which uses the better EAF technology.

The only other real option for reducing steel's footprint is to use less—a practice that's even promoted by the Steel Market Development Institute, a trade group. Aside from choosing North American steel, "the other advice that we always give to architects and especially engineers is just to be as efficient as possible in designs," Thimons told BuildingGreen. "We really encourage the concept of working with an integrative process. It can result in some of those kinds of savings; more efficient designs result in better and lower environmental footprints."

Structural engineer Mark Webster agrees, advocating for "approaches like composite design, where the steel and concrete slab work together and can reduce the size of the beams." He added that "choice of lateral system can have a big impact on the quantity of steel" as well. Braced frames with diagonal braces use far less steel than moment frames, for example. "You end up with a lot more steel using those moment-resisting frames," he said. "For architects, it's nice to use moment frames because you don't have diagonal braces," but braced frames can be strategically designed to reduce the architectural impact. That's a good reason to get the structural engineer involved early when looking to reduce embodied carbon.

Structural wood

You may have heard (including from BuildingGreen) that building with wood instead of concrete or steel has major carbon benefits. It seems to make sense, since wood products sequester carbon, while concrete and steel are made by burning fossil fuels. Interest in building with mass timber structural products like cross-laminated timber (CLT) has skyrocketed, in part because of the presumed lower embodied carbon impacts.

But a few scientists are asking everyone to slow down, contending that LCAs have grossly overestimated the benefits of wood.

"Wood is very tricky right now," said Stephanie Carlisle, principal at KieranTimberlake and the lead developer of the Tally whole-building LCA software tool. "There is a big debate happening." And that's frustrating for designers who want guidance they can use.

"The more we've dug, the more [the numbers] seem to be all over the place," said Arup's Yang. "There is so much uncertainty carried with them."

This uncertainty has many sources.

First of all, LCAs mostly give wood a free pass when it comes to the state of the forest after harvesting. But a lot of carbon in forests is stored in the soil and below it, and it's unclear how much carbon and methane (a more potent greenhouse gas) is released when harvesting … and how much that depends on *how* the wood is harvested.

Second, there is the question of whether trees are being grown and replaced in such a way that we can truly assume carbon neutrality from forestry. As an

TAKEAWAYS

Structural Wood

- **The carbon impacts of wood** are a source of contention, with a few scientists claiming that LCAs greatly overestimate the benefits.
- What's good for steel and concrete is good for wood: **use only what you need**.
- Wood sequesters carbon as long as the materials are in use; **plan for the long haul** when designing with wood. Consider design for future uses and design for deconstruction (see Re-Framing Sustainability: Green Structural Engineering).
- Choose either salvaged or **Forest Stewardship Council**- certified wood. This helps ensure responsible sourcing—for example, reducing the risk of habitat disruption—and may also have an embodied carbon benefit.
- **Mass timber is a different animal** from the dimensional lumber used for light framing. Laminating adhesives and long-distance truck transportation can have significant impacts.
- Although harvesting wood can cause disruptions that release carbon and methane (a more potent greenhouse gas), **managed forests are more likely to remain forested** rather than being converted to other uses—an overall win.
- Mass timber buildings usually have significant quantities of **concrete and steel**. Don't forget to focus on embodied carbon reductions for those materials as well.
- Look carefully at the **transportation emissions** from trucking mass timber.

example, for Douglas fir in the Pacific Northwest, a harvest cycle of 40 to 45 years is standard in business-as-usual (BAU) forestry practices, according to Mark Harmon, Ph.D., professor at Oregon State University. Harmon coauthored a recent paper implicating the Oregon timber industry as the largest source of carbon emissions in the state. The study found that an 80-year harvest cycle would be more beneficial for carbon storage in the forest because the longer time period allows the trees to build to their optimum volume before harvesting.

Harmon compares a forest to a "leaky bucket": "There is carbon pouring into the bucket [from absorbing CO_2] but always carbon flowing out" as well from harvesting, decomposition, and fires, he explained. "The thing that determines how leaky it is, is related to how long the 'water' [carbon] stays in the bucket. … A 45-year forest is a much leakier bucket than a 90-year one" because carbon is leaving it much more quickly. At 75 to 100 years of age, though, Douglas fir stops growing so quickly, meaning carbon storage slows, so it makes the most sense to harvest the trees then.

Also, as this example shows, there is the issue of regional differences. Douglas fir reaches its optimum volume at a different age than, say, southern yellow pine. And a Douglas fir forest will yield a different volume of wood at harvest than a

Who's Addressing Embodied Carbon?

Program	Type	Description
Buy Clean California	Legislation	A California law requiring acquisition of environmental product declarations for State infrastructure and building projects, and mandating preference for lower-carbon products
E+C-	Building certification	A label in France indicating that a building has achieved net-positive energy and low carbon, including embodied carbon
Embodied Carbon Network	Grassroots group	A grassroots group promoting awareness of embodied carbon in the built environment
LEED v4	Building certification	A building certification with an option to reduce the embodied carbon and other embodied impacts of new construction
Living Building Challenge	Building certification	A building certification requiring a one-time offset of embodied carbon associated with construction
Powerhouse Standard	Building certification	A standard from Norway requiring buildings to produce more renewable energy over their lifetime than used for materials, production, operation, renovation, and demolition
Zero Carbon Standard	Building certification	A Canadian Green Building Council program recognizing buildings that have zero operating carbon and requiring accounting for embodied carbon

Source: BuildingGreen, Inc.

INSIGHT

Carbon and FSC

Wood products certified to the Forest Stewardship Council (FSC) standard have far better environmental credentials than wood products without certification, for a variety of reasons (see Certified Wood: How SFI Compares to FSC). FSC standards require a high level of ecosystem protection and help ensure social equity. And FSC upholds its standards by stripping companies of certification if they don't follow the rules.

But can FSC wood claim a lower carbon footprint as well? Several signatories to a letter released by the Sierra Club earlier this year say it can.

The letter claims that the carbon benefits of mass timber are exaggerated because they do not account for the detrimental effects of business-as-usual forest management practices. It goes on to recommend protection of old-growth forests, increasing the time between harvests, less-intensive management, treatment of forests as ecosystems rather than plantations, and afforestation (creating forests where there were none) of existing land.

"CLT cannot be climate smart unless it comes from climate-smart forestry," the letter concludes. "While a perfect mechanism to identify such products does not yet exist, FSC certification of privately owned forestlands can support progress in the right direction."

New research from scientists at the nonprofit Ecotrust suggests their claims may have some validity, at least when it comes to Douglas fir in the Pacific Northwest. Researchers compared products from business-as-usual forests to those from FSC-certified forests and found a significant carbon benefit—a difference of one to two tons of CO_2 per thousand board feet.

continued

southern yellow pine forest. So each will sequester different amounts of carbon per unit (whether you're measuring by feet or kilograms or some other metric). It's hard to generalize about the benefits or drawbacks of wood, or even about appropriate forestry practices across the board. (This, incidentally, is why Forest Stewardship Council standards differ by region.)

Once the wood is harvested, it requires significant energy to be kiln-dried; most of this energy comes from burning waste wood, which is given a free pass as "carbon neutral" by the U.S. Environmental Protection Agency. But a contentious 2010 report commissioned by the Commonwealth of Massachusetts calls that carbon neutrality into question, saying that the carbon footprint of burning woody biomass depends on a number of factors, including forestry practices, and stating that in some cases burning wood is worse than burning fossil fuels.

There's also the fact that wood products continue to sequester carbon as long as they are in use, but the length of use is all over the map. Harmon's group assumed a useful life of 30 years, while others argue for 60 or even 100.

And what happens when the wood is ultimately disposed of? It's not clear how quickly wood products decay and emit methane in landfills. This dispute is reflected in WBLCA tools, with Athena Impact Estimator assuming relative stability and Tally assuming quicker releases. (Currently, neither Athena nor Tally gives wood initial "credit" for sequestering carbon in a whole-building LCA, although in the upcoming new version of Tally, this will be optional.)

"For those of us in the building industry, it gets really complicated," sums up Kate Simonen, associate professor of architecture at the University of Washington, adding that people tend to have emotional rather than scientific responses to the available data. "I have not found anybody who has made a fully rigorous

They attributed this benefit to increased stream protection and the fact that FSC-certified operations must leave more wood standing in the forest. "There is nothing particularly surprising about that," said David Diaz, one of the researchers, because "when you leave more trees, there is more carbon standing."

Diaz said the study did not look specifically at Sustainable Forestry Initiative-certified wood, but he added that SFI standards do not require "change above and beyond" what's considered legal in Washington and Oregon when it comes to stream protection and green wood requirements. "We would expect business-as-usual to be equivalent" to SFI, he said.

Because the study was specific to the Pacific Northwest, Diaz cautioned against drawing conclusions about carbon tonnage per board foot in other regions and for other tree species. Overall, though, "Leaving more trees makes pretty straightforward carbon sense," he said.

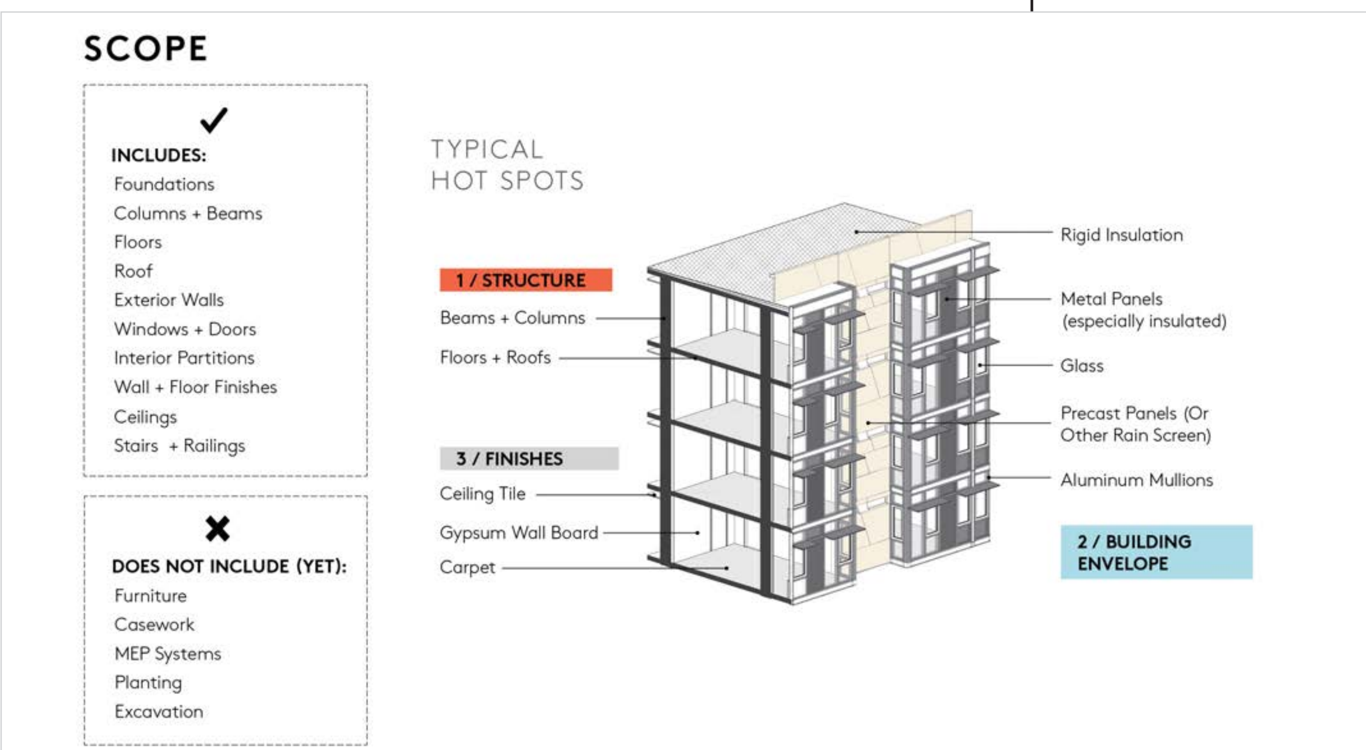

Image: Mithun (Meghan Lewis)

This diagram shows the typical hot spots that are found while using LCA tools, helping designers identify where to spend time to make the biggest impact.

connection that satisfies both of the extreme sides of the story, which makes it really difficult to interpret."

Simonen advises building professionals to use the material that makes the most sense for their projects and to optimize its use however they can. "If you take the average concrete building and compare it to an average wood building, you might see that many different studies show wood tends to have a lower carbon footprint," she noted. "That doesn't say you couldn't have optimized the concrete system to be at a similar level."

Speaking of optimizing, "you can have twice as much wood between the most optimum and least optimum configuration" in the same building, said Simonen. It's better to follow the same rules for wood as you would for concrete or steel and use only what you need.

Additionally, a huge trend toward mass timber might not be a great thing for forests, Simonen continued. "It is not necessarily better for the environment to start radically increasing the amount of wood. If we started cutting down way more wood, we are changing the rate at which we remove carbon from the forest." Hence, we would need to plan ahead for that eventuality and start planting more trees now to meet the demand in the coming decades.

And let's not forget the other impacts beyond embodied carbon that all our building materials have, cautions structural engineer Kestner. "Some impacts like smog and eutrophication and acidification might be closer to each other" when comparing wood with other systems, he said. "You wouldn't want to only look at carbon."

Kestner added that, given the small number of mass-timber-producing plants in North America, it's important to take transportation impacts into account as well. "I think that one thing that should certainly be considered if you are using CLT and shipping it a very large distance is to understand the transportation impacts as you make your decisions," he said.

The upshot? Wood can be beneficial for its reduced footprint, but don't use wood as a get-out-of-carbon-jail-free card. Consider which materials and systems make the most sense for the project, and optimize how you use them, preferably with whole-building life-cycle assessment as a guide. And when using wood, choose FSC-certified products—or salvaged wood, to extend the carbon benefit of using wood products.

Considering Enclosures

Structural systems bear the bulk of the embodied carbon footprint of buildings, but the enclosure is also significant, representing up to 15% of the global warming impact of a typical commercial office building, according to Duncan Cox, associate at Thornton Tomasetti. (This number varies considerably by building type, he emphasized.)

Cox said that, based on WBLCA studies he's conducted over the years, the carbon hot spots in the enclosure tend to be aluminum curtainwall and foam insulation (the latter because of high-embodied-carbon blowing agents—see Avoiding the Global Warming Impact of Insulation). "When you start playing around with window-to-wall ratios, you can have quite a big impact" because of curtainwall's footprint, he said. The embodied carbon of curtainwall (not to mention the aluminum shading systems that often come with it) is just one more reason to minimize its use, since it has operational energy impacts as well (see Rethinking the All-Glass Building).

On opaque walls, cladding choices can also make a big difference (see Cladding: More Than Just a Pretty Façade). Brad Benke, AIA, at LMN Architects, recently conducted an LCA consider-

TAKEAWAYS

Enclosure Systems

Structural systems are the most **significant source of embodied carbon**, but enclosures are also significant.

Enclosure systems are under the **architect's direct control**.

Because of aluminum's high embodied carbon, **curtainwall systems** have very large impacts. They also have high operational impacts, so it's best to minimize their use.

Some types of **foam insulation** (notably extruded polystyrene) have blowing agents with massive global warming potential. Seek alternatives.

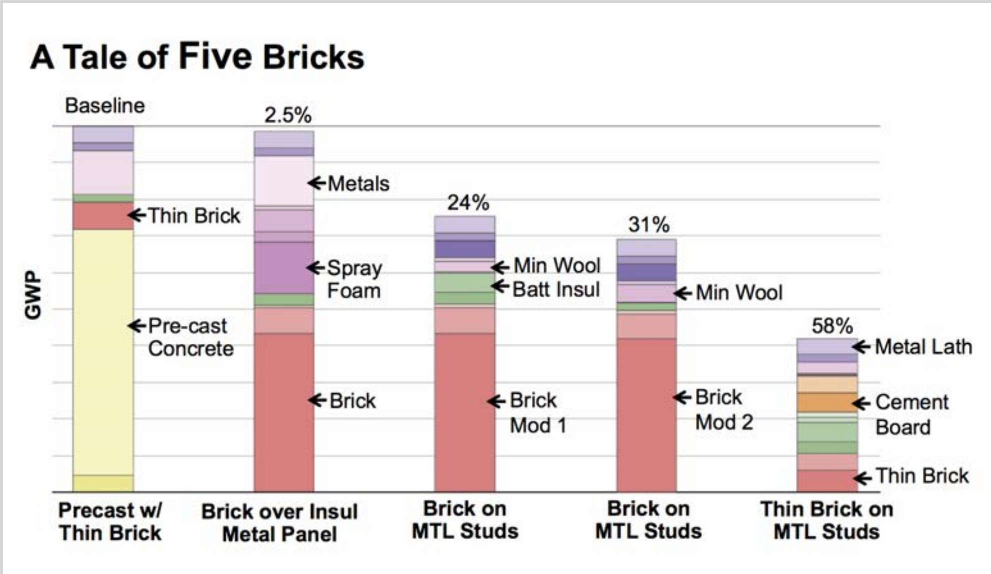

Image: LMN Architects

Architect Brad Benke studied the impacts of brick façade systems and discovered that five functionally equivalent wall types had very different impacts. Thin brick on metal studs, shown at the far right, reduced embodied carbon 58% compared with a baseline wall system (thin brick with precast concrete).

ing different wall systems. "If you only have time to do one thing, hire a good engineer and work to reduce the structural load," he said, but his firm has invested in in-house LCA studies for the envelope. This helps because the firm is seeking ways to reduce impacts across the portfolio—not just on the super-green projects—and "architects are able to make decisions about wall types; they do it all the time." Benke added, "An important opportunity for architects … is being able to make changes without having to ask the owner a ton of questions or spend significant time coordinating with consultants."

With that goal in mind, Benke looked at ten different wall systems, comparing their embodied impacts, then conducted a secondary study looking at five functionally equivalent brick wall types. The winner? Thin brick on metal studs had the lowest embodied carbon among the options, showing a 58% reduction from the baseline building (thin brick with precast concrete). The best part is that this lower-embodied-carbon wall, to a casual observer, looks and functions just the same. Benke said this was a finding that could be shared across the firm to help "improve the baseline of every project rather than just high-profile projects." He added, "We really believe that a lot of firms could be doing work like this. … We don't have a lot of time to *not* do this work. It's critical to start now."

Letting Go of Guilt

"I think it's really easy to get trapped in a lot of guilt," said KieranTimberlake's Carlisle, because the building industry is responsible for such a large percentage of global carbon emissions. But, she said, "There is room to do something on every project. … I hope that can be really empowering for people." She added, "We have an obligation to get involved."

TAKEAWAYS

Embodied Carbon

Embodied carbon is an **urgent issue** because the emissions we release in the next 20 to 30 years are critical to keeping global temperatures at tolerable levels.

The simplest approach to reducing embodied carbon is to **use less material**: consider reusing materials or whole buildings, and with new materials, make sure you're using only as much as you really need.

Whole-building life-cycle assessment is the **preferred way to measure and manage** embodied carbon and other embodied impacts.

The **structural system** is the biggest contributor to embodied carbon, and engaging the structural engineer early can help with reductions.

The **enclosure system** has a big impact as well and is under the direct control of the architect or designer.

Any project team can reduce embodied carbon **without significant costs**.

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Description

Building materials emit massive amounts of carbon long before the lights go on. In this course, BuildingGreen takes an analytical look at the greenhouse gases that are emitted in the process of constructing our buildings in the first place—the embodied carbon.

Climate change is a rapidly escalating emergency, and we have a lot of hard work to do in order to mitigate its effects. For building professionals, that has typically meant increasing energy efficiency and pushing for renewable energy production, thus reducing the amount of carbon generated by the fossil fuels we burn to operate our buildings. Embodied carbon matters just as much as energy efficiency and renewables. The emissions we produce between now and 2050 will determine whether we meet the goals of the 2015 Paris climate accord and prevent the worst effects of climate change.

Learning Objectives

Upon completion of this course, participants will be able to:

1. Define "embodied carbon" and explain why embodied carbon is a significant source of greenhouse gas emissions, which threaten health and safety worldwide by increasing the risks of climate change.
2. Develop strategies to manage the embodied carbon of structural systems and enclosures in order to increase the sustainability of a building's design by reducing its carbon footprint.
3. Understand the importance of whole-building life-cycle assessment, which helps project teams analyze and reduce the environmental impacts of building designs.
4. Assess the sustainability of wood products, especially mass timber products used for structural systems, in order to lighten the overall carbon footprint of the building and increase its sustainability.

QUIZ QUESTIONS

1. The manufacture of building ____ makes up 11% of total global greenhouse gas emissions.

- ☐ a. Mass
- ☐ b. Materials
- ☐ c. Methane
- ☐ d. Monkeys

2. Building reuse and incorporation of salvaged building materials can greatly reduce the embodied carbon of ____.

- ☐ a. Heating system upgrades
- ☐ b. Remodeling
- ☐ c. Transportation
- ☐ d. Construction

3. The most widely accepted method for assessing embodied carbon is ____, but other tools can supplement this as a first step.

- ☐ a. Whole-building life-cycle assessment (WBLCA)
- ☐ b. Aerial carbon reduction assessment (ACRA)
- ☐ c. Monkey tree analytics (MTA)
- ☐ d. Ordered embodied carbon (OEC)

4. One of the most important takeaways from whole-building LCA is that structural systems almost always comprise the largest source of embodied carbon in the building—up to ____, depending on the building type.

- ☐ a. 25%
- ☐ b. 70%
- ☐ c. 80%
- ☐ d. 45%

5. The biggest EPDs drawbacks is that laypeople are not in a good position to compare their results. You definitely can't compare steel to concrete, for example, and it's a tricky business even to compare ____.

- ☐ a. Bananas to oranges
- ☐ b. Trees to hovels
- ☐ c. One monkey to another
- ☐ d. One concrete mix to another

6. Replacing some cement with supplemental cementitious materials (SCMs) like ____ or ____ is a go-to way for project teams to reduce the embodied carbon of the concrete in their projects.

- ☐ a. Fly ash; blast-furnace slag
- ☐ b. Dense cardboard; crushed glass
- ☐ c. Glue; clay
- ☐ d. Dry sawdust; shredded newspaper

7. Electric arc furnaces, along with a cleaner electrical grid, has resulted in a ____ reduction in the industry's carbon footprint since ____.

- ☐ a. 36%; 1990
- ☐ b. 42%; 1988
- ☐ c. 74%; 2005
- ☐ d. 15%; 2000

8. For Douglas fir in the Pacific Northwest, the business-as-usual (BAU) forestry practices harvest cycle is ____ years, but a study found that an 80-year harvest cycle would be more beneficial for carbon storage in order for the trees to reach their optimum volume before harvesting.

- ☐ a. 15 to 25
- ☐ b. 30
- ☐ c. 40 to 45
- ☐ d. 50

9. Structural systems are the most significant source of embodied carbon, but ____ are also significant.

- ☐ a. Enclosures
- ☐ b. Windows
- ☐ c. Lights
- ☐ d. Sidewalks

10. Thin brick on metal studs showed a ____ in embodied carbon from the baseline building (thin brick with precast concrete) in a comparison of ten different wall systems.

- ☐ a. 25% increase
- ☐ b. 58% reduction
- ☐ c. 45% reduction
- ☐ d. 10% reduction

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www.buildinggreen.com/spotlight/carbon