walter p moore | STEWARDSHIP REPORT

EMBODIED CARBON

A CLEARER VIEW OF CARBON EMISSIONS

> As design professionals, we shape the built world. Hence, we should be cognizant of the carbon footprint of our design solutions. We need to use carbon-smart materials and aspire to be climate positive. At Walter P Moore, we have made this commitment and are driven by the challenge.
>
> —**Dilip Choudhuri**, PE
> President & CEO
> Walter P Moore

EMBODIED CARBON

URGENCY

THE DESIGN COMMUNITY IS MAKING GREAT STRIDES to create buildings that are more energy efficient, increasingly electrified, and powered by an electrical grid with growing contributions from renewable sources. Although these interventions reduce carbon emissions from building operations, we must also consider the upfront emissions from building construction—embodied carbon.

While operational emission reductions are often celebrated, embodied emissions have been largely overlooked. Embodied emissions include emissions associated with extracting, processing, shipping, installing, and maintaining the materials used in our buildings. These emissions occur before a building opens rather than operational emissions that happen over a building's life span.

The UN Environment Global Status Report predicts that during the next 40 years, we will build 2.5 trillion square feet of new building stock. Comparatively, this amount of construction is the equivalent of replicating New York City every month for 40 years. To reach the greenhouse gas targets set by the Intergovernmental Panel on Climate Change (IPCC), we must significantly reduce the embodied carbon of buildings constructed during the next 10 years and reach net zero embodied and operational carbon soon after.

Addressing this urgent environmental challenge will require cross-disciplinary collaboration, client education, industry advocacy, development of carbon benchmarks, and innovative low-carbon solutions.

> "The built sector has a vital role to play in responding to the climate emergency. With buildings currently responsible for 39% of global carbon emissions, decarbonizing the sector is one of the most cost-effective ways to mitigate the worst effects of climate breakdown."
>
> –World Green Building Council

Times of change and challenges allow us to reassess our traditional practices and develop new solutions. This Stewardship Report focuses on an issue of relevance for all material specifiers, and that is an essential part of making near-term reductions in greenhouse gas emissions. Throughout this report, our experts will address: What embodied carbon is, and why we must reduce it.

Walter P Moore understands the importance of embodied carbon. Since 2002 we have actively embraced our role as engineers seeking to reduce the embodied carbon of our designs. We continue to improve the design process, refine material specifications, and participate in many industry-leading activities, to both bring awareness and achieve meaningful reductions in embodied carbon in the built environment. This includes our long-term involvement in the Carbon Leadership Forum, leadership on USGBC committees, founding roles in both CLF regional hubs and the SE 2050 Initiative, and our sponsorship of the EC3 tool.

We encourage you to engage with this report, explore resources and tools, and continue the dialogue. **There is room for change in every project.**

Dirk Kestner, PE, LEED AP BD+C, ENV SP
Director of Sustainable Design
Principal

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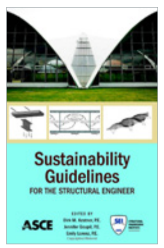
EMBODIED CARBON MILESTONES

2010



SUSTAINABILITY GUIDELINES

Sustainability Guidelines for the Structural Engineer, the first guideline devoted to the structural engineer's role in sustainable design and edited by Walter P Moore's Director of Sustainable Design Dirk Kestner, is released.

2011

APOGEE STADIUM

The first newly constructed football stadium in the U.S. to achieve LEED Platinum certification opens at the University of North Texas. Walter P Moore uses embodied carbon coefficients from the University of Bath's Inventory of Carbon and Energy (ICE) to inform design strategy and quantify the project's embodied carbon reductions. The project saves over 6 million lbs. CO_2.

2012

CLASSES OF CONCRETE

Walter P Moore implements the use of "Classes of Concrete" matrix. This tool, implemented on all new structural design projects, allows teams to tailor performance requirements, including environmental metrics, to minimize embodied carbon on projects.

2013

THE DUKE UNIVERSITY MEDICAL PAVILION

The pavilion opens and achieves LEED Gold Certification. Walter P Moore leads the pursuit of LEED Pilot Credit #1, the first inclusion of WBLCA and embodied carbon quantification in the LEED rating system.

2014

THE CARBON LEADERSHIP FORUM

Walter P Moore joins the Carbon Leadership Forum, an industry-academic collaboration hosted at the University of Washington working to accelerate transformation of the building sector to radically reduce and ultimately eliminate embodied carbon in building materials and construction.

2015

BANK OF AMERICA TOWER

The mat foundation placement takes place. This tower, which will eventually become the highest-rated LEED Platinum LEED v4 project in the world, uses WBLCA to optimize concrete to reduce embodied carbon. The optimized concrete mix saves over 1 million lbs. CO_2 in the foundation alone.

2016

HARC HEADQUARTERS GROUNDBREAKING

This project, which uses WBLCA to evaluate structural and enclosure systems will become The Woodland's first LEED Platinum building. Currently, it operates as Net Positive and has achieved ILFI Net Zero Energy certification.

2017

THE ORACLE WATERFRONT CAMPUS

The Austin, Texas campus opens and is among the first in the Austin Energy Green Building rating system to achieve the Whole Building LCA credit. This credit informed material procurement and embodied carbon reduction and was key to the projects' LEED Gold and AEGB 4-star ratings.

2018

THE SE2050 COMMITMENT

Walter P Moore joins with other leading structural engineering firms and the SEI Sustainability Committee to present an initial vision of the SE2050 Commitment at the Annual SEI Structures Congress. This vision serves as the foundation for the eventual formalization of SE2050.

2019

PILOT SPONSOR OF THE EC3 TOOL

Walter P Moore becomes one of eight Pilot Sponsors of the Embodied Carbon in Construction Calculator (EC3) tool. The EC3 tool is free to access and was developed with input from nearly 50 industry partners that allows benchmarking, assessment, and reductions in embodied carbon.

WHY EMBODIED CARBON MATTERS

In the **World Green Building Council's report**, *Bringing Embodied Carbon Upfront*, they brought long-standing issues surrounding carbon footprint to the forefront. They embraced a bold vision that by 2050, new buildings, infrastructure, and renovations will have net zero embodied carbon, and all buildings, including existing buildings, must be net zero operational carbon. While this is a sizable goal, there are steps that we in the design community have already taken and must continue to evolve as we pursue these aspirations. Walter P Moore's experts explore issues surrounding embodied carbon and expose solutions for future growth.

MEASURING EMBODIED CARBON

by Dirk Kestner PE, LEED AP BD+C, ENV SP

"IF YOU CAN'T MEASURE IT, YOU CAN'T IMPROVE IT." Peter Drucker's quote is well known in the business world and is critically important for tracking embodied carbon. A fundamental piece of tracking embodied carbon is using consistent decisions and assumptions for its measurement throughout the material's lifespan. Relevant life cycle stages include extraction, manufacturing, processing, transportation, construction and installation, maintenance, and demolition, recycling, or end of life.

What is LCA?

Life Cycle Assessment (LCA) is a method of environmental accounting commonly used for assessing environmental impacts associated with all stages of a commercial product, process, or service's life cycle.

When comparing products, it is important that they be functionally equivalent, or that they perform the same function, or functions, and have the same expected life span. LCA is performed per ISO standards to maintain consistency and transparency in the process. LCA can incorporate industry wide data, but becomes increasingly accurate as suppliers provide product specific data such as processes and fuel sources.

LCA can also be applied to the built environment. When applied to multiple assemblies at the building level, it is referred to as a Whole Building Life Cycle Assessment (WBLCA). Green building rating systems such as LEED and Envision include credits for performing WBLCA and choosing less impactful materials and systems.

Why is LCA important?

As more cities and institutions develop climate action plans, including quantifying embodied carbon reduction or limits as a component of the procurement or permitting process, this conversation has gained significant importance.

LCA allows project teams to make quantitative comparisons based on environmental impacts. In the absence of LCA and WBLCA, teams have compared materials based on attributes, such as their recycled content, which provide general indicators if a product may be environmentally preferable, but do not capture the entire picture or allow for robust quantitative comparisons.

In this report we discuss the use of LCA to measure embodied carbon, the greenhouse gas emissions caused by a building's material life cycle. LCA allows owners and designers to compare the impacts of a building's materials to the emissions from the energy consumed during the building's lifespan. By quantifying the material impacts teams can compare the relative benefits of material versus operational carbon savings in units of carbon. LCA may also be used to quantify other measures of air and water pollution, such as smog, acidification, or eutrophication.

> At its simplest, LCA is environmental accounting. You can't have a budget if you don't know how to count, and you can't manage embodied carbon if you don't perform LCA.

At its simplest, LCA is environmental accounting. You can't have a budget if you don't know how to count, and you can't manage embodied carbon if you don't perform LCA.

Diagram courtesy of Simonen, Kathrina. Life Cycle Assessment (PocketArchitecture)

ADDRESSING DATA UNCERTAINTY

by Martin Torres

AS WITH MANY ENGINEERING TASKS, quantifying embodied carbon involves working with uncertain data. With this comes a responsibility not currently addressed in common WBLCA tools such as Tally and Athena Impact Estimator for Buildings—to quantify predictions in our analysis as "uncertainty." Quantifying uncertainty allows LCA practitioners to highlight what we can control while still incorporating unknowns when we report our data. However, for many of us, this process is nothing new.

As structural engineers, we already quantify uncertainty in our codes and designs with methods such as probabilistic design. This way of thinking can and should be applied when reducing embodied carbon so we can make well-informed sustainable design decisions as we do with our structures. This isn't to say we must rethink the whole process before we conduct more WBLCAs we can still operate effectively within the current imprecise framework.

Before we can manage and reduce environmental impacts from building materials, we must be able to properly measure and analyze that data. In the case of embodied carbon, uncertainty in these measurements stems from a variety of sources: material volume assumptions, the usage of industry averages for Environmental Product Declarations (EPDs), and different methodologies for developing impact factors, to name a few. However, by using a simplified approach and focusing on the largest sources of impact, we can validate the directional accuracy attained by our design decisions.

Consider the usage of cement in concrete. Although there are broad assumptions behind the concrete mix data and impact values, we know cement is one of the largest sources of impact in a concrete building. If we focus on simple carbon reduction strategies such as using structural systems with less material or specifying concrete mixes with lower cement content, we can be more confident in our impact reductions.

> Even with uncertain data, we can, and should, take action to achieve significant reductions.

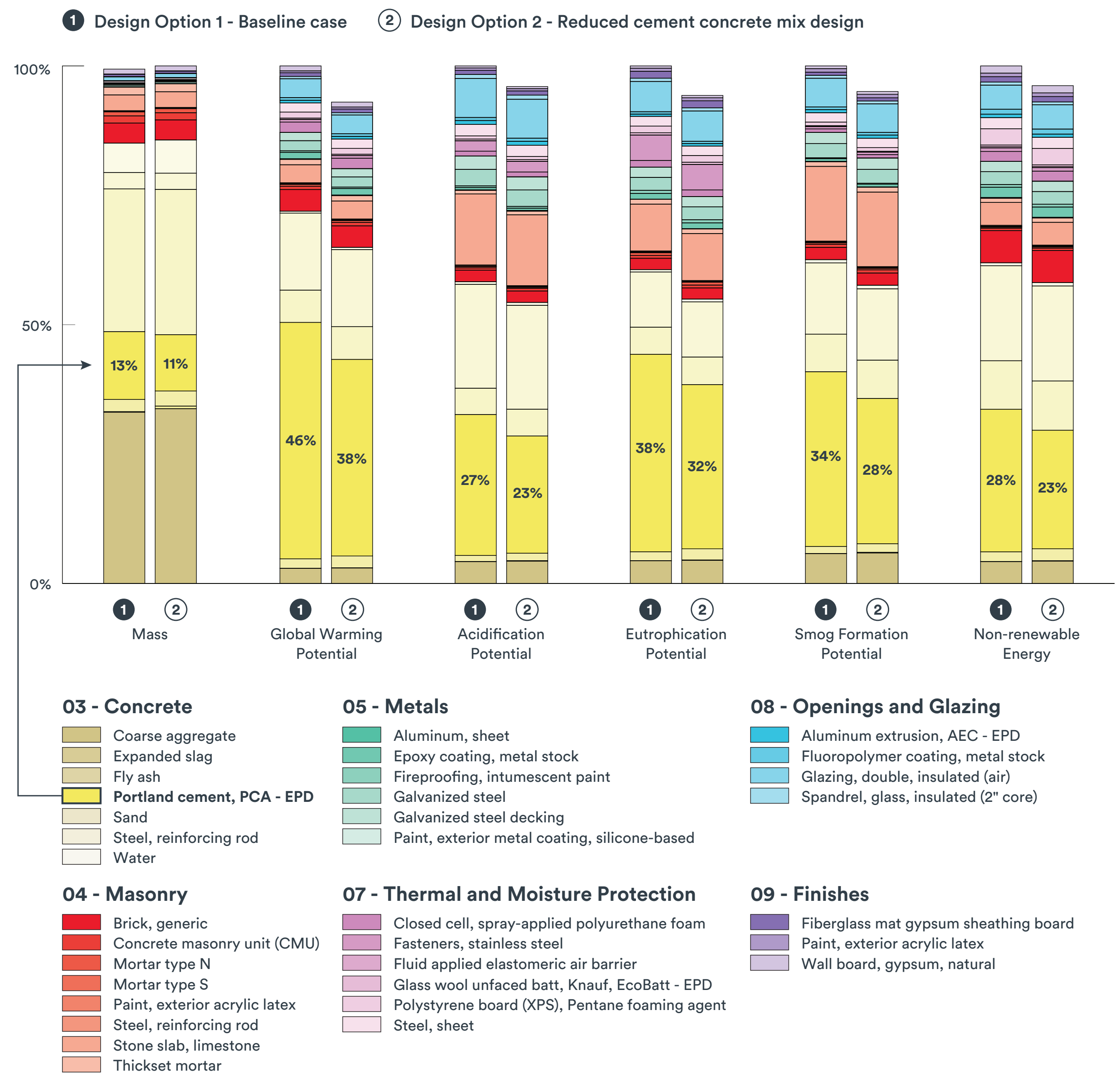
Structural engineers employ methods like probabilistic analysis and design to ensure strength and serviceability requirements are met while still maintaining design efficiency. Although the severity of a collapsed building may be more intuitive than the adverse effects of climate change, there is a prime opportunity for improving sustainable design practices. So, how might we apply this same line of thinking to environmental impact data and reductions?

We must demand more statistically transparent impact data and software that is straightforward about uncertainty and assumptions. It is paramount that we treat impact analysis with the same rigor we apply to structural design. While we have solutions that fit within the current framework, improvements to the methodology are essential to achieving goals such as SE 2050—a charge to eliminate embodied carbon in all projects by 2050 proposed by the Carbon Leadership Forum.

We are tackling a diabolical problem in a compressed time frame. It is our responsibility as building design professionals to improve our practice by identifying shortcomings and developing progressive, forward-thinking ideals. Sustainability is not just about checking a box for a certification. It's about being honest in our efforts and responding quickly to improve our methods as we continue to learn.

Case Study in Cement Reduction

This WBLCA of a concrete structure was conducted using Tally and includes the enclosure, superstructure, and foundation. By using consistent impact data from materials and transportation within Tally and only manipulating the concrete mix design (particularly the cement), we focus on what we know can achieve reductions. Focusing on the minutiae of other materials would be far less effective given the massive contribution of cement in concrete with respect to other materials. Focusing on the highest emitters gives us confidence in our results since we have no access to the uncertainty in this data. Without impact data sets or software that incorporates uncertainty, we are restricted in how we can conduct a proper analysis. Here, we prioritize actual impact reduction, which is far more important than getting an exact value for total output.



ROLE OF GRID DECARBONIZATION

by Mia Jimenez

IT'S NO SECRET that emissions from a building's energy use are inherently tied to the "cleanliness" of the grid. With increasing urgency surrounding anthropogenic climate change, there has been action to pursue less environmentally-taxing energy alternatives. In 2018, only 18% of U.S. electricity generation came from renewable resources. However, while the use of electricity will continue to rise, the switch to renewables is projected to amount to 31% of U.S. electricity generation by 2050.[1] The switch to renewables naturally has the greatest impact on the more energy-intensive processes of operating a building, such as regulating the ambient temperature, managing plug loads, and providing adequate lighting. By increasing renewables to decarbonizing the grid, there is also a direct impact further upstream at the inception of a material's life cycle. Steel and concrete, for example, are two energy-intensive materials that are commonly specified in construction. An important question to think about is how the gradual decarbonization of the grid will ultimately impact the carbon footprint of these materials and, subsequently, how they are used in construction projects.

Up to 96% of CO_2 emissions of a concrete mix are attributable to the cement content. The culprit is the calcination of calcium carbonate accounting for close to 60% of concrete's total CO_2 emissions.[2] In this process, pulverized rock is heated in a kiln resulting in the desired clinker, a chemical binding of the input material. The thermal decomposition naturally produces CO_2 as a result, thus acting as a significant limiting factor in the ability to reduce concrete's carbon footprint. Other contributors to CO_2 output in the manufacturing of concrete accounting for the remaining 40% include aggregate production, concrete plant operations, kiln fuel, and transportation. These CO_2 emissions are byproducts of combustion, a chemical reaction that occurs when using the cement kiln and transporting resources to the cement plant. Most of the energy used to make concrete (as much as 88%) is from non-renewable fuels that are harnessed primarily for the manufacturing of cement. While the energy used for both concrete plant operations and concrete manufacturing is included in the Life Cycle Inventory (LCI), the resources needed to create this electricity and fuels—known as the upstream profile—is intentionally excluded. Because the majority of concrete's embodied carbon comes from the chemical reaction needed to form cement, improvements to the grid would be negligible.

Grid decarbonization will not affect all materials equally.

The two main methods in which steel is produced are the blast furnace/basic oxygen furnace (BOF) and electric arc furnace (EAF). The EAF process uses scrap steel melted via high-current electric arcs while BOF steelmaking blasts oxygen to remove impurities from molten iron to convert it into steel. One of the primary outputs from both EAF and BOF steelmaking is hot-rolled coil that is typically further processed for use in other applications. "In the U.S., all hot-rolled sections are produced using scrap-based electric arc furnaces."[3] Approximately 98% of the primary energy demand (PED) of the formation of a hot-rolled coil is from non-renewables. Upstream processes, including electricity generation, are close to 100% responsible for the PED and are responsible for approximately 35% of the global warming potential (GWP) of the hot-rolled coil.[4] Similar findings from the American Institute of Steel Construction (AISC) Environmental Product Declaration (EPD) for fabricated hot-rolled structural sections reveal that the raw materials supply stage, which includes upstream activities, has the highest PED and accounts for 85% to 95% of impact assessment categories such as climate change potential and ozone depletion.[5]

According to the World Steel Association LCI Study (2018), it is evident that "steel production is an energy-intensive industry and therefore the consumption of energy and electricity is one of the main contributors to the environmental impact of the steelmaking process." Given that electricity is a critical input, steel's environmental impact is a direct function of the grid's energy source. It will also be location dependent as different countries and regions have a distinct electricity grid mix.

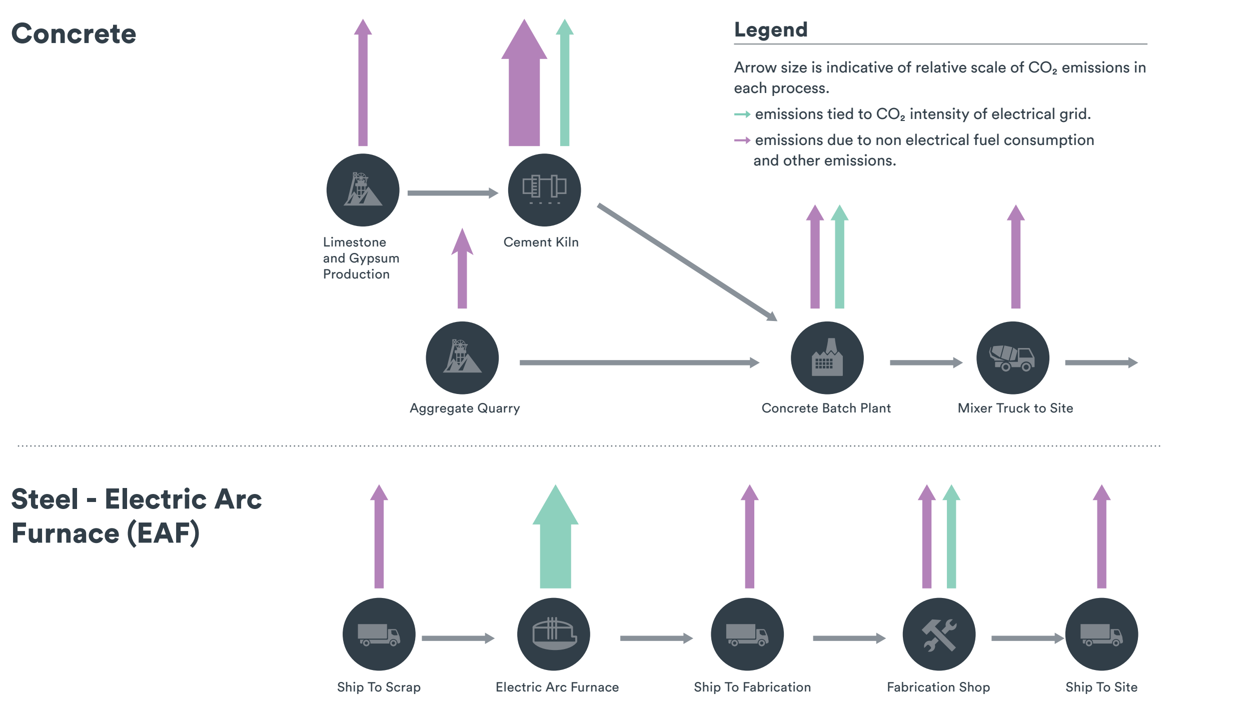
Grid decarbonization will likely have positive impacts on the steel carbon footprint, given steel's high reliance on electricity to transform the raw material into its structural form. The same cannot be said for concrete whose production is fuel-intensive, but mostly independent of the grid and includes emissions due to the calcination process.

A material's embodied carbon is also a function of upstream energy generation—a compelling reason for requesting EPDs from material manufacturers. The distinction between industry-average data and producer-specific data should be made when soliciting environmental impact documentation. For steel, the current de-facto standard is to provide industry-average values, given the variations of processes across fabricators.[6] Nonetheless, asking for product- and supplier-specific data is an important tool the specifier can use to influence individual manufacturer choices and to spur manufacturing innovation.

It is also important to remember that steel and concrete are only two of hundreds of materials that we use in construction, there are other considerations aside from electricity usage that should be weighed to understand their contributions on a larger scale. Transportation arrangements, project schedule and cost, and social equity implications should all be part of the holistic evaluation of a given material. If we want to decarbonize our buildings, our first step should be to consider the materials we specify

[1] U.S. Energy Information Administration (2019) Annual Energy Outlook 2019 with projections to 2050

[2] Portland Cement Association (2007) Life Cycle Inventory of Portland Cement Concrete

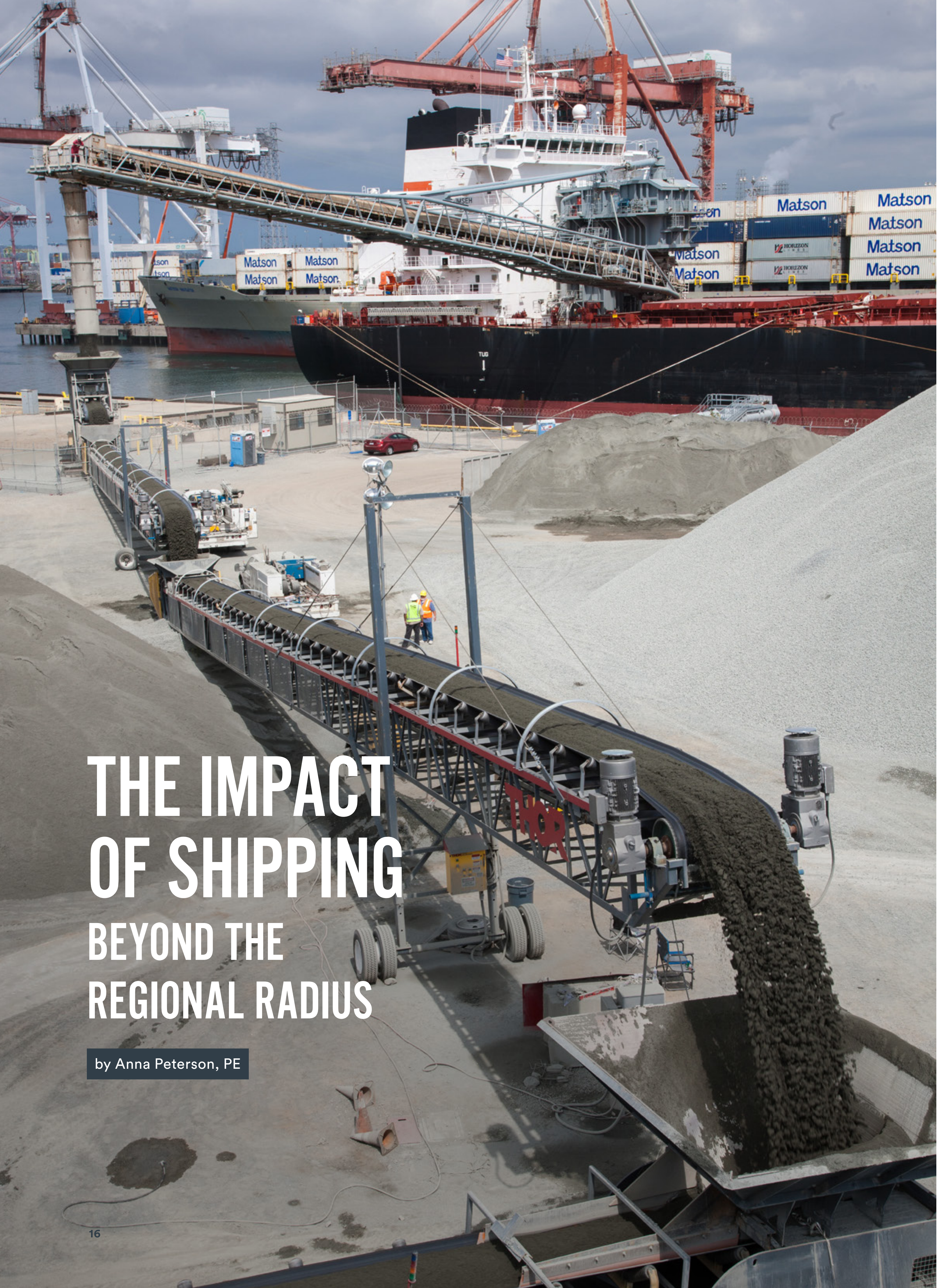


[3] AISC (2018) China, Global Warming and Hot-Rolled Structural Steel Sections

[4] WorldSteel Association (2018) Life Cycle Inventory Study

[5] Environmental Product Declaration (2016) American Institute of Steel Construction Fabricated Hot-Rolled Structural Sections

[6] AISC (2019) Modern Steel Construction



THE IMPACT OF SHIPPING

BEYOND THE REGIONAL RADIUS

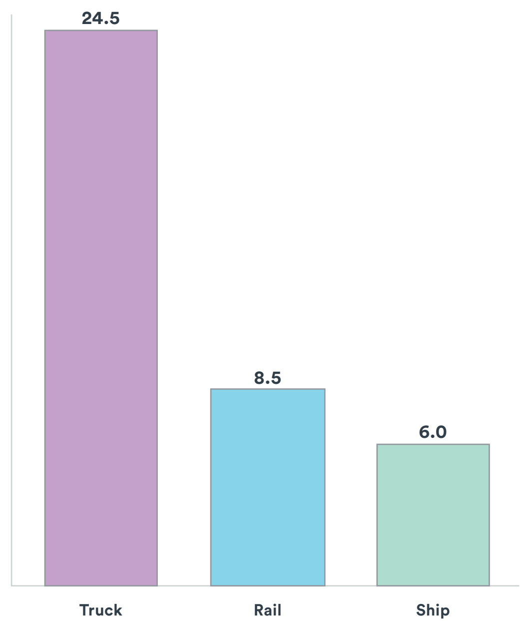
by Anna Peterson, PE

SPECIFYING MATERIALS THAT ARE EXTRACTED, manufactured, or assembled in proximity to a project site can support the local economy and minimize impacts from transporting building materials. Over the last 20 years, LEED has encouraged design teams to focus on selecting regional materials and, in turn, design and construction teams are now adept at documenting a project's regional content.

However, as we become more aware of the importance and urgency of reducing embodied carbon, we must look past a prescriptive approach based only on a regional radius to better identify products that result in the lowest total embodied carbon. While regional materials boost local economies and minimize the impacts associated with shipping and transportation, teams must assess possible tradeoffs between regional production and distant suppliers that provide higher quality products or more efficient processes.

The impact of shipping construction materials is typically proportional to weight, though not all shipping modes produce the same environmental impact. For example, transporting one ton by truck emits nearly four times the amount of CO_2 as transporting by barge. The graph below shows the effects of each transportation method available in Tally. This leads to the question, is there a case where materials from greater distances result in a net carbon benefit?

Lbs. - CO_2eq to move 100 tons of material one mile



We recently faced this question when performing a whole building life cycle assessment (WBLCA) for City of Hope, a concrete framed medical office building in Duarte, California. The project used WBLCA to minimize embodied carbon and to achieve the LEED WBLCA credit. Our initial WBLCA found that the concrete structure was responsible for the majority of the embodied carbon in the building's structure and enclosure.

Using supplementary cementitious materials (SCMs) is a typical, and effective, strategy to minimize embodied carbon by reducing the cement content of concrete. However, a fly ash shortage and other logistical concerns required the team to explore different strategies to reduce cement content.

How can shipping materials from greater distances provide net carbon benefit?

While a local quarry for concrete aggregate is just over two miles from the project site, the team examined whether using a coarse aggregate source from Vancouver, British Columbia— nearly 1300 miles away—could result in an improved environmental impact. The aggregate from British Columbia is stronger, stiffer, and shaped to enable high performance concrete with minimum cement content. Our analysis considered both the additional transportation impacts and savings from reduced cement content. We found that the environmental impact reduction achieved with a lower cement content, even without the use of SCMs, outweighed the increased transportation impacts.

This illustrates the need for project teams to ask suppliers for material-specific product data through producer specific EPDs (Environmental Product Declarations), and to use impact data when selecting material suppliers. While specifying local materials may provide benefits, teams seeking to minimize embodied carbon must make more robust quantitative comparisons that consider not only transportation impacts, but also any impact reductions a non-regional supplier may achieve through manufacturing or procurement optimization.

Image courtesy of Polaris Materials Corporation

BUILDING REUSE

TRANSFORMATION FOR A PURPOSE

by Rachel Calafell, PE

REDUCE, REUSE, RECYCLE; three pervasive words related to consumer products. This hierarchy also applies to the built environment since one of the most effective ways to reduce embodied carbon is to reuse a building rather than construct a new one. This not only saves the emissions associated with extracting and installing new materials, but also significantly reduces the waste produced in demolition.

Unfortunately, while building reuse is environmentally beneficial, it can present significant hurdles for the design, permitting, and construction processes. Due to development patterns, there may not be available space where the demand exists, often making location the first challenge. Even when a building is in the right location, there can be many other challenges such as changes in code provisions, societal desires for space quality, or required performance characteristics (floor rating, HVAC system, space layout). To make effective use of existing buildings, we must find strategies that allow us to efficiently renovate existing buildings and save the emissions sequestered within our building stock. The estimated $72 million renovation and expansion of the 270,000-square-foot Sears department store in Houston's Midtown into South Main's Innovation District (The Ion), illustrates some of the challenges—and solutions—that are required to achieve these goals. In 2017, Rice University's endowment company bought out the remaining years of Sears' 99-year lease for the property which Rice Management Company, owns. Designed to bring Houston's entrepreneurial, corporate and academic communities together into collaborative spaces and programs, The Ion will support businesses at all stages of the innovation life cycle and provide resources for Houstonians seeking to participate in the innovation economy as a part of the South Main Innovation District.

> The most effective way to reduce embodied carbon is to reuse a building.

The transformation from retail store to an innovation hub pays homage to the original art deco style of the 1939 structure, particularly at the ground level storefront. To vertically expand the existing three-story structure by two additional floors, most of the existing spread footing foundations will be strengthened. The existing roof framing has insufficient load capacity to serve as an occupied floor, so new framing will span over it directly to column locations. An additional challenge to repurposing the building includes infilling the existing stairs, elevators, and escalators while framing new stairs and elevators based on the ideal circulation patterns. Introducing daylight into the "concrete box" department store to transform it into a center for technology innovation involves new multistory punched openings in the exterior concrete walls and a new center lightwell angled through the building. Retrofitting the existing structure to accomplish these goals was made more difficult by the fact that the renovated structure will generally not have ceilings and the structural elements will remain exposed. The approach to each retrofitted area had to maintain the aesthetic of the existing exposed concrete flat slab structure with drop panels at each column.

While reusing and repurposing existing buildings is highly effective at reducing embodied carbon, it poses numerous structural challenges. However, it can effectively address challenges while still delivering elegant, redefined buildings.

SALVAGED MATERIALS

by Kelly Roberts, PE, LEED AP BD+C

ONE OF THE MOST OBVIOUS WAYS TO REDUCE our carbon impact is to reuse materials that have already been made. Eliminating waste from the system through reuse and repurposing creates a circular economy within the building sector and can bring both economic and environmental benefits. Although this can be challenging to implement, several product manufacturers have attempted to apply this to their processes with some success. The use of salvaged materials in building construction not only creates a circular economy and tackles the issue of carbon, but also addresses another environmental issue—our ever-increasing landfills. In 2015, the EPA estimated that 548 million tons of building materials or construction & demolition (C&D) debris were generated in the United States.[1] In fact, C&D waste represents approximately 40% of everything thrown away in the U.S. each year. And although most of this material could have been recycled or reused, the infrastructure to enable reuse does not exist in many regions. However, demand from the building community can be a catalyst to rethink and reinvent our waste streams.

In 2011, Walter P Moore participated in the founding of the Life Cycle Building Center (LBC), a nonprofit material reuse center in Atlanta, Georgia focused on reducing the C&D waste sent to landfills. The LBC deconstructs and salvages building materials from structures that are being torn down or renovated and directs the material to a retail center in southwest Atlanta. The materials are then made available to the public at a very low cost or are donated to other nonprofits for free—a win-win.

This organization has created an entirely new stream for building materials in the Atlanta market and allowed the building industry to specify both the salvage of materials and their future use in building projects. For example, when the Atlanta Walter P Moore office was renovated

[1] U.S. Environmental Protection Agency (2017) Construction and Demolition: Material-Specific Data

Images courtesy of Life Cycle Building Center

The use of salvaged materials in building construction not only creates a circular economy and tackles the issue of carbon, but also addresses another environmental issue—our ever-increasing landfills.

in 2014, we ensured that the drawings specified that all material be deconstructed, salvaged, and donated to the LBC.

Recently, Walter P Moore was engaged to provide structural engineering services for a new hospital wing at Emory University. Several abandoned sorority dormitories existed on the site for the new hospital and were slated for demolition. Although the existing buildings had not been used for some time, there were still several usable materials inside such as cabinetry, doors, railing, light fixtures, and various other materials. Walter P Moore was able to connect the project owners to the LBC, and as a result, several truckloads of materials were salvaged and donated to local nonprofits.

Using salvaged materials can also be beneficial to achieve credits or imperatives for green building rating systems. At the Kendeda Building for Innovative Sustainable Design at Georgia Tech, a project that is striving to achieve Living Building status, salvaged 2×4s from the apply this to are being utilized as a part of the structure's nail laminated floor system to avoid using new wood products that would have been more expensive.

While the use of salvaged materials is beneficial to the environment in a myriad of ways, the strategy still remains sparingly used and only for select elements. However, organizations like the apply this to are starting to address crucial elements of the procurement supply chain to enable more material reuse by providing warehousing inventory and connecting salvagers to specifiers. But more action is needed. We must address multiple elements of the procurement supply chain. Organizations like the LBC represent a crucial link—warehousing inventory and connecting salvagers to specifiers. However, we must work to make landfill tipping fees better represent their true cost, while simultaneously developing a deconstruction industry as well as designing our new buildings with consideration for not only how they will be constructed, but also how they will be deconstructed to best retain the value of the salvaged materials.

TIMBER AND CARBON

by Scott Beans, PE, NCARB

Significant pushes have been made for sustainable forestry practices which include harvesting at optimal frequencies, thinning forests in a manner that supports longevity, minimizing impacts to waterways and wildlife habitats, and minimizing the use of harmful chemicals.

IN RECENT YEARS there has been a great deal of excitement about the advent of new timber construction methods. These methods referred to collectively as "mass timber," often involve laminating small pieces of dimensional lumber into large timber slabs, most typically into cross-laminated timber (CLT). The emergence of this technology is coupled with building code revisions that permit timber construction for larger buildings. Often the use of CLT, instead of more "conventional" construction methods, is seen as a key solution to reducing embodied carbon. Wood is aesthetically pleasing, naturally-produced, and carbon-sequestering, leading to positive public perception of mass timber buildings. However, while it is true that trees do sequester carbon during the growth phase, the whole story can't be told without understanding the other phases of the supply chain.

The wood used in mass timber buildings is harvested in select regions of the country. These regions are in areas with high concentrations of affected resources, ranging from waterways to forest wildlife. An environmental product declaration (EPD) must consider not only the carbon sequestration of the wood, but also the impacts that come with harvesting, milling, and shipping this product. Not all forests, forestry techniques, and manufacturing processes are identical; thus, it is difficult to come to an agreement on how best to quantify these

impacts. Additionally, shipping wood products far from their source may negate the benefits of using this product over concrete or steel.

Significant pushes have been made for sustainable forestry practices which include harvesting at optimal frequencies, thinning forests in a manner that supports longevity, minimizing impacts to waterways and wildlife habitats, and minimizing the use of harmful chemicals. A tree's growth (and carbon sequestration) follows a sigmoid curve; accordingly, there is an ideal time at which to harvest a specific species of tree in a specific location. Optimized harvesting will provide the best ratio of material benefit versus environmental impact.

The process of harvesting trees and converting them to functional building materials is not overly complex but varies widely amongst companies and across different geographies.

As life cycle assessments (LCAs) are performed involving these products, the user should consider the comprehensiveness of the inputs defining this product's environmental impact. More than 50% of a tree is lost as waste during harvesting and much of this is left behind in the forest, where it releases its sequestered CO_2. Are the environmental impacts of the waste properly considered? When both primary timber pieces and waste products are converted to building materials, are the impacts of miscellaneous materials such as glues and fasteners properly accounted for? The accuracy of an LCA involving these products correlates directly with the accuracy of the inputs in the product-specific EPD.

In many locales, a wood building is an ideal solution from an embodied carbon perspective. However, all mass timber buildings still utilize concrete and steel in some capacity. Additionally, a mass timber building in location A is not the same building (carbon-wise) as it would be in location B. In fact, if not thoroughly evaluated, a wood building might be a less ideal solution than an optimized steel or concrete building. The ideal approach is to be as efficient as possible with each building material rather than forcing a wood building solution that, on the whole, may have more embodied carbon than a concrete or steel solution.

EMERGING CONCRETE TECHNOLOGIES

by Kelly Roberts, PE, LEED AP BD+C

CONCRETE IS ONE OF THE WORLD'S most ubiquitous and oldest materials, and the second most used substance, after water.[1] Unfortunately, it is also one of the most impactful materials to our environment. Though concrete is a mixture made from portland cement, coarse and fine aggregates, water, and a variety of admixtures, it is the portland cement component in concrete that accounts for its large carbon footprint. In fact, up to 96% of CO_2 emissions of a concrete mix are attributable to the cement content. During the creation of portland cement, carbon is emitted due to the high heat required as a natural part of the chemical reaction. The result is an extremely carbon-intensive process that accounts for 4.4 billion tons of carbon dioxide or 8% of the world's total global carbon emissions per year and the distinction of being the world's second-largest CO_2 emitter.[2]

The first step to reducing the carbon impact of concrete that should be done on every project, every time, is to optimize portland cement usage. Concrete specifications should be performance-based and written to state what strength is needed for each element type. For example, considering longer cure times for elements such as foundations, columns, and shearwalls can lead to mix designs with less portland cement. Additionally, cement may be reduced in some regions by specifying higher quality aggregate or using less water.

Project Drawdown, a comprehensive plan to reduce global warming, identified using Cement Alternatives as strategy #36 and estimated a potential carbon savings of 440 million tons of carbon dioxide emissions annually if the strategy were implemented.[3] Several well-known cement alternatives such as fly-ash (a byproduct of the coal industry) and ground granulated blast furnace slag (a byproduct of the steel production industry) have been successfully used for decades and are quite commonplace in modern mix designs. In the short-term, while other cement alternatives are being researched and introduced into the market, maximizing the industry's use of readily available cement alternatives such as fly ash and slag is one of the most important steps engineers can take to reduce concrete's carbon impact.

Meanwhile, other cement alternatives are emerging to bring even more options to the market. Metakaolin is a pozzolan produced from the calcination of kaolin clay at much lower temperatures than portland cement. However, metakaolin is expensive and only used to replace up to 10% of cement and thus has not been widely used.[4] Another cement alternative being researched, Limestone Calcined Clay (LC3), is a ternary blended cement comprised of portland cement with calcined clay and limestone. Preliminary studies have shown that LC3 is an extremely promising option to achieve lower CO_2 emissions, increase supply capacity, higher return on investment, and potentially lower prices in the construction market.[5] Other possible emerging cement alternatives include recycled glass and volcanic ash.

Several other materials such as plastics, glass, foams, and paper have been proposed as aggregate substitutes in concrete, but most cannot be used without compromising strength and durability. Additionally, since 95% of the carbon impact of concrete is due to the cement, there is not much efficiency in focusing on aggregate substitution.

Another emerging technology in concrete production is to utilize carbon sequestration and injection. Technologies such as CarbonCure®, CarbiCrete®, and Solidia® have been emerging in markets around the country.[6,7] Walter P Moore recently specified the use of CarbonCure® for a commercial office building development in Atlanta, Georgia. On this project, our team was able to work with the concrete supplier for the drilled pier foundations to inject CO_2 into the concrete mixture at the batch plant and reduce the cement content by 7%.

Image courtesy Central Concrete

While availability and acceptance will be barriers to any emerging technology, consistent requests from specifiers for new materials may hasten their availability and research. Another concern is creating "franken-concrete" that may combine multiple new technologies and materials thus resulting in concerns about long-term durability and potential end of life issues, which will require more research. To tackle embodied carbon on our projects, the carbon emissions from concrete must be considered every time as it can be found on every single project. To make a meaningful impact most projects will need to take a multi-faceted approach by incorporating cement reduction, cement replacement, and a variety of new technologies. As concrete designers and specifiers, we need to be nimble, willing to think outside the box, and consider new technologies as they arise.

Up to 96% of CO_2 emissions of a concrete mix are attributable to the cement content.

[1] ScienceDirect (2018) Eco-efficient Cements: Potential Economically Viable Solutions for a Low-CO_2 Cement-based Materials Industry

[2] Chatham House (2018) Making Concrete Change: Innovation in Low-carbon Cement and Concrete

[3] Project Drawdown Alternative Cement

[4] ScienceDirect (2001) Metakaolin and Calcined Clays as Pozzolans for Concrete: A Review

[5] ScienceDirect (2017) Limestone Calcined Clay Cement as a Low-carbon Solution to Meet Expanding Cement Demand in Emerging Economies

[6] Carboncure.com

[7] Carbicrete.com

THE CARBON COST OF WATER

by Christina Hughes, PE, CFM, ENV SP

THE FOCUS OF LIFE CYCLE CARBON ASSESSMENTS is typically the embodied carbon of materials. Although the carbon emissions associated with manufacturing, construction, and transportation of materials are crucial to understanding the overall impact of a project, the water consumed to make these products is not currently included in the embodied carbon value of these materials. In the context of sustainable site development or building project, we are concerned with water availability and flood risk reduction but rarely look at the embodied carbon of water over a project's life cycle.

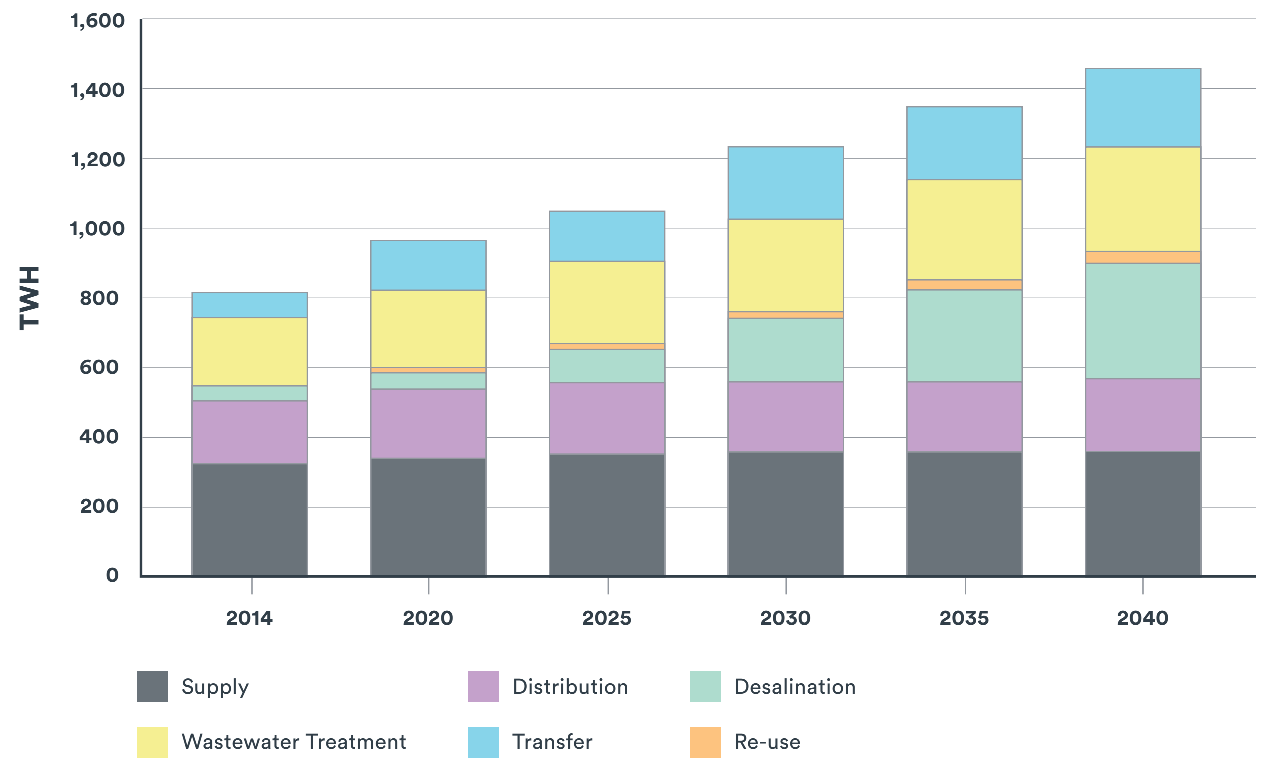
Water usage is tied to everything we do. We use water for our domestic needs, food production, livestock husbandry, landscape irrigation, waste management, materials production, natural resource extraction, and construction, among others. Most importantly, water is part of a feedback loop with energy, known as the Water-Energy Nexus, in which water is needed to provide energy (alternative energy generation and fossil fuel extraction) and energy is needed to provide water.

Energy, primarily in the form of electricity, is required for water distribution, treatment, and heating. The United States uses about 521 million MWh/yr on water supply alone, which accounts for about 13% of the total U.S. electricity consumption.[1] This, in turn, translates to about 290 million metric tons of CO_2 emissions per year, which make up 5% of all U.S. carbon emissions and is equivalent to the annual emissions from over 62 coal-fired power plants.[2]

In terms of embodied carbon, it can be estimated that water usage contributes about 4,900 pounds CO_2/Mgal,[3] or 720 pounds CO_2 per year per household,[4] from water alone.

Electricity Consumption in the Water Sector by Process, 2014-2040

Sources: Luck, et al. (2015); Bijl, et al. (2016); Wada, et al. (2016); IEA analysis. (2016)



Unlike many other trends in systems efficiency and technology, the water-carbon footprint is growing without garnering much attention. As climate change continues to make freshwater sources less reliable, we must resort to energy-intensive means of potable water production more frequently, such as desalination.[5] Additionally, global population growth not only increases water and energy demand but will continue to stress our limited freshwater resources and require additional treatment and distribution infrastructure to keep up with demand. Large-scale treatment facilities used to supply potable water still largely rely on energy-intensive treatment processes.

Water distribution, treatment, and heating accounts for 13% of U.S. electricity consumption.

Luckily, we already have the means to begin reducing the carbon cost of water, and it starts with awareness. Water conservation and water efficiency measures can have a huge impact by reducing unnecessary demand on our water supply systems. Simple-to-implement methods of stormwater management and water capture reuse—such as rainwater harvesting, cooling tower blowdown recovery, building condensate capture, etc.—also provide on-site reuse and recirculation of water. Water reuse is not only smart economically, but reduces the energy demand of water, and thereby the carbon footprint, by reducing distribution distance, treatment volume (restricting potable water from non-potable uses), and even heating and cooling through innovating heat recovery systems.

[1] 2009 Carbon Footprint of Water
[2] 2009 Carbon Footprint of Water
[3] Estimate based on 322 billion gal/year U.S. water usage and 290 million tons/year carbon emissions from U.S. water supply
[4] Estimate based on 100 gal/person average water usage and average four-person household.
[5] The Energy Collective Group (2017) Desalination and Energy Consumption

ENCLOSURE IMPACTS

BALANCING OPERATIONAL AND EMBODIED CARBON

by Laura Karnath, AIA, NCARB

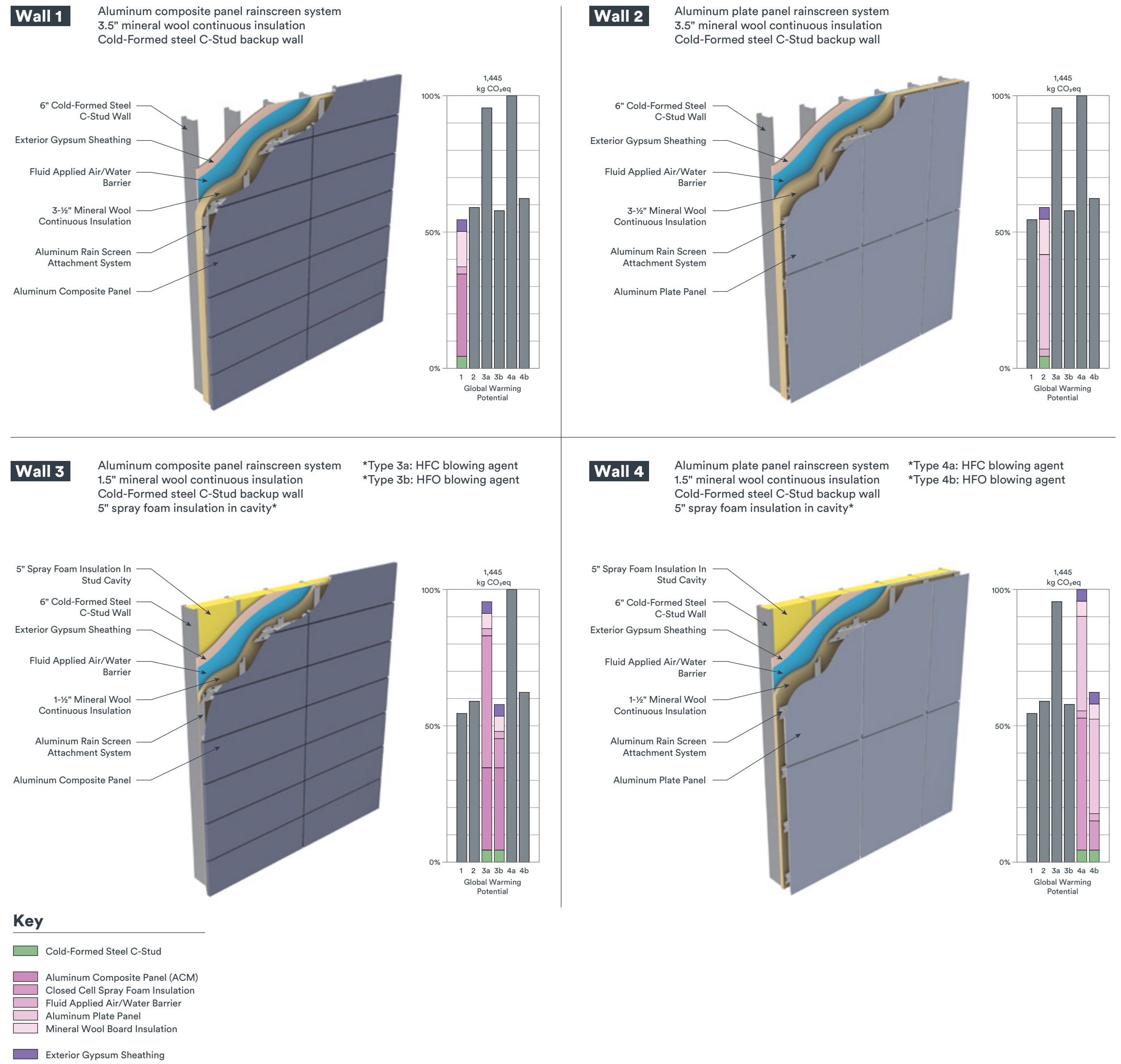
WHEN ARCHITECTS AND ENGINEERS CONSIDER the environmental impacts of building enclosures, we typically think about reducing operational impacts through more efficient building envelopes. Efficient envelopes are essential to carbon reduction goals, however, they are also responsible for significant embodied or "upfront" carbon—emissions that come from extracting, manufacturing, and transporting building materials. Common enclosure materials such as glass and aluminum are significant sources of emissions. The construction industry must reduce near-term carbon emissions to meet the goals of the Paris Agreement. To achieve this, we must reduce both operational and embodied carbon.

The terms "embodied carbon" and "global warming potential" are often used interchangeably. We measure total global warming potential (GWP) because it includes other greenhouse gases in addition to CO_2. Because other greenhouse gases have different levels of global warming potential, overall GWP is measured in kg CO_2e or kilograms of CO_2 equivalents.

Several new tools have become available recently that help designers consider upfront environmental impacts when specifying building enclosure products. Walter P Moore utilizes multiple LCA (life cycle assessment) tools, including Tally (a plugin for Revit) and The Athena Impact Estimator, as well as the Embodied Carbon in Construction Calculator (EC3) tool, which focuses on material procurement.

A recent LCA for a Walter P Moore project further illustrates how these tools better inform design decisions. Team members utilized Tally to analyze two common opaque cladding systems—aluminum composite material (ACM) panels and aluminum plate panels—as well as several insulation options for the metal stud backup wall supporting the cladding.

When designing a wall buildup, it is important to consider thermal bridging to determine how much insulation is needed. In our project example, the backup wall in options 1 and 2 used mineral wool continuous insulation on the exterior of the wall to avoid thermal bridging



through the studs while options 3 and 4 used spray foam insulation in the stud cavity as well as a thinner layer of mineral wool continuous insulation on the exterior. The LCA study illuminates the fact that the material with the greatest global warming potential is spray foam insulation using an HFC (hydrofluorocarbon) blowing agent. However, spray foam can be installed using different blowing agents. Performing an LCA allows the designer to assess the impact of switching to a spray foam product that uses HFO (hydrofluoroolefin) as a blowing agent, showing a significant impact reduction, bringing the global warming potential of wall options 3 and 4 much closer to options 1 and 2.

Where there is adequate space for a thicker wall buildup, continuous insulation may be a better choice as it reduces thermal bridging, thus reducing the overall amount of insulation material required and producing better envelope performance and lower global warming potential.

The ACM panels have a lower global warming potential than aluminum plate panels due to lower weight and less aluminum needed in the panels. However, they have higher impacts in other categories such as acidification and eutrophication potential.

Information about the upfront environmental impacts of building materials is becoming more accessible, empowering architects and engineers to use data to make better choices during design. These analyses allow teams to have more robust discussions with owners, find hot spots within systems, and achieve the reductions in upfront impacts essential to meeting climate goals.

DECARBONIZATION IN PRACTICE

As more cities commit to decarbonization and because buildings are such a significant contributor to emissions in cities, many in the industry expect climate action plans that limit both operational and embodied carbon.

PUTTING IT ALL TOGETHER

NET ZERO OPERATIONS AND REDUCED EMBODIED CARBON

Houston Advanced Research Center

The Houston Advanced Research Center (HARC) is a "not-for-profit research hub providing independent analysis on energy, air, and water issues." HARC collaborates with universities, private organizations, governmental agencies, and community groups to develop solutions to environmental issues and affect policy related to sustainability.

In 2014, HARC's original campus no longer supported its mission, and they sought to build a new headquarters that directly reflected its mission and served as a living example for regionally appropriate sustainable design in the Gulf Coast region. It was also essential that the design respect the financial realities of a not-for-profit research institution.

Minimizing Environmental Impact

Early integrated design sessions, led by Gensler, illuminated HARC's project goals and their focus, not only on operational energy efficiency, but also minimizing environmental impacts due to the materials used within the building, including embodied carbon. While the project achieved LEED Platinum certification under the current version of LEED at the time (LEED v 2009), Whole Building Life Cycle Assessment (WBLCA) was not included in the main body of the rating system. However, based on the owner's interest in reducing embodied impacts, the team elected to pursue a LEED Pilot Credit that allowed the team to apply the LEED v4 WBLCA language in LEED 2009.

As is typical for most projects, HARC's structural design team investigated different structural systems during the project's schematic phase. However, atypically, the team also used a WBLCA tool to compare several structural systems and investigate which assemblies and subassemblies contributed the most to each environmental impact indicator and used those results to drive the design.

Strategy Behind Net Zero

As part of the schematic design, and to establish a benchmark, the design team first considered what would constitute a "typical" structural system for this type of building located in this region. In suburban Houston, a building of this size—two stories and 20,000 sq. ft.—is frequently constructed of site-cast concrete perimeter bearing walls and interior steel framing. The plan dimensions of the building were set at 240 ft. x 62 ft. based on programming requirements and the desire to ensure that all spaces could effectively have access to natural light. For the bearing wall case, this resulted in a single row of columns down the middle of the building with composite steel framing at the second level and steel bar joists at the roof. Belled drilled footings, bearing 15 ft. below grade, and the bearing wall scheme required three lines of drilled footings.

The preliminary WBLCA run of a single bay of the building indicated that a significant amount of the global warming potential, or embodied carbon, was attributed to the concrete panels and the concrete foundations. Walter P Moore then developed an alternate steel-framed scheme with wide-flange girders and composite steel beams spanning between the girders. This allowed the girders to be supported on two-column lines with cantilevers to the exterior walls. This framing system, while slightly increasing the steel tonnage, allowed for the perimeter wall to be a non-load-bearing and framed from cold-formed steel studs that spanned continuously from the top of the perimeter grade beam to the underside of the roof. The continuity of the steel studs allowed a more efficient stud design and eliminated joints in the building envelope at the second-floor level. The steel system also permitted the removal of one line of drilled footings. Drilled footings were only required below the interior column lines and the non-load-bearing perimeter wall was able to be supported on a perimeter grade beam—a strategy that resulted in a significant reduction in the total project concrete volume.

Lessons in Reducing Carbon

Modifying the structural and enclosure system and also refining the concrete mixes to use less cement, resulting in impact reductions in most categories and a 20% reduction in the carbon footprint without increasing the construction cost or schedule. Perhaps more significantly, these carbon savings occurred immediately unlike operational energy savings that build incrementally over the whole lifetime of a building.

The use of WBLCA to inform the structural and enclosure design of HARC's headquarters provided the team additional insight regarding material sourcing and structural system choices and allowed the full design team to understand the project's embodied carbon. It also provided lessons that can be employed by other teams seeking to reduce embodied carbon.

Key Steps

- → Establish baseline representative of typical local construction practices
- → Perform initial WBLCA and identify "hot spots"
- → Perform schematic level WBLCAs of alternatives at a component level
- → Validate alternate assemblies, procurement premiums (if any) with material suppliers
- → Require suppliers to provide Environmental Product Declarations (EDPs)
- → Update the LCA model based on as-built conditions

WBLCA allowed the team to understand the full impact of the building and push as close to a zero-carbon building as possible. In fact, in 2018, HARC received a grant to place additional photovoltaic panels on the roof, an added capacity that exceeds the building's annual electrical demand. The surplus renewable energy will be fed back into the grid and allow the project to begin to offset the emissions associated with the materials used to construct the building—bringing the zero-carbon goal closer than ever.

Accolades

- » LEED Platinum
- » International Living Future Institute Zero Energy Certified
- » 2017 Engineering News Record (ENR) Texas and Louisiana Best Project
- » 2018 Houston Business Journal Landmark Awards finalist
- » Gold Level (highest level) APEX Award from the Association of General Contractors of America (AGC) Houston Chapter
- » 2018 AGC Award: Office Building: Under $20M
- » 2019 ULI Houston Development of Distinction Non-Profit Winner
- » 2019 Project of the Year – US Green Building Council Texas Chapter

SHAPING THE SYSTEM

LESSONS FROM BETA TESTING TO IMPROVE LEED

Bank of America Tower

Bank of America Tower is the first project in the United States—and the highest-rated in the world at the time of its certification—to achieve LEED v4 Platinum Core and Shell Certification. It was one of 100 projects to pilot LEED v4 preceding the formal launch, however, due to the philosophy and values of the project's developer, Skanska Commercial; contractor, Skanska USA Building; and architect Gensler, the project elected to pursue the newest, and substantially more rigorous, version of LEED. Bank of America Tower was one of if not the first large-scale U.S. commercial development to use Whole Building Life Cycle Assessment (WBLCA) to optimize the environmental impacts of the project's structural system.

Shift in Strategy

The pursuit of the WBLCA credit, and a focus on reducing embodied carbon, caused a significant shift in the approach the design team used to evaluate and compare structural and enclosure assemblies. Achieving reductions in embodied carbon was a key project goal and was considered, along with cost and schedule, during both the design and construction phases.

A Collaborative Approach

Early-stage LCA studies showed that more than 75% of the embodied carbon of the structure and enclosure was from the concrete framing. Nearly 35% of the project's concrete volume was in the foundation elements and 40% in the horizontal framing. These studies, and the design team's understanding that portland cement—the binder used in concrete—is responsible for the majority of concrete's embodied carbon, led to an aggressive approach to cement minimization.

It is standard for a structural engineer to specify concrete strength at 28 days. However, because concrete gains strength over time, mixes with high levels of supplementary cementitious materials (SCMs) will typically achieve higher, long-term strengths. To reduce cement content, the design team studied when structural components required their design compressive strength and did not arbitrarily specify concrete strengths at 28 days. For example, the design team specified 90-day strength for the mat foundation.

Many structural engineers permit SCMs in their concrete mixes, but for Bank of America Tower, the design team mandated SCMs to reduce cement content. The concrete mixes in Bank of America Tower required up to 55% fly ash replacement. Design phase communication and iteration between the design team, general contractor, concrete subcontractor, and concrete supplier was crucial to achieving the reduced cement content mixes.

Following Through During Construction

Despite the close collaboration during the design and early procurement phases, communication between the design and construction teams during the full Construction Administration phase was crucial to achieving the reduced cement content mixes. The project experienced a brief hold following the construction of the podium.

Upon restarting, the schedule became a key driver, and the concrete contractor proposed an alternate, faster method for forming the concrete core walls. Instead of forming the core walls on top of each floor, the core wall form work would be supported by the most recently placed section of the core.

This process, called jump forming, increased the early stage strength requirements for the core. Since the initial revised mix to permit jump forming substantially increased the embodied carbon, the design and construction teams collaborated to refine the analysis establishing the early stage strength requirements to enable a lower carbon concrete mix for the walls.

This demonstrates that the structural engineer must remain diligent in the Construction Administration phase to ensure the sustainability goals of the concrete mixes are met. This diligence resulted in a core and shell with significantly less embodied carbon than common construction practices. Even more noteworthy, the mixes developed for Bank of America Tower have since been used on other projects in the region.

Accolades

- 2020 ULI Development of Distinction For-Profit Large Winner
- LEED v4 C+S Platinum

LEVERAGING WHAT WE HAVE

THE IMPORTANCE OF SAVING OUR EXISTING BUILDINGS

Mickey Leland Federal Building

Originally constructed in the early 1980s, the George Thomas "Mickey" Leland Federal Building is a 22-story office tower in downtown Houston. The GSA purchased the building and in 2009, sought proposals to update and re-skin the structure. Since the original construction, new wind load provisions had been added to the code. Additionally, the new skin design included a larger "wind sail" area that required the existing lateral load system be checked for compliance with current requirements.

Deceptively Simple

Saving the existing building stock is easier said than done. In many cases, an existing building may not meet current functional needs. Even if it does, it was likely designed in line with a previous version of the building code or may require new systems that cause the loads to exceed the original design, which can require costly upgrades. However, strategically strengthening an existing building to extend its life instead of building new is one of the most effective ways to reduce embodied carbon.

This was the case for the Mickey Leland Federal Building. To achieve the GSA's improved energy performance goals, the building required a new high-performance curtain wall that included a more prominent crown as a design element. The increased wind exposure area of the new skin combined with an improved understanding of local wind speeds meant that the code prescribed wind loads had significantly increased since the building was designed. The combination of increased exposure area and increased wind pressures significantly exceeded the capacity of the existing lateral bracing system. Previous investigations, which used a traditional analysis method, recommended extensive structural upgrades that were not economically feasible and would divert funding from the systems upgrades that would make the building more operationally efficient.

Applying Lessons from Seismic Design

By applying an analysis method previously used only for seismic design to replicate the building's actual behavior in a hurricane, Walter P Moore was able to strategically target only the specific elements requiring strengthening, thereby generating savings which were applied to additional building system upgrades.

Previous static analyses of the existing lateral force-resisting system showed that many members were significantly overstressed by the higher current code wind loads and new cladding configuration. Instead of strengthening all of these members, Walter P Moore used an innovative analysis approach to better model the building's structural behavior. This performance-based analysis accounted for the non-linear behavior of material using state-of-the-art methods as opposed to the linear methods used in conventional industry practice. While this had been used in seismic design, it had never before been applied to wind loads.

This alternative analysis approach and "surgical" strengthening made it economically feasible to save the entire existing structure by significantly reducing the number of members requiring strengthening and saving on both demolition and new materials. The savings, measured from a conventional retrofit, were approximately 1,500 tons of concrete, 175 tons of reinforcing steel, and 350 tons of cradle-to-grave CO_2 emissions that would have been generated as a result of producing this quantity of structural metals. Measured from a rebuild scenario, retrofitting and saving the existing structure prevented over 15,000 tons of cradle-to-grave CO_2 emissions. The project was awarded a LEED Innovation in Design (ID) credit for demonstrating the savings from this novel approach.

Accolades

- LEED Platinum
- 2015 ABC Houston Excellence in Construction
- 2016 ULI Houston Development Distinction Non-Profit
- 2016 GSA Design Award

Before

After

WHAT YOU DON'T SEE MATTERS

THE IMPACT OF FOUNDATION SYSTEM SELECTION

Toyota Motor North America Research and Development Center

"Environmental Challenge 2050" is Toyota's long-term environmental initiative meant to embolden the company to go beyond zero environmental impact to achieve net positive impact. As part of this program, they targeted LEED v4 Platinum for the 140,000 sq. ft. addition designed by BHDP Architecture for their facility in York, Michigan. In December 2018 the three-story addition, which houses supply chain employees, achieved LEED v4 Platinum certified, the first project in Michigan to achieve such recognition.

A Comprehensive Approach to Project Carbon

The project's LEED Platinum goals led to a comprehensive and integrated approach to project carbon. In addition to high-efficiency mechanical systems and renewable sources of energy, the team focused on embodied emissions. During the early design phase, the team chose to pursue the Whole Building Life Cycle Assessment (WBLCA) credit. Walter P Moore led the effort and performed multiple investigations on options for the project's structure and enclosure.

The pursuit of the WBLCA credit and a focus on reducing embodied carbon caused a significant shift in the approach the design team used to evaluate and compare structural and enclosure assemblies. Achieving reductions in embodied carbon was a key project goal and was considered along with cost and schedule during both the design and construction phases.

Strategies Above and Below Ground

Local construction practices established that the above grade structural system would be composite steel floor framing with steel braced frames. This construction is common in the area and economical. Walter P Moore's initial WBLCA analysis showed that while the steel in the above grade steel structural system caused a considerable impact, the materials required below grade—the foundation—were an even larger contributor to the project's embodied carbon. This was largely due to the volume of concrete in the foundations.

The initial geotechnical engineering report suggested two foundation systems: large diameter drilled piers (caissons) or concrete-filled steel pipe piles. Our initial foundation designs showed that due to the soil properties, the piers would require a large amount of concrete. The concrete-filled pipe piles, while much smaller in diameter, required caps at each column to distribute the column load to a series of piles. The initial WBLCA found that more impact would be due to the material below grade than that above. This led to additional discussions with the project geotechnical engineer, who suggested auger cast piles as a third possibility for the foundation system. This system used larger piles with twice the capacity of the concrete-filled steel pipe piles. While the larger auger cast piles still required caps, their higher capacity meant that half the number of piles was required and the caps were considerably smaller.

In addition to minimizing the volume of material required in the foundations, the design team also worked with the ready mix concrete supplier to minimize the embodied carbon of the concrete mix. The concrete supplier, engaged early in the design process, developed custom mixes for the project and developed "ternary" concrete mixes that use portland cement, fly ash, and slag. These mixes allow the concrete to gain considerable early strength with moderate cement content.

Topping It Off

The team also considered the impacts of the roof. As part of the WBCLA, the team studied the impacts of different roof membrane options. The initial schematic design narrative called for a PVC membrane roof to match the roof used on the adjacent existing building, however, the WBLCA showed that a TPO membrane would be less impactful. This led the envelope design team to consider, and eventually specify, a TPO roofing membrane.

Accolades

» LEED v4 BD+C Platinum

HOW DO WE GET TO ZERO?

by Dirk Kestner, PE, LEED AP BD+C, ENV SP

BUILDING STRUCTURES with zero embodied carbon may sound impossible. It takes energy and creates an impact to produce, transport, and install building materials. However, it is important to understand that zero does not mean all materials and processes are impact-free. Instead, a net zero embodied carbon structure is one built from materials where the emissions from some materials are offset by sequestration from others.

Getting to zero embodied carbon requires a multi-pronged approach. Through a combination of design optimization enabling dematerialization, decarbonization of the electrical grid, material impact optimization, and the inclusion of carbon sequestering structural solutions, there is a pathway to net zero carbon. Not all of these solutions are available today, but through innovation and development in the market, they could become available in the coming years.

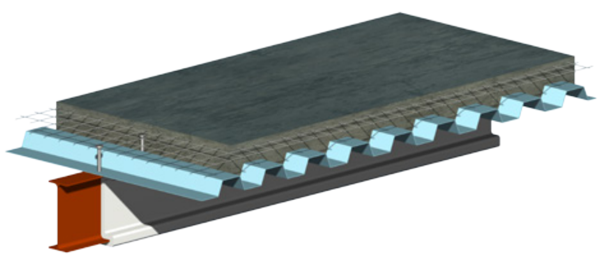
Dematerialization and Design Optimization

The simplest way to reduce embodied carbon is to use less—either at the building scale or the material scale. Retrofits to existing buildings, though sometimes more time consuming from an analytical and space planning perspective, harness our existing resources and produce significantly less embodied carbon than building new.

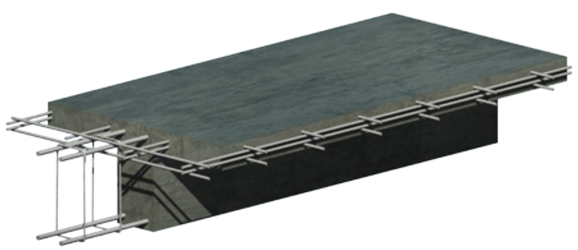
Current design practice is to optimize based largely, if not exclusively, on the cost and time of construction. In some cases a building is presented to an engineer with an established grid and the engineer is asked to size the members to provide adequate capacity. In this approach, or one where we look only at time and cost, we miss easy opportunities to use less material. While column transfers, long spans, and offsets are an inevitable part of some designs, they all create a more complex load path and require more material. Early engagement in the design process allows the team to investigate the drivers of these elements and take the forces to ground more directly. Material optimization can also be achieved by challenging the traditional practice of using repeating formwork sizes to simplify construction and instead, introducing more variation in formwork to optimize the volume of concrete used. More geometrically complex optimizations can be achieved through parametric analysis and organic optimization algorithms that allow teams to quickly assess multiple structural solutions.

The simplest way to reduce embodied carbon is to use less, either at the building scale or the material scale.

We must also consider how our design choices today may influence the ability of a building to be deconstructed in the future. We must transition our design thinking from a linear approach, where the end goal is the building,

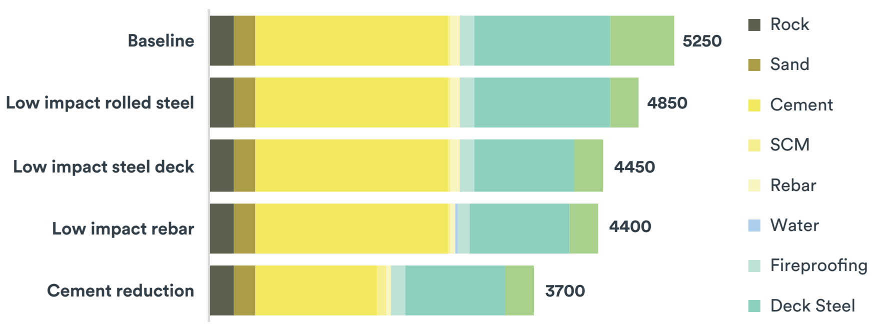


Composite Steel GWP

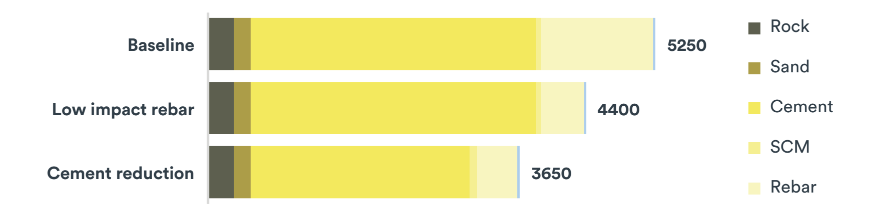


Concrete Beam and Slab

Composite Steel GWP (lb CO_2e)



Concrete Beam and Slab GWP (lb CO_2e)



to a circular approach where buildings are thought of as material banks for the future. This will enable future design teams to more easily use salvaged materials.

Increased Electrification and Renewable Energy

Decarbonization of the electrical grid will affect different materials to different degrees. Even for materials that are highly dependent on electricity-related emissions, such as steel from an electric arc furnace, emissions depend on the power generation sources supplying the electricity to that furnace, not an overall average. Materials with highly grid-dependent impacts will become cleaner, but that will not affect all systems equally. Many emissions related to the manufacture, processing, and installation of construction materials are not directly tied to changes of the electrical grid.

Lower Carbon Material Innovation

Material innovation will not be limited to new materials but will include advances and optimizations to “traditional” construction materials. Both design teams and material suppliers must understand what drives the embodied carbon within their materials and what can be done, either through the supply chain or design optimization, to produce functional equivalency through less impactful materials.

Carbon Storing Materials

Materials that can store carbon dioxide will be the key to offsetting the emissions from other materials. Timber is the most obvious structural material that can sequester carbon dioxide but it is not the only one, and the use of any material will require a clear understanding of the full supply chain. Mass timber construction provides the possibility that large amounts of carbon dioxide could be stored in our structures, but we must also consider the forestry practices and the emissions from other elements of the supply chain like forestry, glues, and processing. We must consider the full life cycle of natural building materials and investigate other scalable biological processes where materials consume carbon dioxide as they are produced. Researchers are currently investigating opportunities related to biocomposites and carbon sequestering aggregates.

The Good News

The good news is that by using available elements of all of the above strategies we can make meaningful reductions today. Consider the two “standard” systems shown. Both are traditional steel and concrete systems. However, the bar charts show how each can be optimized from typical practice with strategies such as metals from electric arc furnaces on cleaner portions of the grid and less impactful cementitious materials.

CONTRIBUTORS

Our team of experts, comprised of specialists in structural materials, green infrastructure, and enclosure design, built this Stewardship Report to address an urgent issue—embodied carbon. Our contributors, who are often recognized in the industry through awards and speaking opportunities, embrace and value the challenges that come alongside developing integrated solutions for high-performance buildings and infrastructure that utilizes resources responsibly. Continue the conversation through this resource and by contacting us for further engagement.

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Christina Hughes, PE, CFM, ENV SP

Mia Jimenez

Anna Peterson, PE

Martin Torres

Structural engineers are uniquely positioned to make significant contributions to reducing embodied carbon. We need immediate and transformative action within the building design and construction industry in order to see radical reductions in embodied carbon emissions.

—**Kate Simonen**, AIA, SE
Director, Carbon Leadership Forum
at the University of Washington

800.364.7300

Stewardship begins within.

Change requires action.

MEASURE

We will estimate our embodied carbon for all of our new design projects, identify embodied carbon "hot spots," and maintain a database of our projects' embodied carbon.

REDUCE

We will provide design solutions that reduce embodied carbon by leveraging our past project experience to inform and enhance our current design processes.

EDUCATE

We will educate our firm, clients, and AEC partners on the importance of design solutions that reduce embodied carbon by embracing new materials and innovative strategies.

ADVOCATE

As industry leaders, we will advocate for the inclusion of embodied carbon as a component of client and owner climate action plans and continue to assist in the development of tools that enhance supply chain accountability and better measurement of embodied carbon.