Webinar Question Responses

Webinar: [Embodied Carbon: Deeper Decarbonization of the Built Environment - New Buildings Institute]()

How was the Life Cycle Assessment data on slide 54 generated?

The analysis on 54 is using BHoM (and the LCA Toolkit), a free open-source tool started by Buro Happold. One major benefit is it has the capability of interoperability between many platforms (Revit, Rhino, Excel, Chrom, IES). Another popular tool is Tally, which is owned by Building Transparency. They are moving towards the use of TallyCAT, which is linked with EC3.

What LCA tools do you recommend?

BHoM Beacon (though it uses EC3 data) and TallyCAT are free, but Tally requires a paid subscription because it accesses a proprietary database (Gabi.) S.E. 2050's ECOM (though they use industry average EPDs.) Some regional AIA chapters have been offering Tally classes with one-year subscriptions. If you're connected with your local AIA chapter, it's worth seeing their interest in supporting the growth of regional WB LCA (Whole Building Life Cycle Assessment) knowledge.

Buro Happold uses various tools: EC3, OneClick, BHoM, Tally--and even Excel. Different circumstances call for different tools in the toolbox!

What's the best whole building LCA tool to use for consultants who receive Revit files from many different architects and thus come with many varied standards? In other words, which software is least dependent on the quality of the Revit files?

There are many LCA tools available now, and I'd say which is best depends on the circumstances. As a consultant performing analysis for LEED, you need to use Tally or OneClick because they have access to life cycle stages A-D. If informing different modeling scenarios early in the design, a parametric model like BHoM may be useful for its flexibility. Any program will rely on quality checking and troubleshooting the original model.

Did Luke use an Industry Average EPD (LCA/with PCA) as a benchmark?

Yes. It's currently typical to industry average EPDs as the baseline for a WB LCA.

Can you share more information on refrigerants?

Fluorinated gas (F-gas) refrigerants are responsible for 2% of total global greenhouse gas (GHG) emissions. According to the International Energy Agency, global refrigerant demand is expected to grow four-fold by 2050 because of the increased adoption of highly efficient heat pumps and the increased demand for cooling. In December 2022, the EPA published Proposed Rule – Technology Transitions Restrictions on the Use of Certain Hydrofluorocarbons under Subsection (i) of the American Innovation and Manufacturing Act. See: Technology Transitions | US EPA

They also generated a fact sheet on the rule: https://www.epa.gov/system/files/documents/2022-12/TT%20Rule%20NPRM%20Fact%20Sheet%20Final.pdf

Can you share more information on the IRA funding?

The Inflation Reduction Act invests $350 million in the EPA's Pollution Prevention program to establish a labeling program for lower embodied carbon construction materials (Section 60116) and a new grant program to provide technical assistance for reducing, measuring, and reporting the embodied carbon of construction materials and products (Section 60112).

EPA is still in the early planning phases, including setting up stakeholder engagement opportunities for winter/spring 2023. In the meantime, follow EPA's website below to track this work and sign-up for a listserv for announcements on stakeholder engagement and grant opportunities.

- EPA Sustainable Marketplace - https://www.epa.gov/greenerproducts
- Listserv sign-up - https://www.epa.gov/greenerproducts/forms/contact-us-about-greener-products-and-services

Are there guidelines on how to do whole building life cycle (WB LCA) for carbon?

Yes! Here are a few:

- https://carbonleadershipforum.org/lca-practice-guide/
- https://content.aia.org/sites/default/files/2021-10/21_10_STN_DesignHealth_474805_Embodied_Carbon_Guide_Part2.pdf (simplified, good starting point)
- https://www.istructe.org/resources/guidance/how-to-calculate-embodied-carbon/ (comprehensive, but focused on structural and U.K. data)
- ISO. 2006. Environmental Management - Life Cycle Assessment - Principles and Framework, ISO 14040: ISO.
- ISO. 2006. Environmental Management - Life Cycle Assessment – Requirements and Guidelines, ISO 14044: ISO.

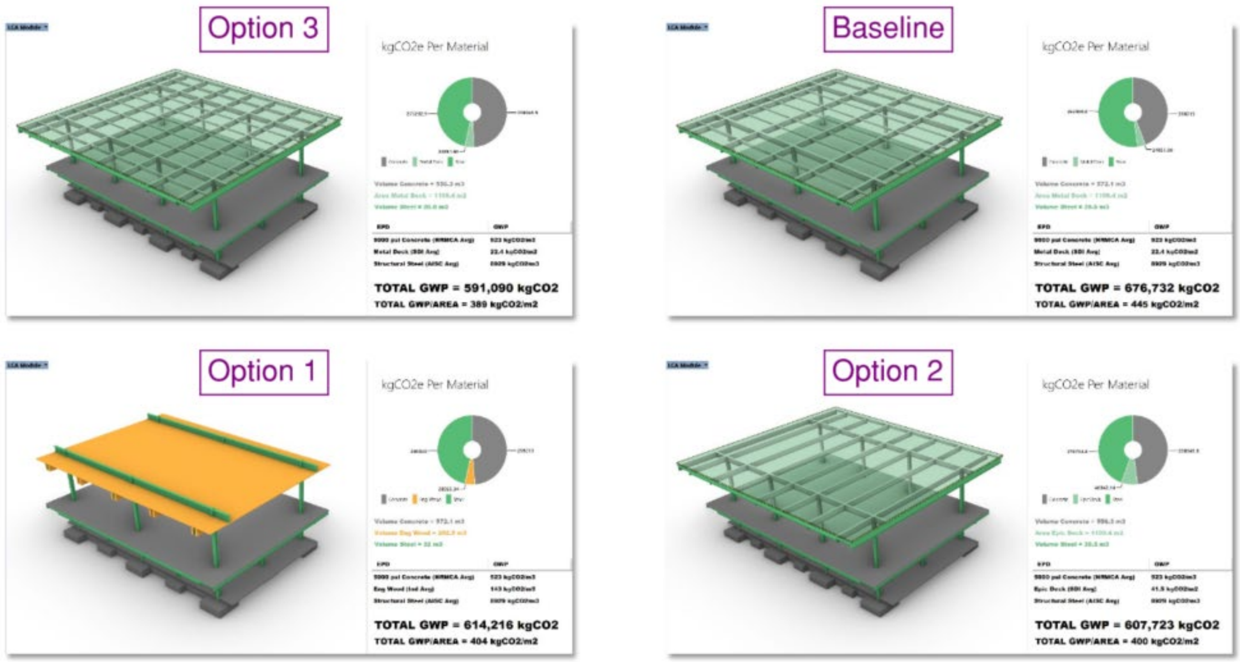
Can Life-Cycle Analysis (LCA) be combined with a Life Cycle Cost Analysis (LCCA)?

Typically, LCCA is done in the context of operational emissions, i.e. cost of purchasing energy over the life of a project. We've seen LCCAs applied less to embodied carbon because the majority of emissions occur at the construction due to purchased goods/services, and the cost of those goods/services are tougher to estimate due to dependence on commodity pricing, location, labor, supply chain, etc. In other words, LCAs and LCCAs are challenging to combine because LCAs measure carbon mostly in the beginning of the life cycle, while LCCAs measure cost that is usually spread out throughout the life of a product. This is, however, a really important topic and perhaps one that could be discussed on a future webinar.

Slide 55 indicated that Lower Embodied Carbon = Lower Cost. What structural options were compared? Is this common across all building assets in your assessment?

This is a comparison of the options on the previous slide.

Cost saving is dependent on the context of the project and should not be considered limited only to the cost of the material or carbon emissions. When looking at scenarios for the same material, i.e. all concrete schemes, optimizing for material will lead to lower cost of the material. However, this can have tradeoffs with schedule and labor. Buro Happold builds a lot in the U.S. with flat plate concrete because the cost of labor to build formwork is high. This gets into some interesting research around optimized forms, standardized modules, and design for circularity.



Luke's presentation included a slide showing various concrete building components relating to variant strength duration (i.e. grade beams @ 56d versus slabs @ traditional 28d strength) What were some of the deciding factors went into those performance based specifications?

For the structural engineer, the main factors of concern are strength and durability--and potentially carbon (GWP). The contractor may have other considerations due to schedule and cost. Some Supplementary Cementitious Materials (SCMs), like fly ash, delay the time it takes to get to design strength. This may be a concern for items like post-tension (P.T.) slabs, that need to reach a certain strength within 3 days without impacting the schedule. Other elements like foundations have flexibility because the design strength is not required to be met until much later. With this flexibility, there is potential for higher SCM %, later specified strength (concrete is expected to gain 30% more strength after 28 days), etc. Hope this answers your question. Happy to provide other resources on performance based concrete specs.

Can you share the links to the resources?

- Lifecycle GHG Impacts in Building Codes - New Buildings Institute
- AIA-CLF Embodied Carbon Toolkit for Architects - Carbon Leadership Forum
- Net-zero buildings: Where do we stand? - Carbon Leadership ForumSustainability - NRMCA
- Top 10 Ways to Reduce Concrete's Carbon Footprint Booklet – Build With Strength
- Embodied Carbon Action Plan - building-transparency.org (buildingtransparency.org)

- https://www.istructe.org/IStructE/media/Public/Resources/istructe-how-to-calculate-embodied-carbon.pdf
- Refrigerants factsheet

Should designers be concerned about glazing embodied carbon in curtainwalls?

Glass can have a high embodied carbon footprint. In some climates, projects are choosing to select double pane glazing over triple pane because the operational carbon is not enough to justify the additional upfront embodied carbon. In curtainwall systems, the metal, steel, or aluminum can also have a high embodied carbon. Designers are interested in lower profile frames to minimize the metal while not compromising the design or the structural integrity. However, there is no one solution to selecting double vs. triple pane glazing because project goals and climate zones may dictate unique needs.

What is the breakdown of greenhouse gas emissions from buildings?

EPA's GHG emissions chart presents all US GHG gases. Many resources note that CO_2 is the most common type of greenhouse gas emitted from buildings. 2014 IPCC report indicates:

- CH_4 (methane) emissions from the building sector are relatively small, accounting for only about 1% of total global greenhouse gas emissions in 2018.
- N_2O emissions from the building sector are also relatively small, accounting for about 3% of total global greenhouse gas emissions in 2018.
- F-gases are 2% of global emissions but it's not clear how much is associated with buildings. Since most US HFC consumption is from residential and commercial refrigeration, it's safe to assume that much of the 2% is associated with buildings.

Will South Coast Air Quality Management District (SCAQMD) requirements be more stringent than California Air Resources Board (CARB) on the low GWP refrigerants?

Not to our knowledge. Without being familiar with all of the SCAQMD rules, it appears that at least for stational A.C. systems, SCAQMD is following CARB rules through the refrigerant management program. Rule 1415.1 appears to be the main one they have covering refrigerants. While the specific requirements and regulations may vary between the two agencies, both are working to reduce the use of high-GWP refrigerants in order to protect the environment and combat climate change.

How may one determine the embodied carbon related to residential electrification (decarb) improvements?

Multiple studies show that in general, electrification retrofits have a relatively short embodied carbon payback period, and that the reduction in operating emissions from cutting out fossil fuels is worth the bump in embodied carbon emissions for the purposes of efficient electrification.

Some studies to look into:

- https://www.sciencedirect.com/science/article/abs/pii/S0378778821002346
- https://www.sciencedirect.com/science/article/abs/pii/S0360132320300020

Are we nearing a point where we can start to use typical established LCA tools to estimate mechanical electrical and plumbing (MEP) impacts?

Not yet. With few MEP product EPDs, the available information about the embodied carbon of products is limited. The standard TM-65 is being adapted for North American use. With the use of the standard, there's hope that more will be known about MEP products and that information will be included in WB LCA tools.

TM-65 specifies the requirements for creating EPDs for construction products, including the type of information that should be included, the methods and data sources that should be used to generate the EPD, and the format of the document. It also specifies the requirements for verifying and validating EPDs to ensure their accuracy and reliability. Overall, TM-65 is intended to help create a consistent and transparent approach to creating EPDs for construction products, which can help stakeholders make more informed and sustainable purchasing decisions.

How does recent federal legislation (IIJA, IRA) impact embodied carbon in buildings and infrastructure?

The Infrastructure Investment and Jobs Act (IIJA), originally known as the INVEST in America Act, was passed in November 2021, and it provides over $1 trillion for transportation infrastructure projects, including highways, bridges, and public transit systems. The Act includes provisions to promote sustainable and resilient infrastructure, such as requirements for the use of low-carbon materials and technologies in transportation projects. These provisions could help to reduce the embodied carbon of buildings and infrastructure by encouraging the use of materials with lower embodied carbon in construction projects.

In addition, the Inflation Reduction Act (IRA) allocates over $5 billion for low carbon material procurement. This includes $2.15 billion to install low-carbon materials in General Services Administration-owned buildings, $2 billion to incentivize the use of low-carbon materials for Federal Highway Administration projects, and hundreds of millions of dollars to help develop and standardize EPDs and to identify and label low-carbon materials for public projects.

Overall, the recent federal laws have the potential to impact embodied carbon in buildings and infrastructure by promoting the use of low-carbon materials and technologies in construction projects. These laws are designed to reduce the embodied carbon of the built environment and contribute to the transition to a more sustainable and resilient future.

Just having an EPD does not necessarily mean the product is low in carbon. How do you decipher between one product or another just by having an EPD?

When comparing two different EPDs of a product, it's necessary to confirm that the two EPDs used the same Product Category Rules (PCR), or else the comparison is invalid, and you'll be comparing apples to oranges. By comparing the EPDs of two different products in the same product category, you can gain insight into the relative environmental performance of the products and make informed decisions about which product has a lower environmental impact. EPDs can provide a consistent and transparent basis for comparing the environmental impacts of different products, allowing you to make more sustainable purchasing decisions.

When comparing the EPDs of two products (i.e., wood vs. tile), there are several key factors that you can consider to decipher the relative environmental performance of the products. These factors can include:

- The carbon footprint of the product: The carbon footprint of a product is a measure of the GWP and the quantity used. By comparing the carbon footprints of two products, you can determine which product has a lower impact on the climate.
- The energy and resource maintenance of the product: Some products will include maintenance and replacement, so the longevity and maintenance products' GWP should be considered.
- The waste generation of the product: The EPD of a product will typically include information on the amount and type of waste generated during its production and at the end of the life. Some products can be recycled, reused, or landfilled.

How important is carbon when compared with methane, and do we have metrics for CO2e for methane emissions in construction?

The calculation of CO2e includes methane, in addition to all other greenhouse gas emissions that are emitted from a project. Furthermore, most calculations of embodied carbon emissions in the production of materials and construction is calculated in CO2e instead of keeping it separated by carbon dioxide, methane, etc., which makes it challenging to make a clear estimate of how much methane vs carbon dioxide is responsible for the total embodied emissions of a project. However, methane is 82 times more potent of a greenhouse gas than carbon dioxide over a 20-year period. Methane is often emitted from the burning of natural gas during various material manufacturing processes.

How EVIDENCE-BASED are construction codes?

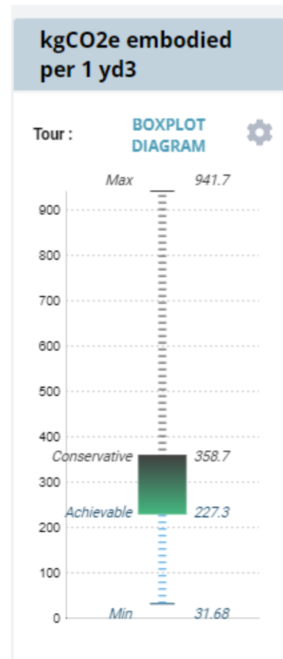
Construction code development aims to follow the most recent building science and engineering guidelines. Code development, like the International Construction Codes (ICC), follows a Standards development process, going through multiple iterations of committee hearings with building experts, in addition to several public comment periods to increase the participation of a wide range of industry, government, and nonprofit stakeholders. More information on ICC's Standards process can be found here: https://www.iccsafe.org/wp-content/uploads/22-21041_COMM_Primer_Stds_Dev_Process_RPT_FINAL_MIDrez.pdf

Since national, state, and local code development is a public process, anyone can get involved to submit proposals or comment on existing code and new proposals.

What if only California progressively addresses their emissions and no one else measures up to their responsibilities? How much harms reduction can ONLY California have?

This webinar was created and marketed with a California audience in mind. However, since California's greenhouse gas emissions are over 400 million metric tons annually and about 7% of the total US GHG emissions, it's an important state to address. Also, California's GDP is 14.62% of the entire country's GDP, making policy in California influential to the rest of the country and the world. Lastly, at the end of the day, any kind of new technology or policy innovation has to start somewhere. As an example, the first policy that limited the burning of fossil fuels in new construction was passed in Berkeley, CA, in 2019. Since then, over 70 different jurisdictions around the U.S. have followed suit and passed some sort of policy that limits the burning of fossil fuels in buildings.

In the 40,000 EPDs for concrete, how much does carbon vary per Ton (or another metric)?



Building Transparency's EC3 tool provides an opportunity to review the range of GWP of several products. For instance, reviewing the 44,753 U.S. concrete EPDs, you can see that the max is 941.7 kgCO2e (GWP) per cubic yard and a low of 31.68 kgCO2e (GWP) per cubic yard. The chart shows the average and achievable average.

It's important to note that the concrete considered here included a wide range of strength and location, providing a lot of variability.

What is on the horizon for significant reduction in carbon to meet the AIA goal of Net Zero in the building sector by 2040?

(National Ready Mixed Concrete Association (NRMCA) has been supporting projects in the Carolinas to reduce embodied carbon in concrete by reviewing EPDs' GWPs and we are seeing a 15% reduction.)

NRMCA has been an important resource in many communities. Brandon referred to the Top 10 Ways to Reduce Concrete's Carbon Footprint, which is a great resource for those new to the topic: https://www.nrmca.org/wp-content/uploads/2022/07/Top10WaysReduceConcreteCarbonFootprint.pdf

Concrete GWPs differ in different regions. Some regions have weaker aggregate which requires more cement. Availability of alternative cementitious materials also determines what is available regionally. NRMCA's document includes a lot of great information on the cement types which can reduce the final product's GWP.

Does NRMCA distinguish (for operational reasons) the NEW buildings (being designed) from existing structures (currently being used)? Otherwise, how can the Architecture 2030 challenge be realized ('reduction of carbon embodied in buildings by 50%)?

Improving existing buildings is largely out of the purview of a concrete producer. Architecture 2030 focuses on grid and appliance improvements for this scope. For new buildings, it comes down to efficient design and use of materials while also using sustainable versions of our primary structural materials to reduce their embodied carbon. Also, for a concrete structure, its thermal mass and low air leakage rates will help reduce the operational energy demands.

We are seeing a move from prescriptive to performance specifications. It appears from Webly's chart that the prescriptive approach is still in vogue.

For individual products, NBI recommends a prescriptive approach to standards. Prescriptive approaches allow flexibility for project teams to determine the best path that would align with their project goals and local product availability. We encourage individual projects to do what is best for their projects.

Overall, the market needs to evolve to move to WB LCA for an overall performance-based approach. With the IRA funding available to support EPD development, we hope that this will quicken embodied carbon knowledge and EPDs to advance to WB LCA for projects.

The Portland Cement Association has stated that they support a performance-based design option, providing flexibility to the design team and concrete contractor. "Adoption of performance-based standards for building materials While lower-carbon cement and concrete materials have been available for some time, the markets for these materials have been, in some cases, limited by overly restrictive or arbitrarily prescriptive procurement policies in both the private and public sector. By transitioning to performance-based material and design standards, policymakers can increase the market for currently available high-performance, lower carbon products like PLC, fly ash cement and concrete, and other SCMs and admixtures."

On slide 7, the pie chart lumps all envelope materials together, which doesn't provide an accurate representation of the unique embodied carbon impacts of each. For instance, masonry has less embodied carbon than many other cladding materials such as metal panels.

The AIA data in question referenced all envelope materials, which includes some very low carbon and high carbon materials. This is generalized and not related to a specific project. NBI does not recommend the use of any one product over another since product choice should be identified by the design team. When teams conduct a WB LCA, a detailed analysis of the individual products will provide more information than this generalized chart.

Do embodied emissions of materials adequately account for land use emissions?

(I ask because the GREET model (biofuels) does not in my opinion include the true scale of ILUC (indirect land use change impacts of biofuels), so I wonder if that is also a missing piece in calculated materials emissions.)

Designers use EPDs to account for carbon emissions. The content of EPDs is set by the Product Category Rule (PRC), which provides instructions (as detailed by ISO 14025) on how a product's LCA data will be communicated in the EPD. The emissions could be reported for modules A1-A3, or include a wider range. Currently, EPDs typically address A1-A3 and exclude transportation from the manufacturing facility onward.

Land use emissions, on the other hand, refer to the emissions that are generated as a result of changes in land use, such as deforestation, land conversion, and peatland drainage. These emissions are typically not accounted for in the embodied emissions of materials, as they are not directly related to the production and use of the material.

However, the land use emissions associated with a material can still have a significant impact on its overall environmental performance, as these emissions can be a significant source of greenhouse gases. For example, the production of certain materials, such as palm oil or soybeans, can require the conversion of forests to agricultural land, which can generate significant land use emissions.

In general, the embodied emissions of products do not account for land use emissions, but the land use emissions associated with a product can still have a significant impact on its environmental performance. It is important to consider both embodied emissions and land use emissions when evaluating the environmental impacts of products, even if it's not included within traditional WB LCA tools.

Why do EPDs not use projections of the carbon intensity of electricity in GWP calculations?

Energy data used to calculate product lifecycle analysis is reported in EPDs based on one year of energy data. While we agree that an inclusion of projected carbon intensity would be useful, the current EPDs are not forward-looking. Since EPDs expire after 5 years, manufacturers may see their energy-related emissions shift based on the local grid energy. For example, Washington state electricity is required to be clean by 2045, which will greatly reduce the GWP of many local products, including aluminum, which is nicknamed "liquid electricity."

Can you comment on the use cases for the NRMCA LCA benchmarks in their industry wide EPD and the benchmarks that can be obtained from EC3 drawing on actual EPDs?

The National Ready Mixed Concrete Association (NRMCA) has developed GWP benchmarks for the concrete industry, which are intended to provide a common basis for comparing the environmental performance of different concrete products. These benchmarks are based on the NRMCA's industry-wide EPD, which provides information on the environmental impacts of ready-mixed concrete over its life cycle.

EC3 is a great tool, but its use needs to be focused and cautious as it is a data dump of sorts. Listing a 4ksi mix as having any specific GWP leads one to believe that that figure is normal everywhere and for every producer, which is not the case. End use and regional availability of materials can dramatically impact the output GWP for a mix.

The NRMCA benchmark takes a region's average constituent makeup per class of concrete to establish what a typical GWP might be with a modest amount of SCMs, which is typical. The industry wide EPD then breaks down into cementitious combinations as that is the primary driver of GWP. Overall, though, end use is a massively overlooked variable in both routes as there isn't a singular 4ksi concrete mix. 4ksi for a slab can be highly different than 4ksi that is pumped 500 feet into a column form. In general, both routes are not end-all-be-all solutions, and the designer will need to apply some judgment as to what can be vs. what would have been.

The NRMCA LCA benchmarks can be compared to the benchmarks obtained from EC3, which is a tool developed by the Embodied Carbon in Construction Calculator (EC3) project. EC3 is a publicly available, open-source tool that allows users to calculate the embodied carbon of building materials based on actual EPDs. EC3 can provide benchmarks for a wide range of building materials, including concrete, based on the actual EPD data available for those materials. The available EPDs in EC3 may include organizations and EPDs that are not included in the NRMCA IW-EPD.

The NRMCA LCA benchmarks and the benchmarks obtained from EC3 can be useful for comparing the environmental performance of concrete products and evaluating their embodied carbon. These benchmarks can provide valuable information for architects, engineers, and other industry stakeholders who are interested in reducing the environmental impact of the built environment.

To what extent does reducing carbon intensity of concrete rely on fly ash? And what happens when fly ash from coal plants is no longer available.

Fly ash is a by-product of coal-fired power plants, and it can be used as a supplementary cementitious material (SCM) in concrete. Fly ash can help to reduce the embodied carbon of concrete, as it can replace a portion of the Portland cement in the concrete mix, reducing the amount of energy-intensive clinker that is required.

Prior to its use in concrete, fly ash was landfilled. There are massive quantities of landfilled fly ash that can be minimally processed (dried/milled) and used in concrete as an SCM or put into a blended cement to be a singular product. This is already in the works in certain regions of the country.

On top of this, the Western U.S. has massive amounts of natural volcanic ash deposits that can and will be used. It has a higher water demand so beneficiating it is an ongoing research endeavor, but versions of it are already used in certain areas. In the Midwest and eastern U.S., clay materials are widely available that can be calcined to produce either an SCM or blended cement as well. This is also already happening.

As coal plants will continue to shut down into the future and the supply of fly ash will decrease, alternative SCMs are being developed, including Limestone Calcined Clay Element (LC3). LC3 is a mix of two readily available raw materials, clay, and limestone. Other raw materials for SCMs include volcanic rocks and lateritic soils, both of which are high in silica and alumina, making them great ingredients for making cement alternatives.

NRMCA's resource includes additional blended cement options: https://www.nrmca.org/wp-content/uploads/2022/07/Top10WaysReduceConcreteCarbonFootprint.pdf

Are preformed or precast concrete GWP values higher or lower than ready-mix? Should precast be used over ready mixed?

Precast concrete generally does have a higher carbon impact due to the form stripping and cycling demands resulting in the need for high early strength. Being in a controlled manufacturing setting though does open the door to some innovations such as geopolymers, alkali activated materials, heated forms with high replacement concrete, etc. Also, many full precast structures are panelized, and if the exterior facade is concrete in-place of glass, they can see even a further benefit to thermal mass impacts on operational energy demands. Precast also is gravitating to more and more built-in radiant heating which further drives down the structure's energy needs. Currently, there are no industry-wide EPDs for precast concrete that are publicly available.

The emissions from pre-formed concrete will depend on the specific production processes and materials used, as well as the transportation methods and distances involved. The production of concrete generates carbon dioxide emissions, primarily from the production of Portland cement, which is a key ingredient in concrete. The emissions from pre-formed concrete will therefore be similar to those from on-site concrete production, but the exact emissions will depend on the specific details of the production and transportation processes.

To sum it up, the emissions from pre-formed concrete will depend on the specific production and transportation processes used, but the use of pre-formed concrete can provide benefits in terms of reducing waste and energy use in construction.

How should the uncertainties surrounding the reported embodied carbon values be taken into consideration in WBLCA's?

WBLCA uncertainties can affect the accuracy and reliability of the WBLCA results. Uncertainties may include data quality and availability, modeling assumptions and choices, and variability in the life cycle stages and processes considered. To address these uncertainties, it is important to use the best available data and methods, and to carefully document and justify all assumptions and decisions made in the WBLCA.

Buro Happold has been working to better incorporate the range of outcomes for a given design scenario. This includes the range of procurement options (info from EC3), contingencies for unknowns, and even ranges for uncertainty in our material estimates (e.g., steel tonnage could be 15-20psf). As the design scheme progresses, these ranges can be narrowed. It's an important point that, like any model, LCA is a tool to inform decisions, but not the absolute truth. We're looking to capture relative performance and estimate absolute magnitude to inform our designs.

How DURABLE is this new lower carbon cement?

It is more durable that traditional cement. Concrete is an inherently porous material, and this porosity is actually the primary function of its durability and expected service life. Lower permeability in reinforced concrete will translate into a longer, nearly indefinite, lifespan. These new cements as well as the use of SCMs, actually increase the durability of concrete by generating a denser cementitious matrix. Environmental exposure factors come into play as well, but this is factored into the code, and again, these materials are the primary means to meet the code for durability, they've just traditionally been used for this purpose and not sustainability.

It's important to add that low carbon cement is not new. In fact, an older version of Limestone Calcined Clay (LC3) was used to construct the Golden Gate Bridge back in 1937.

Overall, low carbon cement is a sustainable and durable alternative to traditional Portland cement, and it can be used in a wide range of construction applications.

NRMCA's resource includes additional blended cement options: https://www.nrmca.org/wp-content/uploads/2022/07/Top10WaysReduceConcreteCarbonFootprint.pdf

How does Mass Timber compare to using Steel or Concrete in relation to building structure safety, i.e., fire, infestation, etc.?

There is no short answer to this. It depends on many factors, from the building to the forest practices. You can read more on CLF about forestry practices or reference this study: https://wecprotects.org/wp-content/uploads/2019/11/Embodied-Carbon-of-Forest-Products_Slides.pdf Mass timber and steel are both commonly used in building construction for their structural strength and durability. Concrete is also widely used for its strength and ability to withstand various types of loads. In terms of building structure safety, all three materials have different properties and characteristics that can affect their performance in different scenarios, such as fire or infestation.

Mass timber, which includes products such as cross-laminated timber (CLT) and glue-laminated timber (glulam), is made from wood and has the potential to be a more sustainable and renewable building material compared to steel and concrete. However, wood is combustible and can be damaged by pests, so mass timber structures must be designed and built to meet appropriate fire and pest resistance standards.

Steel is a strong and durable material that is resistant to fire and pests. However, it can be susceptible to corrosion, particularly in coastal or high-humidity environments. Concrete is also resistant to fire and pests, but it can be susceptible to cracking and other forms of damage over time.

Overall, the safety of a building structure will depend on a variety of factors, including the design and construction of the structure, the materials used, and the local climate and environmental conditions. It is important to carefully consider these factors and consult with a qualified engineer or building professional when making decisions about the materials to use in a building project.

Can you point me to any data/research on the current carbon sink/carbon capture of timber residential construction?

There is a tremendous amount of research on forest systems, and the topic is very complex. This Carbon Leadership Forum (CLF) series (and summary), as well as several CLF videos, are a good starting point.

Trees and forests are known to be significant carbon sinks, which means they absorb and store carbon dioxide from the atmosphere. The carbon that is stored in trees and forests is often referred to as "biomass carbon," and it can be released back into the atmosphere through processes such as decomposition, wildfires, and deforestation.

Timber products, such as wood used in construction, can also act as carbon sinks by storing the biomass carbon that was absorbed by the trees while they were growing. When wood is used in construction, it can continue to store this carbon for the life of the building, potentially offsetting some of the carbon emissions associated with the building's construction and use.

There is ongoing research and debate about the potential for timber products to be used as a tool for carbon sequestration and climate change mitigation. If you would like to learn more about this topic, I recommend researching the available literature on the subject.

Define supplementary cementitious material, please.

Supplementary cementitious materials (SCMs), also referred to as alternative cementitious materials, are materials that are added to concrete mixes in addition to Portland cement. SCMs are typically used to improve the performance and sustainability of concrete, and can include materials such as fly ash, slag cement, silica fume, and natural pozzolans.

The use of SCMs in concrete can provide several benefits, including improved durability and resistance to sulfate and chloride attack, reduced permeability and shrinkage, and enhanced workability and finishability. SCMs can also contribute to the reduction of embodied carbon in concrete, as they can replace a portion of the Portland cement in the mix, reducing the amount of energy-intensive clinker that is required.

SCMs are an important component of modern concrete mixes, and can help to improve the performance, sustainability, and cost-effectiveness of concrete in construction projects.

NRMCA's resource includes additional blended cement options: https://www.nrmca.org/wp-content/uploads/2022/07/Top10WaysReduceConcreteCarbonFootprint.pdf

Is the concrete industry looking at how local zoning codes can increase the need for concrete? (Second floor setbacks increase concrete & steel requirements on residential builds because of the offset structural loads.) Is there an effort to connect zoning code impacts to energy and embodied carbon outcomes?)

Zoning codes can potentially affect the use of concrete in building construction, but the exact impact will depend on the specific provisions of the code and the characteristics of the building project.

For example, if a zoning code allows for higher building density or taller buildings in a certain area, this may encourage the use of concrete in construction to address heavily loaded structures. On the other hand, if a zoning code includes requirements for the use of sustainable or low-carbon materials, this may discourage the use of concrete.

Unfortunately, it can be a cumbersome undertaking as municipalities can often be seen as operating as isolated entities. The primary focus is to encourage a transition to performance-based design and material usage in order to allow for regionally appropriate low carbon strategies and design efficiencies to be used. The materials themselves can be improved greatly and the industry is continually working towards innovation and improvement. As impact per unit rate volume is improved, we can dilute the impact from these inefficient codes.

It's also important to note that in addition to reducing carbon emissions, buildings should balance design and architecture for walkability and livability in cities, which may mean that in some situations, concrete use is maintained or increased than what is absolutely required.

How much do you feel that concrete additives can lower the carbon impact?

Buro Happold looks to NRMCA industry averages for the relative impact of SCM replacement--upwards of +40% with 50% replacement. Portland limestone cement can provide ~10% reduction before SCM replacement. And greater reduction is possible through emerging products like limestone calcinated clay cements. Other additives (like non-chloride accelerators) can be used to mitigate the side effects (e.g., delayed strength gain) of slag/fly ash.

NRMCA's resource includes additional blended cement options: https://www.nrmca.org/wp-content/uploads/2022/07/Top10WaysReduceConcreteCarbonFootprint.pdf

What is the distribution of concrete end use? For example, roads and bridges, residential or commercial buildings, industry, etc.?

Based upon a sample set of production reporting, it varies year-to-year, but on average: Commercial 40-45%, Residential 30-35%, Public Works Structures 10%, Paving 12-15%. In 2021, total ready mixed concrete production in the U.S. was 394 million cubic yards.

Other sources show global concrete production leads to significant GHGs, maybe in the range of 10%. Was that donut chart just for C.A. (where maybe less concrete is made)?

The NRMCA graphs were for CA-specific emissions and productions. Coincidentally, CA has some of the greenest cement production facilities in the world as they are heavily regulated. Unfortunately, though, these pressures, combined with NIMBY efforts, have led to clean facilities closing, forcing the importing of more higher impact cement. Globally, cement impact on GHG emissions is around 7-8% as it is the second most used material in the world. High rises only encompass a small percentage of that.

Thoughts about using synthetic limestone aggregate (made w/ sequestered CO_2 by Blue Planet)? (supposedly enables concrete with ~ -400 lb. CO_2/yd)

Great technology and one of the key innovations in working towards net zero concrete. The product is usually around 40-50% CO_2 by mass, meaning every 100 lbs. of material is roughly equivalent to adding 50 lbs. of CO_2 to concrete. Concrete usually has around 1800 lbs. of coarse aggregate and 1300 lbs. of fine aggregate, so adding a few hundred pounds of mineralized CO_2 will make a huge impact. I have been fortunate to test the product over the years as they improve it and bring it to market. We are in the phase of continual scaling, and hopefully, it will be readily available in the near future. It is a low-density material, meaning it has a lower strength potential compared to traditional virgin aggregate; as such, you wouldn't add 1800 lbs. of it unless it was a low strength concrete. Regardless though, 200-500 lbs./yd along with SCMs will yield carbon neutral concrete.

Do you have an estimate (or Fact Sheet) that breaks down concrete USE by residential, commercial, industrial, and transportation (roadways) sector?

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Presumably, fly ash will become less available as coal plants are retired. Are there other SCMs that are being researched?

Prior to its use in concrete, fly ash was landfilled. There are massive quantities of landfilled fly ash that can be minimally processed (dried/milled) and used in concrete as an SCM or put into a blended cement to be a singular product. This is already in the works in certain regions of the country. On top of this, the Western U.S. has massive amounts of natural volcanic ash deposits that can and will be used. It has a higher water demand, so beneficiating it is an ongoing research endeavor, but versions of it are already used in certain areas. In the Midwest and eastern U.S., clay materials are widely available that can be calcined to produce either an SCM or blended cement as well. This is also already happening.

I have read that the availability of sand appropriate for concrete production is becoming more and more scarce worldwide. Any thoughts?

This is an issue that varies region to region (and supplier to supplier at times). Where it is an issue, it is common to blend in manufactured sand, which is essentially the graded fines and further crushed fines that result from coarse aggregate crushing/processing. This material is generally more angular, which plays into finishability and workability, but can be improved by the use of admixtures. In sand constrained operations, its common to reserve natural sand for slabs and other hand-troweled applications and manufactured sand for general structural applications.

How does concrete enhance energy efficiency, aside from its thermal mass? (Also, it's not clear to me how concrete/cement can continue to expand in use while achieving carbon neutrality.)

Concrete structures, depending on framing, generally have lower air leakage rates, while the thermal mass dampens HVAC energy demand curves. Concrete will one day be the undoubtedly greenest structural material. Bold statement from Brandon, but this stems from the fact that its primary source of emissions is rather simple: firing limestone in a kiln. We can solve this problem and already have to a certain degree. It's a matter of capital investment to scale these solutions. Alternate means of heating a kiln, alternate raw feed that isn't a carbonate or is sequestered carbon, carbon capture, utilization, etc., can all be put together to create a material that is low to neutral to negative in impact. Also, using sequestered CO_2 aggregates is a means of adding CO_2 directly to concrete. Concrete is often a preferred material in use/constructability and resiliency.

How detrimental is carbonization to concrete (reinforcement)?

Internal carbonation of concrete reduces its pH and its passivation effect of protecting against steel corrosion. In general, this is a non-issue when chloride exposure is not present. Carbonation with the exposure of chlorides is where we see pitting and significant reductions in the integrity of reinforcing. When exposure conditions involve chlorides, ACI 318 prescribes material design metrics to prevent this issue. The use of SCMs is the primary means of densifying the concrete and overcoming these issues.

What is your take on why concrete isn't included in Buy Clean California?

Concrete is a regional material. Instead of coming from a few production facilities that cover entire regions as steel is, concrete comes from hundreds of very local plants using local aggregates. These plants can have massive variations in material sources, quality, and availability. This then plays into the fact that concrete is a regional material and, in some regions, the impacts of concrete are lower or higher, so there is no blanket figure or definition of what low carbon concrete is. For example, the greenest concrete you can easily get is in the Bay Area CA, but the C.A. central valley is much more limited while southern C.A. is widely variable. Holding everyone to one singular set of limits will disadvantage some producers and even be impossible to achieve in some markets. End-use also comes into play as there isn't one singular 4ksi concrete mix. 4ksi for a slab can be highly different than 4ksi that is pumped 500 feet into a column form.

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