



Primer for AEC Professionals

EC3 Tool

Embodied Carbon in Construction
Calculator (EC3) Tool

A step-by-step approach
on how to use the EC3
Tool in today's design,
specification procurement,
and construction practice



Overview: Why an Embodied Carbon in Construction Calculator?

Between now and 2060 the world's population will be doubling the amount of building floor-space, equivalent to building an entire New York City every month for 40 years. Most of the carbon footprint of these new buildings will take the form of embodied carbon — the emissions associated with building construction, including extracting, transporting, and manufacturing materials. As a result, owners, designers, engineers and contractors are turning their attention to information on building materials, so they can make informed, smarter choices.

In response to this, the Embodied Carbon in Construction Calculator (EC3) tool was created, with input from a coalition of nearly 50 forward looking and innovative building industry leaders. The EC3 tool focuses on enabling the building industry to easily access and view material carbon emissions data, allowing them to make carbon smart choices when creating reference buildings during design, and most importantly, during material specification and procurement efforts. The EC3 tool encourages projects to set a “carbon budget” during design that can then be managed through material “quantity control” and procurement efforts, that are later validated during the construction process.

This primer presents a strategy for how to include the EC3 tool in today's design, procurement, and construction practice. This strategy, organized by project phase, can be used to help meet a project's structural Embodied Carbon (EC) reduction goals, and targets securing LEED v4 LCA credits and Embodied Carbon Pilot credits.

The EC3 tool is intended to supplement and improve, not to replace, current Whole Building Life Cycle Analysis (WBLCA) efforts. It targets improving the data considered at a critical stage within many WBLCA efforts, when supplier procurement decisions are being made. It makes material Environmental Product Declarations (EPD's) more accessible, easier to compare and with their uncertainties better defined.

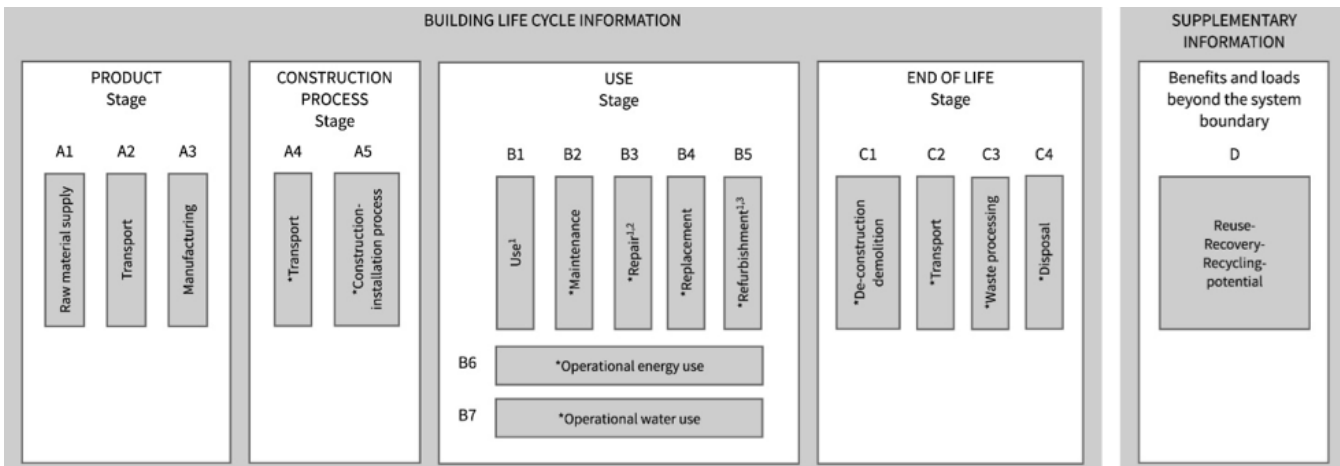


Figure 1: The EC3 Tool Focus

Whole Building Life Cycle Analysis stages per EN 15978, from LCA of Buildings: A Practice Guide¹

For the LCA experts reading this, the EC3 tool focuses on the Product Category LCA stages A1 to A3, or a cradle-to-gate material Environmental Product Declaration (EPD) embodied carbon evaluation. EPDs, for those wondering, are similar to “nutrition labels” that would come with a material, reporting environmental impact data on that specific material. While the EC3 tool does not attempt to address the other whole building LCA stages A4 through D, these other stages are each fundamentally important. Holistically evaluating all aspects of the building's life cycle are critical to understanding the full implications of our choices.

Another long-term goal of this effort is to encourage this next generation database of EPDs, which includes statistical uncertainty evaluations of the EPD data, to be integrated into the current and future generation WBLCA tools being used. As a result, the EC3 tool is a free, open-access tool.

The EC3 tool initially focuses on these materials:

- » Structure: Concrete, Steel, Timber
- » Enclosure: Aluminum, Glass, Insulation
- » Finishes: Carpet, Ceiling Tiles, Gypsum Wall Board

¹ Carbon Leadership Forum, “Life Cycle Assessment of Buildings: A Practice Guide,” 2018, <http://hdl.handle.net/1773/41885>

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The process described below includes having the EC3 tool's information carry forward from what is estimated and measured by the design team, into the contractor's budgeting, procurement and construction efforts, to support the double bottom line accounting process of embodied carbon and cost. The EC3 tool is not conceived of as the final decision-making tool when deciding how to manage the carbon budget or the procurement process of any one material or project. It helps make embodied carbon information and its associated uncertainties available at significant decision-making points of a project, but it is also only one part of a larger decision-making process.

Using the EC3 Tool: A Structural Use Case

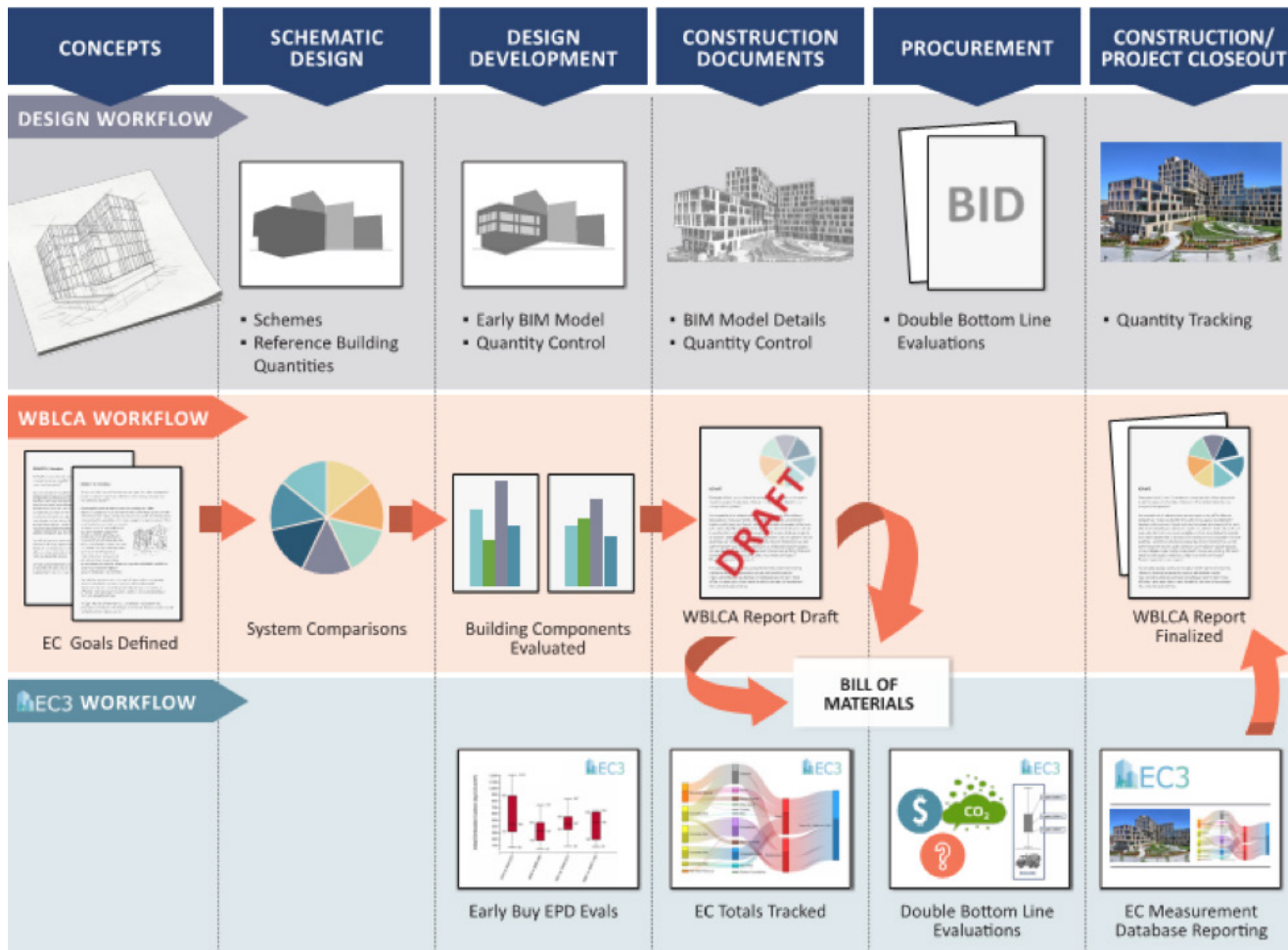


Figure 2: The EC3 Tool Flow Chart

Image developed by Magnusson Klemencic Associates

PHASE ONE

Concept Phase

This is the time for low-to-no carbon ideas to be explored, including the most fundamental decision of renovation, building reuse, or new construction. This decision point itself is often the most "carbon important" decision to be made.

Once the project program and architectural inspirations are defined, multiple material and innovative system options should be considered. It's when to have some fun, but it's also a critical time for setting the project program, budgets, and aspirational goals for going forward.

Making system and material decisions based upon best value and materially efficient use is usually the best starting point. Consider the use of lower carbon footprint materials wherever possible, but keep the primary focus on best value – an optimized design that meets the owner's

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program and goals. Remember that the choice of where the material of a project comes from, how it was made, and if the design concepts are an optimized material use, or not, will often create a bigger swing in a project's final carbon footprint than the choice of the initial material only.

Look for efficient and constructible structural load paths, while also meeting code and project constraints. A good starting point is to consider steel for tension, concrete for compression and locations exposed to the ground, and wood for exposed floor surface areas, where code appropriate. Work with the architect and design team to have structural materials do more than one job whenever possible. Consider material availability and local construction practice skills for what will be both cost effective, and achievable.

At this initial project phase, the EC3 tool can be used to consider different material bounds for what might be possible within a material, but this is largely decision making upstream of the EC3 tools best value use. Current Whole Building Life Cycle Analysis (WBLCA) tools such as Athena Pro, One Click or Tally are specifically targeted for aiding in decision making at this early project time step with more of the variables that need to be considered. For case study evaluations, if project materials can be estimated with a reasonable degree of accuracy for the most repetitious and typical building framing, the EC3 tool can be useful. The real focus at this project stage, though, should be on getting the project fundamentals right for the reasons noted above, and considering WBLCA topics that go beyond the scope of the EC3 tool's boundaries.

PHASE TWO

Schematic Design Phase

You can't manage what you don't measure. Conversely, managing to a budget is one of the keys to best practice project management. It is one of the best ways a design team helps the client meet their project targets. Material quantities are at the center of this, and embodied carbon and cost factors applied to these quantities can be handled similarly and ideally should be tracked, measured, and evaluated together for double bottom line decision making. This is where the EC3 tool information can start to be relevant, depending upon how WBLCA efforts are happening (or not happening) before this design stage.

WBLCA tools such as Tally will perform similarly to the EC3 tool for tracking "industry average" material quantity data from within a Revit model. If you have started a project within Tally at Concept Design, staying within Tally at this stage is appropriate. The value of the EC3 tool is most relevant when a project starts to move from industry average EPD data, to vendor specific EPD data, and for assessing the uncertainty within the different EPD's available, including the industry average material EPD's.

At the conclusion of the Schematic Design (SD) phase, attempting to provide a complete definition of the estimated project quantities and associated project uncertainties is a worthy goal. This is key to any LCA and/or embodied carbon cost analysis efforts.

When BIM modeling is started, decide if it is to be used for material quantity reporting (the best approach of the future), or if you plan to track quantities through a spreadsheet, or rely on the contractor quantity estimates. No matter what quantities are tracked, be consistent. The EC3 tool can accept direct imports from Revit or through BIM 360 to simplify the importing of data. It will also be able to accept imports from Tally, should that WBLCA tool be used prior.

When material quantity data is being collected, be sure to ask overall team questions to make sure budgeting efforts include contingencies for the whole project, including the parts that have not been drawn or designed yet, or that will be designed by others. An example of this for the structure: embedded steel shapes inside of concrete, steel connection material and composite studs, rebar lap splices, and miscellaneous metals not within a normal primary frame structural BIM model are often easily over-looked items that need to be accounted for.

When a BIM model is used for quantity estimating data, also be sure to know that the standard of care for that model will likely be different than what your office might typically do. An appropriate looking picture, and a BIM model that gets the quantities right requires forethought, standards, and a different level of attention to BIM model details.

The EC3 tool allows for different units (metric or imperial, etc.), but make sure whatever units used are consistent with, and in coordination with whomever is providing the project budgeting effort for cost. The quantities reported at this stage of the project can be used to create a baseline "Reference Building" for an overall project "Embodied Carbon Budget." This baseline can become what later design decisions get measured against.

As noted, the EC3 tool has within it both industry average EPD data, for early reference building definition prior to the actual material suppliers being known, as well as US and Canadian vendor specific EPDs to the extent they are known and published. This includes the National Ready Mix Concrete Association's (NRMCA) regionally averaged EPD data sets, the American International Steel Association's (AISC) national average EPD for steel, the American Wood Council (AWC) national average EPD for dimensional soft lumber, and more.

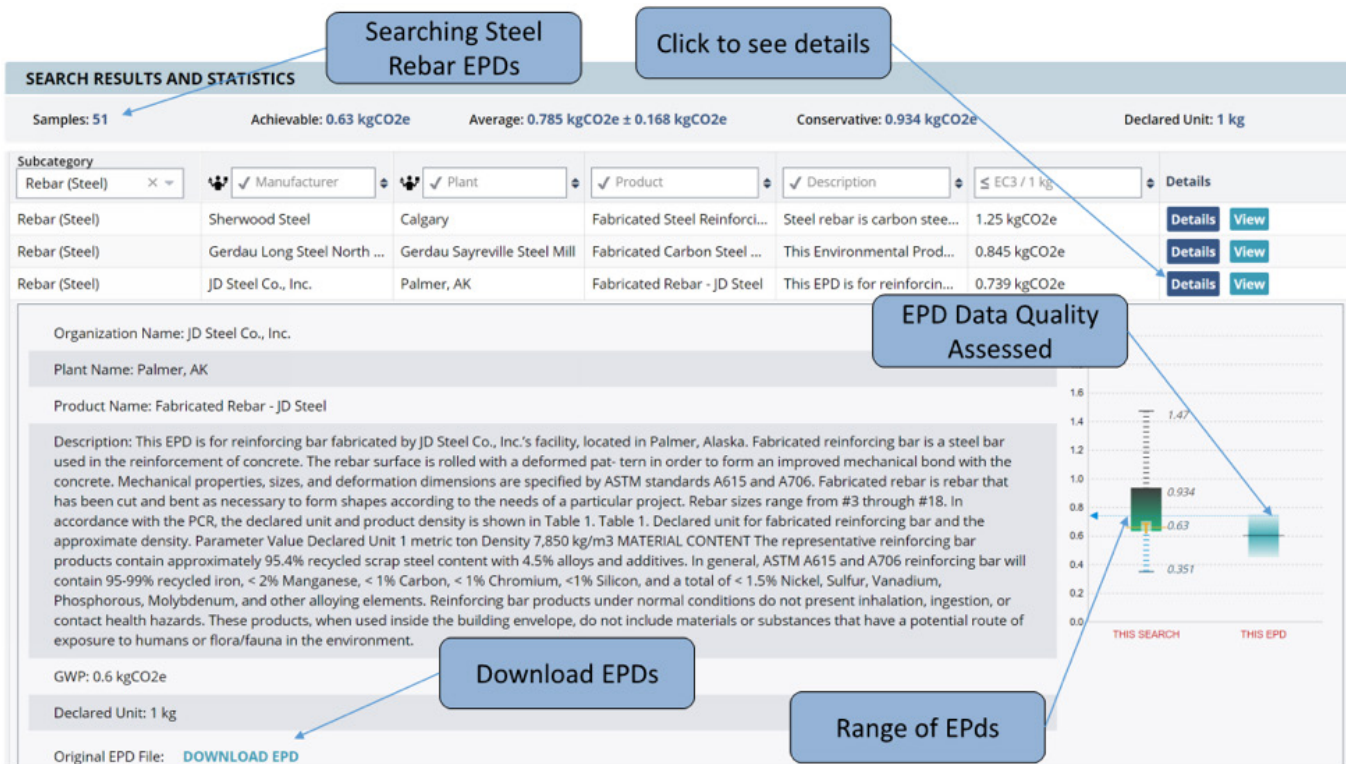


Figure 3: EC3 Tool Showing the Burden of the Doubt Use

For any pre-determined whole project carbon budget targets, conservative to aggressive targets can be set from within the EC3 tool. A key feature of the EC3 tool is that EPD uncertainty and material variability is reported.

For this uncertainty, a “burden of the doubt” approach was developed and the EC3 tool shows all reported EPD data, but defaults to an EPD evaluation ‘high estimate’ (approximately representing at least 80% of the current market) rather than ‘industry average’ (approximate representation of the average of a segment of the market). The EC3 tool’s material Use Guide explains how the different material uncertainties are assessed and then applied to the EPD data within the EC3 tool.

- » ‘Burden of the doubt’ is the opposite of ‘benefit of the doubt’ where even though something has not been proven the best outcome is still assumed – assuming ‘average products’ give the products “benefit of the doubt”.
- » The EC3 methodology takes the approach that if the EPD does not explicitly provide the information required, an uncertainty penalty will be added. That’s the burden.
- » That uncertainty penalty is represented in the reporting diagrams by the fuzzy blue range and whisker bars above and below the line of the reported GWP value in a given EPD.
- » This burden of the doubt process adjusts the embodied carbon number carried forward from the reported EPD’s within the EC3 tool’s aggregated material embodied carbon footprints, but all materials are handled similarly, and fairly, in doing this.
- » The more vendor and material supply chain specific the provided EPD data is, the smaller the uncertainty of the data. This is an incentive for material suppliers to supply both lower carbon footprint solutions and better data.
- » This ‘burden of the doubt’ approach and the daylighting of uncertainties provides for a credible way to combine materials for a whole building comparative conversation, even though their PCRs and EPDs are based upon different baseline assumptions.

Note that when considering total variability reporting within a project -- when materials are combined, but only based upon industry average EPD data -- it usually shows that definitive early project decisions based on comparisons between one material or another are inconclusive or inappropriate, based upon the material choice alone. Trend data can be credibly shown, but the industry average uncertainty bars will typically overlap. This is why making initial material decisions based upon best value and optimized use is a sounder starting point than trying to compare non-compatible industry average EPDs.

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PHASE THREE

Design Development and Construction Documents

As the design progresses, there should be a checking of the structural quantities, and associated embodied carbon, and a reporting at key project milestones, typically at the end of each major project phase. The best success will be when the material quantities (and embodied carbon estimates) are consistently updated in conjunction with the cost estimating effort. The EC3 tool includes an ability to organize materials by either Uni-Format, or Master-Spec definitions, which most contractor cost estimating software will follow.

Tracking quantities at project milestone stages is important for overall project management efforts, and it allows for trend reporting as the design evolves. To achieve optimal performance, and drive change on embodied carbon, is when project suppliers are brought into the team. This is especially true at the Bidding and Procurement stage, but if supply chain commitments can be made earlier, supplier interaction and decisions should be moved farther upstream.

The availability of EPD data varies based on product and location. The EC3 tool highlights where better data is needed. Often the best first step is to request or require EPDs on projects where insufficient data exists to set supply chain specific targets.

Specification language to support the 'asking for and tracking of' vendor specific-EPDs also should be incorporated at the earliest stages possible. The Carbon Leadership Forum provides sample specification language that can be used for this purpose at: <http://carbonleadershipforum.org/projects/model-lca-specifications/>

Using 'performance-targeted LCA specification asks', for vendor-specific EPDs within the project specifications, often leads to detailed discussions on embodied carbon reduction strategies up and down the supply chain. By asking for EPDs and letting this reporting tell the material embodied carbon data story, the vendor is open to select their own strategy for how they choose to compete on this issue. A strategy for success has been to telegraph these intentions well in advance of the actual ask to the potential material suppliers, in order to give them the opportunity to organize around the topic prior to the time of bid.

As the use of vendor-supplied EPDs grows, it will become easier to follow this process. For west coast US cities, it is currently the easiest to compare this data, and EPDs are expanding nationally. Being wise to the market variability of a project's location and engaging the full project team clearly in the process is a key to success.

It is notable how fast the topic of embodied carbon EPD reporting is moving across the industry and across the nation. Large project development clients are starting to express an interest in this information and are requesting double bottom line accounting processes that consider embodied carbon considerations. In response, regional material suppliers are reacting. From the time of the EC3 tool's conception to its launch, the number of available EPDs within the concrete industry alone has grown to over 16,000 EPDs within the EC3 tool.

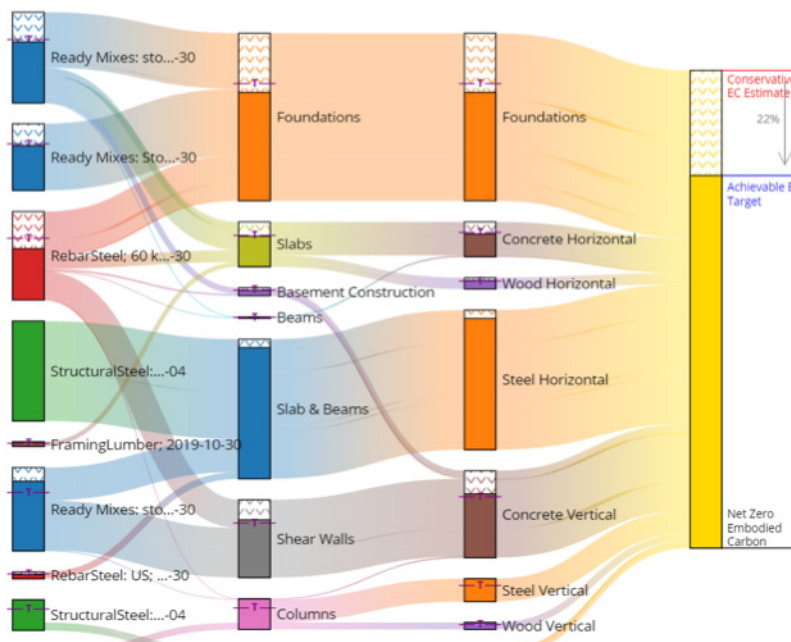


Figure 4: EC3 Tool Sankey Diagram of Carbon within a Reference Building

PHASE FOUR

Bidding and Procurement

Structural sub-contractor bids should contain material quantity assumptions, cost, and EPD embodied carbon information. Tracking the EPD and quantity information inside of the EC3 tool enables the bids to be evaluated against initial assumptions, and the material embodied carbon targets set for the full project within the reference building.

This is where the influence of the EC3 tool is most valuable. The embodied carbon footprint between commodity-based materials can vary widely in today's market, even when the costs are similar. The EC3 tool specifically targets this reality, and it looks to create inner-material competition between suppliers of like products.

The EC3 tool calculations can and should be updated based on the subcontractors embodied carbon data that can be collected during the bidding process. Decisions between like materials can be made at this time of bid, to also choose where to be carbon aggressive and where to be less so. This can happen with due consideration of other project proforma goals around schedule and cost, while still looking to stay within overall project embodied carbon budget goals.

In the case of structural concrete, as an example, where to use alternate mix designs with lower embodied carbon can best be valued. Steel and wood both have different, but large variability issues to consider. Vendor specific EPDs can help to choose between these suppliers and their upstream supply chains. Any schedule or cost premiums, if they exist, can be evaluated against the benefit of the embodied carbon reduction at this time. With this more informed decision-making process, the lower embodied carbon material suppliers can be identified, and best value trade-offs can be considered in the award of that project scope.

It is typically a very competitive marketplace for material suppliers. With the adoption of the EC3 tool, material suppliers will know what variables are being reviewed and tracked at the time of bidding. As they respond, looking for ways to optimize and differentiate around those variables, commitments to superior EPDs and lower embodied material innovations will likely occur.

PHASE FIVE

Construction

As always, teamwork is key in the construction phase. Efforts made during the design and cost estimating process can only be ensured if the project contractor carries that earlier work forward, in a validation process during construction. Tracking and verifying earlier quantity and embodied carbon allowances as they are recorded by the contractor is the ideal scenario. This validation stage is not only important for ensuring that earlier assumptions hold, but it creates a feedback

loop for future projects, allowing teams to learn where their quantity and embodied carbon estimates made early in the design held, and where they needed improvement.

The EC3 tool has been established with the coinstructors' needs in mind, to support this on-going embodied carbon monitoring and accounting summary effort.

PHASE SIX

Project Close-out

As an industry, we can only get better if we follow through and verify if our earlier assumptions hold. At the close of a project, having both a quantity, and embodied carbon feedback loop is significant for our ability to do better on the next project. Don't overlook collecting this information.

The EC3 tool, within its data collection and reporting, has a portal for uploading the project data, anonymizing the information to the level the user putting in the data desires. While some users may want to keep the information completely private and secure, others may want to share portions of the information as part of an ever-growing database of verified building embodied carbon reference buildings. As this database grows, especially when populated with as-built project data, our collective ability to better define reference buildings and starting points for what is possible will result in mutual, shared benefits.

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Conclusion

We all have a stake in improving how we move our industry toward a lower carbon footprint of construction. The design and construction communities are in a unique position to define the process for evaluating embodied carbon and can utilize the supply chain process to deliver more low carbon material options. The tool's use encourages project teams to set a "carbon budget" during design and consistently manage it through material "quantity control" and procurement efforts, that are later validated during the construction process. We invite fellow structural engineers to adopt this vital tool. Current use of the EC3 tool among team members and collaborators have already delivered demonstrated impacts on reducing the embodied carbon footprint in the building industry.



Sign Up Today

Visit <http://buildingtransparency.org> and register to access the EC3 tool.



This EC3 Tool *Primer for AEC Professionals* has been brought to you by the Carbon Leadership Forum. The Carbon Leadership Forum incubated the EC3 tool project to accelerate its development and provide optimal industry collaboration.

Who We Are

- The Carbon Leadership Forum is accelerating transformation of the building sector to radically reduce the embodied carbon in building materials and construction.
- We are pioneering research, creating resources, fostering cross-sector collaboration, and incubating member-led initiatives to bring embodied carbon emissions of buildings down to zero.
- We are architects, engineers, contractors, material suppliers, building owners, and policymakers who care about the future and are taking bold steps to eliminate embodied carbon from buildings and infrastructure.

Learn More

For more information on the Carbon Leadership Forum, its programs and initiatives, including the EC3 tool, visit www.carbonleadershipforum.org.

Resources and links include:

- Video: Bill Gates on manufacturing emissions
- World Green Building Council report 'Bringing Embodied Carbon Upfront'
- Embodied Carbon Facts and Figures
- EC3 Tool: User Benefits
- EC3 Tool: Key Features
- EC3 Tool: FAQ
- EC3 Tool: Primer for AEC Professionals