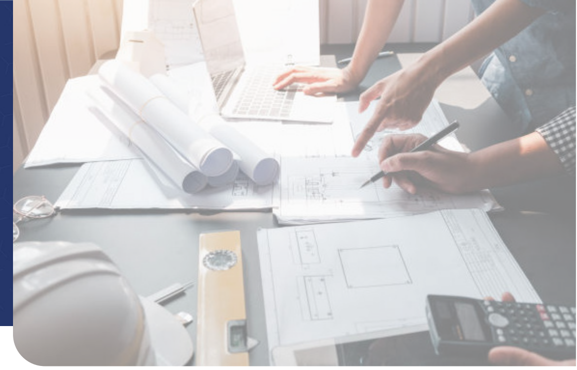
American Chemistry Council

The Benefits of a Whole Building LCA or Total Carbon Analysis:
Using Embodied and Operational Carbon to Holistically Analyze Building Emissions



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Whole building life cycle assessment, or WBLCA, estimates the net impact of constructing and operating a building. Recent industry trends emphasize material selection based on embodied carbon reductions, which could undermine the potential of continued operational carbon reductions and a holistic strategy to address building sector decarbonization. In lieu of a WBLCA, an interim "total carbon" approach can serve as a step toward better decision making. This approach quantifies a material or product's net emissions of embodied carbon and operational carbon benefits realized during a building's operational phase. When a material's total carbon impact is considered, the resulting building design begins to optimize both embodied and operational carbon reduction opportunities. This interim strategy prepares designers to further leverage WBLCA as tools and methodologies improve.

In building and construction, greenhouse gas (GHG) emissions (or "carbon impacts") are often differentiated into two categories: Embodied Carbon (EC) and Operational Carbon (OC). EC is usually discussed at the product level, while OC is usually associated with the building during its use phase.

The buildings sector has been focused on operational energy savings in buildings for the last couple of decades. Recently, that focus has shifted to reducing the embodied carbon impact of buildings and building materials. This shift is influencing emerging policy and procurement requirements that reward those buildings and building materials that demonstrate the lowered global warming potential (GWP) impacts. However, basing policy or procurement decisions on the single attribute of carbon could result in regrettable substitutions or even increased life cycle carbon emissions if not implemented wisely.

The optimal WBLCA and "total carbon" approaches estimate a building or material's embodied carbon and operational carbon use and savings, presenting a combined result. This holistic perspective and approach reframe more accurately depicts the building or material's total life cycle impact.

Therefore, utilizing a WBLCA approach for buildings or total carbon approach for materials closes the gap toward comprehensive carbon reduction opportunities and should be the preferred method used for smart policy and procurement requirements.

Definitions

Embodied Carbon (EC): Estimated greenhouse gas (GHG) emissions of a product, material or building that may be associated with material extraction, manufacturing and transportation, construction, maintenance, replacement or repair, demolition or deconstruction, and disposal.

Operational Carbon (OC): Estimated greenhouse gas (GHG) emissions and emissions savings that are associated with operational energy consumption of the building's systems during the building's use.

Total Carbon: Estimated net of greenhouse gas (GHG) emissions from a product or material's embodied carbon and emissions savings attributed to the operational carbon benefits realized after installation and during the building's use.

Whole Building Life Cycle Assessment (WBLCA): Estimated net of greenhouse gas (GHG) emissions and emissions savings attributed to a building's summed embodied carbon and operational carbon

WBLCA: Powerful Capabilities, Unlocked Potential

WBLCA in its full and realized form is the most accurate carbon accounting method, especially when all building materials are included. But best practices in WBLCA methodology and data quality from all material sectors and their supply chains are still improving. As the methodology and data mature, current and future calculation tools will need to manage increasingly complex data and computational requirements. WBLCA practitioners must also have a reasonable level of life cycle assessment (LCA) knowledge and judgment to complete and interpret the results of the assessment.

Due to the complexities of this method, some firms use an approach referred to as WBLCA, but they are only assessing a portion of the building. For example, they may focus on the embodied carbon of structural elements of the building and the resulting operational energy savings alone and not all of the materials in the building. This abbreviated approach recognizes that the structural components of buildings are usually carbon-intensive and may be the best available opportunity to make significant reductions. However, including a full bill of materials list in a WBLCA would provide a more accurate total carbon approach by considering embodied and operational carbon of the building and all its materials and their estimated impacts throughout all life cycle stages.

A comprehensive WBLCA unlocks the potential for better-informed design and procurement decisions. To get there, we need to improve data quality and availability through stakeholder collaboration, increased education, and experience.

Until WBLCA methodologies, tools and knowledge improve and become more widely available, a total carbon approach is the next best option. It is a sensible step forward in the absence of WBLCA capabilities and considers the embodied carbon and operational savings of materials. Some Building Envelope Thermal Insulation EPDs include a calculation of operational carbon benefits in the use phase in Section 7, Additional Environmental Information. There currently are no set PCR rules for conducting these calculations.

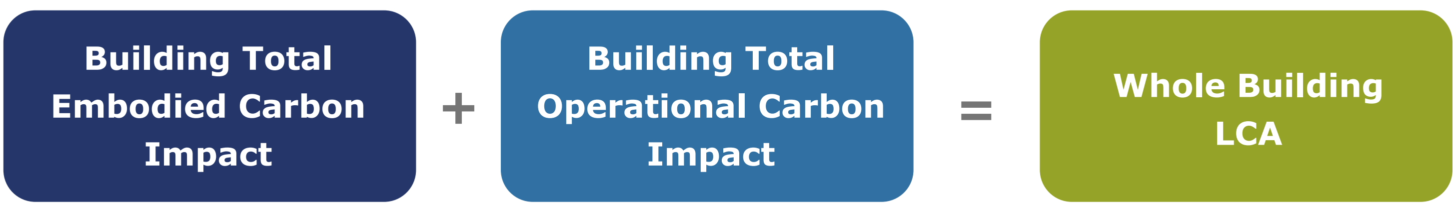

Figure 1. Whole building life cycle assessment evaluates the net GHG emissions and emissions savings attributed to a building's summed embodied carbon impact and operational carbon impact.

Meaningful Policy for Decarbonization is Important

The global building floor area (the aggregate area of every floor in a building, globally) is expected to double by 2060, particularly in the Global South and other rapidly urbanizing regions, making carbon impacts increasingly important.[1] At the same time, much of this new floor area and many existing buildings will still rely on non-renewable energy sources and inefficient energy transmission and distribution in grid operations. A total carbon strategy is needed to reframe decision-making, reevaluate decarbonization strategies in design and construction and help identify materials and construction practices to optimize building energy efficiency and limit the influence of energy regardless of its source.

Due to assumed reductions in operational energy reductions and renewable energy production increases, some believe that by 2050, half of the emissions from new buildings will be attributed to embodied carbon sources and the other half from operational carbon sources.[2] Even though we have a long way to go, the world's energy grids are slowly being transformed, and will place a greater importance on materials. Although operational carbon is responsible for most carbon emissions of new and existing buildings today, it is understood that with grid improvements, embodied and operational carbon will reach a more equal share of carbon emissions responsibility. As a result, both embodied and operational carbon impacts are the focus of many current decarbonization strategies.

1 UN Environment and International Energy Agency (2017): Towards a zero-emission, efficient, and resilient buildings and construction sector. Global Status Report 2017.
2 Why the Built Environment? Architecture 2030. Accessed May 15, 2023. https://architecture2030.org/why-the-building-sector/

Total Carbon: Reducing Embodied Carbon and Operational Carbon Through Informed Material Selection

Recent innovative building technologies demonstrate more efficient methods of design, construction, and operation, but transitioning to a net-zero carbon sector remains a complex technical challenge. However, we can start making better-informed material and design choices by incorporating a total carbon approach to significantly reduce embodied material and operational carbon impacts.

The early design process primarily focuses on the building structure and evaluates the embodied carbon impacts of material options such as wood, steel and concrete. Often missing from this approach is a consideration of how these materials contribute to energy use reduction or how they optimize building performance in the building use phase. This is also true when evaluating thermal envelope design. For example, building insulation helps optimize the thermal efficiency of a building's envelope, HVAC, and piping systems, which reduces the building's carbon footprint through lower heating and cooling energy consumption. This is especially important where access to low-carbon energy sources is and continues to be limited, which is currently still most of the Midwest and the Southeast Sunbelt (primarily Georgia, Alabama and Mississippi).[3]

Selecting materials with lower embodied carbon without sacrificing operational efficiency or other important performance characteristics is the goal of the total carbon decision-making process. A fully optimized building envelope enables the efficient use of energy sources and mitigates the influence of energy grid performance. Combined with improved grid operations like the use of renewable electricity to manage peak utility load demand and support zero energy building goals, choosing optimized materials leads to positive impacts throughout the building life cycle. Material specification also encourages enhanced building design strategies while discouraging compromises, such as carbon offsets used to compensate for a building's operational carbon, that may delay meaningful progress and cost a significant amount more than necessary.

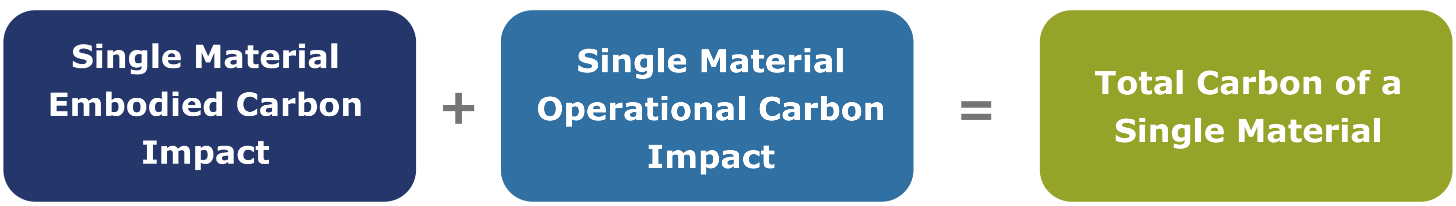

Figure 2. Total carbon of a material evaluates the net GHG emissions from a product or material's embodied carbon and emissions savings attributed to the operational carbon benefits realized after installation and during the building's use.

The material selection or procurement phase of a project usually considers the CO_2 equivalent emissions reported in Environmental Product Declarations (EPDs) (as Global Warming Potential or GWP) of a given product category to evaluate the lowest, or lower embodied carbon options. This practice can significantly influence the procurement process and is susceptible to potential biases in tools and databases, such as overrepresentation of available products in a specific market and a lack of user guidance and interpretation that should supplement decision-making at this stage. EPDs are only comparable within the same product category and when other key characteristics of the underlining LCA are consistent.

EPDs and LCAs should be coupled with an assessment of alternative material or product performance attributes and durability. Product category rules (PCRs) that dictate the completion of a valid product LCA and EPD may specify different functional units (and therefore expected product lifetimes) for product systems that fulfill the same function in the building. For example, when choosing the entryway flooring for a high traffic visitor center, the durability and longevity of the product should be highly factored into the choice as the longer lasting product will almost certainly have a higher GWP than a rapidly renewable option, but when considering the replacement requirements compared to the alternative, it becomes obviously more advantageous to choose the longer lasting product.

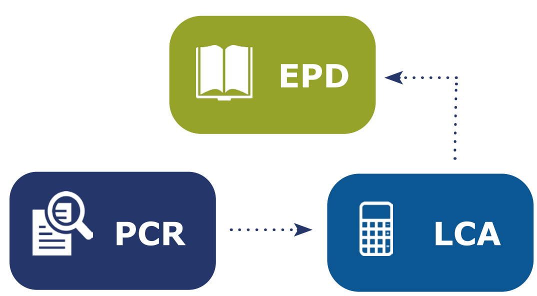

Figure 3. Product Category Rules (PCR) dictate the completion of a valid material or product life cycle assessment (LCA) and environmental product declaration (EPD).

3 Emission Rates. eGRID Power Profiler. United States Environmental Protection Agency. Last Updated on June 5, 2023. Accessed on June 13, 2023. https://www.epa.gov/egrid/power-profiler#/

These attributes can be vital to the performance of the building and contribute to reductions of carbon during the building's operational phase as well as product durability — and reduce or entirely remove the need for product replacement during the building's lifetime. These benefits might be overlooked if focusing solely on CO2 equivalent emissions reporting between product categories, a methodology that still faces data quality issues.

A holistic consideration of how materials behave when the building is operational and how they influence energy or carbon consumption is necessary to sufficiently measure the environmental impact. Lowering energy use means a reduction in environmental impacts of the energy source and grid conditions supporting the building.

Moving Toward True Carbon Reduction Strategies with WBLCA

In conducting a WBLCA, a practitioner can capture a snapshot of a building at a specific point in time (such as at certificate of occupancy, design, or construction) to account for the materials used in construction and estimation of its operational energy use. A WBLCA could also be done on a building that has been in use for several years and could account for all materials used over its current lifespan and utilize real operational energy numbers. ISO standards, as well as computational tools, have evolved over the years to reinforce WBLCA as the most comprehensive approach to quantify potential and actual environmental impacts of a product or service — in this case a building's life cycle impacts.

However, as the use of WBLCA tools increases, the complexity of the analyses and variables grow. With the increasing number of available EPDs from product manufacturers, a healthier view is being taken towards data quality and comparability. The continuous improvements of best practices in WBLCA signal the commitment to leverage this methodology to make informed and optimized decisions toward decarbonization of the built environment.

The results from WBLCA studies require clarification and proper understanding of their interpretation and use. One area for improvement is the identification of impact hotspots that pinpoint top opportunities for carbon impact reductions. As computational methods improve, we will have better capabilities to make iterative changes to a model and see how both embodied and operational carbon impacts are affected. Along with developing guidelines and judgments for interpreting these results, a practitioner could address opportunities without overlooking other carbon-intensive parts of the building life cycle, particularly indirect emissions such as fuel source composition. For example, choosing lower embodied carbon insulation could increase energy usage of the mechanical, engineering and plumbing (MEP) systems if the insulating capacity is affected. Through a holistic total carbon approach and improved tools that cater to technical and non-technical designers alike, more of these winning opportunities can be identified and implemented in a project. Above all, we should seek to avoid burden shifting between embodied and operational carbon results that may lead to diminished potential for addressing total carbon reduction opportunities.

Conclusion

As WBLCA tools and methodologies improve and companies develop more LCAs and EPDs, a total carbon approach is poised to become the cornerstone of WBLCA study and interpretation — paving the way for the development of highly capable tools for WBLCA analyses and managing the environmental impact of our built environment.

Progress is being made but until WBLCA becomes the preferred method for quantifying carbon emissions from the built environment, a total carbon strategy will help practitioners enact and internalize the perspective needed to discern and interpret WBLCA results to support design flexibility and recognize a broader set of solutions that promote decarbonization goals.

Utilizing both total carbon and WBLCA methods promotes and enhances collaboration among stakeholders such as architects, engineers, builders, policymakers, and researchers, and affirms the importance of a coordinated effort to realize wise and informed carbon reductions in the built environment. Collective stakeholder engagement will also incentivize the study and creation of more reliable data, which will improve the tools and methodologies used to inform WBLCA.

The perspective and capabilities to deliver on accelerated decarbonization strategies are rapidly coming together. Coordinating a collective shift to total carbon and WBLCA approaches will equip the built environment's industries to effectively address its share of carbon emissions.