Whole Building Life Cycle Assessment Tools

This paper was developed by WAP Sustainability with the support of the American Chemistry Council. It is not intended and should not be interpreted to endorse or disfavor any particular tool or tools but aims to provide users and product manufacturers useful information regarding the tools as they pertain to specific project needs.

In building and construction, greenhouse gas (GHG) emissions (or "carbon impacts") are often differentiated into two categories: operational carbon (OC) (attributed to operational energy consumption during the building's lifetime) and embodied carbon (EC). Embodied carbon of building materials includes estimated GHG emissions associated with material extraction, manufacturing and transportation, construction, maintenance, replacement/repair, demolition/deconstruction, and disposal). Addressing both OC and EC categories through a "total" or "whole life" carbon approach enables a more comprehensive strategy to reducing emissions throughout the whole lifecycle of a building.

Whole building life cycle assessment (WBLCA) is one of the most comprehensive ways to communicate total carbon impacts of buildings and building materials. WBLCA tools compile data to estimate the environmental impacts of a building throughout its useful life, including its Global Warming Potential (GWP). The results of a WBLCA inform strategies to reduce carbon impacts of the building during its lifetime.

Various tools are available for WBLCAs. These tools range in maturity, sophistication, and accuracy. The WBLCA Tools table provides information on some of these tools' capabilities and limitations that readers can evaluate as they determine which tools best address their own needs and circumstances. Due to space limitations, the table does not include all available tools but provides information on those commonly used. Users are encouraged to evaluate additional informational sources to support informed, independent decision-making. While the presented information is believed to be accurate, no warranties are provided.

Data Quality

The data quality supporting each of these tools is varied. It is affected by multiple factors, such as:

- quality and consistency of life cycle inventory (LCI) data;
- EPD database inconsistencies;
- EPD availability;
- manual input and data transmission errors;
- tool multipliers;
- the inclusion of products data derived from various PCRs and different versions of PCRs;
- differences in background data processing;
- etc.

Additionally, at this time there are few capabilities in these tools to assess and communicate the quality of data sources or provide any indication to users of unreasonable assumptions or uncertainty in the data. This is sometimes partially indicated in the tool documentation, but is generally not emphasized within the tool or user interface. This can lead to compounding errors that are not transparent in the results supplied to tool users and factored into design and procurement processes.

For example, the main sources of life cycle inventory (LCI) data are two databases: GaBi and Ecoinvent. Both datasets offer different and competing levels of quality. LCI data feeds WBLCA evaluations and tool functionality. Industries also often fund LCI development to ensure WBLCA tools are appropriately characterizing the environmental impacts of their products. For now, software tools will use different data sources, variables and assumptions to support modeling based on their individual value proposition to their customers, which creates inconsistencies in results and interpretation.

A study comparing Tally and Athena's assessment results on the same building assembly revealed up to a 42% variance between their calculated global warming potential. In addition, material or assembly data is often very broad and averaged in modeling tools that do not pull product specific LCA or EPD data from a database. Even with specific data, often the underlying assumptions and data transformations, when factored into assembly or building models, are difficult to view and understand. Quality check capabilities are limited and mostly assess integrity of the building model and not quality of LCA data.

In some cases, WBLCA models omit entire categories of materials, such as mechanical, electrical, and plumbing (MEP) equipment, due to lack of reliable LCI data. If it is modeled, the data is very generalized and contributes to issues with using generalized data. Manufacturers in EC-emerging industries are quickly collaborating on rules and best practices for adding their products to WBLCA tools.

It is important for users to understand the limitations of data generation and modeling in the context of making building and material decisions. There is ongoing work throughout the entire process from LCI data consistency to collaboration within industries and updates to WBLCA software improvements to ensure that reliable data is being used to make good decisions. Further, the increasing number of product specific EPDs being developed by manufacturers will likely decrease overall dependency on background LCI data in the future.

Carbon Impact Tool Descriptions

Athena Impact Estimator for Buildings

https://calculatelca.com/software/impact-estimator/

The Athena Impact Estimator for Buildings (Athena IE) evaluates whole or partial buildings from an input of building assemblies or a bill of materials. Athena IE primarily functions as a text-based LCA tool where users describe building assemblies through dialogue boxes that request simple information like bay sizes and loads. The software calculates a bill of materials and the associated environmental impacts. Thus, users select and add elements to represent the building as closely as possible.

Users can also import their own bill of materials from any CAD program, as an alternative to manual input.

Athena IE can be used in any design stage.

Athena IE data is regionally customized within North America and drawn from the proprietary Athena Life Cycle Inventory (LCI) database, the US LCI database, and Ecoinvent. Environmental Product Declarations (EPDs) cannot be accessed from the tool. Transportation, localization, and service life values per material cannot be modified.

Athena IE does not include an operational energy modeling capability, but it does allow users to enter separate energy modeling data to compute total carbon impacts. It also does not have a way to QC the process or results.

The software was updated in 2020, and a new version is expected in 2023.

Buildings and Habitats object Model (BHoM) Life Cycle Assessment Toolkit

https://bhom.xyz/

Buro Happold's BHoM is an open-source model supported by architects, engineers, and software developers that provides a single common language to facilitate data transfer between design and engineering software tools. Instead of creating individual translators between every piece of software, the BHoM serves as the intermediate translator, or central model, between all compatible software. In this way, the BHoM is used to relate data between tools that are normally incompatible or would require a difficult data transfer or significant manual data input.

As an example of the tool's capability, users can pull building information modeling (BIM) data and objects from Revit into Grasshopper, Dynamo or Excel, apply EPD data sets to those objects, and evaluate embodied carbon impacts before pushing the data back to Revit or to other visualization engines for additional analysis. The toolkit also supports direct import of material quantities. BHoM connects material quantities to LCA and EPD data from multiple open-source databases including EC3, Quartz, ICE, etc.

BHoM facilitates interoperability and enhances data and models in other WBLCA tools but is not a standalone tool that is capable of producing a WBLCA on its own. The network of contributors aims to enhance workflows between WBLCA tools and improve their effectiveness in handling increasing informational complexity and volume, which will be important for the increase in EPD development and digitization of EPD data.

cove.tool

https://www.cove.tools/embodied-carbon-feature

cove.tool is a web- and plugin-based suite of tools that focuses on early-stage design phases that require rapid, iterative feedback. Its integrated tools support rapid 3D modeling and prototyping (drawing.tool), energy and daylighting modeling (analysis.tool), HVAC sizing and modeling (loadmodeling.tool), and a lead generator that connects manufacturers and project teams throughout the modeling process (revgen.tool). It does not conduct whole building life cycle assessment or quantify carbon impacts of the building design.

There are some ways to partially understand carbon impacts through cove.tool. It has a cost versus energy optimization feature that runs whole building simulations of multiple material selection options and identifies the optimal combination of material variables based on cost and energy parameters. Embodied carbon is an optional and manual input. Users click through to the Embodied Carbon in Construction Calculator (EC3) and copy and paste the appropriate value, but the value is not factored into the building model's energy optimization determinations.

At the material assembly level, the Assembly Builder feature calculates performance, cost and carbon values for material assemblies based on the EC3 embodied carbon baseline for the component product category. Embodied carbon intensity (kg CO2-eq per unit area) is pre-populated based on the materials selected for the assembly with no indication of how it was calculated or the source data, though the default values and assumptions can be manually updated. An enhanced Embodied Carbon Feature has been announced but no release date has been published.

Early Phase Integrated Carbon (EPIC) Assessment

https://epic.ehdd.com/
https://epic-documentation.gitbook.io/epic/

The EPIC Assessment tool was created to overcome the scarcity of data in early design phases that could inform embodied carbon reductions and assess potential impacts of embodied carbon. EPIC's model includes U.S. regionally-specific data, forward-looking projections, and built-in assumptions (base case energy use intensity (EUI), percentage of onsite fossil fuel combustion, rough building dimensions, and interior fit-out percentage). It allows a user to edit specific project parameters and baseline assumptions to test the effects of carbon reduction strategies for their specific project.

The model scope includes building structure: cladding, glazing, and roofing (and replacement of cladding and glazing); interior fit-out (and replacement of interior fit-out); mechanical, electrical and plumbing (MEP) systems; photovoltaic arrays; and annual landscape maintenance. Material carbon intensity data is taken from other tools and peer-reviewed publications, and are either national averages or product/assembly type averages.

For operational carbon, EPIC includes the emissions based on state-specific grid averages. Onsite fossil fuel use is assumed to be natural gas, and its contribution to total energy use is based on averages from the Commercial Buildings Energy Consumption Survey (CBECS) and Residential Energy and Consumption Survey (RECS) databases. The model can account for biogenic/stored carbon from timber-based structural materials and site landscaping. The tool has an appendix that documents relevant assumptions and the calculation methodology. The beta version of the tool was released in June 2022, and two minor updates to fix software bugs have been released since then.

Embodied Carbon in Construction Calculator (EC3)

https://www.buildingtransparency.org/

EC3 focuses on the cradle-to-gate emissions of construction materials and sets targets for procurement decisions. Users manually enter material quantity data to model their construction estimates or bill of materials.
A Revit plugin is under development.
EC3 contains a database of digitized Environmental Product Declarations (EPDs), which can facilitate a visual and technlogical comparison of key product attributes extracted from static documents for products in the same product category. The tool does not police data inputs.

EC3 is most often used as an EPD comparison tool. Select product categories and associated product EPDs are currently available in the EC3 database. Both product-specific and industry-wide data are included. Users often review product specific EPDs against the Carbon Leadership Forum (CLF) Baseline to determine whether that specific product helps meet their project goals. Rather than take a mathematical average and to account for uncertainty in data, the CLF Baseline marker corresponds to the threshold where 20% of products exceed the desired embodied carbon intensity. Error bars are provided to show that there is some room for error in data comparisons. The most recent material baselines can be found in CLF's 2021 Material Baseline Report.

One Click LCA and Carbon Designer 3D

https://www.oneclicklca.com/
https://www.oneclicklca.com/carbon-designer-3d/

One Click LCA is a fully automated web-based, text-input software tool that also has a Revit plug-in. It takes data from sources such as Revit and other BIM models, costing spreadsheets, or energy models and combines the data into a WBLCA. The software meets requirements for over 40 green building certification programs. Carbon Designer 3D is an add-on early phase tool that estimates a building's carbon footprint based on size and type of building. The tool comes with ready-to-use localized reference buildings and allows users to create their own scenarios. Carbon hotspots are visualized in heatmaps of 3D structure models that allow designers to explain carbon intensity to other designers and project owners.

One Click LCA integrates data from EPD platforms to develop its own construction materials database. EPD data is presented as it pertains to the project's specific geography and target certifications. All data in the One Click LCA database undergoes a ten-point verification using a process that has been reviewed by the Building Research Establishment (BRE). Some EPDs may be deemed to have ineligible results. They can still be added to the database but are not automatically integrated into the software. A warning is displayed for such EPDs. If the error is only minor, a user can manually confirm that they want to use the EPD. The tool also allows users to directly add additional or alternative materials and adjust numerical inputs to compare two or more buildings scenarios. The LCA Checker function informs users if materials are missing or if quantities are reasonable based on project type and size.

tallyLCA (Tally) and tallyCAT (Tally Climate Action Tool)

https://choosetally.com/
https://www.buildingtransparency.org/tally/tallycat/

Tally is a Revit plugin that allows users to determine relationships between BIM elements and information on construction materials from the Tally database. Tally quantifies a building's or material's embodied environmental impacts to land, air, and water systems. Essentially, Tally adds another layer of detail to BIM by recognizing materials that are not modeled explicitly, such as the steel in concrete assemblies. Tally was initially developed to translate mass-based life cycle impacts into the design process and embed embodied carbon information into a building model to understand how material type and weight impact a building's total carbon. Tally utilizes a custom-designed database that combines material attributes, assembly details, and architectural specifications with environmental impact data with little indication of source data and pre-populated assumptions and calculations. The data is specific to the United States. Tally does not have an ability to assess the quality of results.

Building Transparency's new tool, the Tally Climate Action Tool (tallyCAT), provides real-time synchronization of EPD data between EC3 and Revit. This allows designers to identify carbon reduction opportunities in the Revit environment. This addresses a lack of interoperability between LCA tools and BIM-based analysis methods of building design.

Collaborators including Building Transparency, Perkins & Will and C-Change Labs plan to make tallyCAT a whole-life carbon tool and plan to release an updated version in 2023. Both tallyLCA and tallyCAT are on track to become free and open-access tools.

WBLCA Tools

	Athena IE	BHoM	cove. tool	EC3	EPIC	One Click LCA	Tally
Design Stage Applicability SD = Schematic Design DD = Design Development	SD, DD	DD	SD, DD	SD, DD, Procure-ment	Pre-design	Pre-design, Early SD, and DD	SD, DD
Cost	Free	Free	Custom pricing	Free	Free	Custom pricing	Set license fee
General Attributes							
Ability to QC data and results easily							
Ability to sync LCA with geometry updates							
Utilizes or links to open-source data							
Wide variety of building material types*							
Transparency of underlying carbon intensity assumptions (access to kgCO2e/kg value)							
Data Quality and Specificity							
Data quality							
Populated with assumptions for US context (or US data is a subset of globally comprehensive database)							
Are data updated regularly?							
Life Cycle Stages							
A1-A3							
A4-A5							
B1-B4							
B6-B7							
C1-C3							
Module D (Reuse, Recycling, Energy Recovery)							
Can include biogenic carbon accounting							
Customization of Data							
Ability to input energy of construction							
Ability to edit transportation distances							
Ability to edit operational energy and water usage							
Ability to input specific LCA or data without developer assistance							
Output and Results							
Ability to QC output**							
Export to multiple tools (e.g. Excel, Revit, Rhino…)							
Can break out lifecycle impact by material category (e.g. structure, wall assembly, flooring)							
Can break out lifecycle impact by material type (e.g. steel rebar, PVC flooring)							
Can break out lifecycle impact by life cycle stage							

* This criterion assesses how many different product categories' data are integrated into the tool. Product categories available within a tool vary significantly. For example, EC3 has worked with industry associations to integrate select product category types, focusing on common interpretation of data rather than quantity of data. Other tools like OneClick LCA connect to as many EPD databases as possible but do less critical work to resolve discrepancies in data quality prior to integration.

** The ability to quality check the output of the tool typically assesses the integrity and completeness of modelling the building and its required components. For example, it may check structural systems and assemblies for expected components. It will usually not evaluate assumptions, data sources or data quality of the input LCI, LCA or EPD data.

Key

Yes

No

Partial. Some tool aspects address the criterion.

Varies. Tool addresses the criterion but requires the user to know how to manipulate the data or model to fulfill that function.

Unknown. Not enough information to conclude how the criterion was addressed, or desired outcomes are more user- and less software-dependent.