tally™

ENVIRONMENTAL IMPACT TOOL

TALLY™

AIA TAP BIM AWARD 2014

Category G: Process and Technology Innovation Integrating with BIM

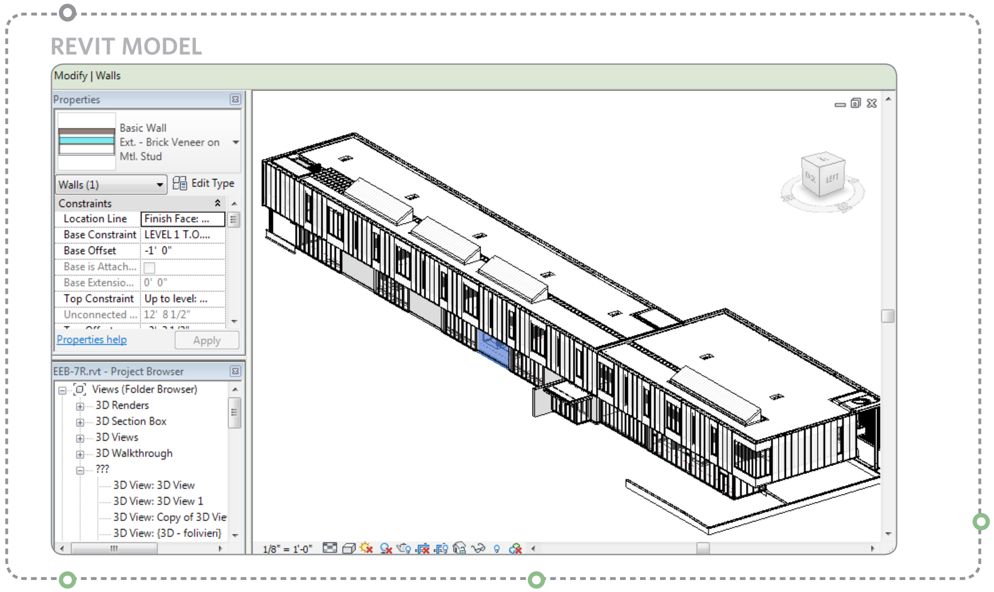
TALLY™

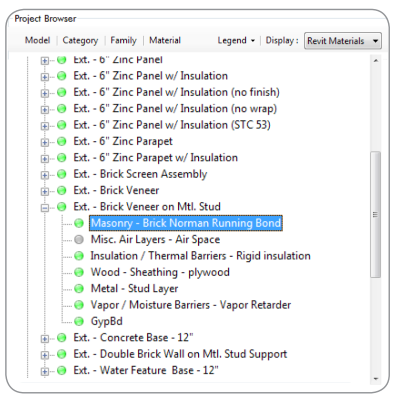
Bringing Impact Data to the Design Process

As energy standards and more stringent codes have driven the operational energy consumption of buildings down in recent years, the environmental impact of materials on a building's overall ecological footprint has gained relevance. Quantifying the impact of materials typically involves a Life Cycle Assessment (LCA), which is generally performed by a trained practitioner. Because the process of conducting an LCA can be time and labor intensive, most are performed after construction.

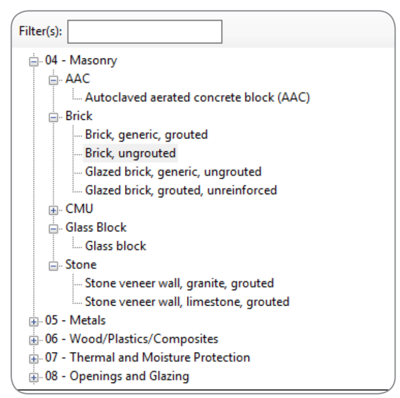
However, at any point during a building's development, designers are confronted with specific questions and decisions related to the consequences of material selection. One may need to compare a whole building to a benchmark, explore variations in building massing or construction type, or compare alternative finishes. For designers to reduce the environmental impact of materials, it is crucial that they consider LCA data at the time of material selection, rather than after a design is complete.

To answer this need, we developed **Tally™**, an Autodesk® Revit® application that allows designers to quantify the environmental impact of building materials for whole building analysis as well as comparative analyses of design options. While working on a Revit model, one can define relationships between BIM elements and construction materials from the Tally database. Through this process one can generate a variety of output reports that speak to a range of questions one might ask during design. The result is Life Cycle Assessment on demand, and an important layer of decision-making information within the same time frame, pace, and environment that building designs are generated.

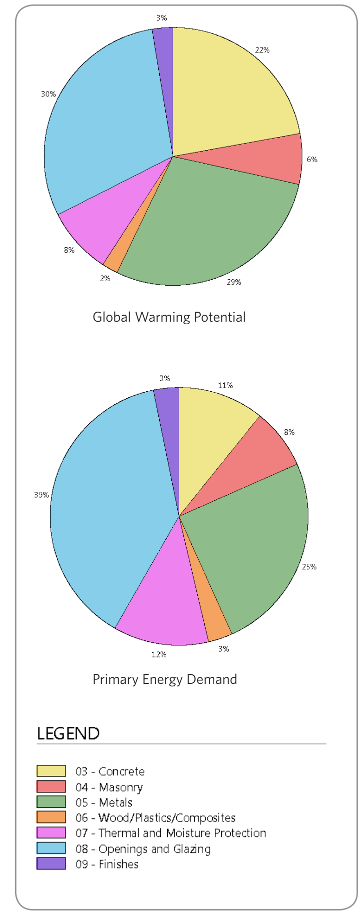




TALLY™ Material quantities are pulled from the Revit model



DATABASE Impacts are captured in an LCA database



TALLY™ REPORT Design and material selection questions are rapidly answered.

BIM DATA EXCHANGES

With Tally, the user leverages the material takeoff methods in Revit to create a full bill of materials and export reports that address the range of questions one might have during design.

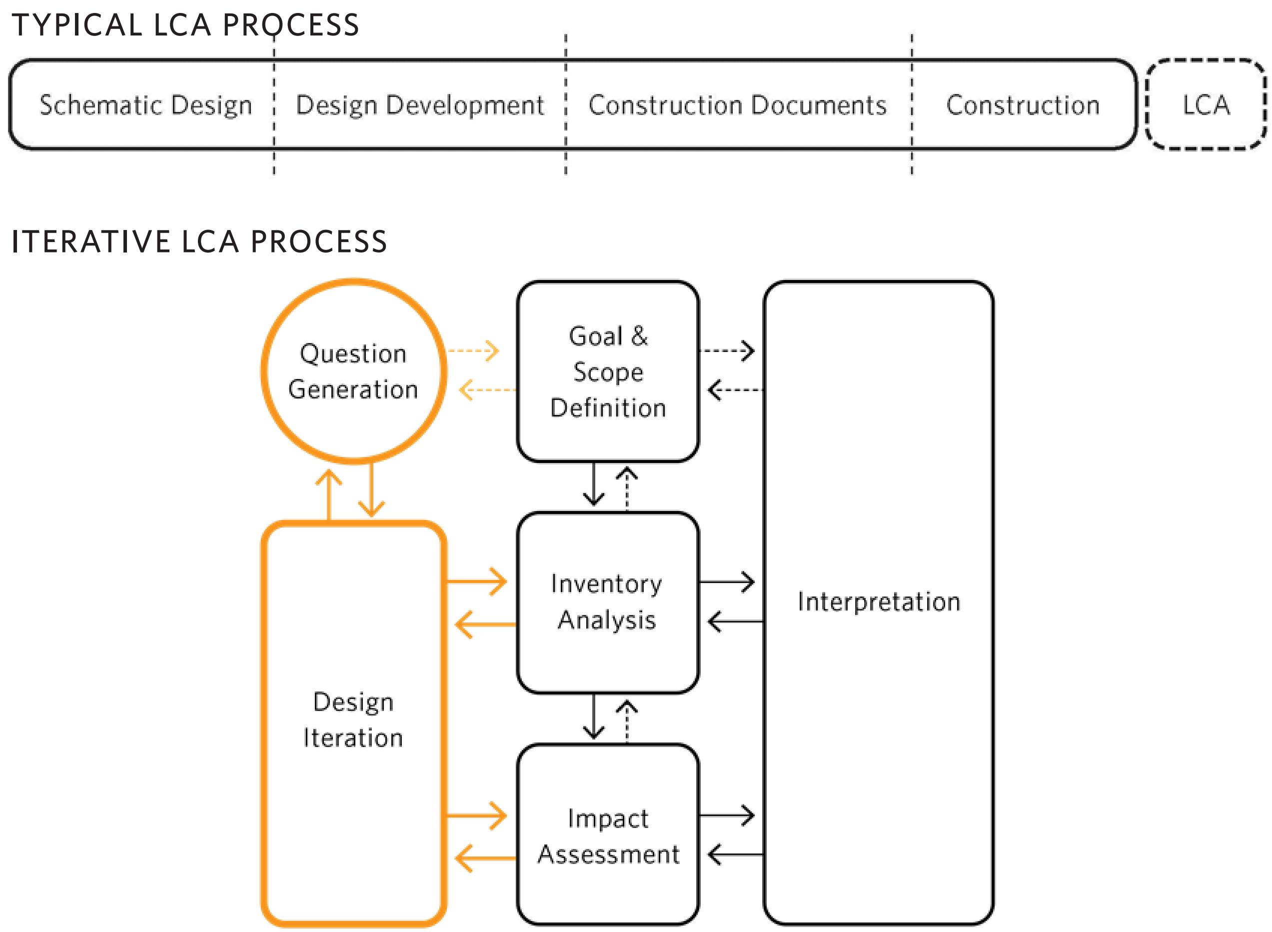
BIM Responsibilities of Each Team Member

Architects developed the application using the Revit API in order to link BIM elements with a custom-designed LCA database. They wrote the software code, designed the graphic user interface, and contributed content to the database.

A **leading LCA software and data company** provided all LCA information to the database, as well as information describing the types of environmental data, and the methodology employed to generate the LCA data.

A **software company** provided direct training in Revit API programming, continual programming assistance, as well as Revit compatibility testing.

Beta testers from leading industry firms and academic research organizations provided valuable feedback on the tool's functionality and ease of use compared to alternative assessment methods.



TYPICAL VERSUS ITERATIVE LCA PROCESS
Feedback on environmental impact is highly useful early in the design process, but conventional methodology and work flows for LCA are so laborious that they are typically performed after construction. Tally enables an iterative LCA process capable of increasing feedback across project stages.

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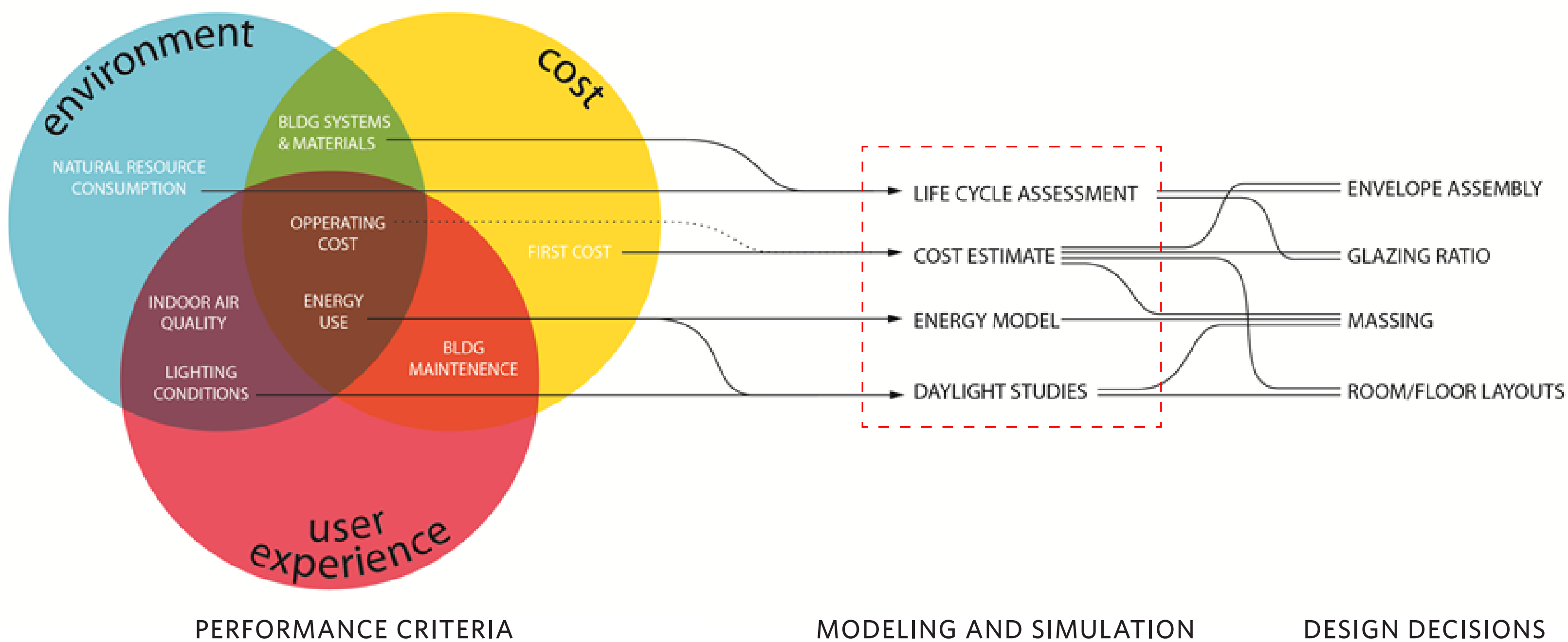
The Relevance of LCA During Design

Life Cycle Assessment is part of a larger framework for reducing the environmental impact of buildings, which includes current standards such as Passive House, Living Building Challenge, and the 2030 Challenge aimed at reducing energy consumption in buildings.

Interest in the full life cycle of buildings is mounting as new standards, such as the United States Green Building Council's LEED v4, reward project teams that utilize whole building LCA. Tally positions architects to meet this demand.

In addition, understanding the environmental impacts of materials alongside factors of cost, energy, and performance allows architects to create beautiful, efficient, lasting buildings.



User Interface and Workflow

The project browser within Tally displays a list of the elements in Revit model that fall within the scope of the assessment selected by the user, along with their constituent Revit materials (Figure 1).

Reference and takeoff information is defined for each entry so that material quantities can be calculated, and subsequent changes to the Revit model will be accounted for (Figures 2 and 3).

After completing all of the material assignments, a report summarizes the environmental impacts of the project according to five TRACI impact categories and three Cumulative Energy Demand categories.

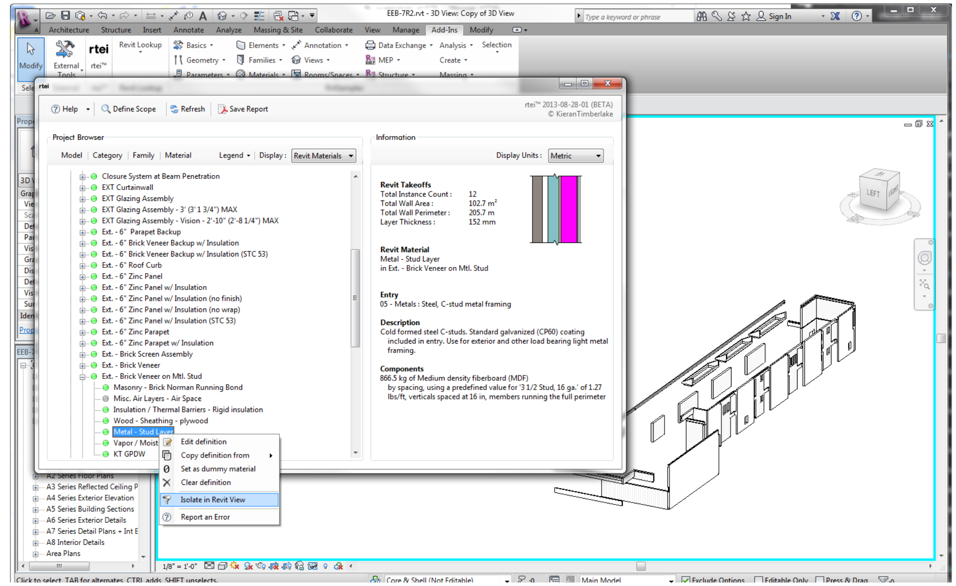


FIGURE 1 - PROJECT BROWSER

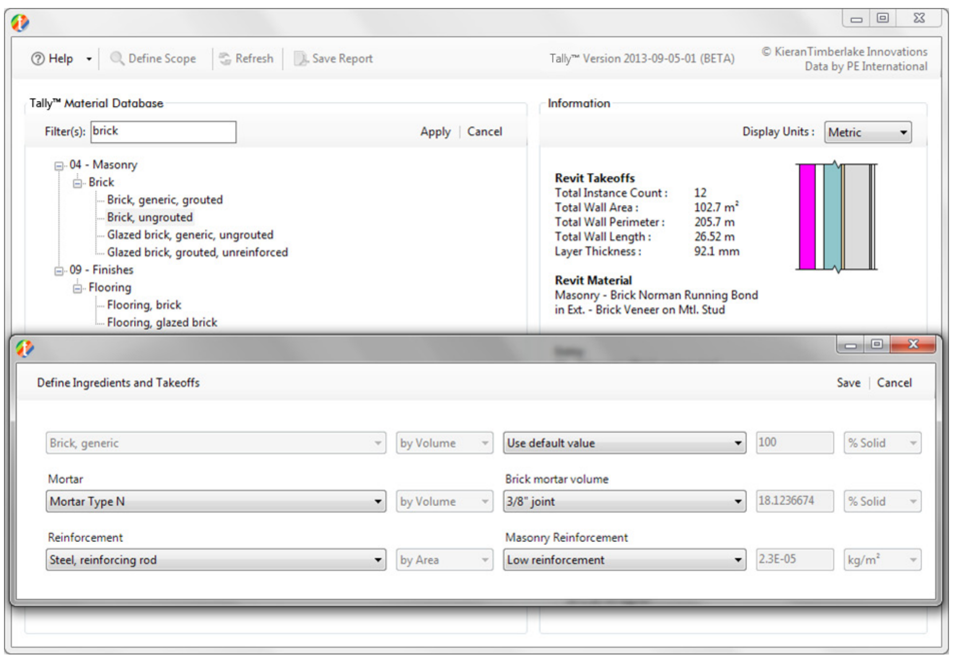


FIGURE 2 - DEFINING INGREDIENTS AND TAKEOFFS

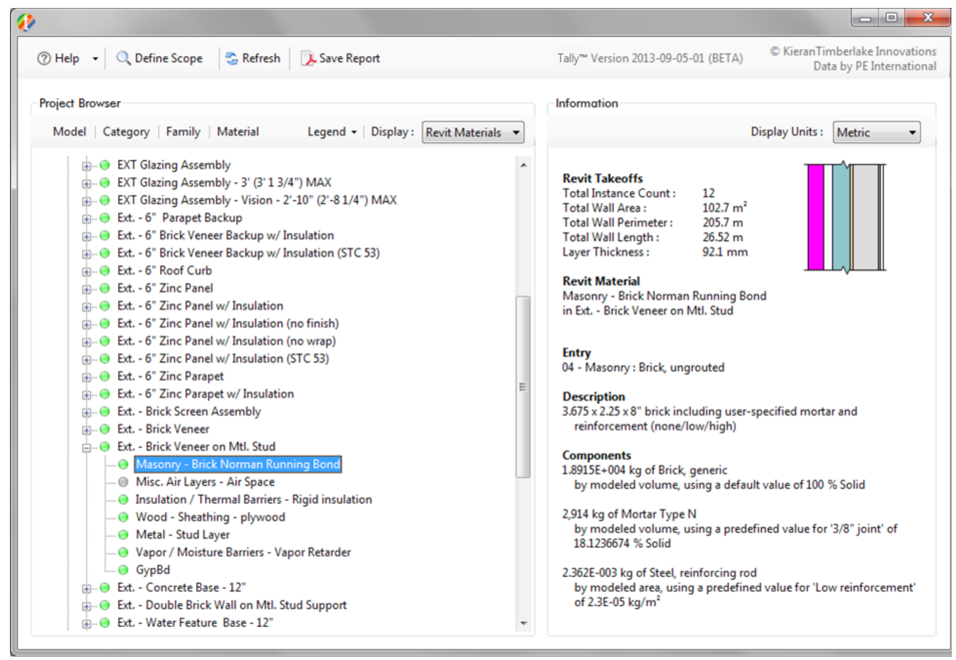


FIGURE 3 - MATERIAL ASSIGNMENTS

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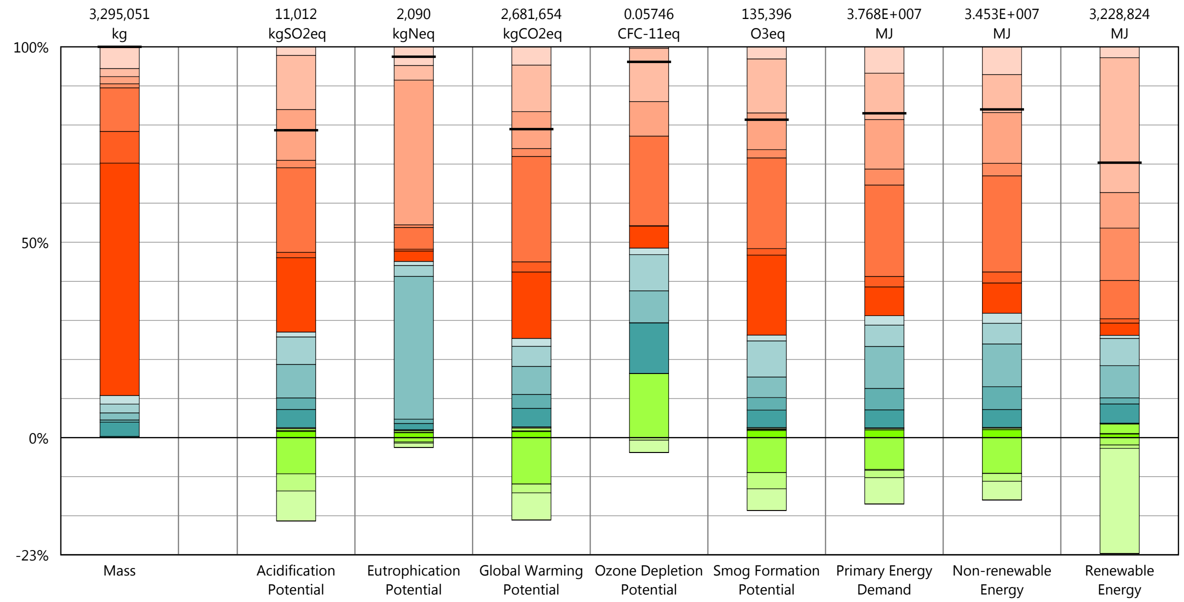
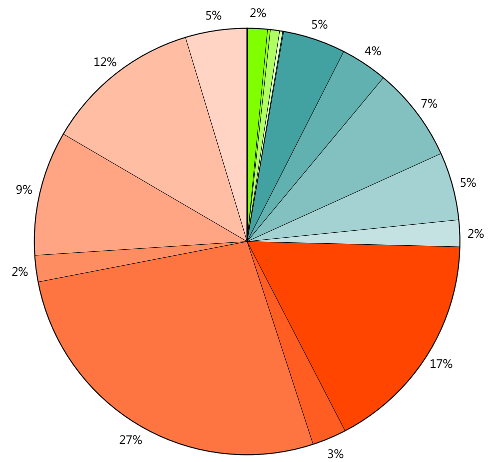
SAMPLE PROJECT
Data shown is derived from the Revit model for The Building Energy Education and Innovation Center (Building 7R).

Types of Assessment

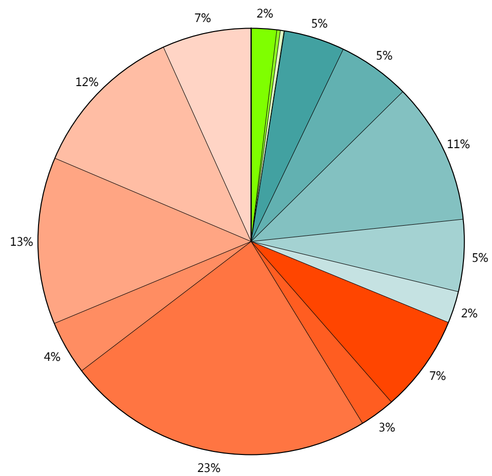
Tally provides two types of assessment: full building assessment and design option comparisons. In a full building assessment, one can study how various parts of the building contribute to environmental impacts. These contributions can be broken down according to Revit category, family type, CSI Division, and material, providing various means for studying and refining material selections. In a design option comparison, the environmental impacts of two or more options can be evaluated side by side. Both types of assessment permit a material selection process in which environmental impact is considered alongside performance, maintenance, cost, and aesthetics.

Results Per Life Cycle Stage, Itemized By CSI Division

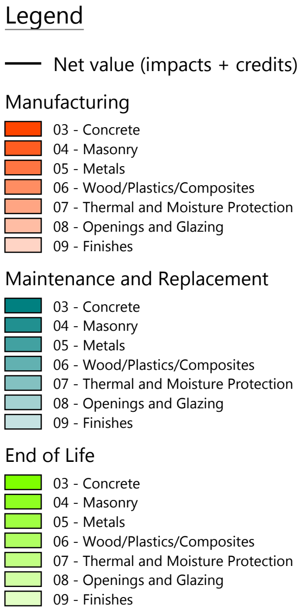




Global Warming Potential



Primary Energy Demand



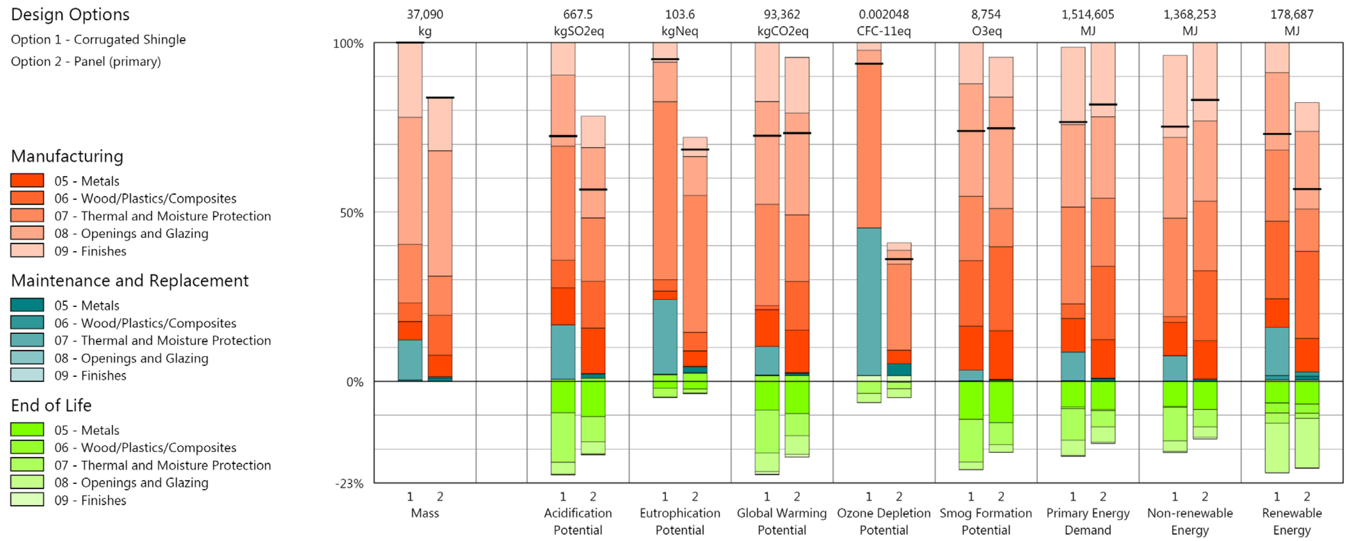
SAMPLE PROJECT

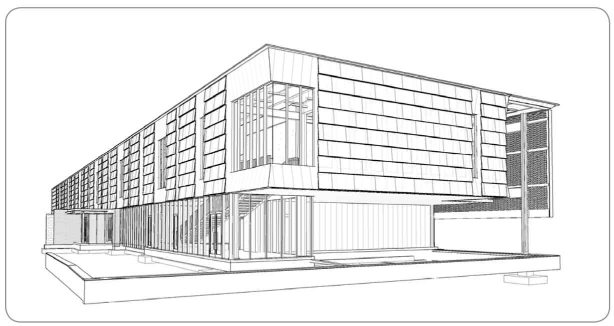
Data shown is derived from the Revit model for The Building Energy Education and Innovation Center (Building 7R).

Design Option Comparison

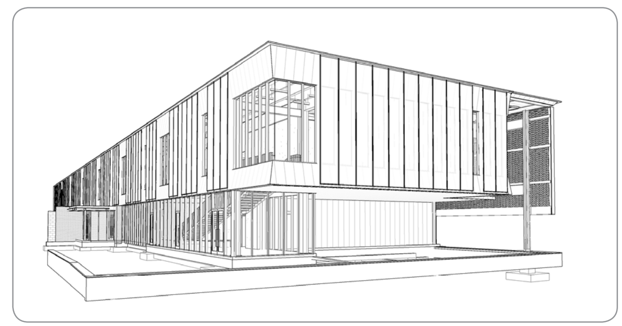
The environmental impacts of two or more options can be evaluated side by side. In this example, the options are fairly equal with a significant difference in ozone depletion potential. It is up to the design team to reconcile this information according to project goals.

Design Option Comparison





Option 1 - Corrugated Shingle Cladding



Option 2 - Translucent Panel Cladding (Selected)

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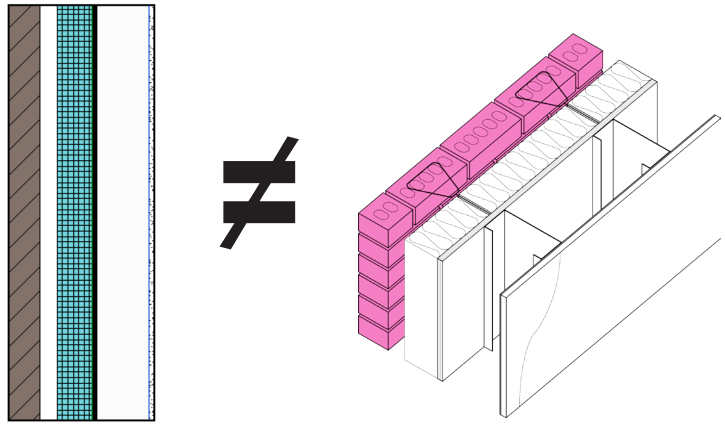
New Concepts Employed

Tally software is created by architects. As it is unusual for an architectural firm to dedicate the resources and seek out partners to develop a software tool, it by nature represents innovative process.

The tool itself is innovative because it leverages BIM's ability to perform material takeoffs, but closes the gap between modeling practices and built reality. In construction documents, it is neither necessary nor practical to design at the same level of detail required for LCA calculations. Tally facilitates the process of assigning discreet building materials and quantities such as those modeled without accurate volume and accessory materials (screws, sealants, finishes, etc.) that are not modeled at all, to provide a complete bill of goods. Material quantities are automatically updated as the design changes.

No other environmental assessment tools are capable of achieving this kind of inventory at the same resolution.



BRICK, GENERIC
Used in the following Revit families:
Ext. - Brick Screen Assembly
Ext. - Brick Veneer
Ext. - Brick Veneer on Mtl. Stud
Ext. - Double Brick Wall on Mtl. Stud Support
Int. - Brick Veneer

Used in the following Tally™ entries:
Brick, generic, grouted
Brick, ungrouted

Description:
Generic brick, 3.675 x 2.25 x 8

Life Cycle Inventory:
2000 kg/m^3 fired brick

Manufacturing Scope:
Cradle to gate
Entry excludes mortar, anchors, ties, and metal accessories outside of scope (<1% mass)

End of Life Scope:
50% recycled into coarse aggregate (includes grinding energy and avoided burden credit)
50% landfilled (inert material)

Entry Source:
DE: Stoneware tiles, unglazed PE (2011)

STEEL, REINFORCING ROD
Used in the following Revit families:
Auditorium Concrete Tiered Slabs
Brick Wall Cap
CMU - 8"
Concrete Slab on Grade 12"
Concrete Slab on Grade 6"
Concrete Slab on Mtl Deck 6"
Int. CMU - 8"
Water Feater Conc Base2

Used in the following Tally™ entries:
Brick, ungrouted
Cast-in-place concrete, reinforced structural concrete, 3000 psi (20 Mpa)
Hollow-core CMU, grouted
Reinforced slab, exclusive of deck

Description:
Steel rod suitable for structural reinforcement (rebar), common unfinished tempered steel

Life Cycle Inventory:
Steel rebar

Manufacturing Scope:
Cradle to gate

End of Life Scope:
70% recovered (product has 69.8% scrap input while remainder is processed and credited as avoided burden) 30% landfilled (inert material)

Entry Source:
GLO: Steel rebar worldsteel (2007)

MORTAR TYPE N
Used in the following Revit families:
Ext. - Brick Screen Assembly
Int. CMU - 8"
Int. CMU - 8" with GPDW

Used in the following Tally™ entries:
Brick, ungrouted
Hollow-core CMU, grouted

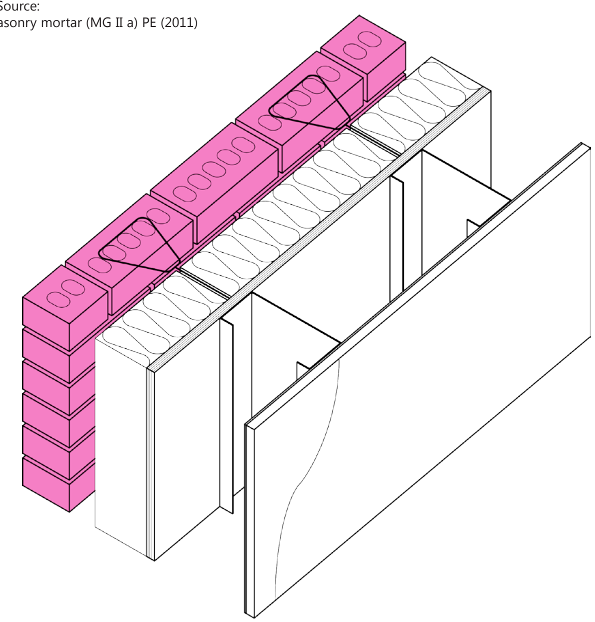
Description:
Mortar Type N (moderate strength mortar for use in masonry walls and flooring)

Life Cycle Inventory:
77% aggregate
12% cement
11% water

Manufacturing Scope:
Cradle to gate

End of Life Scope:
50% recycled into coarse aggregate (includes grinding energy and avoided burden credit)
50% landfilled (inert material)

Entry Source:
DE: Masonry mortar (MG II a) PE (2011)



Maintaining the Concept

Application development was guided and maintained by a set of non-negotiable goals, all of which were met.

The end product had to be:

1. Integrated in Revit, the primary tool used by designers.
2. Intelligible and easy to learn and use.
3. Capable of providing data at the same pace as design.
4. Relevant, addressing questions of interest to design teams.
5. Transferable, operating at the same scale of resolution.

Most Important Advantages Gained Through BIM

The most important advantage gained through BIM is the closure of time between design and analysis. BIM is the central enabler for conducting whole building or component based LCA during the design based on modeled BIM elements. There is no comparable tool for the rapid feedback offered by BIM.

Calculation Methodology

Studied objects

The LCA results in the report represent an analysis of a single building. The object of study may represent the complete architectural, structural, and finish systems of a building or a subset of those systems, and it may be used to compare the relative contributions of building systems to environmental impacts and for comparative study with one or more reference buildings.

Functional unit and reference flow

The functional unit of the study is the usable floor space of the building under study. The reference flow is the amount of material required to produce a building designed according to the given goal and scope of the assessment, over the full life of the building. It is the responsibility of the modeler to assure that reference buildings are functionally equivalent in terms of scope, size, and relevant performance. The expected life of the building is also indicated by the model author. The default life span of a building is 60 years.

System boundaries and delimitations

The analysis accounts for the full cradle-to-grave life cycle of the design options studied, including material manufacturing, maintenance and replacement, and eventual end-of-life (disposal, incineration, and/or recycling), including the materials and energy used across all life cycle stages.

Architectural materials and assemblies include primary materials and all additional materials required for the product's manufacturing and use (including hardware, sealants, adhesives, coatings and finishing, etc.) up to a 1% cut-off factor by mass with the exception of known chemicals that have high environmental impacts at low levels. In these cases, a 1% cut-off was implemented by impact.

Manufacturing includes cradle-to-gate manufacturing wherever possible. This includes raw material extraction and processing, intermediate transportation, and final manufacturing and assembly. Due to data limitations, however, some manufacturing steps have been excluded such as the material and energy requirements for assembling doors and windows. The manufacturing scope is listed for each entry, detailing any specific inclusions or exclusions that fall outside of the cradle-to-gate scope.

Transportation of upstream raw materials or intermediate products to final manufacturing is generally included in the GaBi datasets utilized within this tool. Transportation requirements between the manufacturer and installation or use of the product, and at the end-of-life of the product, are excluded from this study.

Infrastructure (buildings and machinery) required for the manufacturing and assembly of building materials, as well as packaging materials, are not included and considered outside the scope of assessment.

Maintenance and replacement encompasses the replacement of materials in accordance with the expected service life. This includes the end-of-life treatment of the existing products and cradle-to-gate manufacturing of the replacement products. The service life is specified separately for each product.

End-of-life treatment is based on average United States construction and demolition waste treatment methods and rates. This includes the relevant material collection rates for recycling, processing requirements for recycled materials, incineration rates, and landfilling rates. Along with processing requirements, the recycling of materials is modeled using an avoided burden approach, where the burden of primary material production is allocated to the subsequent life cycle based on the quantity of recovered secondary material. Incineration of materials includes credit for average US energy recovery rates. The impacts associated with landfilling are based on average material properties, such as plastic waste, biodegradable waste, or inert material. Specific end-of-life scenarios are detailed for each entry.

Data source and quality

Tally™ utilizes a custom designed LCA database that combines material attributes, assembly details, engineering and architectural specifications with environmental impact data that are the result of collaboration between
LCA modeling was conducted in GaBi 6 using GaBi databases and in accordance with GaBi database and modeling principles.

Geography and date: The data used are intended to represent the United States region and the year 2012. Where representative data were unavailable, proxy data were used. The datasets used, their geographic region, and year of reference are listed for each entry. An effort was made to choose proxy datasets that are technologically consistent with the relevant entry.

Uncertainty: Uncertainty in results can stem from both the data used and the application of the data. Data quality is judged by its precision (measured, calculated or estimated), completeness (e.g., unreported emissions), consistency (degree of uniformity of the methodology applied on a study serving as a data source) and representativeness (geographical, temporal, and technological). The LCI data sets from the GaBi LCI databases are widely distributed and used with the GaBi 6 Software. The datasets have been used in LCA models worldwide in industrial and scientific applications, both as internal and critically reviewed and published studies. In the process of providing these datasets, they are cross-checked with other databases and values from industry and science. The application of datasets to model each entry is based on technological, geographical, and temporal representativeness. The uncertainty introduced by the use of proxy data is reduced by using technologically, geographically, and/or temporally similar data. It is the responsibility of the modeler to apply the predefined material entries appropriately to the building under study. An effort should be made to utilize entries that are technologically similar to the material being modeled.

Tally™ methodology is consistent with LCA standards ISO 14040-14044.

SAMPLE DEFINITIONS FROM APPENDIX

BIM Standards Employed

Successful use of Tally requires that all team members use Revit in accordance with BIM Standards. Everyone must speak the same language, assigning materials appropriately and consistently. Teams must execute a BIM plan; encouraging best practices from the project start.

Team Member Roles

A **Software Developer** was responsible for coding the application. **Researchers** were responsible for ensuring the compatibility of LCA data with architectural conventions, refining the logic of the tool function in accordance with architects' workflow, and for defining the useful life span and typical quantities of materials. They were further charged with creating glossary of terms and defining typical assemblies (i.e. the appropriate spacing and unmodeled materials in a wall assembly, such as paint). **Architects** experienced in specification provided a detailed review to ensure adherence to construction standards. A **Commercialization Manager** was responsible for broad oversight of tool development to meet the goals, organizing the team, negotiating the partnerships, conducting the beta test, and marketing the tool. **LCA data providers** were responsible for making data measurements equivalent, and for bringing atypical materials into a database geared for architectural use.

Benefits Achieved

Tally, integral with BIM, puts LCA information in the hands of designers. **Sample insights include**:

1. In retroactively reviewing the design of a single-family home, we found the insulation alone accounted for half of the building's embodied carbon. This insulation was specified in a far larger thickness than code mandated and was equivalent to seven years of operational energy. Given that the house was primarily a vacation home raised the question: If this information had been available at the time of design, would the same decision have been made? This reinforced the need for way to account holistically for operations energy, embodied energy, and a true understanding of program.

2. In looking at two design options for the exterior cladding, one employing zinc and another employing glass and brick, it was found that the zinc, despite constituting a fairly minor component by both mass and volume, accounted for a nearly 50% increase in environmental impact across a number of categorization schema relative to the glass and brick option. Without the use of Tally, the significant impact contribution of what was a minor material by composition, would not have been evident.

3. A project making use of a multi-layer PET cladding system that raised concern due to the high embodied energy and carbon of plastic relative to glass. While this conclusion was true on a kg to kg basis, the reality was that the amount of PET required for cladding the house, despite covering a significant amount of area with a four layer system, was found to be large in area but quite small in mass. When compared to the amount of glass required to enclose the same area, the PET represented a weight savings on the level of 2 orders of magnitude. The end result was the PET, despite a significant environmental impact by weight, was deployed in such modest amount to the glazing equivalent, and represented a vastly improved environmental option.

Non-technology Factors for Success

The momentum around the issue of LCA, and the recognition that environmental impacts are not purely from building operations, has helped propel the development of Tally, in concert with the widespread adoption of Revit as the primary tool for building design.

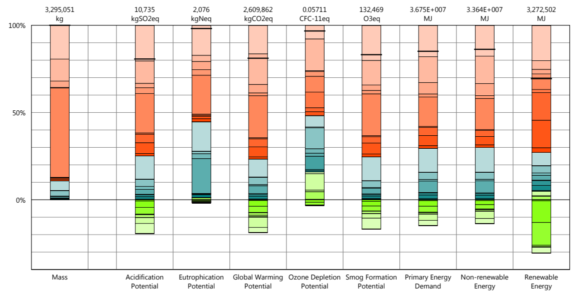
The participation of a select group of highly qualified beta testers, coupled with a rigorous beta testing period, ensured high quality feedback that was incorporated into the tool. This feedback ensured modeling practice compatibility and adequate materials in the database to make the tool useful to a broad range of practitioners.

TALLY™

EEB-HUB 7R
10/28/2013

Full building summary

Results per Life Cycle Stage, itemized by Revit Category



Legend

— Net value (impacts + credits)

Manufacturing

- Ceilings
- Curtain Panels
- Curtain Wall Mullions
- Doors
- Floors
- Roofs
- Stairs and Railings
- Structure
- Walls
- Windows

Maintenance and Replacement

- Ceilings
- Curtain Panels
- Curtain Wall Mullions
- Doors
- Floors
- Roofs
- Stairs and Railings
- Structure
- Walls
- Windows

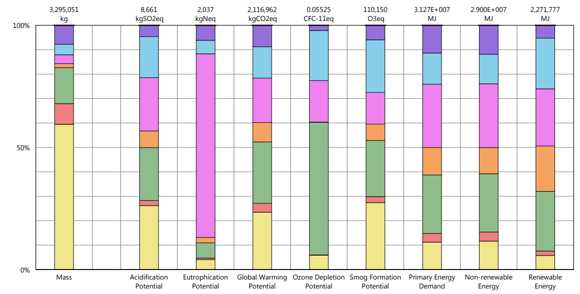
End of Life

- Ceilings
- Curtain Panels
- Curtain Wall Mullions
- Doors
- Floors
- Roofs
- Stairs and Railings
- Structure
- Walls
- Windows

EEB-HUB 7R
10/28/2013

Full building summary

Results per CSI Division



Legend

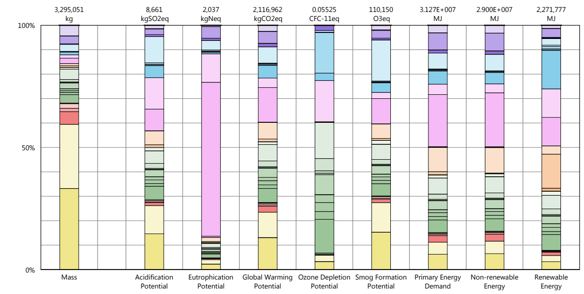
CSI Divisions

- 03 - Concrete
- 04 - Masonry
- 05 - Metals
- 06 - Wood/Plastics/Composites
- 07 - Thermal and Moisture Protection
- 08 - Openings and Glazing
- 09 - Finishes

EEB-HUB 7R
10/28/2013

Full building summary

Results per CSI Division, itemized by Tally™ Entry



Legend

03 - Concrete

- Cast-in-place concrete, reinforced structural concrete, 3000 psi (20 Mpa)
- Concrete, unreinforced, generic, 3000 psi (20MPa)
- Reinforced slab, exclusive of deck

04 - Masonry

- Brick, generic, grouted
- Brick, ungrouted
- Hollow-Core CMU, grouted

05 - Metals

- Stair, steel with concrete fill
- Steel, Angle
- Steel, Bar
- Steel, Channel
- Steel, composite form deck
- Steel, C-stud metal framing
- Steel, Furring Channel
- Steel, Hollow Structural Section
- Steel, MC Section
- Steel, Plate
- Steel, roof decking
- Steel, Round Tubing
- Steel, Wide flange shape
- Steel, WT Section
- Zinc sheet

06 - Wood/Plastics/Composites

- Domestic hardwood
- Paneling, interior
- Plywood, exterior grade
- Polycarbonate, cellular, sheet

07 - Thermal and Moisture Protection

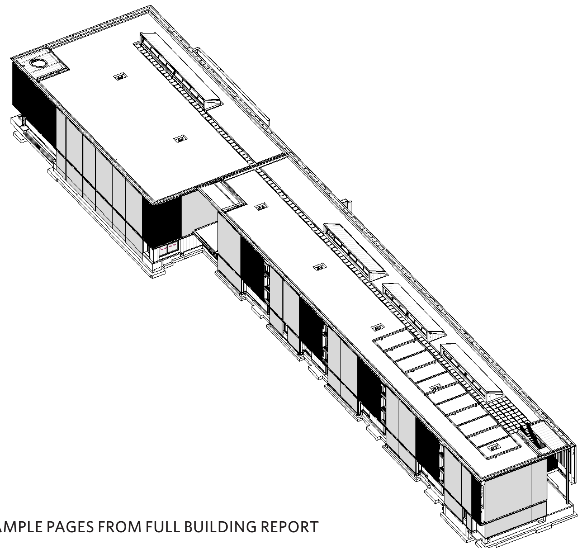
- EPDM, roofing membrane
- Polyethelene sheet vapor barrier (HDPE)
- Polyisocyanurate (PIR), board
- Stainless steel flashing and trim

08 - Openings and Glazing

- Aluminum mullion
- Door frame, aluminum, powder-coated
- Door, exterior, aluminum
- Door, interior, wood, mineral core, flush
- Door, toilet partitions, steel
- Glazing, double pane IGU
- Window frame, wood

09 - Finishes

- Carpet, nylon
- Ceramic tile, unglazed
- Engineered stone tile
- Stone tile
- Wall board, gypsum



SAMPLE PAGES FROM FULL BUILDING REPORT