Performing a Life Cycle Assessment Within a Revit Model

Autodesk University 2014 (AB6328-L)

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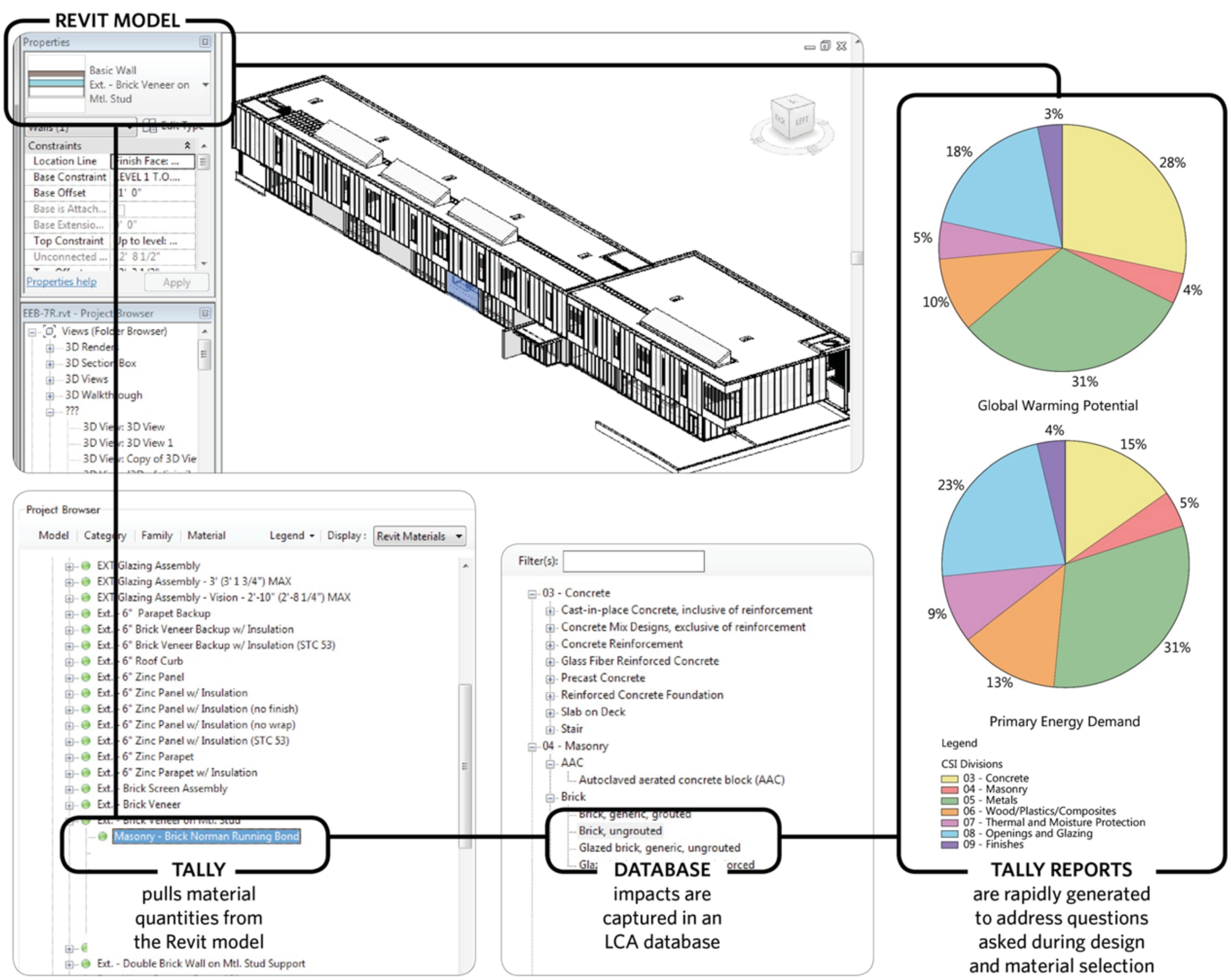


Hands-on Lab Schedule

Thursday, Dec 4

10:00 - 10:10	Introduction and General Overview Review of schedule and handout material
10:10 - 10:25	LCA #1 - Single Component Study Design option comparison of a simple wall assembly Discussion of functional unit Introduction to Tally interface and database content
10:20 - 10:30	LCA #1 - Interpretation Discussion of Tally report content Rerun report with alternate materials, service lives, building life (time permitting)
10:30 - 10:50	LCA #2 - Full Building Assessment Introduction to category, workset, and phase filters Discussion of cached definitions Tips for speeding up input Discussion of operational energy inputs
10:50 - 11:00	LCA #2 - Interpretation Discussion of contribution assessments
11:00 - 11:10	LCA #2a - Multiple Component Study Substitution of multiple assemblies from full building assessment
11:10 - 11:20	LCA #2a - Interpretation Examination of results in relation to full building assessment Discussion of LEED v4 credit for “Building life-cycle impact reduction”
11:20 - 11:30	Wrap-up and Q&A

Introduction

Course Description
Life Cycle Assessments (LCA) are gaining relevance as a way to minimize a building's environmental impact. This seminar will demonstrate how to conduct an LCA on architectural projects at any stage of the design process using Tally®, a Revit add-in developed by KT Innovations, an affiliate of KieranTimberlake, and PE International, with support from Autodesk.

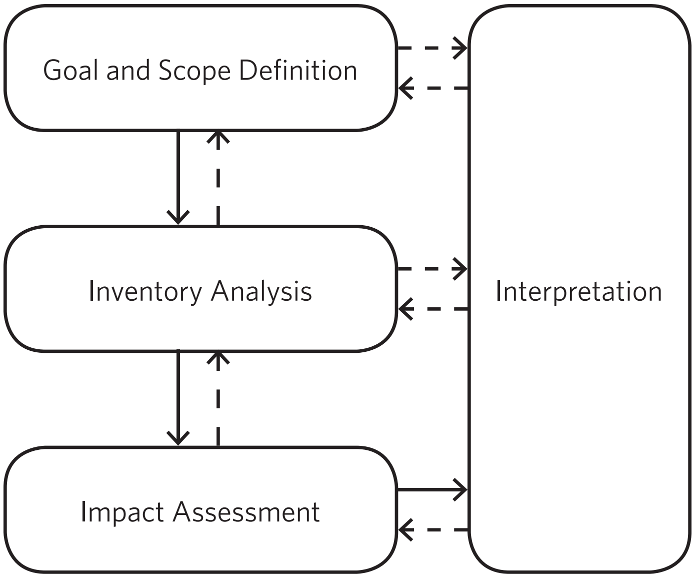
The session will acquaint the audience with LCA through a comprehensive review of key concepts and their relation to building materials. Instructors will give hands-on demonstrations of Tally with a sample Revit model. Assessments will address all project phases and range in scale from discrete component studies, to design option comparisons of multiple assemblies, to whole-building assessments appropriate for the new LEED v4 LCA credit. We will tie these assessments back to core LCA concepts, highlighting the magnitude of the impacts found through assessments as compared to the modeled operational impacts of the demonstration projects.

Course Packet
This document serves as a primer on key concepts common to both LCA and Tally. While we will refer to portions of this primer during the hands-on lab, in order to make the most of everyone's time, we will assume that you have read the following material in advance.

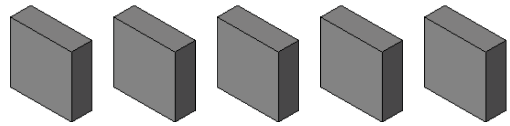
Should you have any specific items you want us to cover in the lab, or if you have any follow-up questions, please send a query to support@choosetally.com.

LCA Process

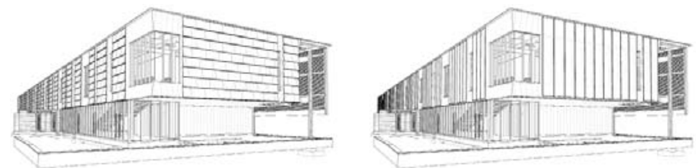
Goal and Scope Definition



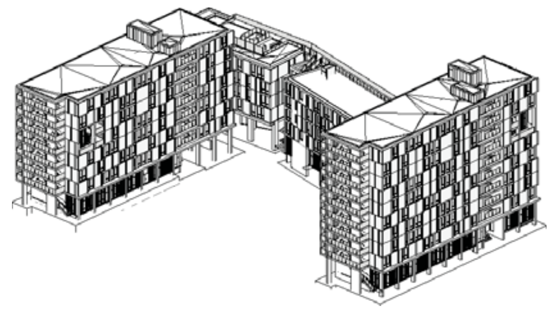
LCA Phases (ISO 14040 : 2006)



Functional unit containing a single building component



Functional unit containing multiple assemblies



Functional unit containing a building's core and shell

While most members of the AEC community are familiar with LCA terminology such as *Cradle-to-Grave* and *Global Warming Potential*, the methodologies and data behind LCA remain obscure to mainstream practice. The International Organization for Standardization (ISO) defines LCA as the "compilation and evaluation of the inputs, outputs, and the potential environmental impacts of a product system through its life cycle" (ISO 14040 : 2006). It lays out a 4-phase process for conducting an LCA.

Goal and Scope Definition

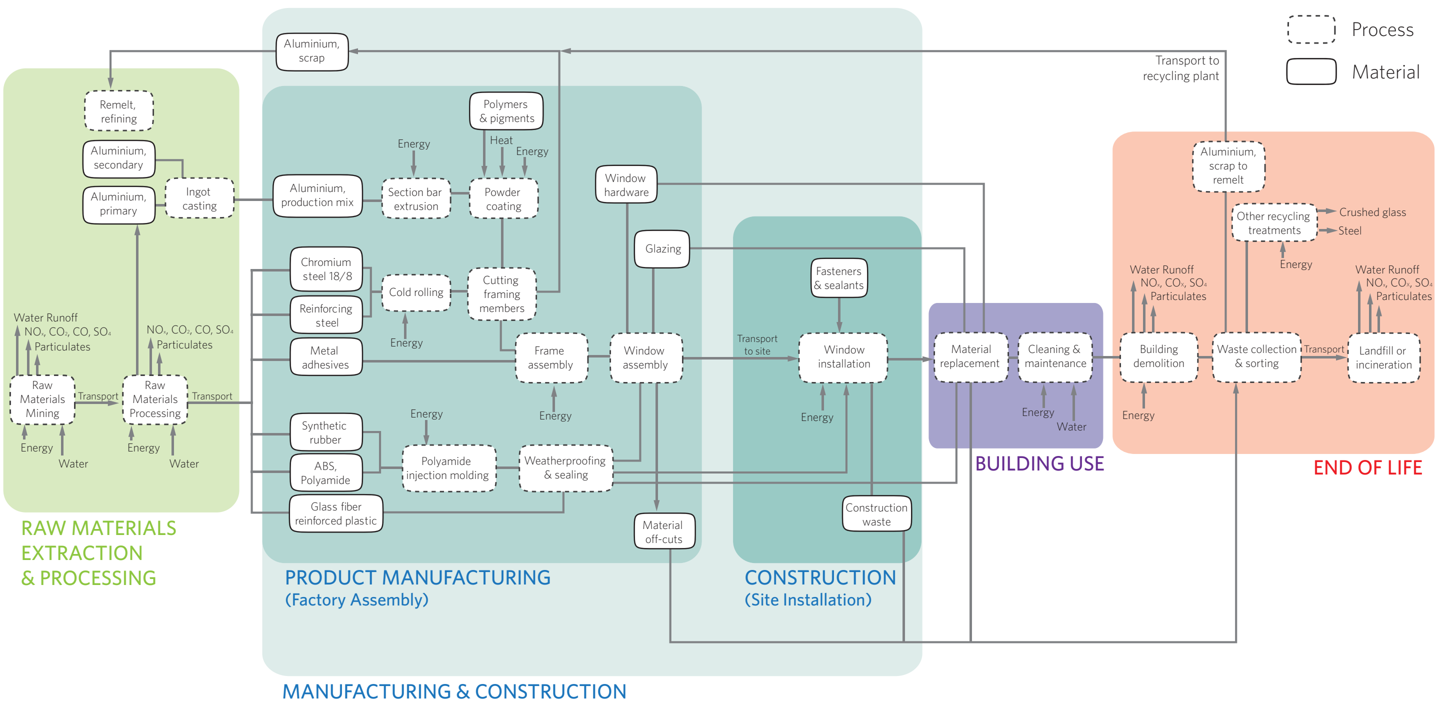
Before conducting an LCA, one needs to define the scope of study, which considers the function and performance of the product in question along with the processes that are to be included in service of that goal. If we consider a whole building as our functional unit, then we also need to specify what building systems and life cycle stages are to be included or excluded from the assessment and what data source(s) we will use. If our assessment seeks to compare wall insulation products, then our functional unit would indicate a reference area and performance criteria (e.g. provide R-20 insulation for 60 years). In both cases we must ensure that we choose a consistent scope for any systems we wish to compare in order to achieve meaningful results.

Inventory Analysis

In order to quantify environmental impacts for a chosen system, we next need to quantify all of the inputs and outputs to the system across all life cycle stages pertinent to our study, in a process known as a Life Cycle Inventory (LCI). Among these figures are the energy and materials required for material extraction, manufacturing, use, and end-of-life, along with the processes and emissions to air and water that occur as a result.

LCI data is collected in transparent, verified, international databases by LCA professionals, drawing from thorough research into material science, manufacturing and industry. The upstream and downstream inventories are collected for material datasets that can be used by applications such as Tally. In Tally, material selection, quantity takeoffs, and expectations regarding use and service life are handled by the project team.

LCA Process
Invetory Analysis



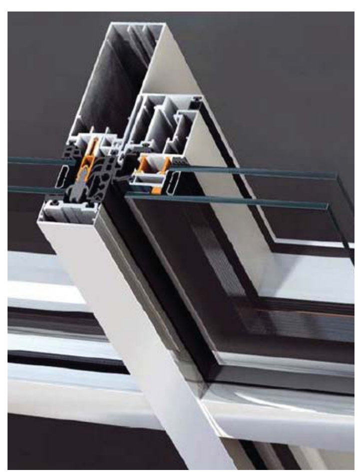
Life cycle inventory diagram of an aluminum window framing product

http://metiviergallery.com/artists/Edward-Burtynsky/mines

Resource Extraction

http://www.theguardian.com/business/2009/dec/07/rusal-flotation-aluminium-russia-deripaska

Material Processing



http://www.zprime.gr/en/products-prime-zahariou/aluminium-prime-zahariou/curtain-wall

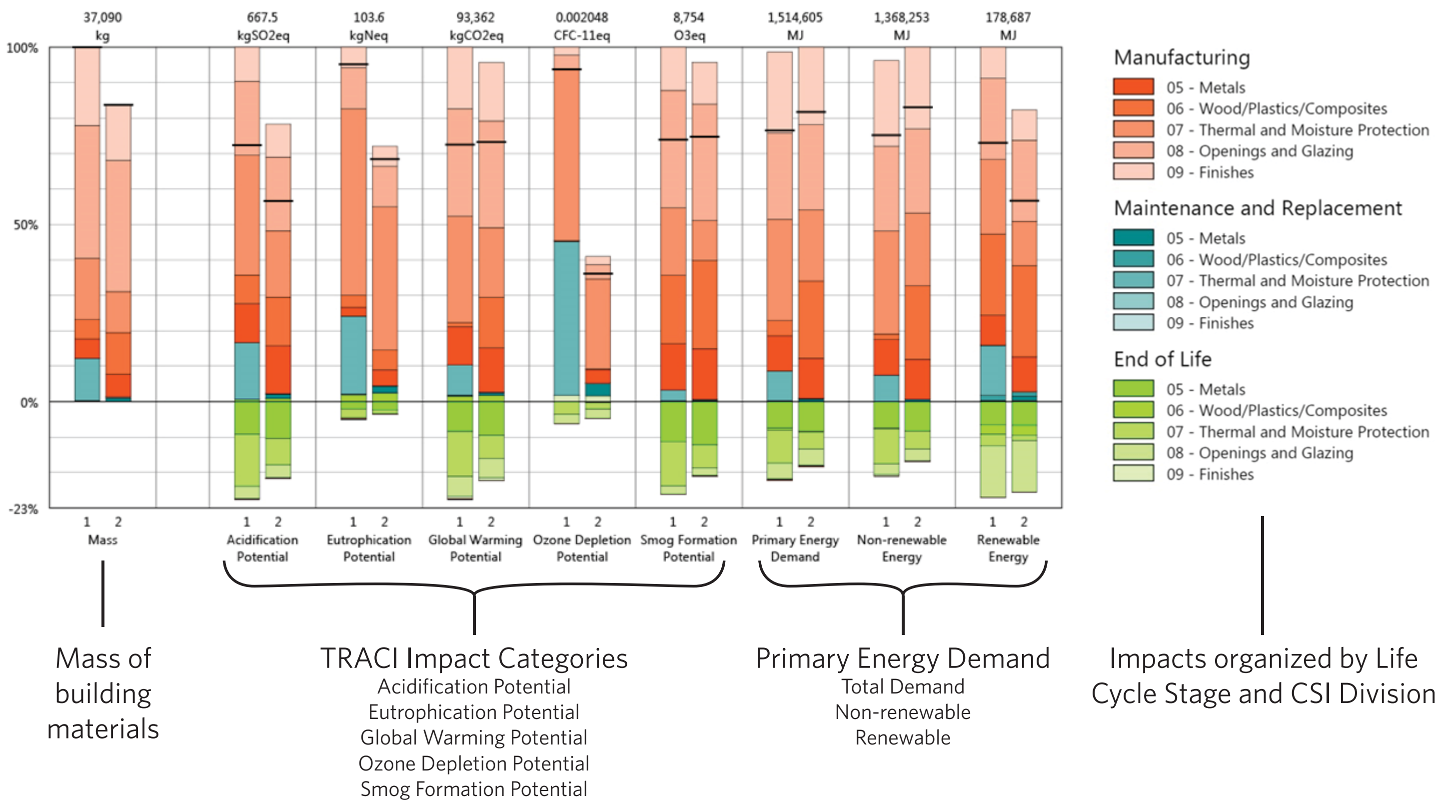
Manufacturing and Construction

http://www.scotsweb.com/images/membersphotos/ubxp9lpfz2uny7sseww.jpg

End of Life

LCA Process

Impact Assessment



Impact Assessment

In order to effectively communicate the (potential) environmental impacts of a product system, an LCA must first distill the raw data quantified by the LCI into more meaningful figures. Characterization schemes, such as TRACI, ReCiPe, and IMPACT do so by establishing conversion factors between quantities of consumed or emitted resources and environmental impact indicators. For instance, chemicals that contribute to global warming, such as methane and carbon dioxide, are each converted into a CO_2 equivalence and subsequently combined to express cumulative global warming potential (in terms of kg CO_2 eq). Certain chemicals may contribute to multiple environmental impact categories; nitrogen oxides, for instance, contribute to smog formation and global warming potentials.

Tally results are reported in terms of primary energy demand and five TRACI environmental impact indicators. These indicators are established by the US EPA and align with those chosen by USGBC for the LEED v4 Whole Building LCA credit.

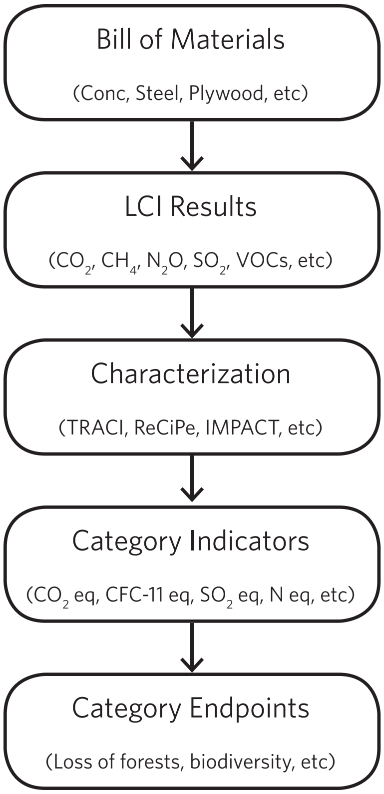
Environmental Impact Categories

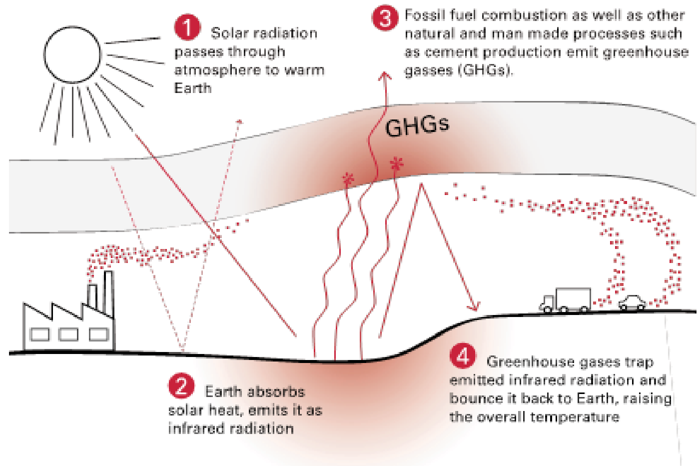
The following list provides a description of environmental impact categories reported according to the TRACI 2.1 characterization scheme (Bare 2010, EPA 2012, Guinée 2001).

Acidification Potential (kg SO_2 eq)
A measure of emissions that cause acidifying effects to the environment. The acidification potential is a measure of a molecule's capacity to increase the hydrogen ion (H+) concentration in the presence of water, thus decreasing the pH value. Potential effects include fish mortality, forest decline, and the deterioration of building materials.

Eutrophication Potential (kg N eq)
Eutrophication covers potential impacts of excessively high levels of macronutrients, the most important of which are nitrogen (N) and phosphorus (P). Nutrient enrichment may cause an undesirable shift in species composition and elevated biomass production in both aquatic and terrestrial ecosystems. In aquatic ecosystems, increased biomass production may lead

LCA Process
Impact Assessment





K. Simonen, Life Cycle Assessment, Routledge, 2014

Climate impacts from greenhouse gas emmisions

to depressed oxygen levels because of the additional consumption of oxygen in biomass decomposition.

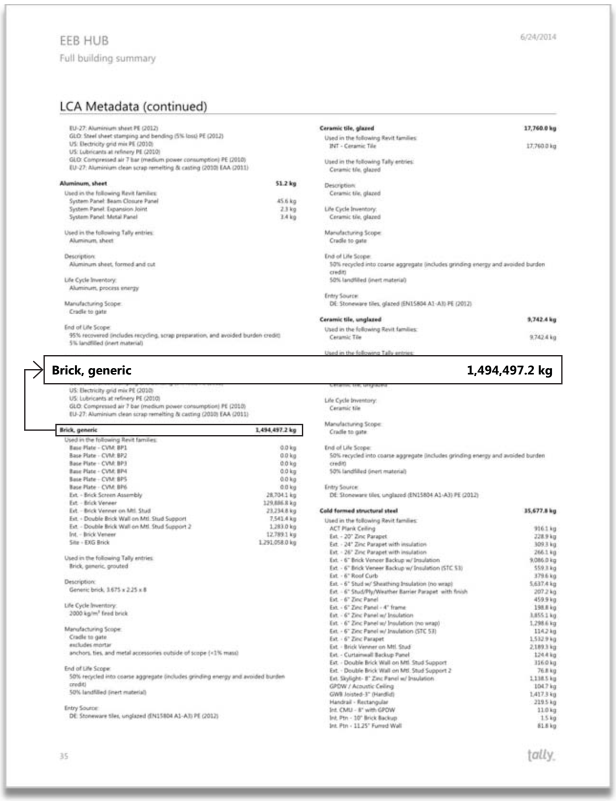
Global Warming Potential (kg CO_2 eq)
This is a measure of greenhouse gas emissions, such as CO_2 and methane. These emissions are causing an increase in the absorption of radiation emitted by the earth, increasing the natural greenhouse effect. This may in turn have adverse impacts on ecosystem health, human health, and material welfare.

Ozone Depletion Potential (kg CFC-11 eq)
This is a measure of air emissions that contribute to the depletion of the stratospheric ozone layer. Depletion of the ozone leads to higher levels of UVB ultraviolet rays reaching the earth's surface, with detrimental effects on humans and plants.

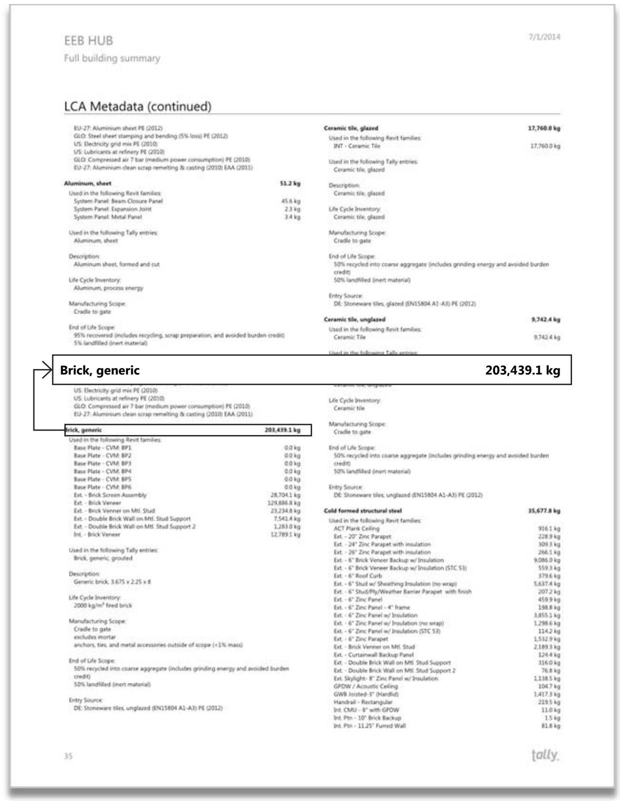
Smog Formation Potential (kg O_3 eq)
Ground level ozone is created by various chemical reactions, which occur between nitrogen oxides (NO_x) and volatile organic compounds (VOCs) in sunlight. Human health effects can result in a variety of respiratory issues, including symptoms of bronchitis, asthma, and emphysema. Permanent lung damage may result from prolonged exposure to ozone. Ecological impacts include damage to various ecosystems and crops. The primary sources of ozone precursors are motor vehicles, electric power utilities, and industrial facilities.

Primary Energy Demand (MJ)
This is a measure of the total amount of primary energy extracted from the earth. PED is expressed in energy demand from non-renewable resources (e.g. petroleum, natural gas, etc.) and energy demand from renewable resources (e.g. hydropower, wind energy, solar, etc.). Efficiencies in energy conversion (e.g. power, heat, steam, etc.) are taken into account.

LCA Process
Interpretation



Initial LCA report with site paving improperly included in scope



Revised LCA report with site paving removed from building scope

Interpretation
The interpretation phase of an LCA involves validation of the model assumptions, invesigation of the sensitivity of results to those assumptions, and—if necessary—revision of the scope of the assessment.

Since LCI data come prepackaged in Tally's database, the primary means by which Tally users can engage in model validation is through the report appendix. This contains an itemized list of each material used in the project along with the mass used in each family type. One should carefully examine this list to make sure that the material quantities seem appropriate to each family.

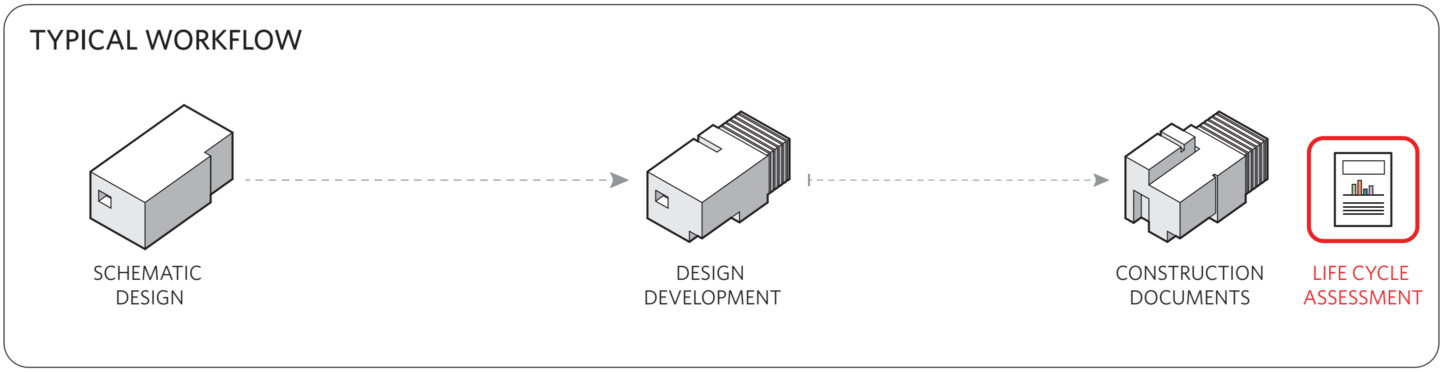
The two most common errors occur when elements that should be excluded from the scope have been placed on a workset that is inside the scope of study (or vice versa) and when a material is assigned improperly, resulting in an erroneous quantity takeoff. When such errors are discovered, one can use the Tally project browser to isolate the entry in question, examine the quantity takeoff methods, and make any necessary revisions.

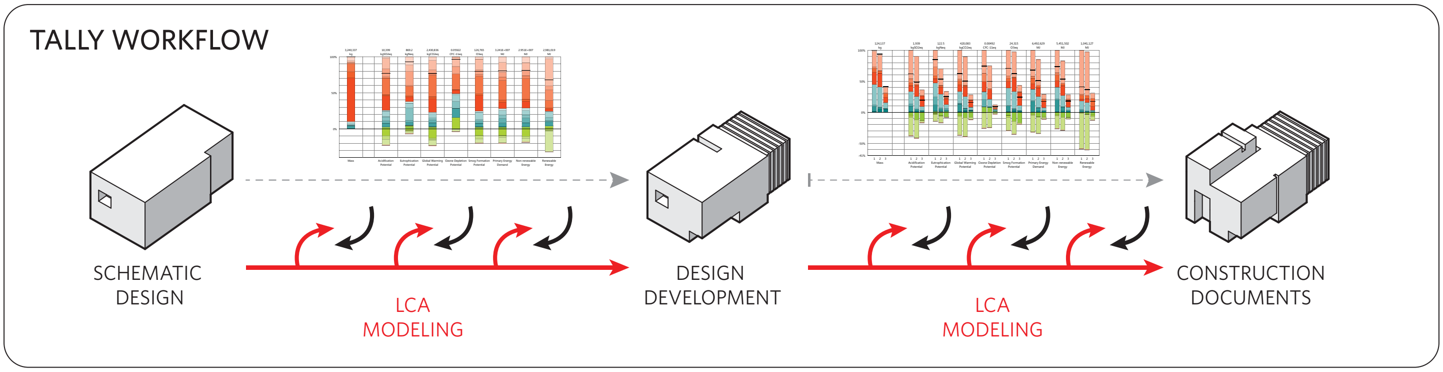
The LCA results contained in Tally reports should be examined carefully during this phase in order to understand the relationship between building materials and environmental impacts. The stacked-bar graphs, known as contribution assessments, provide a visual description of the part-to-whole relationship of environmental impacts for each component in the study.

For instance, if a breakdown by CSI division shows that concrete is the most significant contributor to a building's global warming potential, then we may want to consider conducting a subsequent sensitivity analysis to see how reducing the volume of concrete in our project or changing the mix design will affect our results.

In a study of exterior cladding systems, we may instead look to a breakdown by life cycle stage to understand tradeoffs between materials that are more impactful at day one and those that need more frequent replacement or refinishing. Such insights could inform further studies of alternate backup systems or different replacement rates.

LCA Process
Iteration





Iteration

Like energy modeling and cost modeling, LCA is not simply a benchmarking tool, but a resource to guide decision-making. It is true that we can benchmark a building upon project completion, but only through successive studies of a building and its constituent materials can we hope to achieve meaningful reductions in environmental impact.

In schematic design, before a complete building has been modeled, we can make meaningful and efficient comparisons with a well chosen object of study. A comparison of concrete and steel structural systems could be accomplished by modeling a single structural bay of each type. A comparison of exterior wall assemblies could consider a representative area as its functional unit. As these systems become more fully developed, such preliminary studies could be revisited at the same scale, or at the scale of the full building.

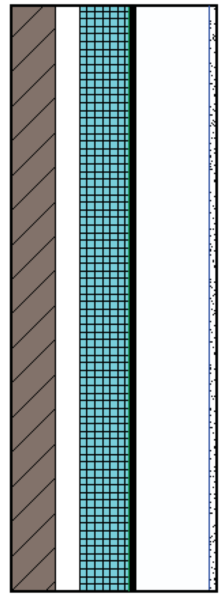
In design development, once we have a building substantially modeled in Revit, we could run a whole-building study to identify which assemblies and materials are the most significant contributors to environmental impact—and therefore offer the greatest opportunity for impact reduction through material substitutions and design modifications. We can also conduct comparative assessments of particular building features in isolation using Revit's design option feature.

In the construction documentation phase, when building systems have been further elaborated, we can capture our project-specific knowledge by updating prior Tally work. For instance, a rainscreen assembly that was defined in DD using default settings for structural material and weight could be revised to reflect manufacturer specifications for our basis-of-design product. Through product-specific Environmental Product Declarations (EPDs), we can apply this methodology to compare several manufacturers' products in terms of environmental impact as well as cost, performance, and aesthetics. Finally, with the growing number of LCAs produced by the AEC community, we may soon be able to benchmark our building against industry averages to see if our efforts have indeed paid off.

Tally Concepts

Bill of Materials

Material	Mass (kg)
03 - Concrete	**1,078,745**
Admixture	3,885
Cement	159,324
Coarse aggregate	98,479
Expanded shale	1,087
Expanded slag	110
Fly ash	732
Glass fibers	2,016
Perlite	2,053
Sand	39,099
Steel; reinforcing rod	16,095
Structural concrete; 3000 psi; generic	706,728
Structural concrete; 4000 psi; generic	19,812
Water	29,324
04 - Masonry	**277,094**
Brick; generic	181,976
Hollow-core CMU; 8x8x16 grouted	54,429
Lime mortar (Mortar type K)	24,829
Mortar type N	15,726
Steel; reinforcing rod	134
05 - Metals	**470,950**
Cold formed structural steel	86,444
Galvanized steel	23,838
Galvanized steel composite form deck	23,269
Hot rolled structural steel	183,775
Powder coating; metal stock	5
Steel; framing member	113,390
Steel; sheet	12,252
Structural concrete; 3000 psi; generic	1,652
Zinc sheet	26,324
06 - Wood/Plastics/Composites	**53,250**
Domestic hardwood; US SE	154
Exterior grade plywood; US	23,937
Paint; interior acrylic latex	481
Polycarbonate; cellular; sheet good	27,777
Veneer; birch	736
Wood stain; water based	164
07 - Thermal and Moisture Protection	**62,383**
EPDM; roofing membrane	427
Expanded polystyrene (EPS); board	15,184
Polyethelene sheet vapor barrier (HDPE)	837
Stainless steel sheet; Chromium 18/8	45,934
08 - Openings and Glazing	**53,432**
Aluminum window fitting; EPD - FSB	10
Aluminum; extruded	24,415
Door frame; aluminum; powder-coated; no door	294
Door hinge; EPD - FSB	97
Door; interior; wood; mineral core; flush	2,799
Door; toilet partitions; stainless steel	1,538
Glazing; double; insulated (air); low-E	21,331
Hollow door; exterior; aluminum; anodized; with large vision panel	1,187
Metalic fluoropolymer coating; metal stock	430
Stainless steel; door hardware; lever lock + push bar; exterior;	353
Stainless steel; door hardware; lever lock + push bar; interior;	887
Stainless steel; door hardware; lever lock; exterior; commercial	31
Window frame; wood; operable	60
09 - Finishes	**257,808**
Ceramic tile; unglazed	1,306
Commercial low-traffic carpet; high pile weight	4,433
Engineered stone tile; generic	98,014
Flooring adhesive; carpet	998
Paint; exterior acrylic latex	5
Paint; interior acrylic latex	6,906
Stone tile	1,432
Thinset mortar	312
Wall board; gypsum; natural	144,403
Grand Total	**2,253,661**

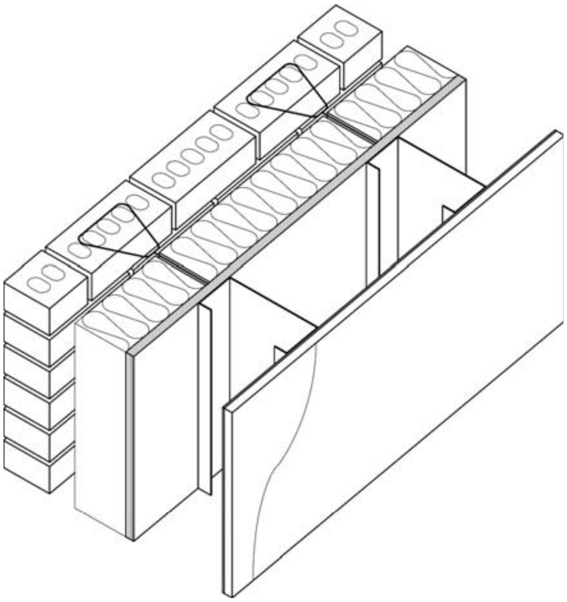


Brick	3-5/8″
Insulation	4″
Plywood Sheathing	3/4″
Vapor Barier	0″
Metal Stud Layer	6″
Plasterboard	5/8″

Representation of a wall assembly in BIM

Exterior grade plywood, US	**23,937.5 kg**
Used in the following Revit families:	
Ext. - 6" Parapet Backup	1,671.8 kg
Ext. - 6" Brick Veneer Backup w/ Insulation	5,454.2 kg
Ext. - 6" Brick Veneer Backup w/ Insulation (STC 53)	83.1 kg
Ext. - 6" Roof Curb	58.8 kg
Ext. - 6" Zinc Panel	641.2 kg
Ext. - 6" Zinc Panel w/ Insulation	5,896.0 kg
Ext. - 6" Zinc Panel w/ Insulation (no finish)	158.3 kg
Ext. - 6" Zinc Panel w/ Insulation (no wrap)	27.9 kg
Ext. - 6" Zinc Panel w/ Insulation (STC 53)	105.4 kg
Ext. - 6" Zinc Parapet	1,134.6 kg
Ext. - 6" Zinc Parapet w/ Insulation	33.9 kg
Ext. - Brick Veneer on Mtl. Stud	890.3 kg
Ext. - Double Brick Wall on Mtl. Stud Support	450.3 kg
Ext. Zinc Soffit	465.2 kg
Ext. Zinc Soffit With Insulation	3,089.2 kg
Int. 6" Framing Wall	1,174.6 kg
Int. Ptn - 11.25" Furred Wall	440.3 kg
Lecture Hall Acoustic Panels3: Lecture Hall Acoustic	791.4 kg
Roof Clerestory	1,059.7 kg
System Panel: INT Spandrel Panel	83.2 kg
System Panel: INT Wood Veneer Panel	203.3 kg
System Panel: Interior Device Strip Panel	25.0 kg

Tally Concepts
BIM vs BOM



Representation of a wall assembly in LCA

Brick, generic	(bldg life)	18,915 kg
Lime mortar, Type K	(bldg life)	1,990 kg
Steel, reinforcement	(bldg life)	84 kg
Polystyrene board, pentane foaming agent	(30 years)	209 kg
Exterior grade plywood, US	(bldg life)	890 kg
Polyethylene sheet vapor barrier (HDPE)	(bldg life)	29 kg
Cold-formed galvanized sheet steel	(bldg life)	965 kg
Wallboard, gypsum	(30 years)	1,304 kg
Paint, interior acrylic latex	(10 years)	20 kg

Bill of Materials
One of the most time consuming steps in LCA involves quantifying the materials required for a given product system. It is this bill of materials that is combined with LCI/LCA data to determine the system's environmental impacts.

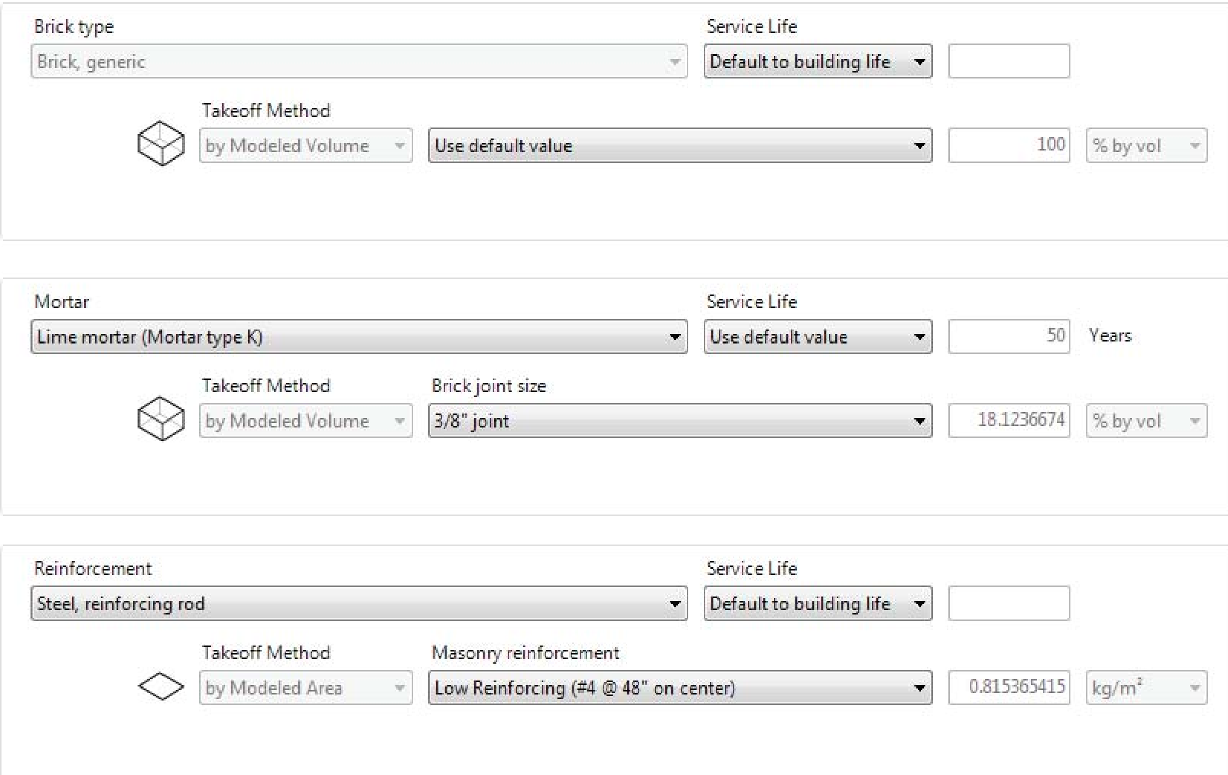
Even in a small building, materials may number in the dozens or even hundreds, and each of these materials may occur in any number of assemblies in the building, making it difficult to keep quantity takeoffs current with the project as the design evolves.

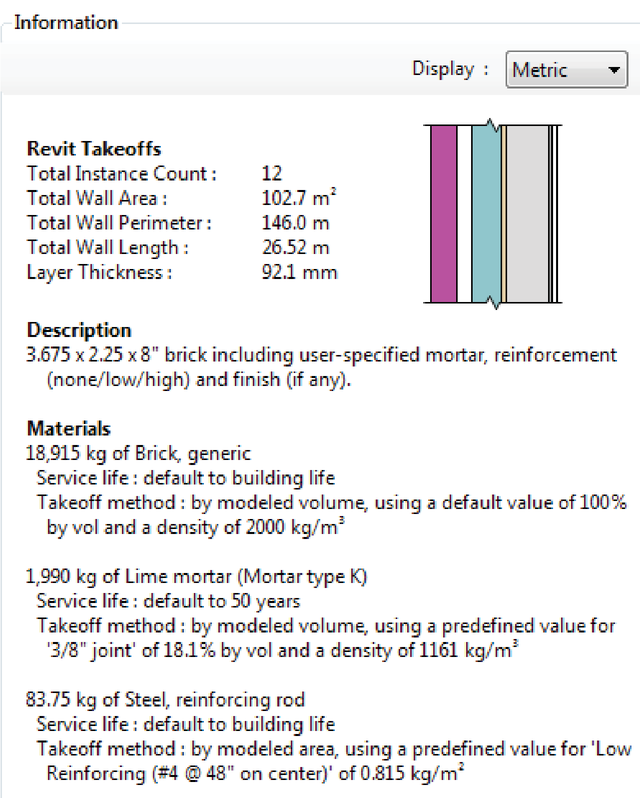
To avoid this pitfall, Tally provides an interface that allows users to define quantity takeoffs parametrically, so that new totals are generated automatically as the project evolves. Instead of spending days generating a new bill of materials at each project milestone, users can instead spend that time conducting iterative studies that build on their prior work in Tally.

BIM vs BOM
At first glance, it may seem that a Revit model already contains the information necessary to generate an itemized bill of materials for a project. However, a brief examination of a simple brick veneer wall assembly reveals several key differences in resolution between a building information model and a bill of materials.

It is neither necessary nor practical for a Revit model to contain the mortar and reinforcement in a masonry layer; nor is it practical to model individual framing members in a metal stud layer; nor is it common to model a wallboard's painted finish. These details are better left to specifications and finish schedules, yet they form an integral part of LCA, as each of these materials bears environmental impacts in its manufacturing, replacement, and ultimate disposal.

Tally's quantity takeoff methods allow users to make use of materials and dimensional information from Revit where it exists—and to inject additional materials and quantity takeoff information where it does not.



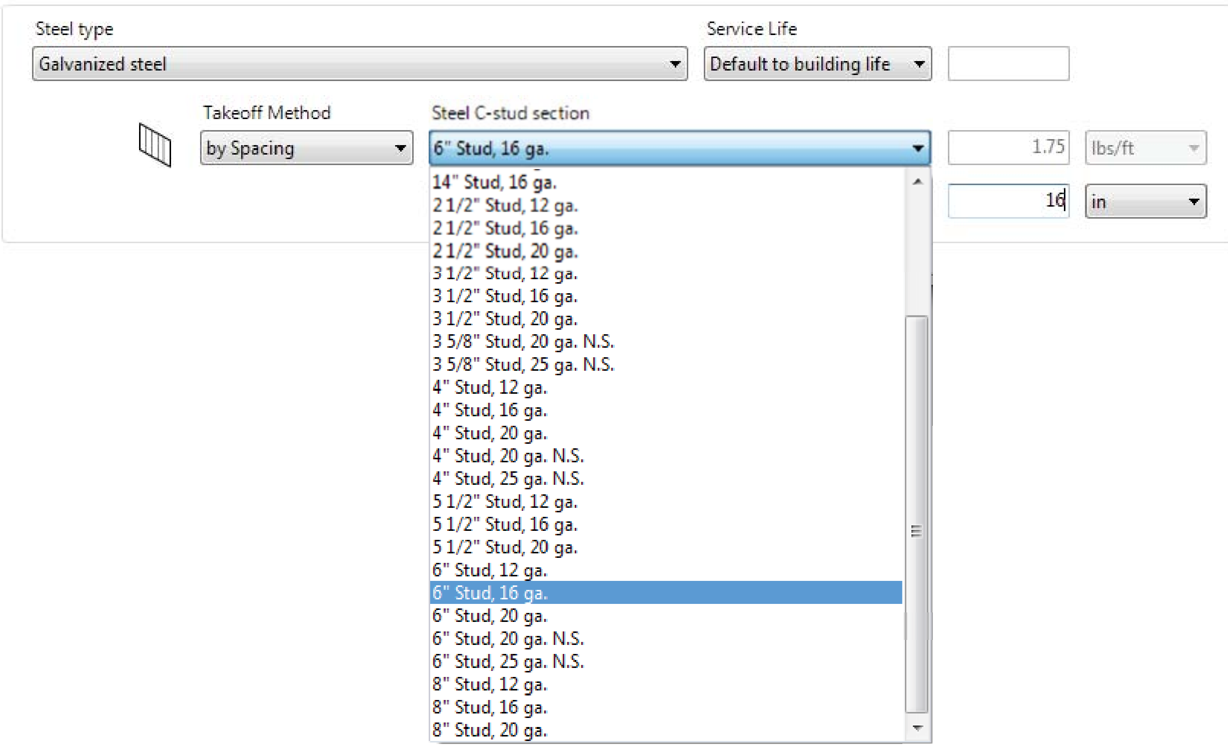


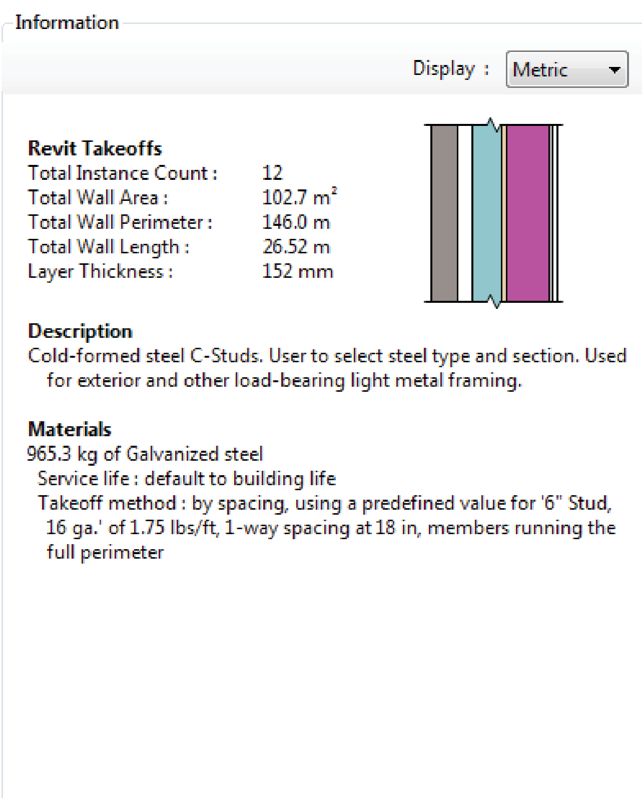
Assemblies and Co-products

As the masonry wall example illustrates, multiple materials are often represented by a single Revit material. The Tally database is structured to anticipate such situations and to guide the user in order to ensure that all of these materials are included in the LCA.

When we select a brick material, we are also prompted to select a mortar type and reinforcement. Each of these materials comes with a quantity takeoff method and a reference table of conversion factors, such as common quantities of reinforcing per unit wall area. If we are just beginning a project, then these references will serve as a useful guide. However, they can also be set manually as more details become known about the assemblies later in the project.

Tally's information window provides a brief description of the dimensions pulled from the Revit model, the quantity takeoffs generated by Tally, and the takeoff methods used to arrive at those figures. This information is essential to verifying the accuracy of the model inputs and can be reviewed at any time during the LCA process.





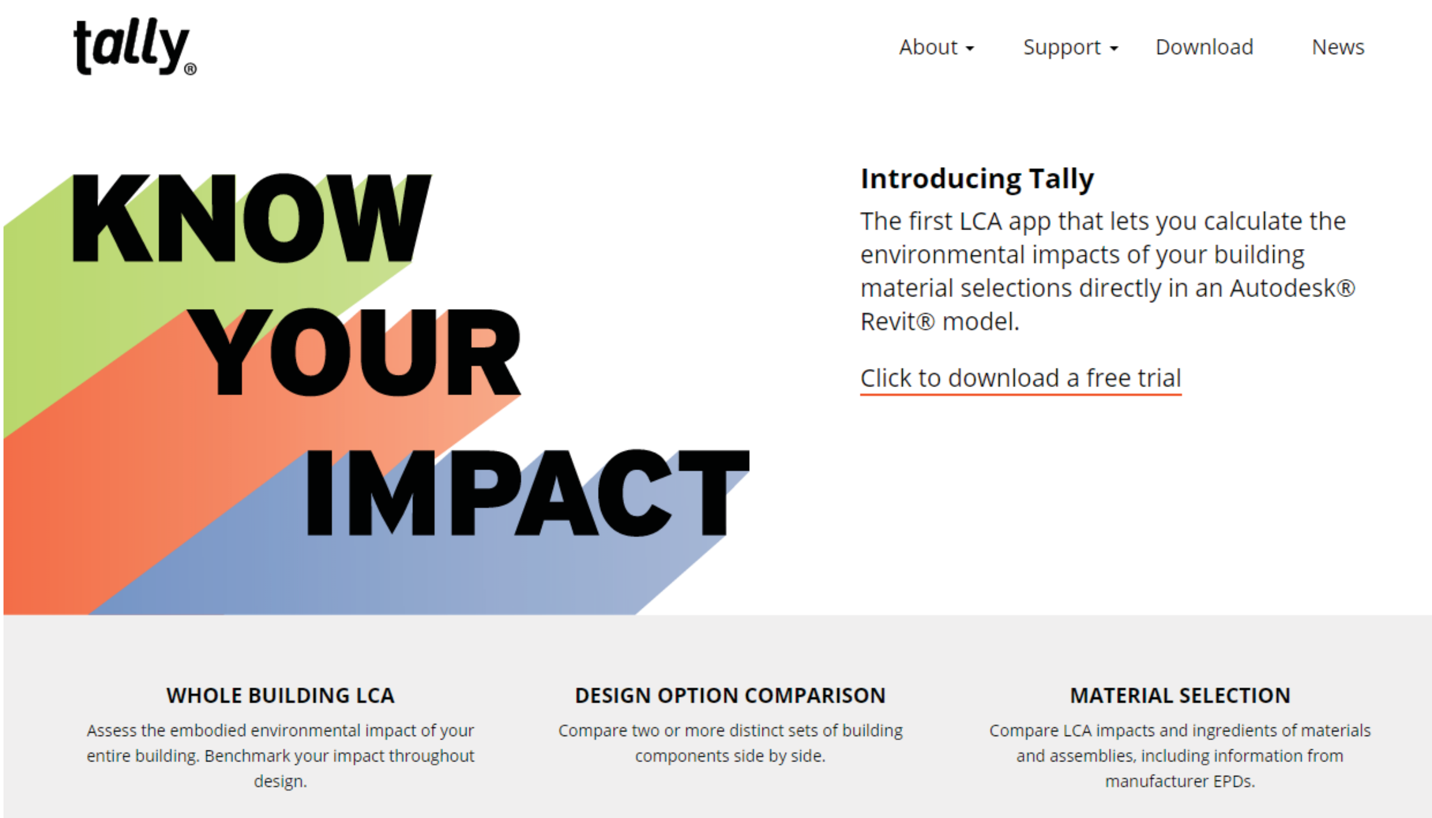
Quantities and Takeoff Methods

When quantity takeoffs cannot be pulled directly from the Revit model based on a unit area or volume, Tally provides alternate methods for determining the mass of material used in an assembly.

For instance, curtainwall mullions are typically modeled as rectangular solids, so a volumetric takeoff would grossly overestimate the quantity of aluminum used in an actual member. When we choose an aluminum mullion, Tally provides a list of common sections and combines our selection with the modeled length to determine the quantity of material needed for that member.

Likewise, stud layers in wall and ceiling assemblies typically account for stud depth while omitting individual framing members. When we choose a C-stud and select a section, Tally prompts us to specify a spacing interval. These figures are combined with the wall area to determine the actual quantity of framing required in that wall. This method is also frequently applied to guard rails with evenly spaced members.

Resources



Additional Resources
In addition to the materials presented here, a number of web-based resources are available at **http://choosetally.com**. Here you will find an overview of the tool, various tutorials on Tally workflows, and frequently asked questions. If you haven't tried Tally, we encourage you to download a free 30-day trial and to use the tutorials as a guide.

For those seeking a more thorough primer on LCA and buildings, we recommend Kathrina Simonen's *Life Cycle Assessment* (Routledge, 2014).