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LEED V4 LCA Credit and Case Study

The purpose of this paper is to describe and explain the LEED V4 Whole Building LCA credit and present a case study to demonstrate how it might be achieved.

LEED V4 represents a major change in the LEED suite of tools, with new credit categories, new credits, and an amalgamation of several different LEED certification categories[1] from the previous LEED 2009 version.

LEED Version 4 is believed to be the most comprehensive LEED green building rating system available and represents, in the author's opinion, a leap forward in technical quality of the assessment tool. LEEDV4 is coming fast, and it represents the biggest change in LEED since it was introduced. One of the most radical, exciting and talked about changes relate to the material credits. Notable changes include product material ingredient reporting and optimization, manufacturer supply chain optimization, raw material source and extraction reporting, environmental product declarations, and life cycle analysis.

The Materials and Resources (MR) credit category within LEED focuses on minimizing the embodied energy and other impacts associated with the extraction, processing, transport, maintenance, and disposal of building materials. According to the USGBC, the requirements are intended to reflect and support life-cycle thinking.

LEED (Leadership in Energy and Environmental Design) originated as a green building assessment tool in 1998 and has since evolved into a suite of tools serving the building design, construction, renovation and operation market around the world. According to the United States Green Building Council (USGBC), the LEED rating systems aim to promote a transformation of the construction industry through strategies designed to achieve seven goals:

- To reverse contribution to global climate change
- To enhance individual human health and well-being
- To protect and restore water resources
- To protect, enhance, and restore biodiversity and ecosystem services
- To promote sustainable and regenerative material resources cycles
- To build a greener economy
- To enhance social equity, environmental justice, community health, and quality of life

[1] LEED V4, Building Design + Construction: This category is intended for new building design or major renovations of most commercial building types, including office, K-12 educational, retail, data centers, warehouses and distribution centers, hospitality, or healthcare, and mid and high-rise residential buildings'

However, there is an inherent problem in this regard, as a system is often required to compare and effectively weight different sustainability attributes of materials. For example, a designer might require to choose between wood, steel or concrete, but after some research might figure out that wood is natural, concrete is local, and steel has high recycled content. Each of these attributes is important, but how does one compare them? LCA offers a quantitative comparison of materials across a range of environmental impact performance metrics, rather than using the imperfect prescriptive or qualitative measures common in green building assessment programs up to now. Using LCA can allow designers to make more informed decisions about the environmental impact of material choices.

The whole building life cycle assessment (WB-LCA) credit in LEEDV4 is largely misunderstood, and believed by the industry at this time to be difficult or impossible to achieve for most building projects. However, with free tools available, such as the Impact Estimator for Buildings tool from the Athena Sustainable Materials Institute ("Athena"), up to three points can be fairly easily achieved if lower impact materials, such as wood, are selected early in design.

Within LEED V4 for Building Design and Construction, there are 110 credits and 12 prerequisites, that when combined are intended to be a reflection of the seven goals of LEED.

LEED V4 Whole Building LCA Credit

LEED V4 contains a new credit path, titled Whole Building Life-Cycle Assessment. This credit path is an option within the Building Life Cycle Impact Reduction credit. The Building Life Cycle Impact Reduction credit can be used with the four project options below:

1. Historic Building Re-use: Re-use and renovate an historic building as part of the building project so that it maintains its designated historic status. (5-6 points)

2. Renovation of Abandoned or Blighted Building: Maintain and renovate at least 50% of an existing abandoned or blighted building as part of a building project (5-6 points)

3. Building and Material Re-use: Maintain 25% or more of an existing building structure, shell or interior walls and/or purchase and use salvaged or used building materials for these purposes. (2-5 points)

4. Whole Building Life-Cycle Assessment (3 points)

Options 1 to 3 would be rarely pursued in North America, as most building projects do not include an historic or abandoned building, and very few include the renovation of an existing building where significant percentages of the existing building are maintained. However, option 4, LCA, is available for almost every LEED project, including entirely new building construction.

The assessment to be undertaken in pursuing the LCA Credit must include consideration of the complete structure and building envelope. It also must support the following environmental impact indicators, which cover a wide range of environmental impacts[2]:

-Global warming potential

-Ozone depletion potential

-Acidification potential (land)

- Eutrophication potential (fresh water)

- Formation of tropospheric ozone, and

- Depletion of nonrenewable energy resources

The LCA credit has only one threshold. To achieve the three available credits, it must be demonstrated a:

a. 10% (minimum) reduction in global warming potential; and

b. 10% (minimum) reduction of two of five other environmental impact measures (discussed below) when compared to a baseline building' and

c. 5% (maximum) increase in any other measure when compared to the same baseline building.

Note that there is also a defined innovation point available for this LCA credit. If the team demonstrates an improvement over the required credit thresholds in all six impact measures, then an additional exemplary performance credit would be available.

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[2] More information on LCA and environmental impact measures is available at http://www.athenasmi.org/resources/about-lca/

A detailed description of the requirements of the WB-LCA credit is available within the LEED V4 reference guide, available from the USGBC (http://www.usgbc.org/leed/v4/). A simplified description of requirements and best practices to achieve this credit is as follows:

1. Commit to the LCA credit very early in the project, preferably before the structural and envelope materials have been selected. Committing to the credit later in the design makes it much more difficult and costly to achieve.

2. Commit to an LCA software. Even if technically feasible, LCA is much too complex to perform on a material by material basis for an entire building. All LCA results must include a full cradle-to-grave assessment, beginning at the extraction of raw materials, through manufacture and construction, product maintenance and replacement over a 60 year service life at a minimum, and through to demolition. The software should also enable LCA results for footings, foundations, parking garages, windows, roofs, exterior walls, beams, columns and floors, and other envelope and structural components. Uncommon materials not referenced in the LCA software can be used, but their LCA results must be available and would need to be similar in scope to that of the LEED requirements.

3. Determine if an LCA specialist is required. The use of materials not supported by available software may necessitate a specialist. Also, non-standard methods at achieving the required environmental footprint reductions could also require a specialist to help confirm that the system boundaries between the baseline and proposed design buildings are the same, and to assist in work-arounds using the software.

4. Determine a building service life. The service life must be a minimum of 60 years, so replacements of assemblies (such as roofing) within the service life must be considered. Note that some LCA tools, such as Athena's, inherently include maintenance and repair / replacements over a buildings life cycle.

5. Conceptualize and develop an LCA model of the base building based on the functional building requirements, and common building materials for the region. There are many rules defining the limitations of the base building, as described in the LEEDV4 reference guide, but a few important considerations are as follows:

    a. The building must have the same gross floor area, orientation, and function.

    b. Both baseline and design building must meet the LEEDv4 Energy Efficiency prerequisite (EAp2).

c. Whole Building Energy Modeling to prove the baseline building performance is not required. In general, the baseline building must have insulation and glazing that would make it a reasonably efficient user of energy.

For a more detailed description of how to develop an appropriate baseline building, see the guidance document at http://www.athenasmi.org/

6. Conceptualize and develop an initial LCA model for the design building. Initially this could be identical to the baseline building, or it could account for any radical acceptable changes to the design, such as changes to floor to floor height, elimination of materials, etc.

7. Optimize the concept design using the LCA model as a design assist tool.

8. Iteratively investigate proposed changes to the design using the tool, tending to adopt changes that have positive impacts and rejecting those with negative impacts. Recognize that some changes will have positive environmental impacts in some measures and negative impacts in others.

9. The goal is to reduce impacts across all measures, and LEED will recognize a reduction across all measures with an innovation point.

10. Note that in most cases, you should not change the baseline building. Exceptions to this would include if a change is made in design that requires a change to the baseline building (such as gross area), or if an assumption made in the baseline was proven to be false (e. g. If a cladding system assumed was found later to be uncommon for that region). Note that there are a wide array of options in optimizing the design from an LCA perspective, including changing spans, fundamental systems, heights, materials, etc.

Examples of Potential Changes Between the Baseline and Proposed Building Designs	
Acceptable Changes	Unacceptable Changes
Lower floor to floor slab heights	More efficient interior plan resulting in a smaller gross floor area
Use of low impact insulation	Increased thermal mass (affects energy use)
Use of different cladding materials	Elimination of interior non-load bearing walls, ceiling tile, or carpet (not part of structure or envelope)
Different stud spacing or stud types	Use of a high environmental impact material when it is uncommon in the region for that building type
Alternative spans resulting in more efficient material use for floors or beams	Use of uncommon long spans resulting in inefficient material use
Elimination of exterior sheathing product	Using high impact cladding material when it is uncommon for that type of construction
Replacement of slab on grade concrete on the lowermost parking level with alternative low-impact material.	Different service life chosen for the baseline and design building.
	Change the shape or footprint of the building to reduce material use

11. Document the results, as per the LEED reference guide, including:

    a. Description of the LCA assumptions and scope, baseline building and proposed building. Describe the differences between the two buildings and the service life of each building.

    b. Lifecycle impact assessment summary, showing results of the baseline and proposed building, and including a table showing the percentage change for all impact indicators between the baseline and design buildings.

    c. Description of the data sets used to represent each material or assembly and confirmation that the same data sets were used for both the baseline and design buildings.

    d. Description of the software and characterization model used (e.g. TRACI) for all impact category characterization factors.

    e. Source of data for any work-arounds or product proxies not referenced in the software, for both the baseline and the proposed buildings.

A case study demonstrating how working towards the WB-LCA credit might work in a fictional commercial building project is attached.

Yours truly,
Morrison Hershfield Limited

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About the Author

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Case Study: LEED V4 WB-LCA Credit

This case study is a fictional office warehouse complex[3] located in Minneapolis, Minnesota. The owner envisioned the following, which was adopted as the baseline model for life cycle assessment:

- 100,000 sf, 40' high warehouse with attached 40,000 square foot office component (2 story, each 20,000 sf).
- Energy efficient design (envelope, M&E, lighting)
- Office walls: Curtain wall with 4" glass fiber insulation, 3 ½"steel stud and gypsum board on interior of back pans. 30% window to wall ratio (double glazed),
- Warehouse walls: bottom 10' concrete block with 4" glass fiber insulation and steel cladding on metal Z-girts, top 20' 6" steel stud with glass fiber insulation, interior metal pan and exterior steel cladding. No windows
- Roofs: EPDM roof membrane, with 4" expanded polystyrene insulation
- Structure: Steel columns and beams with open web steel joists and steel deck, 40' spacing in both directions, 30' height in warehouse, 12' floor to floor height in office. Second floor of office is OWSJ with steel deck and concrete topping. Ground floor is slab on grade, 4" thick in office, 8" thick in warehouse

The software selected for the project was the Impact Estimator for Buildings developed by the Athena Sustainable Materials Institute. A description of the software, largely taken from Athena's web site (www.athanasmi.org) is as follows:

The LCA background data within the tool draws from life cycle inventory (LCI) and LCA data files that are downloaded along with the software. These files are proprietary to the Athena Institute and are encrypted for security; they additionally are not appropriately viewed as stand-alone files because they are designed to work only in the context of the data integration undertaken by the Impact Estimator for Buildings software. However, it is the intent of the Athena Institute to provide as much transparency as possible regarding the data and inner workings of our software. Therefore, much of the data is available in reports downloadable from the Athena Institute web site including the software user guide.

[3] Although the case study is fictional, each of the presented changes or innovations were based on other real projects, and are therefore presented as realistic opportunities to reduce the LCA impact.

The embedded data is the result of on-going research since the inception of the Athena Institute, and is periodically updated. Data development by the Athena Institute includes life cycle inventories or life cycle assessments of specific industries, product groups, transportation, construction processes and maintenance tasks. Athena's work is conducted in accordance with the ISO 14040 and ISO 14044 standards and other standards as appropriate, and compliant with their own research guidelines including internal review and is, when warranted, externally peer reviewed.

The Impact Estimator for Buildings takes into account the environmental impacts of:

- Material manufacturing, including resource extraction and recycled content
- Related transportation
- On-site construction
- Regional variation in energy use, transportation and other factors
- Building type and assumed lifespan
- Maintenance and replacement effects
- Demolition and disposal

The Impact Estimator for Buildings provides cradle-to-grave results for the following impact indicators:

- Global Warming Potential
- Acidification Potential
- Human Health Respiratory Effects Potential
- Ozone Depletion Potential
- Photochemical Smog Potential
- Eutrophication Potential
- Fossil Fuel Consumption

Note that the first six impact measures listed above are based on mid-point impact estimation methods developed by the US Environmental Protection Agency (EPA) and reported in the EPA's Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACIv2.1, 2012).

A preliminary Athena model of the office warehouse complex baseline building was developed based on standard construction for this type of building. The results of the model are as follows (extracted directly from the software):

Summary Measures	Foundations	Walls	Columns and Beams	Roofs	Floors	**Total**
Fossil Fuel Consumption (MJ)	9,264,806	10,724,343	7,380,716	17,322,447	1,367,855	**46,060,168**
Global Warming Potential (kg CO2 eq)	1,148,076	870,509	359,426	807,104	111,692	**3,296,807**
Acidification Potential (kg SO2 eq)	5,739	7,231	2,778	4,650	606	**21,004**
HH Particulate (kg PM2.5 eq)	2,128	2,089	248	6,366	135	**10,966**
Eutrophication Potential (kg N eq)	200	301	480	326	48	**1,355**
Ozone Depletion Potential (kg CFC-11 eq)	0.0103	0.0101	0.0000	0.0007	0.0004	**0.0214**
Smog Potential (kg O3 eq)	94,548	53,374	21,358	47,455	6,923	**223,658**

The above table represents a starting point from which to investigate possible changes, such as where to focus to achieve the larger reductions in environmental impacts by each summary measure. Note that Human Health Particulate is not required for LEED4 compliance. Also note that LEED requires consideration of total "non-renewable energy use" which includes energy from both nuclear and fossil sources, rather than the "fossil fuel consumption" measure noted in the table above. The Impact Estimator software offers a more detailed report that includes both fossil and nuclear fuels, thereby enabling a LEED compliant result.

As part of the design process, the following innovations were adopted:

1. Height was dropped to 30' in 75% of warehouse. This was achieved after the owner acknowledged they only required the 40' height for one specialty piece of equipment. The owner decided to adopt this change, partly for the LCA results, but also because of lower capital cost and energy savings with less space to condition.
   This resulted in a reduction in impact of between 3 – 6% for most measures.

2. An innovation was adopted to re-locate the second floor of the office to within the warehouse. This would result in 15,000 ft2 of warehouse with a ceiling height of 12', reducing materials associated with the building envelope and

reducing operating energy cost. As the gross area of the two scenarios remains the same, it is believed this would be acceptable[4] to account for this material reduction in the analysis.
This resulted in a slight increase in impact for acidification and ozone depletion but slight reductions in other measures.

3. Different envelope, wall and floor materials were investigated, and it was decided to change the office component to a partly wood based building, with wood stud walls, wood truss floor and roof, and exterior cedar cladding.
   This resulted in a reduction in impact of between 3 – 7% for most measures. The cumulative effect of the above three changes results in a reduction of greater than 10% in all measures except ozone depletion and smog potential. The cumulative effect of the above changes, results in a reduction of greater than 10% in global warming potential and more than two additional measures, and no increase in any of the six measures, thus achieving the threshold for three LEED points plus an innovation point. However, we proceeded with the exercise to determine if we could achieve a reduction of 10% in all measures.

4. The baseline building had no supplementary cementicious materials (SCMs) in the concrete. It was determined to change the slab on grade to 25% fly ash and the foundation walls and footings to 35% fly ash.
   This resulted in a reduction in impact of between1 – 5% for all measures. The cumulative effect of the above changes results in a reduction of greater than 10% in all measures except smog potential.

5. Research was done using the Athena software on the material effects of different roof materials. It was determined that high density glass fiber has significantly lower impacts than the expanded polystyrene, and a switch to glass fiber roof insulation was made. It was also determined that the EPDM membrane was performing well from an embodied effects perspective, and no change was made to membrane type.
   This resulted in a reduction in impact for four of the measures but a significant increase in ozone depletion. The cumulative effect of the above changes results in a reduction of greater than 10% in all measures except ozone depletion.

   Several attempts were made to reduce ozone depletion to the level below 90%, but this proved to be very difficult. Accordingly, it was decided to abandon option 5.

[4] Note that this innovation could potentially be rejected by the LEED assessor. Although it has the same gross floor area and orientation, an assessor could reject it because of the potential change in building energy use. A credit interpretation ruling (CIR) would be required to definitively answer this question.

6. After testing the effects of several proposed changes to the design using the Athena software, with the goal of reducing smog potential without significantly increasing other measures, it was determined to abandon option 5 above, and to replace the concrete block lower warehouse walls with wood stud walls with a double layer of 5/8" gypsum board (for toughness) on the inside face. The upper wall of the warehouse was also changed to wood studs (from steel studs). Cladding and insulation remained the same.
This resulted in a reduction in impact of between1 – 2% for all measures. The cumulative effect of the above changes, except change 5, results in a reduction of greater than 10% in all measures, thus achieving the threshold for three LEED points plus an innovation point.

Table 2: Reduction in embodied effects from baseline to final design building

Summary Measures	Baseline	Final Design	% Reduction
Fossil Fuel Consumption + Nuclear (MJ)	**80,360,168**	**69,838,917**	13.1%
Global Warming Potential (kg CO2 eq)	**3,296,807**	**2,774,425**	15.8%
Acidification Potential (kg SO2 eq)	**21,004**	**18,315**	12.8%
HH Particulate (kg PM2.5 eq)	**10,966**	**9,627**	12.2%
Eutrophication Potential (kg N eq)	**1,355**	**1,185**	12.6%
Ozone Depletion Potential (kg CFC-11 eq)	**0.021**	**0.018**	14.9%
Smog Potential (kg O3 eq)	**223,658**	**201,191**	10.0%

Graph 1: Cumulative Impacts of different Options