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The Importance of Integrating LCA into the LEED Rating System.

Hamoud Dekkiche*, Ali Taileb

"School of Architecture & Interior Design, Canadian University of Dubai, P.O Box 117781, Dubai, U.A.E"
Durham College, School of Science and Engineering, 1610 Champlain Avenue, Whitby, Canada, ON L1N 6A7

Abstract

LEED (Leadership in Energy and Environmental Design) is a rating system that rates green buildings; LCA (Life Cycle Assessment) is a tool to evaluate the environmental impacts of building materials. The aim of this paper is to demonstrate the importance of integrating LCA into LEED to enhance its rating system. The LEED Gold building presented in this research is the Centennial College Progress Campus located in Toronto, Canada. Using ATHENA® Impact Estimator version 4.5 to conduct the LCA, this study analyses how different building envelope solutions and building materials affect the results of the environmental assessment of a whole building over the building's life cycle of 60, 80 and 120 years. Environmental impact assessment of LEED buildings is discussed, further research topics are suggested; for example how to develop specific LCA software tools and integrate them into LCA analysis for green building rating system.

Peer-review under responsibility of the organizing committee of ICSDEC 2016

Keywords: LEED, LCA, Life Cycle Assessment, green buildings.

1. Introduction

LEED is becoming in many countries the tool for rating green buildings. The aim of rating building is to minimise their environmental impacts and create more sustainable buildings. Thus, architects through their architectural design and selection of materials would create sustainable designs.

* Corresponding author. Tel.: 971 4 7096 159;
E-mail addresses: hamoud@cud.ac.ae (Hamoud Dekkiche), ali.taileb@durhamcollege.ca (Ali Taileb)

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1.1. Sustainable development

Sustainable development is a way of human development in which uses of resources clearly intent to meet needs of present human generation without any compromise to meet the needs of future generation meanwhile safeguarding the sustainability of natural systems and the environment. Green buildings are constructed by considering efficient and responsible use of resources along with environmentally responsible processes throughout a building’s life cycle; Starting form site selection, design process, construction, operation, maintenance and demolition. This needs an integrated approach which emphasis on creating strong integrated loop between all the team members involved in the project at all different project stages.[1] The Green Building practice expands and complements the classical building design concerns of economy, utility, durability, and comfort.[2]

1.2. Green Building and Canadian Green Building Council (CaGBC)

Green buildings are becoming an important aspect in one’s life in construction industry. As a result, construction industry is seeing a large surge in green building programs and initiatives especially across developed countries. Owners and Investors are being informed about the advantages of green building; construction related material manufactures are more aware about environmental benefits of their products; builders are learning about new techniques and technologies that purport to reduce environmental impact; and lenders, insurers, municipalities, code officials and design professionals are reinterpreting their roles in terms of green design objectives.

Green buildings are forerunner of sustainable development in this era; by focusing on social, economic, and environmental balance of sustainability [3] [4]. Green building has a potential to create environmentally efficient buildings by incorporating an integrated approach of design so that the negative impact of building on the environment and occupants is reduced. Additionally rating system like LEED offer an effective framework for assessing building environmental performance and integrating sustainable development into building and construction processes; as it can also be used as a tool for designing sustainable design strategies and decision-making processes [4] [5]. Furthermore it also reduces the operating and maintenance costs, market value of the building, occupant comfort and productivity is increased [6].

1.3. LEED and its rating system

This section describes the main categories of LEED (CaGBC, Canadian Green Building Council). LEED rating systems is a framework developed by the USGBC (US Green Building Council) and CaGBC committees is a third-party verification of green buildings. Prerequisites and credits for New Construction and Major Renovations 2007 and in the LEED Canada for Core and Shell Development 2007 address six topics (Table1):

Table 1: LEED Canada-NC 1.0 Categories (CaGBC)

LEED Categories	**Possible Points**	**Centennial LEED Gold Building**
1. Sustainable Sites (SS)	14	**7**
2. Water Efficiency (WE)	5	**4**
3. Energy and Atmosphere (EA)	17	**9**
4. Materials and Resources (MR)	14	**7**
5. Indoor Environmental Quality (IEQ)	15	**11**
6. Innovation and Design Process (ID)	5	**4**
Total	70	**42**

LEED Canada- NC 1.0 for New Construction 2007 certifications are awarded according to the following scale:
Certified 26 – 32 points Silver 33 – 38 points Gold 39 – 51 points Platinum 52- 70 points

The LEED® Canada NC rating system applies to new construction and major renovations of commercial and institutional buildings, i.e., buildings regulated by Part 3 of the National Building Code. It also applies to retail, mid-rise and high-rise multi-unit residential buildings (MURBs), public assembly buildings, manufacturing plants, and other types of buildings (CaGBC). Table 1 shows the rating systems achieved by Centennial College LEED building, a total of 42 points. Under materials and Resources (MR) the building had achieved 7 out of 14 possible points.

1.4. Life Cycle Analysis

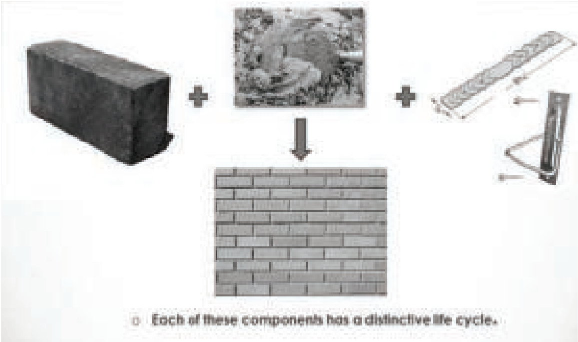


Fig.1. LCA of a brick wall, (Taileb, A & Dekkiche, H (2013).

LCA is a methodology for assessing the environmental performance of a service, process, or product, including a building, over its entire life cycle. The concept of environmental life cycle assessment (LCA) was developed from the idea of comprehensive environmental assessments of products, which was conceived in Europe and in the USA in the late 1960s and early 1970s. Originally, LCA was used as a tool by environmental consultants. Eventually, it became clear that different LCAs carried through by different consultants resulted in diverse and sometimes conflicting conclusions. The steps of most concern here are the life cycle inventory analysis (LCI) and the initial stages of impact assessment.

An LCI involves detailed tracking of all the flows in and out of the system of interest — raw resources or materials, energy by type, water, and emissions to air, water and land by specific substance. The LCI data can then be characterized in terms of impact potentials (e.g., global warming, ozone depletion, etc.). While the indicators do not answer the question of ultimate environmental impacts, they do provide a convenient way to summarize and compare the masses of inventory data, and at least make decisions on the basis of whether an alternative is likely to result in a reduction of flows from and to nature.

1.5. Thesis statement

This paper emphasis understanding of environmental impacts of wall systems, belonging to LEED gold certified building. Does a LEED building have low environmental impacts? Do the selected building materials have low environmental impacts? Are there any other options for building materials? The focus on this research is primarily on embodied energy and global warming potential of wall systems in all phases of the life cycle (60 years, 80 and 120 years). Centennial college library building of the progress campus has been selected for purpose of this study. This building is a LEED gold certified by the Canadian Green Building Council.

2. Aim of the Research

The aim of this study is to analyse how different building envelope solutions and building materials affect the results of the environmental assessment of a whole building over the building's life cycle of 60, 80 and 120 years. The research aims also at examining the environmental impacts (Fossil fuel consumption and Global warming potential) of different wall systems (wood cedar and stucco) and compared to the base case. For the LCA analysis ATHENA® Environmental Impact Estimator version 4.5 software was then used. The environmental impacts studied in this research include: Fossil Fuel Consumption (MJ) and Global Warming Potential (kg CO2 eq).

3. Methodology

In order to achieve the objectives of this research, several major research methods are employed in this study. Take offs of building components: wall systems, building areas, building materials using architectural drawings, details and sections. Electrical consumption was based on 2012- 2013 estimated at (8,576,763 kWh). ATHENA® Impact Estimator software version 4.5 was used for LCA analysis.

1.6. Centennial College: LEED Gold building

The Library building at Centennial College is located in Toronto, Ontario. The four-story building has a gross floor area (GFA) of 9400 m2. The certified LEED-NC 1 gold was designed by Diamond Schmitt Architects and certified by the Canadian Green Building Council in 2011 under LEED NC 1. The building's main wall systems (W1) (Fig 2) are cast in place concrete with modular bricks and are used for cladding along with fiberglass rigid insulation. The second prevalent main wall system is the copper clad (W2) (Fig 2), composed of 152 mm steel frame system, an air/vapour barrier, a 100 mm rigid insulation, steel sheathing and cladded with copper panels. Window frames are of aluminium and the building also has an exterior copper cladding and curtain walls. Some of the building's sustainable features include a Living Wall bio filter which purifies indoor air, minimizes both heating and cooling costs, provides natural humidifying. Therefore it generates an environment that is both healthier and more appealing green roofs, pervious pavement and extensive landscaping that create green space and keep storm water from being added to local waterways. Collection of rainwater that is reused in the building to flush toilets offered a 57% reduction in water usage. In addition, advanced energy-efficiency upgrades, including high performance windows, improved ventilation systems and smart fluorescent lighting with controls according to daylight and occupancy. Innovative atrium and window design that provides natural light to over 75% of the building.

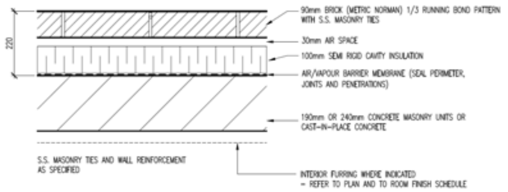
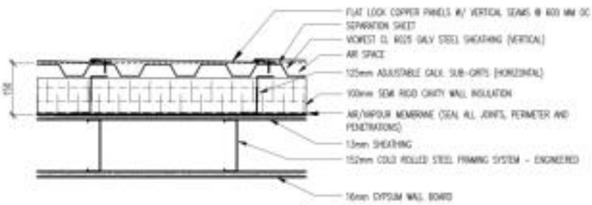
Wall systems	
W1	W2
	

Fig. 2. Wall system components (base case), reference: Diamond Schmitt Architects.

4. LCA Analysis

This study analyses how different building envelope solutions and building materials affect the results of the environmental assessment of a whole building over the building's life cycle of 60, 80 and 120 years. In order to be able to analyse how the different structural components and wall materials affect the results of the environmental assessment of a building over the life cycle, buildings with different wall components are compared and analysed.

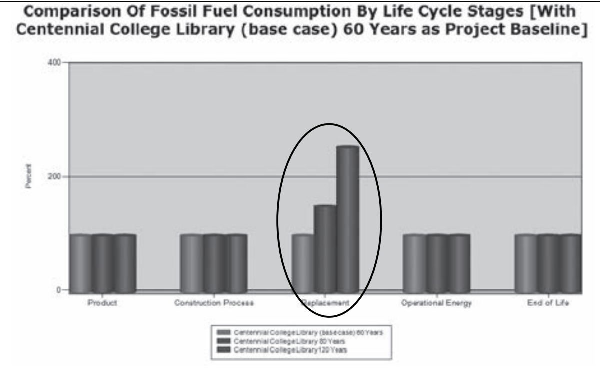


Fig. 3. Comparison of Fossil Fuel Consumption by Life Cycle Stages.

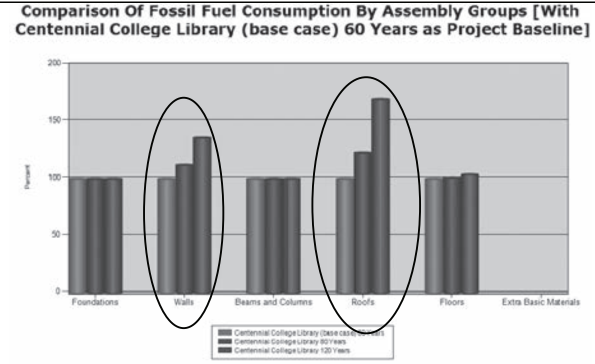


Fig. 4. Comparison of Fossil Fuel Consumption by Assembly Groups

Figure 3 compares Fossil fuel consumption by different life cycle stages; there is an increase of Fossil fuel consumption during 80 and 120 years life cycle of the building mainly due to replacement of building components. Figure 4 compares Fossil fuel consumption by assembly groups; there is an increase of Fossil fuel consumption during 80 and 120 years life cycle of the building mainly due to replacement of building components in walls and roofs.

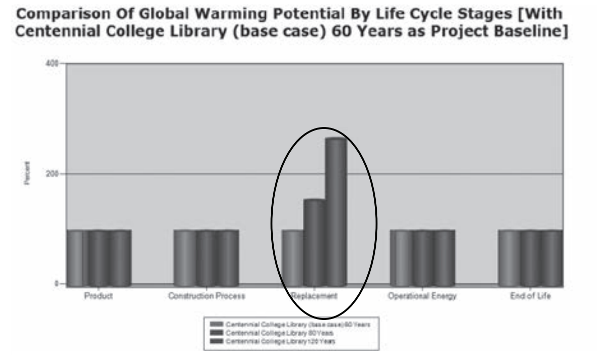


Fig. 5. Comparison of Global Warming Potential (GWP) by Life Stages

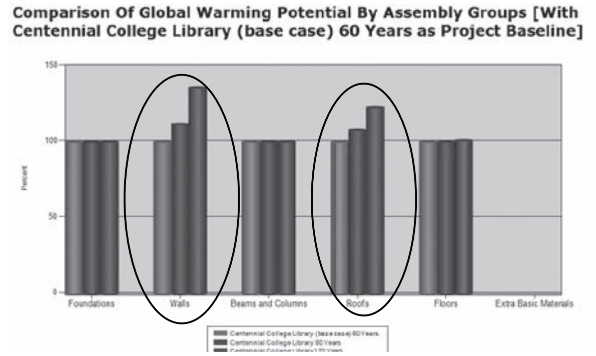


Fig. 6. Comparison of Global Warming Potential (GWP) by Life Stages

Figure 5 compares Fossil fuel consumption by different life cycle stages; there is an increase of global Warming Potential during 80 and 120 years life cycle of the building mainly due to replacement of building components. Figure 6 compares Global Warming Potential (GWP) by assembly groups; there is an (GWP) during 80 and 120 years life cycle of the building mainly due to replacement of building components in walls and roofs.

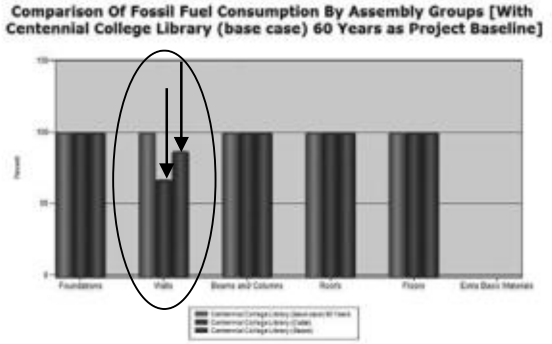


Fig 7: Comparison of Fossil Fuel Consumption by assembly groups

Two options were examined and compared to the base case, the first option was to replace Copper wall system with Cedar cladding system and the second option was to replace the bricks with stucco. Figure 7 shows the comparison of Fossil Fuel Consumption by different assembly groups, from Figure 7 it is noticeable that by replacing Copper to Cedar wall system will result in significant reduction of Fossil fuel.

Table 2. Comparison of Fossil Fuel Consumption (MJ) and Global Warming Potential (kg CO2 eq) of different wall systems compared to the base case.

Summary Measures	Base Case	Option 1 Cedar wall system	Option 2 Stucco wall system
Fossil Fuel Consumption (MJ)	2849568.576	1902267.441	2482612.845
Global Warming Potential (kg CO2 eq)	242663.7024	146208.7002	211697.0902

Table 2 shows summary of environmental measures (Fossil Fuel and Global Warming Potential) of the base case, option 1 (replacing Copper clad with Cedar) and option 2 (replacing brick wall system with Stucco).

Table 3. Comparison of Fossil Fuel Consumption by assembly groups

Summary Measures	Base Case	Cedar wall system	Ratio Cedar/ Base case	% Reduction
Fossil Fuel Consumption (MJ)	2849568.576	1902267.441	0.667563314	**33%**
Global Warming Potential (kg CO2 eq)	242663.7024	146208.7002	0.60251574	**39.75%**

Table 3 shows the percentage of reduction of Fossil Fuel Consumption in (MJ) and Global Warming Potential (kg CO2 eq) compared to the base case. By replacing the exterior copper clad with cedar cladding a 33% of Fossil Fuel Consumption is being achieved and a reduction of 39.75% in terms of Global Warming Potential.

Table 4. Comparison of Fossil Fuel Consumption by assembly groups

Summary Measures	Base Case	Stucco wall system	Ratio Stucco/Base case	% Reduction
Fossil Fuel Consumption (MJ)	2849568.576	2482612.845	0.87122411	**13%**
Global Warming Potential (kg CO2 eq)	242663.7024	211697.0902	0.872388776	**13%**

Table 4 shows the percentage of reduction of Fossil Fuel Consumption in (MJ) and Global Warming Potential (kg CO2 eq) compared to the base case. By replacing the exterior brick with a stucco system a reduction of only 13% of Fossil Fuel Consumption is being achieved and a similar reduction of 13% in term of Global Warming Potential.

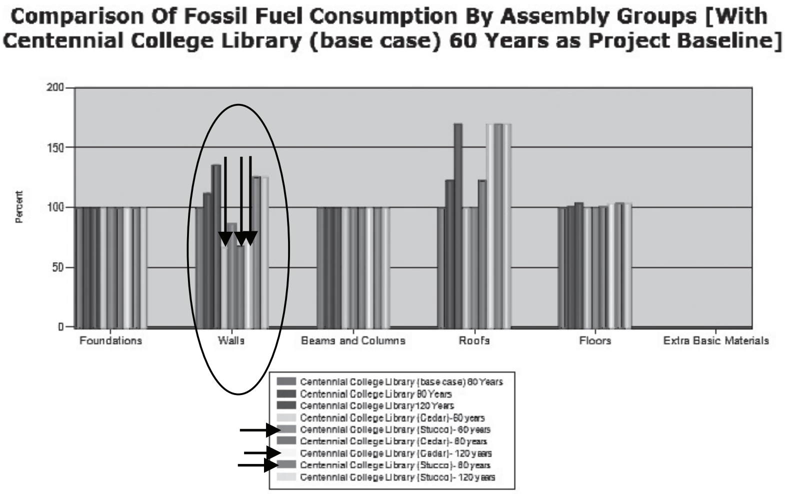


Fig.8. Comparison of Fossil Fuel Consumption (MJ) by Assembly Groups during the lifecycles of 60, 80 and 120 years.

Figure 8 shows the comparison of Fossil fuel consumption by assembly groups during life cycles of 60, 80 and 120 years, the chart shows the lowest consumption of Fossil fuel the Cedar wall system during 60, 80 and 120 years.

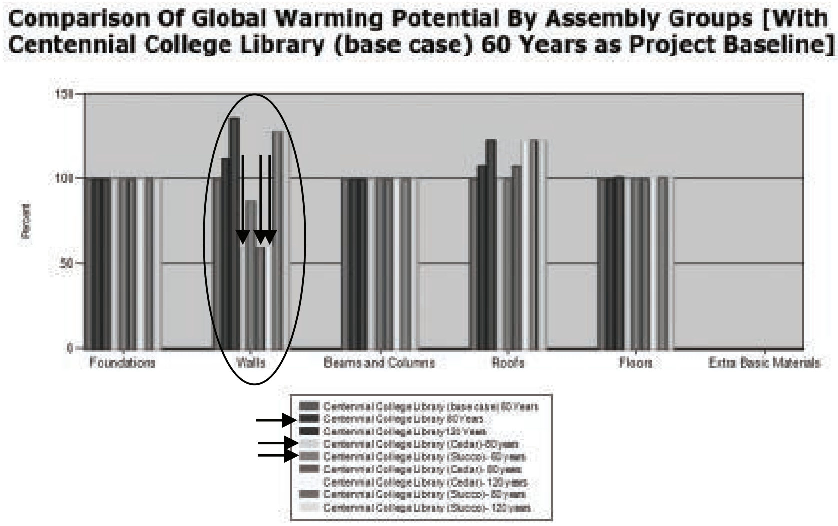


Fig.9. Comparison of Fossil Fuel Consumption (MJ) by Assembly Groups during the lifecycles of 60, 80 and 120 years.

Figure 9 shows the comparison of Global Warming Potential (GWP) by assembly groups during life cycles of 60, 80 and 120 years. The chart shows the lowest Global Warming Potential for the cedar wall system during 60, 80 and 120 years.

5. Conclusion

This study analyses how different building envelope solutions and building materials affect the results of the environmental assessment of a whole building over the building's life cycle of 60, 80 and 120 years. Two options were examined and compared to the base case, the first option was to replace Copper wall system with Cedar cladding system and the second option was to replace Bricks with Stucco. The study has shown that by replacing the exterior copper clad with cedar cladding a 33% of Fossil Fuel Consumption is being achieved and a reduction of 39.75% in terms of Global Warming Potential. Also by replacing the exterior brick with a stucco system a reduction of only 13% of Fossil Fuel Consumption is being achieved and a similar reduction of 13% in term of Global Warming Potential. The study has shown that Cedar wood as a cladding system displayed the lowest value in term of consumption of Fossil Fuel the Cedar wall system during 60, 80 and 120 years compared to the base case and Stucco. As seen in the study when LCA is implemented, higher standards of sustainability can be achieved. Hence, this paper demonstrates the importance of integrating the LCA tool in the LEED rating system in order to accurately evaluate green buildings.

6. The importance of including LCA in the LEED rating system

This study shows clearly that LCA is an added value to the rating system. It has been shown in this analysis that when LCA is implemented the results will considerably enhance the sustainability assessment of buildings.

7. Need to develop similar LCA programs adaptable to different contexts

Furthermore the analysis shows the importance of LCA as a measuring tool to evaluate building in terms of sustainability. ATHENA software can be customized to different environments and many countries are already adopting it. Similar software should be considered for assessing the environmental impacts of building to different context. Further research in the area of LAC is also required as well as construction companies need to be more proactive in sharing their data.

8. Limitations of Athena Impact Estimator:

- Database is very limited and software needs to be more flexible with options and Inputs.

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