Available Online at http://www.recentscientific.com

CODEN: IJRSFP (USA)

International Journal of Recent Scientific Research
Vol. 8, Issue, 6, pp. 17288-17292, June, 2017

ISSN: 0976-3031

International Journal of Recent Scientific Research

DOI: 10.24327/IJRSR

Research Article

PARAMETRIC ANALYSIS FOR COMPARABLE APPROACHES TO ACHIEVE SUSTAINABILITY RATING CREDITS USING LCA

*Attallah S[1]., Davison C[2] and Hassan M[3]

[1,2]Technology Department, Ball State University, Indiana, USA
[3]School of Civil Engineering, Purdue University, Indiana, USA

DOI: http://dx.doi.org/10.24327/ijrsr.2017.0806.0323

ARTICLE INFO

Article History:

Received 05th March, 2017
Received in revised form 21st April, 2017
Accepted 06th May, 2017
Published online 28th June, 2017

Key Words:

Sustainability-Life Cycle Analysis-Parametric Analysis-Rating Systems-Green Construction

ABSTRACT

The construction industry has a significant negative impact on resource consumption and the environment. To reduce this effect, sustainability rating systems like Leadership on Energy and Environmental Design (LEED) have been introduced to evaluate the performance of buildings from sustainability perspective. This evaluation is carried through a merit/credit system where each credit addresses a specific sustainability concern and is assigned a certain weight. Although newer versions of these rating systems have included some points that adopt the concept of life cycle analysis (LCA), one further way to optimize utilization of credit systems is to perform an objective analysis of the credit weights through quantification of the potential positive impact associated with each credit. This study covers a simplified parametric analysis using an LCA technique to assess different approaches that can be pursued to achieve the target credits. The parametric analysis helps to identify the optimum approaches that, while achieving the target scores, lead to maximum saving of environmental impact.

INTRODUCTION

The construction industry is recognized to be one of the high contributors to the environmental issues facing human beings. A Plethora of reports and research papers have confirmed this fact. For example, the United Nations Environmental Program's revealed that construction industry consumes 40% of Europe's energy, in addition to being responsible for a large contribution to the greenhouse gases concentration in the United States (UNEP) (2002). Also, it has been reported that while sustainable energy practices have been implemented within the process of construction, almost three percent of total energy consumption in the United States is attributed to construction efforts (Sharrad *et al*., 2007). In an attempt to understand the environmental impacts and reduce this energy consumption, building sustainability rating systems have been established. Of particular interest is that of LEED, or Leadership in Energy and Environmental Design. A similar system is initiated in the state of Qatar for the purpose of serving the construction industry in the middle east areas under the name Qatar Sustainability Assessment System (QSAS). These rating systems, among others, have been established to provide standards of environmentally-friendly buildings, as well as to use credits that address specific environmental issues within construction projects. Furthermore, these credits are then comprised to form categories, in which subjective scores are given and summed to determine the various levels of certification that can be obtained (Kyrkou and Karthaus 2011). In essence, it provides a standard for determining a "green" target level for a building project.

While LEED and QSAS are established green-building rating systems that have not only gained prominence in the United States, its country of origin, and other various countries, there is always room to improve results. While LEED, QSAS and other rating systems are efficient in evaluating project design, it has been argued that they are somehow unable to effectively choose environmental friendly and optimal methods when constructing a building (Ding, 2008). To address this, the U.S. Green Building Council, which is the organization responsible for LEED, has implemented regional credits to address specific environmental issues that pertain to different areas in the country (Civil Engineering, 2009). With efforts such as these, as well as the utilization of Life Cycle Analysis (LCA), the methodology of LEED, QSAS and other rating systems that attempt to enhance the sustainability and environmental awareness of construction projects can improve. LCA is a methodology used to analyze the full impact of using a specific product or process on the environment. According to ISO standard 14040 issued by the International Standards

Corresponding author:* **Attallah S
Technology Department, Ball State University, Indiana, USA

Organizations (ISO 2006), the analysis takes into consideration the impact of all processes involved in the life cycle of such materials on the environment starting from extraction, through manufacturing, transportation, installation, operation until disposal. LC A closely examines each stage of the product, from the conception of the material to the disposal after a project is completed, displaying the evolution of the product throughout each cycle including the extraction, manufacturing, and use of construction materials; stages that can lead to a direct threat to the environment (Sy & Mascle, 2011). Pollution, destruction or eradication of natural habitats, and the depletion of natural resources are just a few of the consequences during construction projects (Lin *et al*. 2012). Using LCA for assessing comprehensive impacts in construction projects can enhance sustainable building processes and procedures. To do this, LCA follows a specific process that encompasses four stages. The first stage is that of the goal and scope definition phase, followed by inventory analysis, impact assessment, and interpretation. This comprehensive approach of LCA is vital in understanding the accurate and true impact that construction has on the environment (Lin *et al*., 2012).

Background

To understand how changing elements of a project design can have an impact on the environmental performance of a building, parametric analysis is necessary. By performing such analysis, it is possible to conduct comparison between the changes in design elements. Furthermore, each change within the project design can then be quantified in terms of its effectiveness by utilizing an objective scale such as LCA. Various changes in the design or the construction processes of a building project can lead to achieving the required scores in LEED or QSAS credits. Which approach will lead to optimal savings from an LCA perspective? This is the question that the authors of this research article are attempting to answer. LCA works well whenever there is a need to do carry out an objective quantifiable comparison either between alternative products, alternative methodologies or, as in this research, alternative approaches to achieve the same credit scoring in LEED or QSAS.

To effectively utilize LCA, analyzing the design and assessment manuals are the first step. In essence, this is done to understand the proposed enhancements that can increase sustainability in the design, and to understand how the scores are calculated for each particular project at hand. Therefore, the objective of this first step is to fully grasp the sustainability approach in a design, as well as understanding how the target scores for achieving credits are calculated. Following this analysis, the project parameters that need to be altered must be addressed in order to achieve the target score. Identifying these project parameters is a critical step, as it is crucial to understand what elements of the design need to be addressed and changed. Following the above methodology, the identified project parameters are then converted into inventory data in order to quantify the LCA impacts. By transforming the parameters into saved inventory, an LCA impact assessment can then occur, quantifying the reduced impact of the saved inventory. This LCA assessment relays information about how the changes in the project parameters have impacted the environment. Impact categories are compiled as a result of the identified saved inventory, which are then translated into the LCA single score to understand the changes that took place within the project. Figure 1 is an illustration of this methodology.

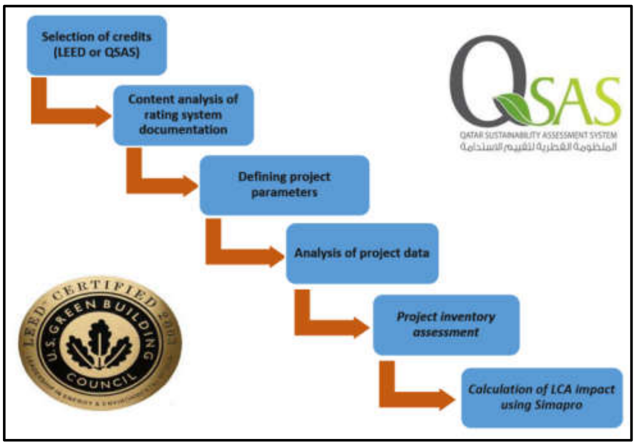

Figure 1 LCA Assessment Methedology for Credits of rating Systems

As LCA is used to understand the evolution of a project element and its environmental impact through the implementation of a project, parametric analysis can be vital in assessing optimal design methods in an effort to produce sustainable buildings. This study sought to understand how identifying and altering specific project parameters influence energy consumption and thus, environmental impacts through an LCA perspective. Using parametric analysis, five various elements within a project design were altered in an attempt to understand how target scores can still be achieved by utilizing a different approach. In an effort to understand the comprehensive (life cycle) consequences of these parameter changes, energy consumption was assessed prior to and after the changes were made in the sample building of the design. Specifically, the parameters that were assessed comprised the following; set thermostat temperature, glazing system for windows, roof specifications in relation to insulation, and the efficiency of the HVAC system. The following sections of the paper provide details on the methodology adopted, the results along with discussion and recommendations based on the findings.

METHODOLOGY AND RESULTS

As illustrated in the developed LCA evaluation methodology, the target score for each credit in any of the target sustainability rating systems can be achieved through different approaches. More specifics are detailed by Attallah *et al*. (2013). Different changes to the baseline design or construction plans could lead to the same score for a specific credit. This is detailed in the design guideline manual of the target rating system. The design manual includes a list of the ideas that can be introduced to reduce the environmental impact of the project element that is under consideration. These ideas, although they lead to similar score, are different in nature and involve different materials and construction methods. Therefore, from a life cycle analysis perspective, these various changes lead to different reduced environmental impact. The objective here is to conduct parametric analysis to identify the differential reduced impact of the different introduced changes that lead to similar accreditation using the developed LCA evaluation methodology.

The objective is to measure how sensitive the actual potential reduced impact to changes of approaches that achieve the same or similar scores within the same credit. This can help in two ways. First, within the accreditation process for any given credits, the assessment methodology may possibly be reconsidered to reflect the actual impact of different approaches. Second, it can also assist stakeholders to optimize sustainable performance of the project through selection of the approaches that lead to maximum reduced impact and still achieve the same scores for accreditation purposes. The study presented in this paper was done on selected QSAS credits. The same methodology can be applied to LEED credits or any similar rating system. In this study, energy credits 1 and 2 in QSAS were selected to conduct the target analysis andwill be explained in the following subsections.

Identification of comparable approaches under selected credits

The first step here is to identify the comparable approaches through due investigation of the design and assessment manuals. The design manuals are the first documents to be investigated as they provide details of the ideas that can be introduced to achieve scores for different credits. QSAS energy guidelines, which is the equivalent design manual for the energy category. For the purpose of this analysis, credits 1 and 2 in the energy category were investigated to identify the possible comparable introduced changes to achieve similar scores. The following changes were identified:

1. Change of technical specifications of the roofing system to introduce better insulation system and therefore increasing the resistance (R-Values) or decreasing the U-values, which the rate of heat flow through the installed system.
2. Change of the HVAC system to improve efficiency and reduce electrical consumption.
3. Change of the thermostat set temperature, which affects the load on HVAC systems.
4. Change of glazing system of windows.

The above selected approaches will serve to achieve the same objectives for credits energy 1 and 2. However, the objective here is to explore which approach provides optimum reduction of the environmental impact.

Measuring achieved scores through QSAS system

A sample building was chosen to use actual numbers for the changed parameters through a QSAS assessment system. For the purpose of the presented parametric analysis, a simple one floor building without internal partitions was selected. Then, for each of the chosen aforementioned four parameters, a change in the design was introduced. First, a poor performance parameter was entered to QSAS calculation sheets to calculate the score for the credit, which is recorded. Second, this parameter is changed to represent a better performance and the score for the credit, which is a better score in this instance, is also recorded for analysis purpose. Figure 2 shows a sample of the QSAS calculation sheets, which are used to calculate the score for credits. This case is the energy credits sheet where different dropdown menus are available for the user to select the applicable choice. The calculator file, as shown, includes one sheet for the choices, another sheet for the guidance, and sheets for the assessment methods and the final score achieved based on the choices made.

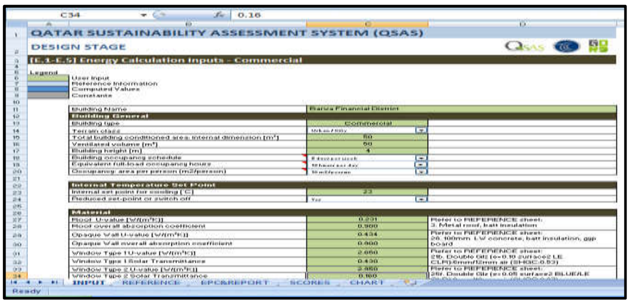

Figure 2 QSAS Assessment Sheet for Energy Credits

Table 1 shows the output of this step where the initial choices are shown with their associated scores and also the introduced changes are listed with their associated new score. The score here is in terms of Energy Performance Calculator (EPC), which is explained as the ratio between the design value for energy consumption and the reference (target) value. The lower this value is, the closer the design is to the reference or optimum design. The last column shows the improved EPC, which is required for conducting the parametric analysis.

Table 1 Gained Credits for Different Approaches in QSAS

Changed Parameter in QSAS Calculator	From		To		Achieved Improvement (EPC scale)
	Initial System	EPC	Improved System	EPC	
Roofing material (better insulation)	Membrane on Metal Deck (0.452 U-Value)	193	Wood Shingles, batt insulation with Gypsum board (0.231 U-Value)	189	4
Efficiency of HVAC system (EER Value)	2.8 (combined factors)	167	5.9 (combined factors)	115	52
Thermostat Set Temperature	22 C	218	23 C	211	7
Glazing	Single clear glazing 3 mm	270	Double glazing with 6 mm air	211	59

LCA evaluation of the introduced changes

To measure the differential effect of the aforementioned changes from an LCA perspective, eQUEST, an energy modeling software, is introduced to simulate the energy consumption of the sample building based on the initial conditions and again after the introduced changes. This software is used to analyze the overall energy consumption in terms of consumed electricity and natural gas for the subject building. To begin, the first building information is fed to the software. Then, for each of the 4 elements, the initial conditions are fed to the system and a simulation is run to calculate the annual consumed electricity and natural gas. Figure 3and Tables 2 and 3show samples of the output of the simulation which includes annual consumed electricity and natural gas for the selected sample building. The total annual electrical consumption in KWH and total gas consumption in BTU are shown at the bottom of each of the consumption tables.

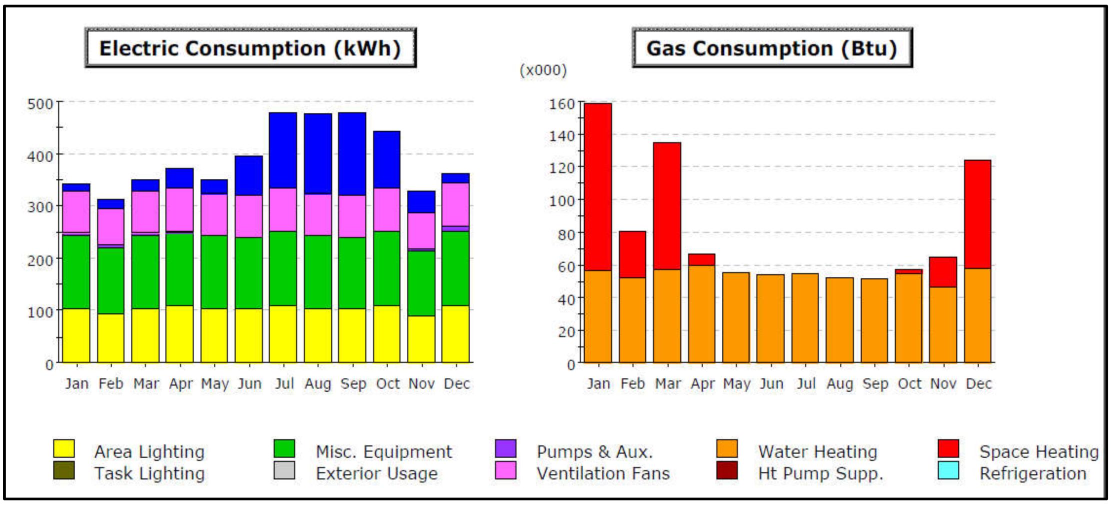

Figure 0 Annual Electricity and Gas Consumption - eQUEST Output

Table 2 Detailed Monthly Electrical Consumption (KWH) - eQUEST Output

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
SpaceCool	12	17	21	38	2	76	143	154	160	108	41	19	819
Vent. Fans	79	71	79	83	79	79	83	79	79	83	68	83	948
Pumps&Aux.	7	5	6	1	1	-	-	-	-	0	3	10	32
Misc. Equip.	139	126	139	141	139	137	143	139	137	143	126	143	1649
Area Lights	104	94	104	109	104	104	109	104	104	109	90	109	1246
Total	342	314	349	373	350	397	478	477	480	443	328	363	4694

Table 0 Detailed Monthly Gas Consumption (Btu) - eQUEST Output

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
SpaceHeat	103	29	78	7	-	-	-	-	-	2	18	67	303
HotWater	57	52	57	59	55	54	55	52	52	55	47	58	653
Total	159	81	135	67	55	54	55	52	52	57	65	125	956

Upon simulation, based on the initial conditions stated for each of the 4 parameters, each parameter is changed to reflect the improved conditions based on the change introduced in QSAS calculation sheet. Then, the model is run for the new conditions and annual consumptions are recorded for analysis purposes. Table 3 shows results of simulations based on the initial and improved conditions. The difference between initial and improved conditions for each parameter is the inventory that is analyzed through LCA software, in this case SimaPro, as explained in the LCA evaluation methodology. SimaPro is simply used here to calculate the saved environmental impact resulting from moving from the baseline design to the improved design conditions.

The input to the software will be the saved inventory and the output would be the saved impact under the LCA impact categories, which can be weighted and summed in one single score. The last column of Table 3 shows the LCA single score corresponding to the saved environmental impact. The LCA single score is the final step of the analysis where the results in all impact categories are weighted accordingly and combined based on these relative weights to be presented in the form of one number.

Based on the results of the aforementioned steps, there is possibility to compare the actual contribution of the different comparable approaches, which achieve similar scores, with the corresponding contribution for certification.

Table 0 Performance of Improved Systems - eQUEST Output

Changed Parameter in eQUEST	**From**		**To**		**Saved Inventory**	**Achieved LCA improvement (Single Score)**
	Initial System	**Energy (kwh)** **Gas (1000 Btu)**	**Improved System**	**Energy (kwh)** **Gas (1000 Btu)**	**Energy (kwh)** **Gas (1000 Btu)**	
Roofing material (better insulation)	metal frame with 1" Polystyrene	5,025 914	Wooden frame with R60 batt + 6" polystyrene	5,025 907	0 7	0.02
Efficiency of HVAC system (EER Value)	2.8 (combined factors)	8,170 802	5.9 (combined factors)	6,042 802	2,128 0	80.39
Set Temperature	22 C	10,840 839	23 C	9,470 827	1,370 12	51.80
Glazing	Single Glazing 1/8" air	5,269 844 828	Double glazing 1/4" air	5,170 802 819	99 42 9	3.88

Table 4 shows normalization of the actual improvement or potential reduction of environmental impact for every 100 points improvement of on the scale of credits 1 and 2 of the energy category according to QSAS system.

Table 5 Normalized LCA Score for 100 QSAS points

Changed Parameter in QSAS Calculator	Achieved Improvement (QSAS - EPC scale)	Achieved LCA improvement (Single Score)	Normalized LCA score for 100 points QSAS scale
Roofing material (better insulation)	4	0.02	1
Efficiency of HVAC system (EER Value)	52	80.39	155
Set Temperature	7	51.80	740
Glazing	59	3.88	7

The normalized figures shown in Table 4 enable easy interpretation of the results of this parametric analysis where the higher numbers at the last column represent the most efficient approaches from an LCA perspective compared to how they are perceived by the QSAS credit scale.

DISCUSSION AND CONCLUSION

The presented research is a trial to evaluate comparable approaches to achieve certification under rating systems using LCA technique. Several comments can be drawn based on the presented results:

1. There are considerable differences in the estimated actual saved impact for the same achieved score through implementing the above comparable approaches for credits 1 and 2 in the energy category. This illustrates that some of these approaches are, in fact, very efficient in saving environmental impact compared to other approaches.
2. Changing the set temperature by only one degree Celsius is very effective as it affects the operation of the HVAC system, which is a major consumer of the electrical power in a construction project. This result could lead to more serious consideration of limiting the control of thermostat set temperature especially in work environment.
3. The results of glazing could be much improved in case of bigger areas or higher percentages of the envelope system.
4. The LCA evaluation methodology could possibly be used in supporting decision-making at a very detailed level of choosing approaches in the same credit.

The above proposed method provides an objective quantifiable way to compare different approaches that can be pursued in building design to achieve the same scoring for rating system credits from an LCA perspective.

This comparison enables the decision makers at a project level, be it the owner or the architect, to make choices that will optimize the reduction of the environmental impact associated with the project.

One main limitation in this context would be not taking the cost implication of the different approaches into consideration. A highly recommended future research effort is combining the environmental impact and the cost associated with alternative approaches.

References

Attallah, S., Senouci, A., Kandil, A., & Al-Derham, H. (2013). Utilization of life-cycle analysis to evaluate sustainability rating systems for construction projects with a case study on Qatar Sustainability Assessment System (QSAS). Smart and Sustainable Built Environment, 2(3), 272-287.Ding, G. (2008). Sustainable construction-The role of environmental assessment tools. *Journal of Environmental Management*, 86(3), 451-464.

International Standardization Organization (ISO). (2006). ISO 14040 - Second Edition, Environmental Management- Life Cycle Assessment-Principles and Framework.

Kyrkou, D. and Karthaus, R. (2011). Urban sustainability standards: predetermined checklists or adaptable frameworks? Procedia Engineering, 21, 204-211.

Lin, K. Y., Levan, A., &Dossick, C. S. (2012). Teaching life-cycle thinking in construction materials and methods: Evaluation of and deployment strategies for life-cycle assessment in construction engineering and management education. *Journal of Professional Issues in Engineering Education & Practice*, 138(3), 163-170.

Pérez-Lombard, L., Ortiz, J., & Pout, C. (2008). A review on buildings energy consumption information. *Energy and buildings*, 40(3), 394-398.

Regional Credits Included in New LEED Program. (2009). *Civil Engineering* (08857024), 79(6), 33.

Sharrard, A., Matthews, H., and Roth, M. (2007). Environmental implications of construction site energy use and electricity generation. *Journal of Construction Engineering and Management*, 133(11), 846.

Sy, M., &Mascle, C. (2011). Product design analysis based on life cycle features. *Journal of Engineering Design*, 22(6), 387-406.

United Nations Environmental Program (UNEP). (2002). Industry as a partner for sustainable development. United Nations Environmental Program publications and reports, Brussels, Belgium.

How to cite this article:

Attallah S *et al.*2017, Parametric Analysis for Comparable Approaches To Achieve Sustainability Rating Credits using LCA. *Int J Recent Sci Res.* 8(6), pp. 17288-17292. DOI: http://dx.doi.org/10.24327/ijrsr.2017.0806.0323

****