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Life-cycle analysis as an indicator for impact assessment in sustainable building certification systems: the case of Swedish building market

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Abstract

This paper assesses the prevailing sustainable building certification systems in Sweden, based on a critical analysis of their characterization for human and environmental impacts through the integration of life-cycle analysis. The aim of this study is to compare sustainable building certifications systems in terms of their assessment categories. In the Swedish market, BREEAM SE, LEED, Green Buildings and Miljöbyggnad are the most used building certifications. Therefore, their guidelines are reviewed to evaluate which of them has comprehensively included human health indicators. This research presents useful information for transforming existing and developing future sustainable building certification systems.

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Keywords: BREEAM SE; LEED; green buildings; Miljöbyggnad; LCA; human health indicators

1. Introduction

Even though sustainability and efficient usage of resources are the targets of building certification tools, few of their criteria include human toxicity and the risks to human health due to building materials. In Sweden, in 1993,
Boverket has developed 6 environmental indicators to measure the environmental impact between 1993-2007 that also include a human health factor [1]. These indicators are based on Life Cycle Analysis (LCA) approach, which considers the environmental impacts of production, the use of product and the disposal of the product [1]. These indicators are energy use emissions of greenhouse gases, nitrogen oxides, atmospheric particles, in addition to waste generation and health endangering chemical products [1]. These indicating components used in construction have an impact on people inhabiting the building. LCA studies provide a step-by-step process definition of a construction and the relationship between process steps that have effects on human body and environment. LCA studies consider the long-lasting impact of chemicals and emissions by scoring the chemical impact using weighting as a pre-study before a construction starts. The selected impact categories and weighting scores are based on the priority to select material and define processes by the construction company or building owner. Therefore, using LCA before construction starts, provides opportunities to reduce or mitigate waste. Pollutants released from the waste of construction material that lead to production of chemicals that endanger human health. The waste management plan plays a crucial role in LCA to reduce environmental impacts of pollutants that negatively impact air and water quality. The endangering happens when pollutants impact air and chemicals impact water sources. Both pollutants and chemicals in air as well as water impact and endanger human health [2].

By probing the impacts of waste, the types of endangering chemicals are clarified in this study. Water contaminating materials release endangering chemicals that include ammonia, sulfur dioxide and nitrogen oxide. These substances cause eutrophication and acidification [3]. First, eutrophication causes water sources leading to the increase of algae that hinders sunlight. Then, the increased algae cause green habitat species to die [3]. Second, acidification causes pollution in forests, fresh water sources and soil. Acidification is experienced by acid rains and leads to contamination of soil [3]. Second, acidification causes pollution in forests, fresh water sources and soil. Acidification is experienced by acid rains and leads to contamination of soil [3]. To mitigate these negative effects, LCA is a useful tool to assume the possible harmful chemicals in material selection phase. In addition, the usage of LCA before construction begins helps to plan the treatment of waste. Also, waste can be used as a resource for heating or recycling instead of allowing waste to be hazardous to the environment. For example, during the material selection stage of plans, selecting materials such as plastic, wood, carpet, metal and steel products that are recyclable help reduce waste created during construction. The aim of this study is to compare the existing sustainable building certification systems in terms of their usage of LCA in their assessment categories in Swedish construction. The comparison presents an understanding of which certification system has comprehensively included human health indicators. To achieve this aim, this study critically analyses the categories connected to human health in sustainable building certification systems implemented in the Swedish building market. Data is collected from literature reviews of scientific articles and Swedish building regulations. Articles pertaining to human health endangering products that are considered in sustainable building certification systems (BREEAM SE, LEED and Miljöbyggnad) were analyzed and compared to point out the distribution credits related to LCA.

Several articles [4, 5] have been written regarding the usage of LCA for building construction projects; many of them highlight the benefits of LCA. The integration of LCA in building certification tools began in the USA to provide building materials that are environmentally friendly and to assess approximate payback time in 1992 [4]. LCA was used due to the high amount of consumption by involved with building construction in the USA. Todd [4] finds that, more than 30% of consumption of resources and contamination of natural sources is related to emission of solid waste and pollution. The mortality rates due to air pollution is approximately 11% globally and diagnosed as pneumonia and tuberculosis each year [4]. Todd [4] gives facts from US building market, which has the highest usage number of LEED and BREEAM certified buildings. Three main principles are listed to integrate LCA in these building projects to select the suitable construction materials [4] The principles are the optimization and evaluation of environmental footprints involved in building construction, evaluation of material impacts on human health and environment during the life cycle of building; as well as comparison of the payback periods of materials. Todd ’s [4] study effectively presents an overall picture of using of LCA and facts in USA, but there is no information about Sweden. Mattoni, et al. [6] argue that, most sustainable building rating tools lack indicators to assess the sustainable performance of building envelopes such as material and economic efficiency and indicators based on life time parameters (life cycle cost, embodied energy etc.). Thus, there is the need to identify and implement more sustainability indicators that can be adjusted for unique building environments. Since the existing
indicators are not enough to make them adaptable for different local situations according to given credits and weights. Adjustable sustainable building rating tools align with the definition of “global” sustainability concept recognized internationally, simultaneously providing a means to assess sustainability performance at a “local” level [6]. The study of Mattoni, et al. [6] explain the issue in more detail, even though the study does not have validation linked to a case study. Humbert, et al. [5] compare the necessary requirements of LCA with LEED indicators to understand which requirements are most effective. The listed requirements to have LEED certification system were used for a building project in Emeryville, California, USA. The researchers included the LEED requirement components of the building footprint, materials, transportation, electricity, water, natural gas usage and the discharged waste. In addition, the LCA indicators that they compared were human health, ecosystem quality, climate change and resource consumption [5]. The commuting of employees by vehicles and use of electricity have more impacts on the environment than the used building materials [6]. Due to low heating demand in Emeryville, California, most of heating provided from electricity, which does not release solid waste, lead to pollution or water contamination. Therefore, the usage of electricity does not impact the environment in all categories [5]. If the same analysis was done in Sweden for example, the results would be very different. Project location and local sources are important components to analyze environmental impacts [5]. Due to geographical differences, the credits of LEED which have high LEED scores, for example reduction of water, land use and recycling are not always accurate [5]. On the other hand, the goals to achieve high LEED scores for example with the production of green electricity by renewable energy technologies, reduction in commuting and energy consumption as well as recycling waste were found useful [5]. Their study was found a useful source for this paper in terms of their comparison of requirements in LCA and LEED to comprehend their necessity to achieve sustainability. LCA analysis has been adapted to some of the building certification tools in Sweden. As mentioned above, LEED and BREEAM SE have certification indicators for waste treatment in LCA. In addition to LEED and BREEAM SE, Miljöbyggnad, a national sustainable building certification tool in Sweden, has an assessment criterion of harmful effects of chemical components in materials, which might damage human health. Another building certification tool called Green Buildings require only 25% reduction in energy demand. There are no other categories related to LCA for human health; therefore, Green Buildings certification tool is eliminated from the analysis in this paper. LEED and BREEAM SE systems have more similarities due to having similar categories. One difference of BREEAM SE is that, it has been adapted to the Swedish market and is based on country specific building codes and policies, which considers waste. However, LEED is usually selected to be used by large Swedish companies, which often have international construction activities and prefer the same certification in all their buildings, since LEED is known internationally.

This study starts with the explanation of the usage of LCA in building certification systems from recent academic research studies. It further continues with a critical discussion of a comparison of sustainable building certification systems. The results of this paper finally bring a focus to methods of waste treatment to cope with health endangering chemical products, a component of LCA. The discussion presents useful information about the usage of LCA in existing sustainable building certification tools in Sweden. The paper concludes by enhancing the need to identify unique variables of locations and environmental contexts of building sites in order to evaluate accurate environmental building certification scores.

2. Research method

This literature review uses data gathered from Swedish Environment Protection Agency regulations, Code of Statutes of the Swedish National Board of Housing, Building and Planning, as well as the guidelines of four building certification tools called BREEAM SE, Green Building, LEED and Miljöbyggnad. The literature review analyzed key words contained in the guidelines of building certification systems: “human toxicity”, “eutrophication”, “acidification”, “materials”, “waste”, “products”, and “human health” as found in the reports of Boverket, the Swedish Environment Protection Agency and building certification tools. The reports analyzed are the “Boverket’s building regulations – mandatory provisions and general recommendations, BBR” [7] and the Swedish Environment Protection Agency called “From waste management to resource efficiency, Sweden's Waste Plan 2012–2017” [8].
3. The usage of LCA in sustainable building certification tools to mitigate human health damages

BREEAM SE and LEED assessment systems include an evaluation of indoor comfort through an assessment of how daylight is utilized, and heating-cooling systems are used by occupants. Amount and use of daylight and occupant behavior are not analyzed in LCA [4]. Different from this, LCA the impact of chemicals by their amount of usage during the life cycle of a building. This is done in LCA by defining the raw materials, their chemical components and their impacts considering ISO dataset. Two kinds of approaches have been used in sustainable building certification tools; multi-criteria credit system and synthetic environmental indicators by using LCA [9]. A multi-criteria credit system of scores are measured with appropriate weighting scales in various environmental aspects for each component [6]. Usually, sustainable building certification tools use multi-criteria credit system [9]. The second approach is synthetic environmental indicators and their effects on environment due to ISO impact categories, connected to LCA [9].

First usage of LCA in sustainable building certification tools were conducted in 2008 by BREEAM SE, to analyze the level of released chemicals in water to determine possible harm to environment and human health. BREEAM SE assessment also covers climate change factors during the life cycle of a building. Between 2008 and 2011, almost 1500 different types of construction materials and their chemical components were analyzed by BREEAM SE, in terms of their dangerous components to people and the environment [4]. LEED placed importance of recycling opportunities to reduce or mitigate waste in building sites since the 2009, instead of focusing on chemicals [4]. However, in 2012, LEED developed another assessment criteria which considered chemicals and their impacts not only on human health and environment, but also on animal habitat and biodiversity [4]. That’s why LEED has a category called materials and resources that evaluates heat island effects, thermal comfort and occupant behavior [9]. Also, LEED included another criteria, indoor environmental quality, to evaluate indoor human comfort in 2009 [9]. Subsequently, LEED developed a sustainable sites category to rate the level of pollution due to transport and waste emission in 2009 [9]. A human health and wellbeing category was added by BREEAM SE later, in 2011. Also, BREEAM SE puts higher weight per credit scores to waste management by 7.5 % credits, and 13% for materials and resources than LEED [6]. The same components are graded with 10% by LEED [6]. Miljöbyggnad gives credit to materials and chemicals criteria, which assesses their impact on human health [10]. After the review of certification guidelines listed above, it is understood that BREEAM SE focuses more on health and well-being by a score of 15% [10]. Also, LCA criteria is comprehensively used in BREEAM SE [6]. To sum up, BREEAM SE has a comprehensive understanding of both used material and waste impacts on human health. The following table compares the four building certification systems in terms of their indicators, weighting, score and typical costs. There is no standardized methodology for comparing the different categories, as each system weights the indicators on their own accord.

Table 1 Comparison of four building rating systems (adapted from the study of Aulin and Elland [10]).

<table>
<thead>
<tr>
<th>Factors</th>
<th>BREEAM</th>
<th>LEED</th>
<th>Miljöbyggnad</th>
<th>Green Building</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scoring Indicators</td>
<td>Energy 19%</td>
<td>Energy 37p</td>
<td>Energy Indoor climate</td>
<td>Energy 100%</td>
</tr>
<tr>
<td></td>
<td>Health/ well-being 15%</td>
<td>Material &amp; resources 13p</td>
<td>Indoor climate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Material 12.5%</td>
<td>Indoor climate 12p</td>
<td>Material and chemical</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Management 12%</td>
<td>Water 10p</td>
<td>Special environmental</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Land use &amp; ecology 10%</td>
<td>Bonus</td>
<td>requirement</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pollution 10%</td>
<td>Design Innovation 6p</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Transport 8%</td>
<td>Regional priority 4p</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Waste 7.5%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Water 6%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Innovation (bonus) 10%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grades</td>
<td>Pass</td>
<td>Certified</td>
<td>Bronze</td>
<td>No grades, rating is based</td>
</tr>
<tr>
<td></td>
<td>Good</td>
<td>Silver</td>
<td>Silver</td>
<td>on the capability to reduce</td>
</tr>
<tr>
<td></td>
<td>Very good</td>
<td>Gold</td>
<td>Gold</td>
<td>energy usage by 25%</td>
</tr>
<tr>
<td></td>
<td>Excellent</td>
<td>Platinum</td>
<td></td>
<td>against the energy</td>
</tr>
<tr>
<td></td>
<td>Outstanding</td>
<td></td>
<td></td>
<td>declaration or BBR</td>
</tr>
<tr>
<td>Costs</td>
<td>Ca 750,000+ SEK</td>
<td>Ca 750,000+ SEK</td>
<td>Ca 100,000-250,000 SEK</td>
<td>Ca 0-100,000 SEK</td>
</tr>
<tr>
<td>LCA</td>
<td>Mentioned</td>
<td>Mentioned</td>
<td>Mentioned</td>
<td>Not mentioned</td>
</tr>
</tbody>
</table>
4. A critical discussion of point systems in building certification tools for waste treatment

One of the main critics of the certification systems such as LEEDS or BREEAM SE, are their point-based systems. The criteria of LEED and BREEAM SE are all important, but they are weighted with unequal significance in some cases. This creates a tendency to chase points in easy criteria to get the maximum score possible, potentially overcoming lower scores in difficult criteria. Therefore, the pointing system creates conflicts when trying to integrate mutually exclusive systems just to gain points from the different indicator categories. Point chasing mentality also hinders innovation by only putting importance on specific scoring indicators. For example, constructors focus on reaching the established level determined by the certificates, in contrast of going beyond that such as using an experimental method. 150,000 companies and organizations developed and updated technical criteria of LEED by evaluating buildings to receive LEED certificate [4]. However, sustainable building certification tools lack understanding of local characteristics of different contexts since they use general criteria. For example, LEED in Sweden makes a poor attempt to adjust national adaptations, such as giving scores to district heating.

3.1. National regulations for waste treatment in Sweden

In Sweden, 83% of waste is discharged from mining, the remaining waste is generated from pulp and paper production; energy, water and construction sectors; and from households. Municipalities are responsible to allocate and manage household waste [8]. Building regulations of Sweden requires each neighborhood or adjacent neighborhood to reserve a place for gathering waste. According to municipality there shall be spaces or installations for the handling of waste near or adjacent to a building that can be used by all users of each neighborhood [7]. The majority of waste gathered from households includes paper, plastic and textiles, which provides a potential for reuse and recycle to reduce greenhouse gas. Due to the recycling efforts of waste in Sweden, the rate of disposal of household waste by landfilling in sites quickly reduced more than other European countries [3]. The majority of waste generated from road construction. The recycling of construction waste does not lead to pollutions that risk human health in Sweden [2]. Environmental protection agency is working to develop a strategy for “a toxin-free environment” to reduce the impacts of waste on human health and environment. The plan is to increase landfill taxes to reduce landfill waste. This plan encourages reusing and recycling waste materials from households, industry and construction sectors [7].

In addition, to mitigate damages of waste to human health, The Swedish Environmental Protection Agency (EPA) has established rules and routines to deal with hazardous waste. The requirements of EPA guide producers to take some responsibility. EPA has a number of priority areas where action is still needed, such as the waste management in construction and engineering sector, household waste, management, resource efficiency in the food-chain waste treatment and illegal export of waste. EPA plans to increase the reuse, recycling and material utilization of non-hazardous construction and demolition waste from 50 to 70 percent by 2020 [8]. The Swedish National Board of Housing’s (Boverket) building construction regulations provide general guidelines in terms of material and product selection relevant to the building requirements, and economically reasonable working life. However, there are no specific guidelines for material selection, human health impact or waste disposal from an LCA perspective [7]. The structure and the hierarchy of these guidelines, rules and objectives vary from national, regional to the local level. In some cases, local rules complement each other but they do not establish a clear and specific guideline to the main actors in the building construction sector. Therefore, the building certification tools may fill the gap between the unclear regulations and building during local implementation. Small actors in building sector who are environmentally conscious play an important role in the development of sustainable frameworks in the construction industry, especially for renovation purposes. To sum up, the country level projections to mitigate the harmful effects of waste have already been developed by EPA, which have more comprehensive rules than BREEAM SE and LEED, while Boverket’s building codes do not have strict rules for waste management for local implementation.
5. Conclusion

A rigorous and trusted certification method should not be profit oriented. Sweden has examples of business models ran by the state that focuses on the citizens’ benefits. A certification system should work in line with this type of model. A building certification system should also be inclusive of cooperation between academia and businesses, as both institutions have in their best interest for a mutual collaboration in the development of sustainable materials, methods and technologies. There should be a constant dialog and updates about the direction towards where the construction industry should lead. The national Swedish building assessment tool very generally considers LCA. However, waste should be managed by an unbiased third party, preferably a public organization like Boverket. A municipality requirement for all companies to conduct an assessment by providing a free access LCA tool with an updated database would be a good and efficient way to improve scores achieved through credential systems. The environmental impact of building materials on human health should also be a critical part of assessment. Furthermore, new waste disposal methods could be encouraged by extra points. Finally, each project should be considered according to its unique contexts of location, local resources, as well as other variables and building objectives to be accomplished.

References