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The Use and The Need of LCA Automatisation in Building Certification

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The thesis discusses the state of the construction sector Life Cycle Assessment (LCA) automatisation from the client's (e.g. designer, subcontractor) perspective. The main purpose was to investigate the use and the need of a sertain software tool that different companies use in different countries in order to maximize the environmental performance of a building. The questionnaire was sent to different professionals working in the construction sector, and who potentially are working with certifying the buildings (BREEAM, LEED).

The main focus with the questions was very practical and considered how the users felt using the LCA software tools in general. The questions covered basically the user history and future prospects of an LCA for the target audience – if they had ever been involved in an LCA process, if they think that they would be, and possibly how many times in the following year. The questionnaire also covered questions of the felt need of the LCA – whether it was considered beneficial to use LCA to achieve the desired sustainability or other goals or not. The questionnaire reached an answer return rate of 5%, thus one must be critical when interpreting the results.

Keywords	

1 Introduction

Sustainability in the construction industry is constantly increasing it's share in the business strategies of different construction companies, and the companies working in the construction sector. Companies more and more want to optimize their environmental performance and energy efficiency during the whole life cycle of the building, and one way to reach these goals is to perform a life cycle assessment (LCA) for a building.

There are various needs and demands associated with improving the environmental performance of a building coming from the clients and regulators, that need to be answered. Performing an LCA helps to meet these constantly rising demands by increasing transparency and the overall environmental performance. LCA is a tool that helps the designers or sub-contractors to improve and make the right material and technological choices when designing or refurbishing a building in order to optimize the energy efficiency throughout the building's lifetime in accordance with the ISO standard. With an LCA it is easier to optimize the energy efficiency and different resources in order to reduce costs.

There are different kinds of life cycle assessment tools in the market. These are softwares, that perform the life cycle assessment efficiently without the need of collecting the data and perform the calculations and analyses' yourself. The softwares are used by different design- and construction companies, who are working in the construction sector and seeking to develop a sustainable product portfolio in order to gain competitive advantage in opposition to their competitors. Using the software it is faster and easier to build a functional sustainable strategy and meet the desired sustainability targets.

This theory part of this thesis covers the concepts of Life Cycle Assessment for Construction and two of the market leaders in building certification, being BREEAM and LEED. It also briefly discusses the categories that are important to consider when designing an energy efficient and sustainable building, and the concept of sustainability. However, the main focus is on the performed thesis questionnaire that was conducted in order to receive information on how the users of a certain LCA software tool experience the use of the software, and what possible improvements are to be made in order to optimize the product development associated with the software. The thesis questionnaire is covered in the Results chapter.

2 Theoretical Background

This chapter covers the fundamental concepts of sustainability related to buildings and construction. The chapter focuses mainly on energy related issues such as energy consumption and energy saving as a part of a fully functioning sustainable building. However, it is recommendable to notice the limitations with this approach, as the the building's energy efficiency is just one part of the life cycle assessment, which is the main subject of this thesis. The other aspects will be covered briefly later on in other chapters.

The term of sustainability has become rapidly increasing despite the fact that there is no officially accepted definition for it. In some parts of the globe the building sector has even been accused of *green washing*, and marketing buildings as sustainable without any reference for it, or in a confusing way. [1]

According to The United States Green Building Council's guide to LEED and Green Building, *green building* is a continual improvement process, which helps the building sector to create communities with more vitality, healthier indoor and outdoor spaces and developed connections to outdoors. [2] In addition to improving the quality of life in communities by sustainable construction, the building construction sector has a global responsibility on decreasing the greenhouse gas (GHG) emissions and energy consumption, as buildings are responsible for 40% of the energy consumption and 30% of the energy-related GHG -emissions. [3]

The building sector is also responsible of approximately 30% of the humanities resource consumption, such as fresh water usage, and producing solid waste. Urbanization constantly increasing, and the world's most populous countries continuously growing, sustainable construction plays an essential role in achieving the sustainable development goals 2020. [3]

The global use of the material resources has increased by 60% since 1980, reaching close to 63 billion metric tonnes (Gt) of materials harvested, extracted and consumed by the year 2008. One of the primary growth drivers for the increased demand of the material resources has been the demand for construction minerals. [4] The energy consumed per unit of floor space in green buildings is 24% lower than in typical buildings, states the study published by the New Building Institute [5] Green building is considered to be a strong brand of energy efficiency and energy saving. [8]

2.1 Sustainable Buildings

A sustainable building is a building that is a product of a *Green Building process*, where the created structures and processes are environmentally more responsible and resource-, and energy efficient compared to a classical reference building. This responsibility and efficiency can be considered throughout the building's whole life-cycle with the *cradle-to-grave principle.* The cradle-to-grave process refers to the whole lifetime of the building, including the siting and the design, construction, operation, maintenance, refurbishment and the deconstruction of the building. Sustainability in buildings can be considered as an expansion of the classical building designs, that focus on the economy, utility, durability and comfort. Sustainable building is also known namely as a high performance building or a green building. [10]

2.1.1 Energy Consumption and Energy Efficiency in Sustainable Buildings

The construction sector has a great responsibility on designing and constructing sustainable buildings for the modern and future society. In the European Union countries, buildings have 41% share in primary energy consumption, which includes both thermal energy and electricity consumption. In the USA, buildings have 40% share in primary energy use, and they account approximately 33% of the carbon emissions. The mentioned shares in this context do not include the emissions originating from building material extraction, transportation, processing or assembling.

The potential for reducing energy consumption and carbon emissions technologically wise in buildings is considerable.

The technologies used in energy production in the future are expected to be suitable for buildings with high energy efficiency as well as easily repairable and simple. These cleaner technologies are expected to reduce the used amount of environmentally unfriendly methods. It should be expected that the development of these energy production systems for sustainable buildings would include renewable energy sources for production, such as solar, waste and/or bioenergy. Electrical systems should be based on solar and wind systems and advanced energy storage technologies should be applied. The appliences should be integrated into buildings and in their structures.

2.2 Life Cycle Assessment

LCA (Life Cycle Assessment) is a process that can be applied to building construction and design. Energy modeling of a building is a tool that can predict and reduce the operational energy in buildings, when designed well. LCA is a tool of its own that guides different building professionals and architects to understand the energy use and also aknowledge other environmental impacts associates with all of the building life cycle phases. These phases include namely the “cradle-to-grave” phases, such as procurement of the construction materials, construction of the building, the building’s operation and the final decomissioning of the building.

LCA has been developed originally by chemical engineers, industrial ecologists and chemists who were seeking to reduce the impacts created in manufacturing and in process chemistry. Currently LCA is more promoted being a tool for environmental impact analysis for buildings and helping with the decision making in order to reduce these impacts.

When concidering the output of an LCA, it can be said to be a wide range environmental footprint of a building. It includes different aspects such as the energy use, the potential of global warming, resource depletion and greenhousegas and toxic emissions. LCA emphasizes the building components that are causing the highest environmental impacts, and if these impacts are coming primarily from the site selection or from the operation of the building. With the help of an LCA, the building designers can assess tradeoffs in the design phase, for example when choosing to use steel or concrete frame, or a stone veneer or clay mansonry. [13.]

The following screenshot (Picture 1) has been taken from Bionova Consulting's website and it shows the results report summary of an LCA for LEED (CML) / International, made with the LCA Software tool "One Click LCA":

LCA for LEED (CML)

For LEED 2009 and v4; CML version. The whole-building LCA option takes into account a wide range of effects. These include global warming potential, stratospheric ozone depletion, acidification of land and water sources, eutrophication, formation of tropospheric ozone, and depletion of nonrenewable energy sources. This is whole-building LCA in compliance with LEED New Construction v3/v2009 ((BD+C)): Pilot Credit MRpc63: Whole building life cycle assessment (1 points) and LEED v4 Full Reference Guide and credit MRc: Building Life-Cycle Impact Reduction. This LCA software and related datasets are fully compliant with ISO 14044. The impact assessment method used is CML version 2002 (November 2012, or later). This LCA methodology follows LEED requirements and this software is third party verified.

Whole-building Life Cycle Assessment, ISO 14040 & ISO 14044 (CML 2002; November 2012)

	Sector	Global warming kg CO2e	Ozone depletion potential kg CFC11e	Acidification kg SO2e	Eutrophication kg PO4e	Formation of ozone of lower atmosphere kg Ethenee	Depletion of nonrenewable energy MJ	
A1-A3	Construction Materials	1,34E6	1,36E-2	2,87E3	3,4E2	5,32E2	1,1E7	Details
A4	Transportation to site	1,79E4	3,53E-3	8,38E1	1,79E1	1,78E0	5,09E5	Details
B1-B3	Use, maintenance and repair	2,39E5	4,15E-2	3,95E2	1,27E2	1,77E1	3,51E6	Details
B4-B5	Material replacement and refurbishment	2,19E4	7,18E-5	3,08E1	4,89E0	3,74E0	9,4E4	Details
C1-C2	Deconstruction and transport	6,76E4	1,2E-2	1,61E2	4,92E1	5,29E0	1,24E6	Details
C3-C4	Deconstruction waste processing	2,39E4	5,34E-4	1,47E2	3,78E1	2,01E1	4,39E5	Details
	Total	**1,71E6**	**7,12E-2**	**3,69E3**	**5,76E2**	**5,81E2**	**1,68E7**	
		Show graph	Show graph	Show graph	Show graph	Show graph	Show graph	

Picture 1. http://www.oneclicklca.com/premium-leed-credits-with-one-click-lca/

Above in the Picture 1., one can see different Environmental Impact Categories that are "mappings from quantities of emissions to the environmental impacts that these emissions cause" [13]. Each of these categories are indicators of the contribution of a sertain product for a spesifically named environmental problem. The categories mentioned are defined by Life Cycle Impact Assessment methods that are described briefly below.

Global Warming Potential (GWP): GWP characterizes the change in the greenhouse effect due to emissions and absorptions. The unit for measurement is grams equivalent of Carbon Monoxide (CO_2) per functional unit of a product. It is important to understand that in this content CO_2 equivalent refers to an impact, not to an emission.

Ozone Depletion Potential: The unit of measurement for Ozone Depletion Potential is CFC-11 per functional unit of the product. This is a measurement for the impact caused by thinning ozone layer, the function of protecting the earth from a sertain part of the radiation spectrum. Emissions from sertain processes cause this layer to thin.

Euthrophication Potential (EP): Euthrophication means the addition of mineral nutries to the soil or water. In excess amounts, the extra nitrogen or phosphorous results in waters to increased biological oxygen demand (BOD). Euthrophication reduces ecological diversity by creating undesirable shifts in a number of species inside a spesific ecosystem. The unit of measurement is grams of nitrogen per functional unit of a product.

Fossil Fuel Depletion: The impact of nonrenawble energy is measured in mega joules (MJ) of fossil-based energy per functional unit of the product. It addresses the depletion aspect of fossil fuel extraction but excludes the extraction impacts. This category is helpful in demonstrating positive environmental goals, e.g. the energy reduction in the energy demand in production of a sertain product, or producing a product with energy coming from a renewable energy source.

Acidification Potential (AP): The two main compounds invloved in acidification are sulfur and nitrogen compounds. They reach the soil and water mainly by dissolution in rain. The unit of measurement for AP is grams of hydrogen ions per functional unit of product. [13]

There are different variants of LCA. The other primary mean of conducting an LCA is the Process-based LCA Method and the other one is an Economic Input-Output-Based LCA. In this thesis only the Process-Based LCA is under focus, as the construction industry’s

LCA’s are based primarily on that spesific process. [13] The Process-Based LCA Method the inputs, meaning materials and energy resources, and the outputs, meaning emissions and waste to the environment, are itemized for given steps, when producing a product. [14] See the different types of process-based LCA’s shortly explained below:

Cradle-to-Grave

This LCA type is the full Life Cycle Assessment starting from the manufacturing of a product “the cradle”, to use phase and to the final disposal phase “grave”.

Cradle-to-Gate

The cradle-to-gate as an assessment method means the assessment of a partial life cycle of a product from the manufacture, to the factory gate (before transporting it to the consumer). These assessments can be used as a basis fo EPD’s (Environmental Product Declarations). If this method was ought to be used for buildings, it would include the manufacturing and depending on the carrying out of the LCA, the construction stage.

Cradle-to-Cradle

In this assessment the end-of-life disposal step of the product is a recycling process, so it is in a way a cradle-to-grave assessment comparable. From the recycling process new, identical or different products can be originated.

Gate-to-Gate

This is a partial LCA method, in which only one value-added process in the production chane is being examined. An example of gate-to-gate LCA is when we are only concidering the emissions and energy consumption originating from oilseed crushing in a vegetable oil refining process.

2.2.1 EN Standards 15978 and 15804

The EN Standard 15978 is a European standard, which is focused on the environmental impacts caused by construction on a building-level. The *EN Standard 15978;2011 Sustainability of construction works* is an assessment of environmental performace of buildings, the calculation method. There are calculation rules for the environmental performance assessment for new and existing buildings, and this mentioned standard provides with these calculation rules. As it has been mentioned previously, the EN Standard 15978 describes the building-level environmental performance assessment, whereas EN Standard 15804;2012 describes the methodology for producing an Environmental Product Declaration (EDP) on a product-level. Based on this is can be concluded that the building-level must be considered while working with the product-level assessment of environmental performance, as the product-level assessment has sertain implications when the information is forwarded for the assessment to the building-level.

Table 3: Life Cycle Stages and their Relationship to the Product and Building Contexts

Life Cycle Stage			**Influenced by**	
Life cycle stage (module)		**Description**	**Product**	**Building**
Product stage	A1	Raw material supply	✓	
	A2	Transport of the materials	✓	
	A3	Manufacturing	✓	
Construction stage	A4	Transport to construction site		✓
	A5	Construction, Installation		✓
Use stage	B1	Use		✓
	B2	Maintenance		✓
	B3	Repair		✓
	B4	Replacement		✓
	B5	Refurbishment		✓
	B6	Operational energy		✓
	B7	Operational water		✓
End of Life stage	C1	Deconstruction, demolition		✓
	C2	Transport of wastes/ demolition material		✓
	C3	Waste processing		✓
	C4	Disposal	✓	
Benefits and loads beyond the system boundary	D	Reuse, recovery, recycling	✓	✓

Picture 2. Life Cycle Stages and their Relationship to the Product and Building Contexts

The table in the Picture 2 represents the life cycle stages described in both of the standards 15804;2012 and 15978:2011 and it also shows the interdependency described earlier between these two standards. From the table we can for example see, that the environmental impacts from A1 to A3 are dictated by the product, whereas the environmental consequences from the stage A3 to stage C3 are influenced by the building. [20.]

2.2.2 BIM (Building Information Modeling)

The integration of Life Cycle Assessment within a BIM software is said to significantly enhance the predictability and modeling of the building’s environmental performance. Integrating LCA to a BIM software would allow the users to understand better how to construct the building in order it to gain maximum environmental performace and energy efficiency throughout it’s lifecycle.

2.3 Certification Schemes

Certification in general means a confirmation, that sertain products and systems are being met, and continue meeting with the assigned standards. Certifying a product or a system involves continuous checking in order to confirm that they continue to meet the assigned standard. A Third Party Certification, as both BREEAM and LEED certifying schemes are, is said to be the most reliable form to certify projects. Third Party Certifications are confirming that the people, systems and products have met and are going to meet the required standards, usally through repeated audits. Third Party Certificates are also independent from vested interests, for example supplier or manufacturer. [18.]

Manufacturers use building certifications to distinguish their construction related products positively against their competitors, in a way that it will be recognized and accepted by the purchasers. Using certification provides also benchmarks in performance, a better understanding of the whole supply chain impacts, and offers the opportunity to identify and cut out the inefficiencies in the environmental performace of the building. The building designers and other related professionals also gain benefits in avoiding confusion when concidering the so called green credentials and can rely on the fact that the selection of construction products and materials, as well as systems, are spesified in the standardized means of environmental performance. [19.]

2.3.1 BREEAM

BRE describes BREEAM as the world’s leading sustainability assessment method, that plans projects, infrastructure and buildings. BREEAM was the first founded assessment method for measuring the sustainability of a building. It is used for assessing buildings in over 70 countries and has approximately 80 % market share in the European market. There are thousands of licensed BREEAM assessors globally.

BREEAM is developed to add sustainable value to building project development. It is useful for different kind of professionals working in the field of construction to use natural resources in an efficient way. The standards that BREEAM promotes, add the capital cost of the building, but this should be considered in the overall value of the building’s sustainability goals, that need to be reached.

The reduction in operational costs of the building is a substantial part of the certification goals. Sweett Group and BRE have carried out a research, where it was found out that office developers in the most typical cases invest up to 2 % more while targeting the highest BREEAM ratings. This additional investment is recovered then later on (2-5 years time) through water and energy bills. It was also concluded that the desire to achieve the lower ratings of BREEAM delivered no additional costs, or if any, they were minor. The evolving regulations as well as the global climate change are creating new and different kind of challenges for construction sector – for investors, buildings and their owners. Buildings need to be equipped for the future needs, that are set by sustainability standards, or otherwise they are likely to face the risk of devaluation and turn into stranded assets.

The BREEAM assessment is based roughly on 10 different categories: Energy, Health and Wellbeing, Innovation, Land Use, Materials, Management, Pollution, Transport, Waste and Water. These categories are divided into sub-categories of a range of issues, from which each is promoting the use of new targets and aims, and benchmarks. Each target reached means a credit awarded. The final credit score, or performance rating, is then based on the total amount of credits achieved. [16]

2.3.2 LEED

LEED (Leadership in Energy & Environmental Design) is, like BREEAM, a sustainable building certification system. It gives a third-party verification for building's construction and design, that are aimed to reduce the energy and water use, as well as promoting a better indoor air quality.

LEED categories are the following: Location and Transportation, Materials and Resources, Water Efficiency, Energy and Athmosphere, Sustainable Sites, Regional Priority Credits, and Innovation. As in BREEAM, the LEED certification is achieved by earning credits by using and integrating the opportunities offered by the sub-categories.

3 Methodology

The purpose of this thesis was to find out the current market potential that automatisation of Building Life-Cycle Assessment has in the construction sector by the means of interviewing professionals with the help of a online survey and how they experience the LCA process and what would be the potential drivers to make them use more of the LCA in their work. The questionnaire was sent to 800 different level professionals in different companies, who were presumed to have the possibility to use Life-Cycle Assessment in construction projects.

The questionnaire was sent to recipients to Europe and USA, to target the professionals using different kind of and different versions of the environmental certification schemes in their construction projects, such as the previously mentioned USA-based LEED and UK-based BREEAM. The professionals targeted were project engineers and consultants, architects, product manufacturers, as well as property and facility owners.

Google Forms Questionnaire Template was used as a template for the thesis questionnaire, and it was sent to the recipients through SurveyMonkey. The contacts were received from the Finnish consultation company Bionova Ltd. involved with the thesis, and many of the answers received came from the company’s already excisting client contacts.

The questionnaire reached an positive answer return of 5,2%, by 41 answers received from the 800 pieces of sent questionnaires.

The thesis questionnaire contains 25 questions, which were targeted to determine the level of interest among professionals to perform life cycle assessment as a a way of achieving the desired credits (points) for their building certification for a certain construction project. The aim of the questions was to probe the use and the felt need for LCA in building certification and to study how it is correlated with the need of automatizing the process.

The questions are presented in the Results chapter in their original form taken directly from the Google Forms Questionnaire Template.

4 Results

In this chapter the results of the thesis questionnaire are represented by first introducing the questions and then interpreting the results. When reading this chapter, one needs to take into account the fact that the questionnaire received answers from 41 people and the results are represented as percentages. This should be taken into consideration, as the amount of answers is rather limited to make realistic conclusions of the state of mind of the whole group of professionals working with LCA in the construction sector.

4.1 The survey questions and answers

The very beginning of the questionnaire started by asking the socio-demographics of the respondents, such as age and places of operation. The company in which the recipient was working in was also asked but will not be included in the thesis due to irrelevancy related to the research.

The share of age group among respondents can be seen below in the Figure 1:

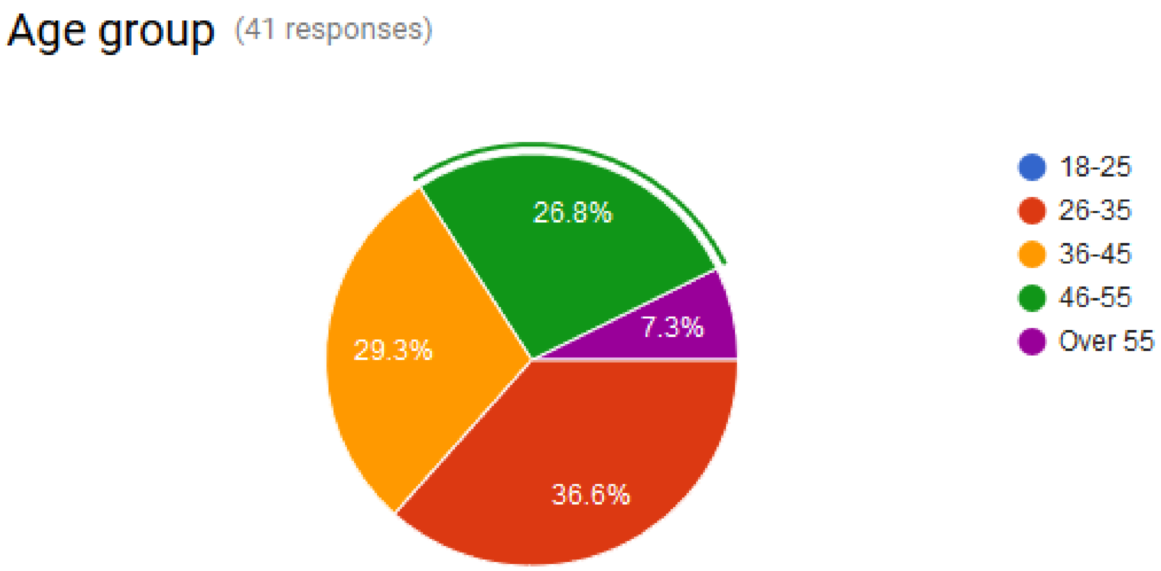


Figure 1. Age group shares of the respondents

As it can be seen in Figure 1, the majority of the recipients are aged between 26 and 45 years. When reading further on this thesis study, it can be concluded from the results that the use of LCA in building certification in is the interest of many professionals of rather young working age. This could correlate to a bright future of the use of LCA in building projects, as young workforce still have plenty of working years ahead of them.

The countries of operations was also asked in the questionnaire in order to determine the market potential for LCA tools (Life-Cycle Assessment calculating Software) in different countries. The respondents answered where the company they are working for is operating geographically, thus it does not necessarily tell where the respondents are located themselves and therefore does not give an overall picture, where the LCA is geographically used. However, in this research we can use it as to give a direction for the conclusions, as the majority of the companies announced were also Swedish and therefore it could be assumed that the respondents were also of Swedish origin.

The countries of operations can be seen in the Table 1 below:

Table 1. Countries of operation of the companies. Other countries included in this survey are China, Germany, Italy, Lebanon, Norway, Poland, Serbia, Spain, Japan and Greece.

Country	**%**
Sweden	18,6
Finland	9,3
Estonia	6,9
France	6,9
Turkey	6,9
United Kingdom	6,9
The Netherlands	4,6
Russia	4,6
Others	35,3

The positions of the respondents ranged from Sustainability Consultant to Business and Product Development Director. They also included Environmental Engineer, Project Manager and Architect. As it can be concluded from these results, many professionals involved in the construction process in it's different phases are potentially working with LCA in the fields of engineering, architecture, construction, product management, consultancy and property and facility management.

One of the most interesting questions with maybe the most predictable answers was, "*Which of the environmental certification schemes the respondents are using"*. See the answer results in Figure 2 below:

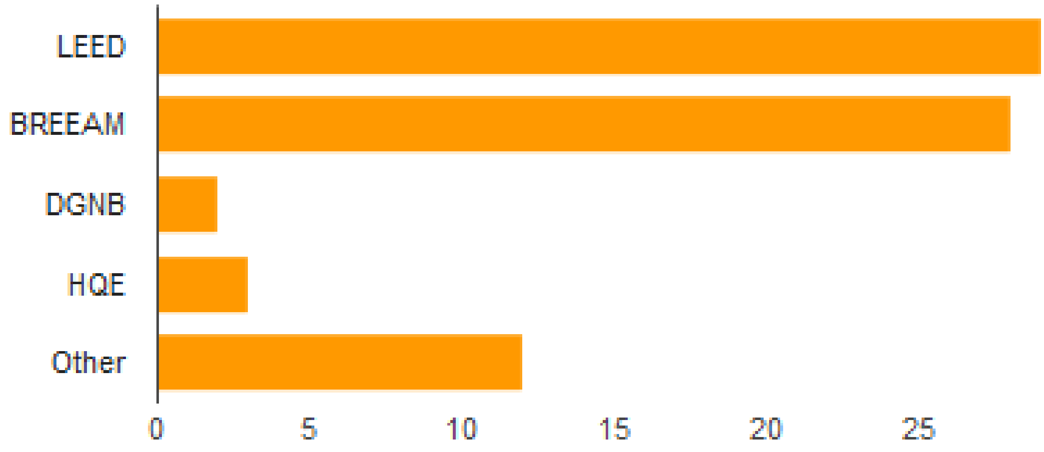


Figure 2. Which of the certification schemes are you using, if any?

As it has been stated already in the Theoretical Background chapter, LEED and BREEAM are environmental certification market leaders, thus the results of the survey in this context are not surprising. BREEAM was used by 75,7% of the respondents and LEED by 78,4% of the respondents.

The respondents were operating mostly in the Nordic countries such as Sweden and Finland, hence it also can be presumed that the survey's option "Other", with the share of 32,4 %, includes national certification schemes, for example Miljöbyggnad (Swedish environmental certification scheme by Swedish Green Building Council) or other national schemes.

In the survey, the respondents were also asked to evaluate or give a fact based indication on how many construction projects are their company annually involved in. The answers ranged from 8 up to 300 projects, and of these projects typically only 0 to 15 projects were certified.

The next thing in the survey was to determine, how many of the companies perform life-cycle assessment and how many of the respondents performed it, or are planning to perform it by themselves. The results are presented below:

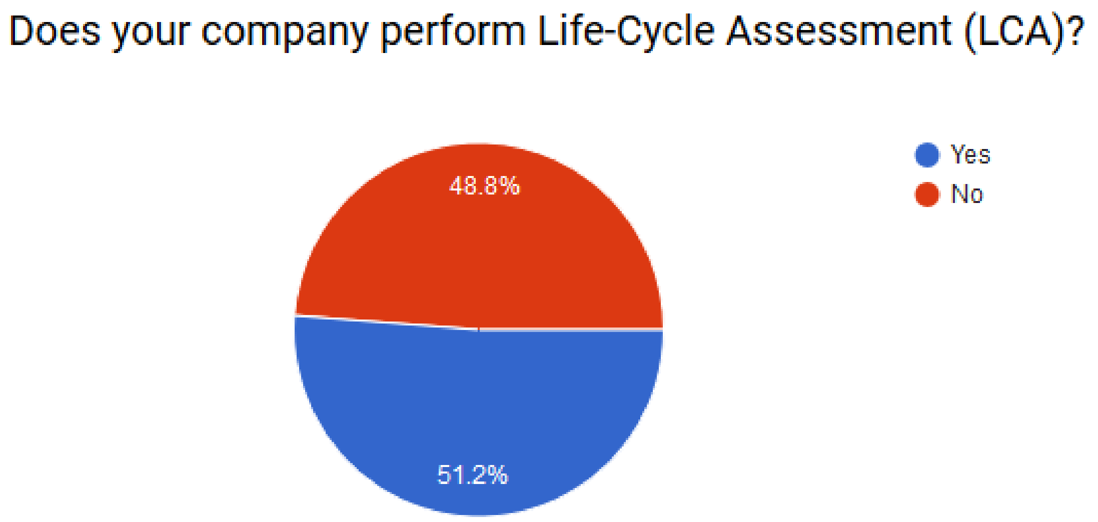


Figure 3. Share of companies performing LCA. 41 responses.

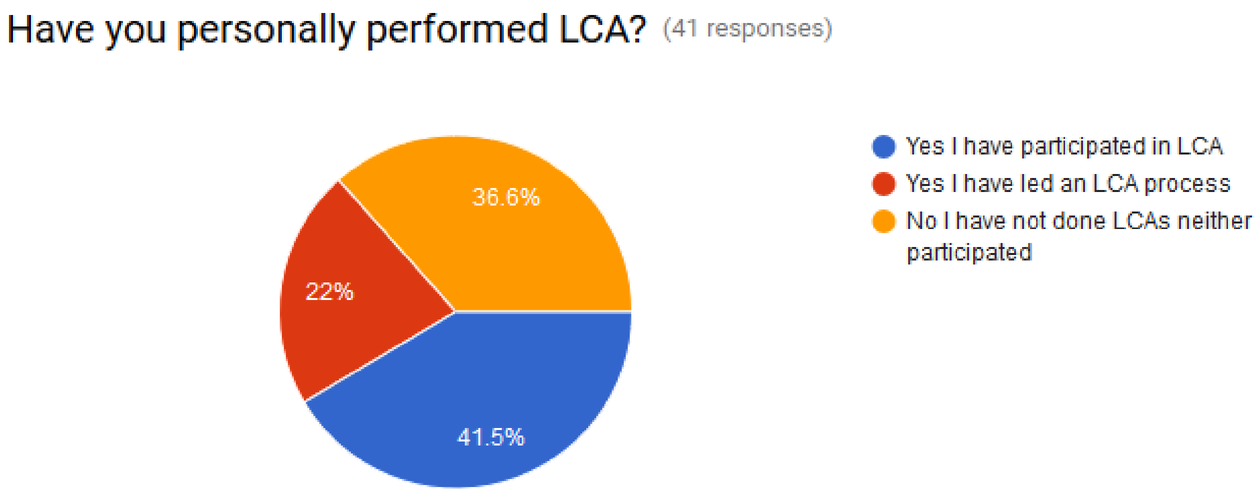
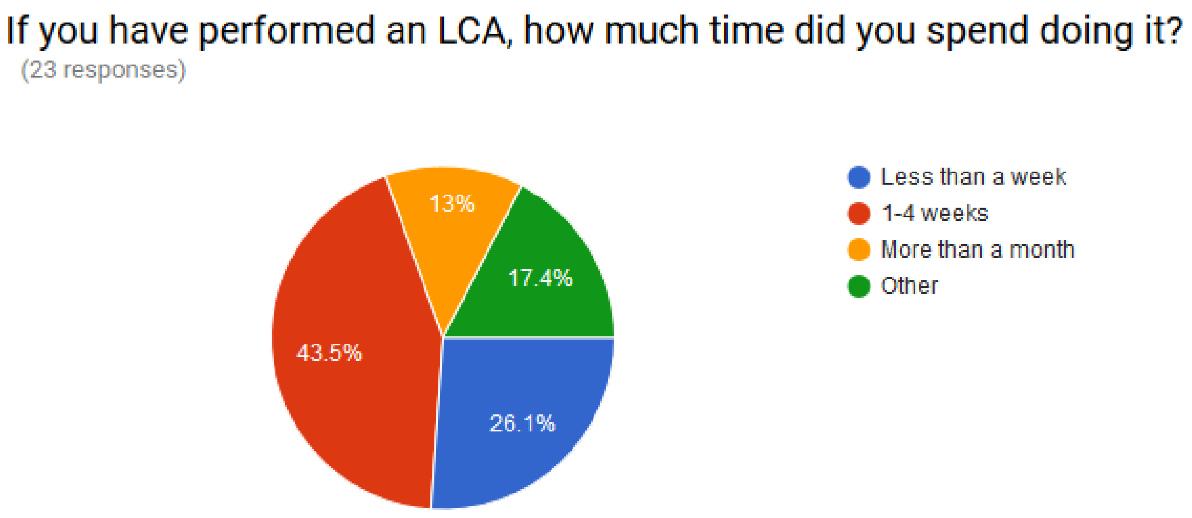


Figure 4. Share of respondents participating in performing an LCA.

From Figure 4, it can be seen that the majority of the respondents have taken part to an LCA process. However, it also can be seen that 36,6% of the respondents have not participated in LCA process. The reason for not participating in a LCA process was also asked in the survey. Most of the answers with the answer share of 55% claimed that they have not needed to, or they did not have the client requirement to perform an LCA study.

From the LCA automatisation point of view, it was important to ask the recipients how much time they spent on performing the LCA, as an easy to use LCA software with a large database can save a considerable amount of time, and earn so called “easy credits” for certification. The results were the following:

Figure 5. Time spent on performing an LCA among the respondents who did it.



From the Figure 5 above, it can be seen that the majority of the respondents spend 1-4 weeks in performing an LCA, and 13% more than a month. This can indicate that there would be a need for an efficient and time saving LCA software that would save the respondents more time in their project work. The relatively long time used to perform the LCA , according to the questionnaire, could be explained with experienced difficulties in finding the data, that was a problem for 96% of the recipients. Other problems faced were difficulties using the right tools among 16% of the recipients and that it takes too much working hours according to 7% of the recipients. 4% also reported having difficulties in calculations and 12% have experienced other unknown problems with performing an LCA. 77.8% of the recipients responded that they would use LCA more, if it would be easier. Only 5.5% answered that they would not use it, if it was easier (see Appendix 1).

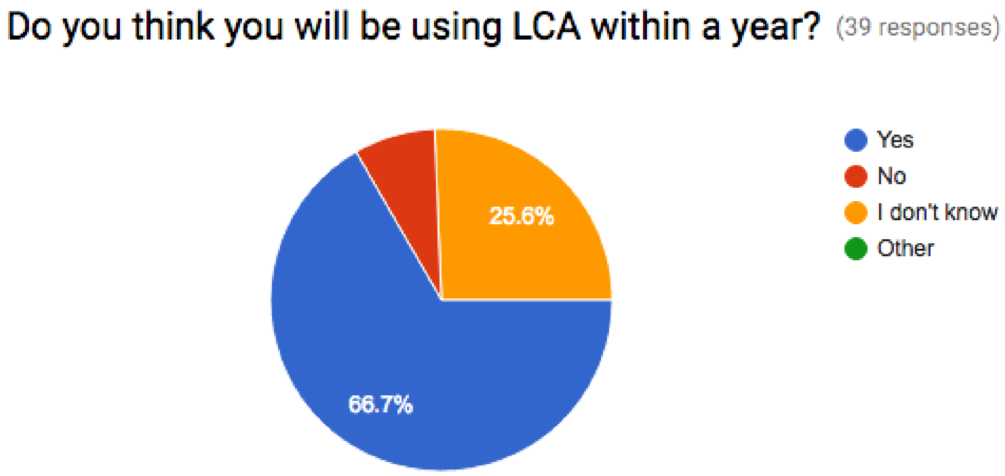


Figure 6. Future visions for LCA use.

In Figure 6 above, it can be read that 66.7 % of the recipients would actually use LCA within the following year (questionnaire was conducted 04/2016) and 25.6% of the recipients were unsure. Only the remaining 7.7% were sure not to use it according to the questionnaire.

The relevancy of BIM (Building Integration Modelling) in perfoming an construction LCA was also considered in the questionnaire. 56.4% of the recipients answered that they are currently using BIM in their projects, and 86.5% answered that they would use LCA if it was integrated in the used BIM software, as it can be concluded from the Figure 7 below:

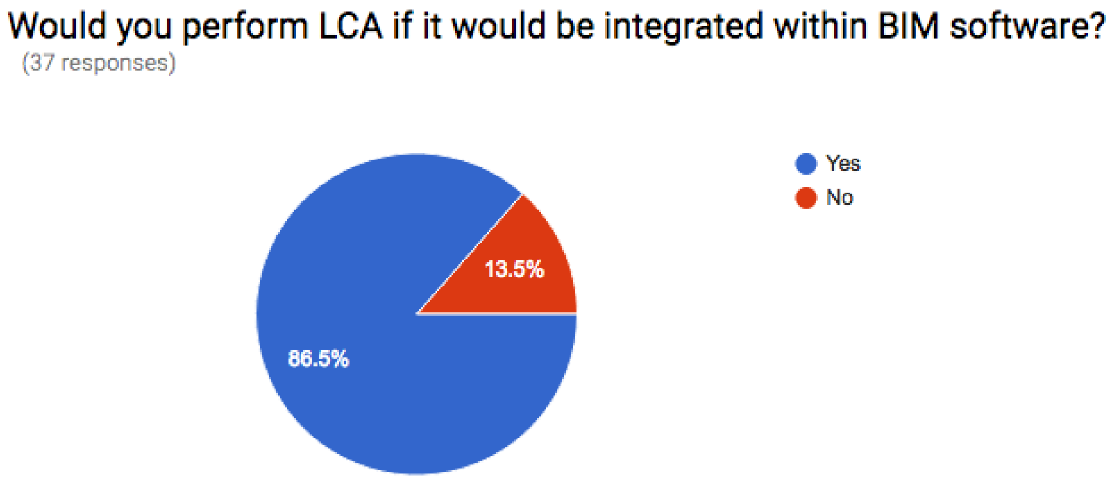


Figure 7. LCA integration within a BIM software.

The factors that influence the strategic planning of a project and are important for the project developer, were also asked in the questionnaire (see the Appendix 1, "*Which of these factors are important to your customer?"*). The answers divided in the following way:

1. Reduced environmental impact – 61%
2. Reduced investment cost – 75.6%
3. Reduce life-cycle cost – 58.5%
4. Imporoved building quality – 68.3%
5. Improved company image – 68.3%
6. Attracting investors – 56.1%
7. Fulfilling certification criteria – 58.5%

As it can be seen from the listing above, reducing the investment cost of the project was seen as most important driver for strategic planning, followed by imporving the quality of the building and the company image. Reducing the environmental impact of the construction and the building was also seen as an important factor.

The usefullness of LCA in relation to different aims and goals was also asked in the questionnaire (see the Figure 8 below).

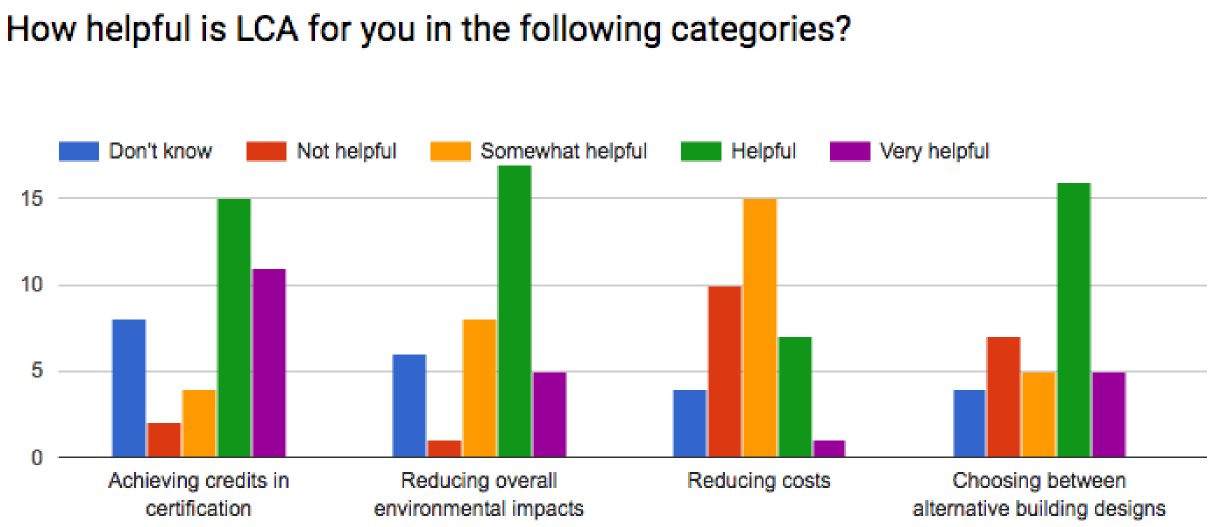


Figure 8. Usefullness of LCA in different categories.

This was an important question to find an answer in the questionnaire, as it can be assumed that the helpfullness of the LCA is in straight correlation with how much professionals want to use it – what are their goals and what is the easiest and the most efficient way to achieve a sertain desired goal.

As it can be seen in the Figure 8 above, LCA is concidered to be mostly helpful in all of the other categories, except when it comes to reducing costs. This is of course an unfortunate result, as it was stated earlier, the project developers see the reduction of investment cost and the reduction in the life cycle cost as the most important drivers in their strategic planning.

The factors that the recipients concider important when they are choosing a software to use in order to conduct an construction LCA were also covered in the questionnaire (See Appendix 1, *“Which factors do you consider important when choosing an LCA Tool”*). The answers were the following:

1. Price – 57.6%
2. Support – 48.5%
3. Quality of the databases – 84.8%
4. Precision of the results – 54.5%
5. Simplicity of use – 63.6%

6. How many certification credits you can achieve – 30.3%
7. Automated data transfer from BIM – 33.3%
8. Other – 12.1%

As it can be seen from the listing below, it can be concluded that the certification credits do not play the highest role when choosing the software. When choosing the software for performing the LCA, the quality of the data and the simplicity of the use were ranked as the most important factors. The price itself does not seem to have a tremendous influence, presumably as the projects are costly and the impact of an LCA software in that spesific budget does not play a significant role.

The satisfaction towards the used LCA software was also asked in the questionnaire (see Appendix 1, *“How satisfied are you with the LCA tool(s)/software(s) your company is currently using?”*. The scale used was from 1 to 5, where 1 equals to *Not satisfied* and 5 to *Very satisfied*. 45.5% of the recipients gave a 3, and 18.2% gave 2. No one of the recipients gave a 5, hence there was no one very satisfied. These results imply that there are still development and improvement needed to be done with the LCA softwares in the market. The tools and softwares used were 360Optimi, Gabi, GreenCalc+, BREEAM Mat 1 Calculator, BRE Greenguide, COCON, and other templates used by the companies.

5 Discussion and Conclusions

The significance and the market value of sustainability will continue to remain high and increase in the future among the companies in the construction sector. Different financial opportunities offered by sustainable buildings, such as the increase in brand value and accessibility to new markets will be playing a significant role in green building.

As the value of sustainability is constantly increasing for large businesses, the need for fulfilling different kind of client needs, values and goals increases. Overall, on the basis of the results of the thesis questionnaire, it can be presumed that the future is bright for different life cycle assessment software tools as the demand grows through legistelation and through standards, and increased knowledge and demand for optimal environmental performance and energy saving.

Based on the questionnaire results, it can be concluded that the value of LCA is high for most of the recipients and it would be performed a lot if there was a demand from the client and the sufficient knowledge of the LCA tools available.

The integration of Life Cycle Assessment within a BIM software is said to significantly enhance the predictability and modeling of the building's environmental performance. Integrating LCA to a BIM software would allow the users to understand better how to construct the building in order it to gain maximum environmental performace and energy efficiency throughout it's lifecycle. Based on the survey's results, LCA integration withing a BIM software is a advantage for the LCA software developer and it would increase the use of LCA significantly.

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