Survey on LCA results analysis, interpretation and reporting in the construction sector

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Abstract: *Life Cycle Assessment (LCA) is widely recognized as the most relevant tool to evaluate building environmental impacts. Previous works have proposed different building LCA tools to spread LCA in the building sector practices. However, as initial questions are different depending on the user profiles, answers should be different from a building LCA tool developer's perspective. Indeed, one single LCA tool embedding a single methodology and a single way to analyse and express the results will not fulfil the needs of all stakeholders. In this study, a national survey was conducted in order to better understand the needs of these building stakeholders to feed back LCA tool developers. Focus was put on the interpretation and reporting steps of the LCA method as defined in ISO 14040. Results showed different practices, expertises, and scope of studies. Stakeholders not familiar with LCA prefer easy-to-go interpretation while experts still prefers keeping detailed results. Outcomes of this survey can now be used by building LCA tool developers to better ajust the analysis and interpretation tools in their software to match the user needs.*

Key words: Life cycle assessment, energy efficient building, building environmental assessment, renewable energy, allocation, dynamic

1. Introduction

The building sector is a major contributor to the environmental impacts including climate change, energy consumption, waste generation and air pollution [1]. In that context, the Life Cycle Assessment (LCA) method can serve as an instrument to assess the environmental performance of buildings and building products [2] providing a holistic overview of their life cycle. LCA is standardized through the ISO 14040-14044 standards and, for the construction sector, the European standards EN 15804 and EN 15978 provide general calculation rules for LCA of building products, technical equipment and buildings [3]. In the construction industry, LCA is increasingly used in research projects and in daily practice. Building certification schemes (e.g. BREEAM, HQE or DGNB) have started relying on LCA to assess the environmental performance of buildings. To ease the operational practice, guidance documents have proposed study types to adapt the levels of details of the LCA calculation rules to the project stages and objectives (e.g. screening, simplified and complete LCA) e.g., in the EeBGuide Infohub for building LCA [4].

Reviews of LCA tools for buildings are available in Ortiz et al. [5], Bribian et al. [6] and more recently in Lasvaux et al. [7]. These state-of-the-art of building LCA tools in Europe revealed different levels of maturity between the tools and different choices for the databases, the methodological rules and the environmental indicators. Indeed, no existing tools match all the user needs because they have been developed with different starting points e.g. as decision making tools for architects or thermal anlyisis engineers or in opposite for certification purposes. Despite the high number of available tools, using LCA in practice is still not a common practice [8]. While a complete harmonization of the different philosophies, there is a need to better link users' expectations and the interpretation and reporting aspects within building LCA tools. Very few research works have been conducted in the field of LCA results interpretation for the specific case of the building sector. Saunders et al. [8] analyzed the practice of LCA in the US building sector. The authors concluded that even though stakeholders are aware that LCA provides information about environmental impacts, the lack of building related metrics was highlighted as a prominent barrier.

In this study, a survey is conducted to better understand the link between the different user profiles of LCA in the building sector and the types of interpretation and reporting methods. The next section presents the assumptions used to build the survey and section 3 presents the results.

2. Methodology

2.1. Online survey

A web-based survey using Google Drive ™ was set up and diffused using differen tools to increase the visibility (e.g. mailing lists, social networks, expert forums, etc). No particular restriction was adopted since the study objective was to reach various user profiles and stakeholders interested in LCA. The survey went live from the 07/15/2013 to the 02/10/2014 and collected a total of 121 responses. Except questions on LCA result display, the survey contains parts to characterize the sample at both levels: general profile information (professional duty and organization size) and LCA knowledge.

2.2. Sampling methods

The results of the survey were grouped according to two criteria:

- Type of stakeholders (see Table 1)
- Level of LCA expertise (see Table 2)

The first grouping criterion is based on work typology. Table 1 presents the stakeholders' groups and the number of answers collected per group. The respondents come from a wide range of professions in the building.

Table 1: Number of answers based on professions

Stakeholders groups based on their professions	Sample
Architects	3
Consulting engineers for contracting authority	13
Design office	36
Trade unions	8

Building certification engineer	4
Construction engineer	14
Building manufacturers	11
Prime contractor	7
Contracting authority	6
Public policies experts	6
Researchers	12
Economist	1
Total	***121***

A second grouping criterion was proposed according to the level of LCA expertise of the survey's participants. Considering:

$$C_{th_n}: theartitical\ knowledge\ level\ of\ participant\ n$$
$$XP_{pr_n}: pratical\ experience\ level\ of\ participant\ n$$
$$N_{mod_n}: number\ of\ LCA\ study\ performed\ by\ participant\ n$$
$$N_{lect_n}: number\ of\ LCA\ report\ red\ by\ participant\ n$$

Thereafter, calculating both indicators:

$$SE_n = C_{th_n} + XP_{pr_n}: self - estimation\ of\ participant\ n$$
$$PQ_n = 3 \times N_{mod_n} + N_{lect_n}: practical\ quantification\ of\ participat\ n$$

The factor "3" applied on the number of performed LCA study allows increasing the weighting of LCA practitioners. Then, these two conditions are considered:

$$If\ SE_n \geq 7\ then\ t_{1_n} = 1\ else\ t_{1_n} = 0$$
$$If\ PQ_n \geq 10\ then\ t_{2_n} = 1\ else\ t_{2_n} = 0$$

Wherein:
$$t_{1_n}: condition\ 1\ results\ for\ participant\ n$$
$$t_{2_n}: condition\ 2\ result\ for\ participant\ n$$

Finally, the sum of both test results gives the expertise level:

$$If\ t_{1_n} + t_{2_n} = 0 \rightarrow low\ expertise\ level$$
$$If\ t_{1_n} + t_{2_n} = 1 \rightarrow middle\ expertise\ level$$
$$If\ t_{1_n} + t_{2_n} = 2 \rightarrow high\ expertise\ level$$

The global sample can be splited up in three groups as shown in Table 2 and helpful to study:

- The possible modification of interpretations from a group to another,
- The posible modification of interpretations from a group to the whole simple.

Table 2: Number of answers based on LCA expertise

Stakeholders groups based on LCA experience	Sample
Low expertise level	64
Middle expertise level	21
High expertise level	41

2.3. Topics included in the survey

Next to the general information asked to better characterize the panel, a complete set of LCA indicators was included in the survey. The stakeholders are asked to give priority to each

environmental aspect (e.g., climate change, raw material extraction and depletion, water consumption).

Similarly, they are asked to give their opinion in the normalisation and aggregation steps of a LCA. These two steps enable to summarize the LCA results into single score and into equivalent units to be able to identify the most relevant actiosn to take. For instance, such tools can help focusing on energy consumption rather than eutrophication in the building sector due to the high share of this sector in the global energy consumption.

3. Results

3.1. LCA understanding, knowledge, practice and goals

Figure 1 presents the relationship between the theoretical knowledge and the operational practice of the different respondents. Average values are represented for each group. Despite an important proportion of low-practical level respondents (43 % responding 1 or 2 whathever the group, not shown in Figure 1), a majority of people states having a pretty good theoretical level as shown by the averages values in Figure 1 (from 2,5 to 4,5).We notice a linear relation of the results in X (theoretical knowledge) and in Y (operational practice). The least knowledge is reported for the group "economist" (only 1 respondent) while the highest knowledge and operational practices correspond to the building manufacturers. About 25% of the answers came from design office engineers both energy and environmental experts. It is important to mention that in every group a substantial variability of the knowledge and practice exists though the average value should be taken as indicative. The next section presents the results of the survey.

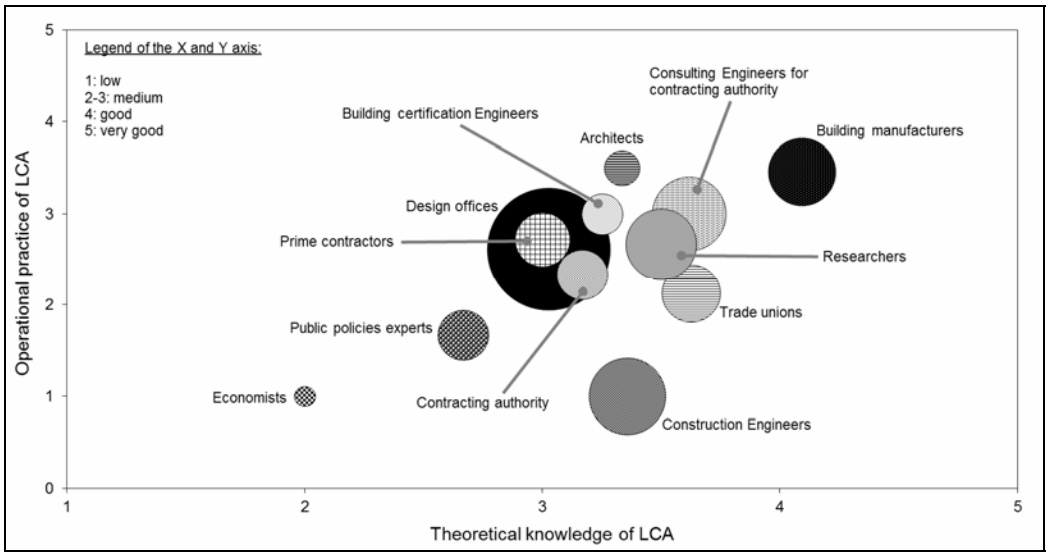

Figure 1: Stakeholders' group respondents' knowledge and practice in LCA. The size of the bubbles indicates the number of respondents in each group. The centre of the bubble represents the average score for the theoretical knowledge and operational practice.

Figure 2 presents the shares of the type and number of LCA studies either conducted or red by the diferent stakeholders. First, a large part concerns building LCA and product LCA, only

minor parts (less than 20%) go for process or neigboorhood LCA. Second, most of the people have conducted less than 10 LCA studies (resp. read less than 10 LCA studies).

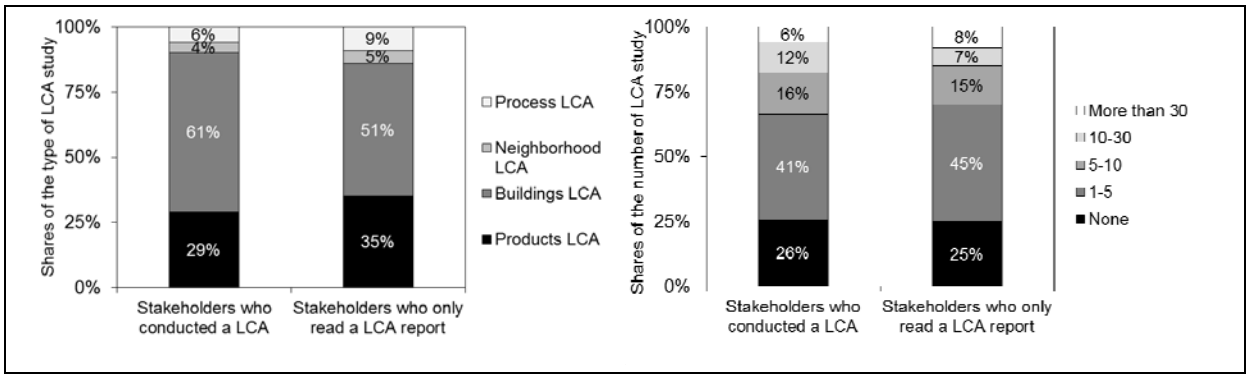

Figure 2: Shares of the type of LCA study conducted or red by the stakeholders.

To the question "*would you estimate yourself relevant to understand and use building LCA results?*" 48 % of the respondents answer "*yes*". That highlights two notable points:

- Half of the respondents would give relevant trails thanks to their knowledge and understandings of the difficulty.
- Half of the respondents would give relevant trails by clearly underline the lack and hotspot without any background.

The last question concerns the goal and scope of the LCA. Most LCA practitioners mentioned *eco-designing*, *decision support* and *certification/labeling* as primary goals.

3.2. LCA interpretation: environmental indicators' ranking

In the survey, a list of environmental indicators has been proposed among the most commonly indicators found in LCA tools for buildings in France. People were asked to qualify their priorities on a four-grade scale (1: not useful, 2: not very important, 3: moderately important, 4: highly important). Based on the percentage got for the four ranking grades of each indicator among the sample of construction stakeholders', two types of weighting factors are calculated. The first one is only based on the 1st and 2nd rankings while the second one is based on all rankings. These factors are calculated with the formula below:

$$W_i = \frac{\sum_j R_j \times P_j}{4}$$ With: W_i *: weighting factors for indicator i*

$j \in [1;4]$

R_j*: grade of ranking j*

P_j*: percentage of ranking j*

Even if the weighting factors are only indicative, they describe stakeholder's priorities. As an illustration, Figure 3 presents the scatterplots of the two types of weighting factors for the LCA indicators used in French building LCA tools according to stakeholders' choices.

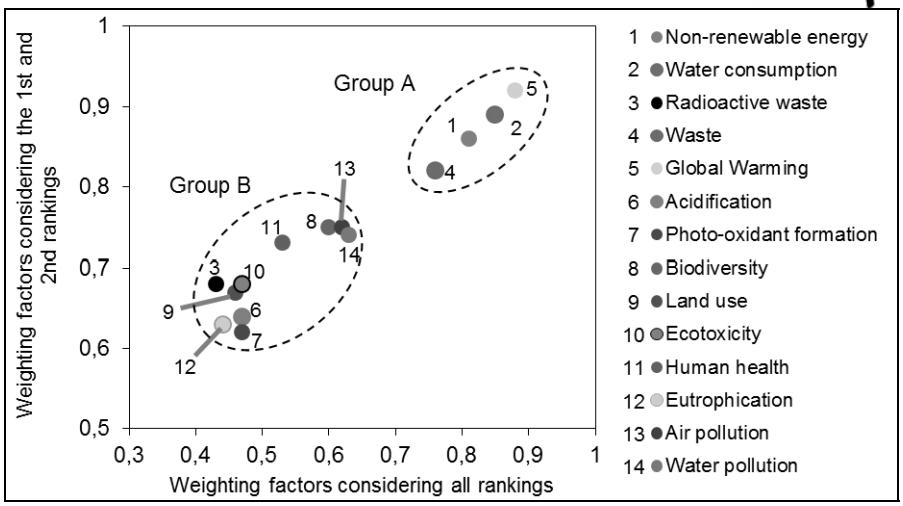

Figure 3: Representation of the weighting factors for each LCA indicators based on stakeholder's priorities

Two groups of indicators can be separated based on the results of Figure 3. The first one gathers four indicators: the primary energy, the global warming, the water consumption and the waste generation. The weighting factors vary from 0,75 to 0,92. The other group has all the other indicators with weighting factors around 0,5 (from 0,4 to 0,63). Interestingly, the top four indicators match with the public policies priorities in France following the "Grenelle de l'Environnement". The results are relatively stable whatever the level of expertise of the respondents.

3.3. Other results for the LCA interpretation: normalisation and weighting

Normalization is the prior step to weighting and aggregation. In this survey, people were asked to give their opinion on two types of normalization factor systems. Two choices were proposed: the first one is a customized factor system (i.e., each practitioner could set his own factors) and the second one is a default factor e.g., based on LCA tool developers assumptions or other national or European statistics (energy consumption, CO2 emissions in the building sector etc.). We found that t presents the answers of both questions about the needs of customizable normalization factor system and default normalization factors in the tools.

Table 3: Stakeholders' needs for normalisation factors

	Stakeholders answers	
Questions	YES	NO
Customized normalisation factor system	57%	43%
Default normalisation factor in LCA tools for buildings	62%	38%

We found that the two solutions are approved by the majority of respondents. Similarly, Table 4 presents the results of the stakeholders' needs in single score's indicators.

Table 4: Stakeholders' needs for an aggregation system and single score display

	Stakeholders answers	
Questions	YES	NO
Get a unique score for LCA result display	56%	44%
Customized aggregation factor system	51%	49%
Default aggregation factors in tools	55%	45%

Table 4 shows the interest in aggregated score to express building LCA results (percentages of “yes” between 51 to 56%). It seems that people are slightly more interested in getting default aggregation factors than having the possibility to create their own factor set.

3.4. LCA reporting

The last point of the survey consists in exposing users to LCA reporting document examples. The aim is to test several display formats and get an appraisal about each. Four different documents were proposed.

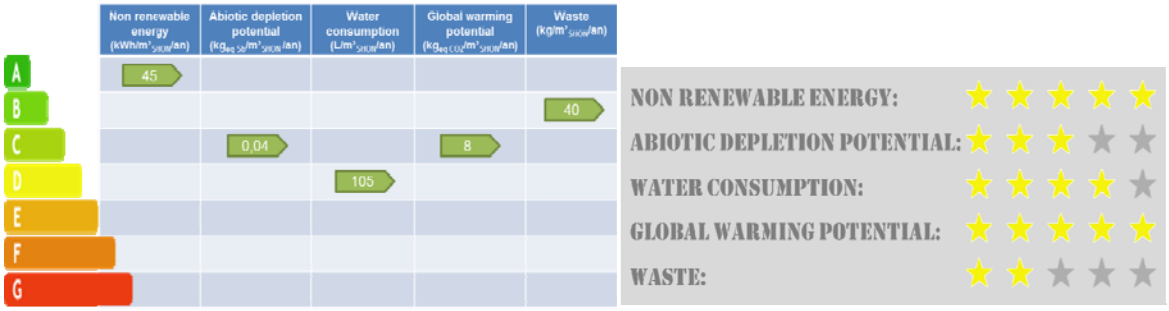

Figure 4: Two examples of impact indicators display submitted in the survey one with both classified and raw values (left) and a very synthetic one with only classified values (right)

Figure 4 shows two examples of display solutions exposed in the survey. The top one is predominantly preferred as it gives on the same succinct insert an easily understandable classified system for non experts and the raw values for higher expertise level.

A third document gives a well-appreciated solution with a radar chart for comparison to a reference building. This helps people to evaluate and put into perspective a project to the common practice. A solution to match all needs with a synthetic format could be to provide on the same LCA report the classified/raw values table (as in Figure 4 top) and a radar chart.

4. Discussions and conclusions

Since the questionnaire was sent exclusively in France, the findings of this study are particularly relevant for this national context though some general conclusions are valid whatever the context. According to the survey’s results, stakeholders judge important to focus on primary energy, greenhouse gases emissions, water consumption and waste generation. The inclusion of normalization factors is preferred by a majority of respondents of this survey. Indeed, such a system enables to identify the most relevant indicator to work on in terms of impacts’ shares for the building sector (e.g., expressed in equivalent inhabitants per year). Another way to normalize is to compare the LCA results to the actual construction practice mean impacts. Generally speaking, they prefer the use of aggregation system but with the possibility to modify the weighting. Similarly, they agree on sets of weighting e.g., based on default values (or based on public policies).

Last but not least, the findings of this survey reinforce the need to have public consultation and practitioners’ meeting during the development (or the update) of a LCA tool of building to be sure that the user needs will be taken into account.

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