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Experiences with LCA in the Nordic building industry – challenges, needs and solutions

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Abstract

"NORNET - Innovative use of LCA in the development of sustainable building and refurbishment strategies" is a Nordic network aiming at extended and improved use of LCA in the Nordic building sector. The NORNET LCA network has studied the challenges and needs of the Nordic building industry in the development in Building Life Cycle Assessment (LCA). The study applied a semi-structured interview technique with 57 interviewees from the Danish, Finnish, Norwegian and Swedish building sector. The study was conducted using a combination of in-depth phone interviews, email interviews and an online multiple-choice questionnaire. The interviewees represented different stakeholders in the Nordic building industry with varying knowledge of LCA, including building product manufacturers, entrepreneurs, building owners, architects, consultants, organizations and research institutes. The interviewees emphasized the need for a better understanding of the relative significance of different factors and building parts and the need to refine and harmonize the existing building LCA tools and databases. The results from this study provides valuable insight in how the Nordic Building Industry experiences the use of LCA. The results also raises awareness of the issues that are needed to be addressed in order for the industry to accelerate and expand the application of LCA in the near future.

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Keywords: LCA; Nordic Building Industry; Survey; LCA in building sector

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1. Introduction

In its Communication on Integrated Product Policy [1], the European Commission concluded that Life Cycle Assessment (LCA) provide the best currently available framework for assessing the potential environmental impacts of products. LCA is widely used as a tool for evaluating the environmental impacts associated with all life cycle phases of the building. LCA can be applied to buildings on different levels, including at the level of the building materials and products, building parts and elements, whole buildings and even entire neighborhoods. LCA is applied in building certification schemes (e.g. BREEAM) as well as for environmental labels (e.g. Environmental Product Declarations (EPD)) in order to quantify, communicate and manage environmental impacts from the whole building or from building components. Building information modeling (BIM) is considered as an effective platform for overcoming some of the difficulties of acquiring the necessary building data in the early design stages [2, 3]. Although the outcome of an LCA analysis should be reliable and valid for decision makers to make optimal decisions, the lack of transparency and/or uncertainty of the inherent data affects the accuracy of LCA results. In addition, performing an LCA is a complex and time-consuming task. LCA experts and research communities are constantly improving the methodology in order to solve issues related to inconsistency, transparency, comparability and data quality and availability.

In all the Nordic countries, there has been a growing use of LCA in assessment of environmental performance of construction products and buildings in the recent years. Finland has strong research environments providing long-span research about the environmental impacts of the built environment. The Technical Research Centre of Finland (VTT) has carried out a large number of LCA related research in collaboration with research institutes and the Finnish building industry. Recent research has focused on the significance of embodied emissions, environmental impacts of nearly zero energy buildings (nZEB), energy-efficient refurbishment at building and district level and the use of LCA approaches in the design processes [4-8]. VTT has developed a tool, ILMARI, for environmental assessment based building information modelling (BIM). ILMARI combines IFC based quantity take-off data from design softwares with generic carbon footprint data of products [9]. IFC is a standard for open information transfer in design and building [10]. The Building Information Foundation (RTS) in Finland recently published a new version of the Finnish EPD scheme. The Green Building Council Finland has led the development of building performance indicators and guidelines for the measurement of the environmental and energy efficiency of buildings, their life-cycle costs, and occupant well-being.

In Norway, there are strong research environments and a growing market demand for the application of LCA in buildings. A national Research Centre on Zero Emission Buildings (ZEB), hosted by SINTEF and the Norwegian University of Science and Technology (NTNU) is setting targets for zero emission buildings based on LCA considerations [11]. Recent research from the Norwegian ZEB center include LCA studies of insulation materials [12, 13], building-integrated photovoltaics [14] and LCAs on pilot buildings within the ZEB centre [15, 16]. The new research center on zero emission neighbourhoods in smart cities (ZEN) aims to enable the transition to a low carbon society by developing sustainable neighbourhoods with zero greenhouse emissions. Norway has experienced a growingly large market demand for EPDs on building products, even though LCA documentation is not included in any current Norwegian building code or regulations. The demand for EPDs increase rapidly when BREEAM-NOR, the Norwegian adaptation of BREEAM, is launched and gives credits for use of materials documented by EPDs in order to encourage the use of products with lifecycle information [17]. Today, manufacturers report an intense demand for EPDs initiated by the building owners. Another driver in the marked is Statsbygg, the Norwegian government agency responsible for managing publicly owned buildings, pushing reduction of greenhouse gas emissions in their building projects. Statsbygg developed a publically available online tool, klimagassregnskap.no [18], for calculation of carbon footprint of buildings. Furthermore, the Norwegian standardization organization is now working on Norwegian standard for greenhouse gas emissions calculations for buildings, to be published in the end of the year 2016 or the beginning of 2017.

In Sweden, the National Board of Housing, Building and Planning (Boverket) has recently started a project which investigates if Sweden need to regulate building LCA, and how it should be done. There is a government assignment

on the climate impact of buildings. Currently the building industry are investigating the difference between concrete and wood as the load bearing construction using LCA. Another rising issue is LCA on energy improvement measures to prevent that the environmental impact during the operation phase is shifted towards the production phase instead.

Denmark has had considerable research on sustainable buildings and life cycle approaches in recent years, which also has initiated development of practical tools and methods applied in the building sector. Two main drivers for the ongoing development are; the decision to use the system of the Danish Green Building Council (DGNB) for certification of sustainable buildings in 2011 based on thorough investigations [19], and secondly political interest within sustainable buildings in the period 2011-2015 [20]. Later political interests initiated mapping of the sustainability elements already included in the Danish Building Regulations and possible extensions in 2013 [20], followed by a Danish governmental building strategy in 2014, which introduced sustainability of buildings as one of five focus areas for the future political work within the sector. Subsequently, a wide range of sector stakeholders were involved in developing the "LCAbyg" tool to assess the life cycle environmental impacts of buildings, launched as a free open source tool in spring 2015 [21]. Several projects were initiated in order to raise the general knowledge on LCA of buildings [22] and understanding of the main life cycle impacts of typical new buildings [23] and refurbishment projects [24].

With reference to the above-mentioned effort on building LCA across Scandinavia, The Nordic countries can be introduced as forerunners in sustainable building. Deeper collaboration and the development of common approaches for the innovative use of LCA in the development of sustainable building and refurbishment would reinforce the Nordic collaboration, status as strong actors of sustainable building, and the business opportunities of the Nordic building industry. "NORNET - Innovative use of LCA in the development of sustainable building and refurbishment strategies" is a Nordic network aiming at extended and improved use of LCA in the Nordic building sector [25]. Under the NORNET network project, Denmark, Finland, Norway and Sweden have come together in order to support and enable the Nordic construction industry to extend the utilization of LCA. Three of the main objectives of NORNET includes: 1) to establish a Nordic network for the common development of innovative use of LCA in decision making in all the phases of a building project, 2) to reinforce the status of the Nordic research on LCA and sustainable building in the international research community, and 3) to develop innovative use of LCA methodology in the building sector in order to better understand the significance of methodological choices. The NORNET networking project organizes four workshops, one in each country, in order to create an opportunity for the network members to meet and exchange experiences and learn more about the newest findings on the building LCA within national and international research.

In addition, the experience with applying LCA that the various stakeholders in the industry have is very valuable information for the NORNET network. NORNET LCA network has studied the challenges and needs of the Nordic building industry in the development in Building Life Cycle Assessment (LCA). The purpose of this study is to facilitate research-industry dialogue and identify the challenges and needs of the Nordic building industry in the development and use of building LCA in order to finding solutions and facilitate innovative use of LCA. In order to get further information from different stakeholders on the status of LCA application and challenges in the different Nordic countries, a survey was performed by LCA research communities involved in the NORNET network, collecting information from 57 interviewees.

2. Methodology

The analysis was conducted on the basis of information collected from stakeholders in the Nordic Building industry. The information was collected through a survey on the form of a semi-structured interview with a combination of multiple-choice type questions and questions requiring more elaborated answers and comments, during the period April 2015 to July 2016. The survey was sent to a wide range of stakeholders in the Nordic building industry, focusing on stakeholders that were known to have some experience with LCA in their business. The survey was created with the online-tool Survey Monkey [26]. The interviewees were allowed to answer the survey directly online or through email. Email surveys was collected and fed into the survey monkey tool. In order to get more in-depth knowledge, some of the interviewees were asked to join a longer telephone interview in which the same questions form the survey was discussed more in depth. The results of the survey were further analyzed with the help of the discussion and comments that came out of the survey. The results were also analyzed in order to examine the correlation between participants' background and their responses.

The survey had four main parts including participants' background (including the country and type of business they represented and their experience with building LCA), knowledge gaps and issues in building LCA, need for collaboration between the Nordic countries and, finally, the role of BIM in building LCA. The complete questionnaire is given in Appendix 1.

A total of 57 individuals from the Nordic countries (Denmark, Finland, Norway, and Sweden) participated in the survey, out of which 16 was answered by email and the rest was answered directly online. Out of these, 12 interviewees agreed to participate in a deeper phone-interview. The interviewees represented stakeholders in the Nordic building industry, including building product manufacturers, entrepreneurs, architects, consultants, organizations and research institutes with varying knowledge of LCA

The main limitations of this study is the risk of misinterpretation or varying interpretation of the surveys collected online and through emails. Interpretations can vary from country to country, from business to business and from person to person. However, there is reason to believe that varying interpretation is less of a problem in a questionnaire with such a clear focus on the LCA-method, as opposed to a questionnaire on a broader sustainability subject. The risk of misinterpreation is minimized in the longer phone interviews, but another limitation applies to these interviews as they were performed in different Nordic languages and furthermore translated into English. The questions in the study asks for different aspects of challenges, needs and solutions in building LCA, and there is a risk of mixing some of the more similar questions. This is however not considered as an important problem as the responses are carefully reviewed by the authours, and because the questionnaire is designed so that mixing questions will not lead to opposite or wrong conclusions.

Another limitation of the study is that the references to litterature on similar studies performed in other countries are limited.

3. Survey findings and discussion

This section presents the analysis of the results obtained from the survey. It should be noted that, in some of the survey results, the number of respondents add up to more than 57 because some of the participants gave multiple answers.

3.1. Respondents background

The questionnaire starts by collecting the background of the interviewees and their experience with LCA. The interviewees mainly represent environmental/energy consultants (17 of the respondents), producer/manufacturers (12), architects (8), entrepreneurs and builders (9), organizations (6) and research institutes (4). One respondent answered "other", and wrote in the comment that she/he represents a municipality. The participants are from Denmark (27 respondents), Finland (13), Norway (9) and Sweden (8).

In the survey, the interviewees were asked about their experience with LCA. 42 of the respondents reported that they had experience with LCA at the building level, and 39 of the respondents had experience with LCA at the material level. It should be noted here that, the number of respondents add up to more than 57 because some of the participants have experience on LCA both at building level and at material level. From the comments in the survey, and from background knowledge of the repondents in general, the respondents have encountered LCA in connection to research, consultancy, procurement, building projects, environmental labelling of their products and/or through their work with waste management, and also in educational situations.

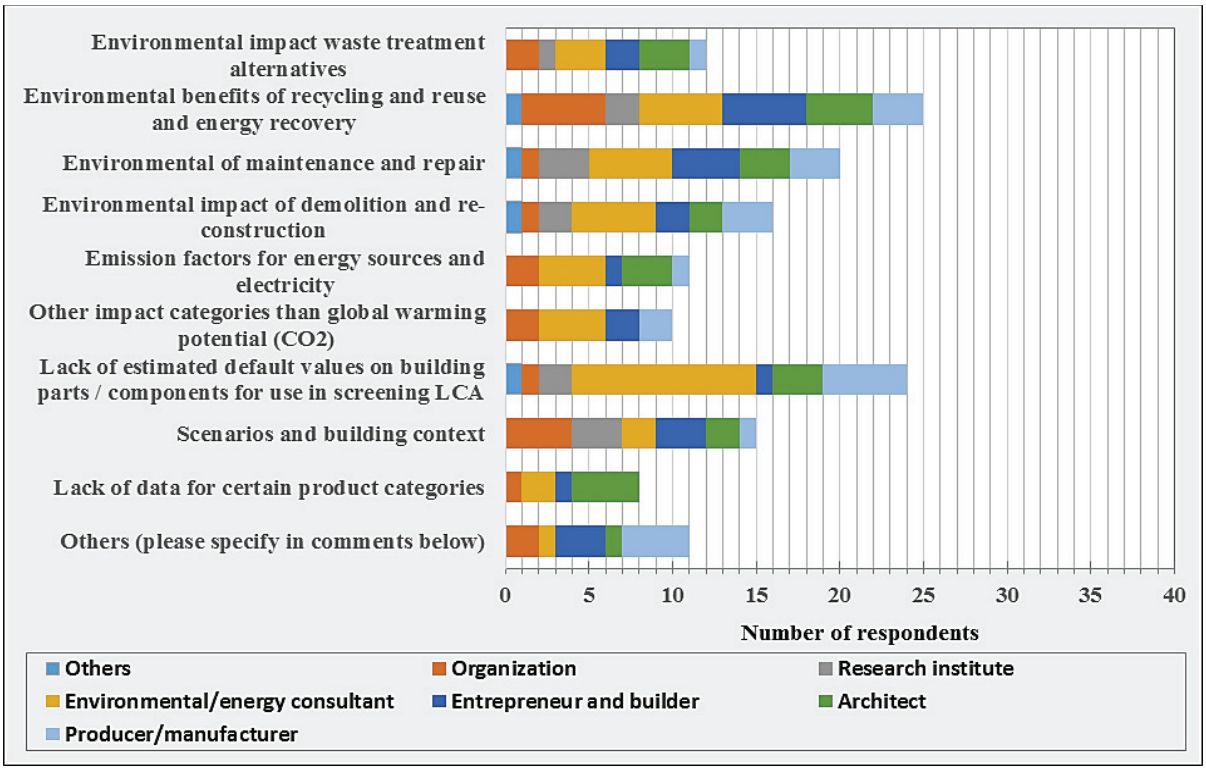

Fig. 1. Responses to the question "In your opinion, what are the most important knowledge gaps in building LCA?"

3.2. Knowledge gaps in LCA of buildings

The most important knowledge gaps in building LCA were evaluated through the survey. Fig. 1 shows the main knowledge gaps in building LCA, as identified by the interviewees. 25 of the respondents confirmed a knowledge gap in the area of environmental benefits of recycling and energy recovery. 24 of the participants described "lack of estimated default values on building parts or components for use in screening LCA" as a main challenge. The environmental impact of maintenance and repair (20 respondents), scenarios and building context (15), environmental impact of demolition and re-construction (16), emission factors for energy sources and electricity (11), other impact categories than global warming (10) and lack of data for certain product categories (8) was also chosen by the respondents as important challenges for performing LCA in buildings.

The results show that the environmental benefits of recycling, reuse and enery recovery are representing an important knowledge gap in the building industry.

Screening LCA is valuable in the early design phases of a building, were details of the life cycle inventory is not yet known. The LCA methodology requires detailed data of the product under study, and it is a well-known dilemma that LCA is difficult to apply in the early design phases when decision support is most applicable and most needed. Solutions to this problems include sensitivity analysis of different likely design scenarios, focusing on the most important building parts instead of the details. The respondents in this study accentuated the need for predefined default values/reference values on building elements that can be used in such situations. One respondent put it quite simply: "would like to know what parameters/changes will have the biggest impact on the LCA for a building". The importance of LCA reference values for different types of buildings was also mentioned.

Through the comments section in the online survey and through the in-depth phone interviews, the respondents reported a lack of data for; energy production (especially local energy production), transport distances and means of transport and technical equipment in buildings (e.g. photovoltaic panels). One respondent said "It would be useful to have an overveiw over typical transport distances and means of transport, including transport distances for various waste fractions". Furthermore, the current available databases were critiqued by a few respondents, commenting that they are incomplete and in need of updates. Finally, it was commentet that other impact categories than global warming potential should play more important roles. For instance, the consideration of harmful substances/chemicals were described as an area that needs further research.

The respondents were then asked to identify which parts of the building life cycle that are missing data and guidelines for assesment. The results are displayed in Fig 2. The use stage (30 respondents), end-of-life (26), benefits beyond system boundary (15), construction and installation (12), transportation to building site (9) and product stage (7) were identified as life cycle stages with missing data or guidelines.

The use stage was given most response, and the respondents commented upon difficulties in treating service life and replacement cycles, and commented adaptability of the building design that can increase service life of the building components should get more attention. Some respondents reported need for better understanding of how LCA could be used for renovation projects, and when deciding whether to renovate deep or to build a new building.

The use phase is also were the energy consumption of the building is reported. Some respondents called for better understanding of the significance of type of heating and the effect of local/on-site energy production.

This part of the study shows that the scenarios, the parts of the building life cycle that comes after the product stage, are where missing data and guidelines is described as the major challenge in building LCA. Some of the respondents commented that most EPDs are declaring environmental loads only at the the product stage (from cradle to gate), whereas the scenarios are either not declared or poorly documented. End-of-life, and recycling in particular, can be seen together with benefits beyond the system boundaries, and together these parts of the building life cycle was chosen by 41 respondents (72%). Robust treatment of recycling effects may require revision of current LCA practices. One respondent said "Common methods for handling marked effects of recycling would be useful. Can we implement consequential-LCA thinking to evaluate for instance the use of recycled aluminium or fly ash?".

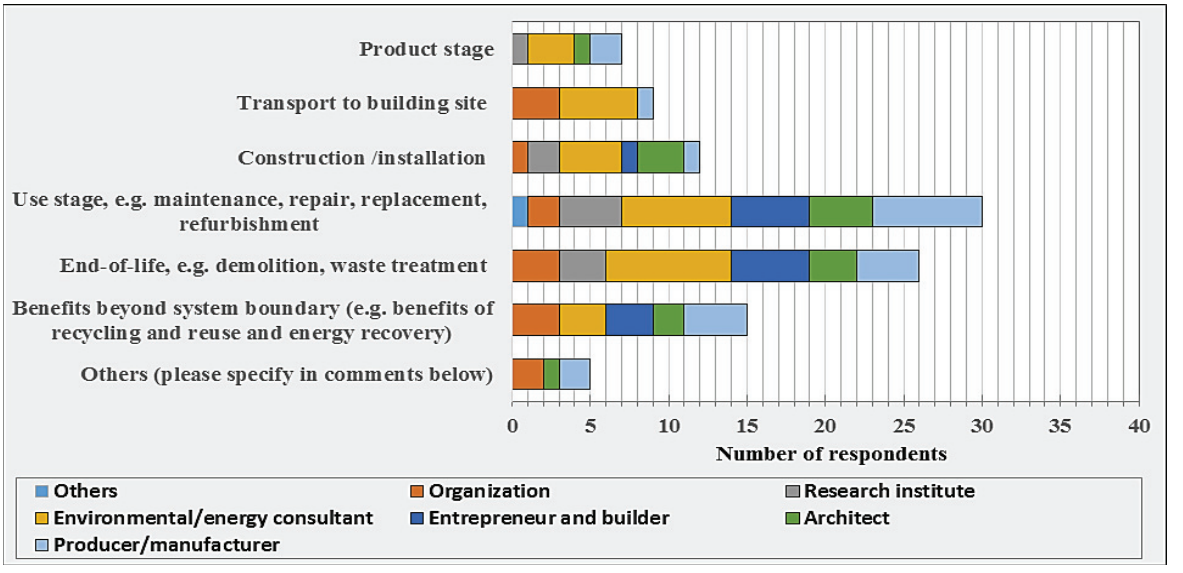

Fig. 2. Responses to the question "In your opinion, which parts of the building life cycle are missing data and guidelines"

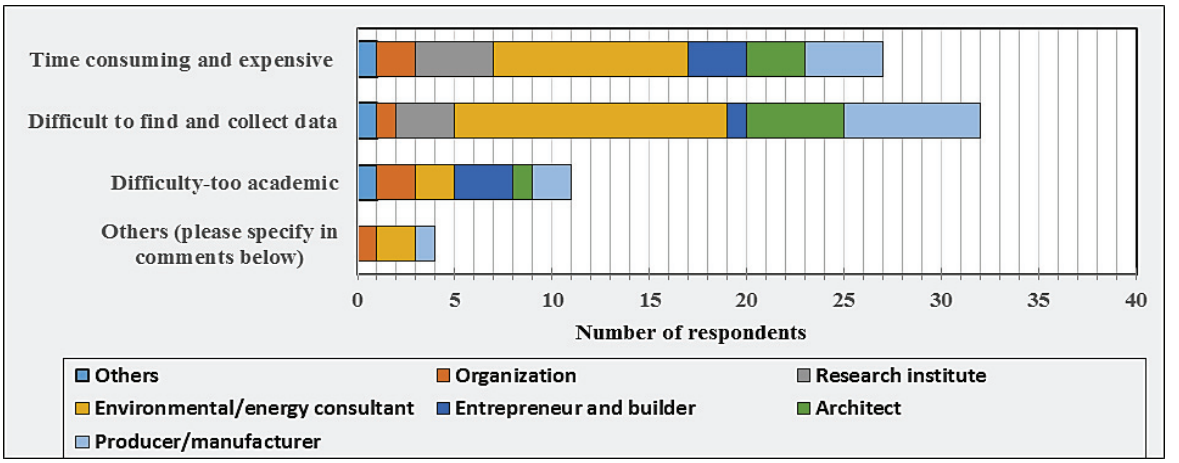

Fig. 3. Responses to the question "In your opinion, which issues can make building LCA difficult to apply?"

Some respondents, however, suggested to put more weight on the early life cycle stages in order to count for the time effects of GHG emissions. The LCA methodology traditionally used for buildings does not give any weighting to environmental impact based on the time they are happening. However, considering the 2 degree target for global warming, the UN IPCC has shown that cuts in greenhouse gas emissions in near future are much more effective than planning for cuts further ahead [27]. Further research is needed on this issue and on possible weighting factors.

In addition, lacks of data and guidelines on the emissions from land use and occupation, transportation of persons in the use phase and emissions to indoor air were commented by the repondents.

The questionnaire also asked the participants about challenges in the practical application of LCA in their respective businesses. The answers are shown in Fig.3. 32 respondents indicated that they find it "difficult to find and collect data", 27 respondents indicated that they find performing building-LCA "time consuming and expensive", and 11 respondents indicated that LCA is difficult and too academic. Two Finnish and one Swedish respondent commented here that there were little market demand for LCA from their perspective.

The results show that the respondents of the study find it difficult to find and collect data. Data on energy carriers, transportation and waste treatment was reported to be needed in particular.

Many of the respondents reported that they find LCA work too time-consuming. One respondent commented "Depending on the scope set in the project, performing a full-building LCA, at stages where the results can influence choices made, can be very time consuming. Attention to detail in terms of quantifying the whole building and the entire lifecycle might reduce the resources available for identifying, analysing and addressing big-hitters". This result can also be seen in relation to the results of the questions of knowledge gaps, to which 42% of the interviews answered "lack of estimated default values on building element/parts for use in screening LCA". There is reason to believe that the industry could benefit from having estimated default LCA values for building elements and predefined construction options. Developing simplified tools for performing LCA in order to reduce the time, specially the data collection phase, were also described as a solutions. One respondent wrote "We should [...] develop [a] way of using LCAs during the design processes. [...] We should be able to use the method in flexible way so that it really supports designers and owners to find optimal solutions."

Furthermore, the survey asked about application and interpretation of LCA results. The responses can be seen in Fig.4. The respondents described difficulty in comparability (29 of the respondents) between countries and various products, lack of transparency (25) in the background data, assumptions and choices made while performing LCA and quality of input data (20) as the major problems when using LCA results. Knowledge gaps and misunderstanding when evaluating LCA results (19), need for more precise guidelines (15), and difficulty-too academic (8) were also described as challenges to understand, and use LCA results.

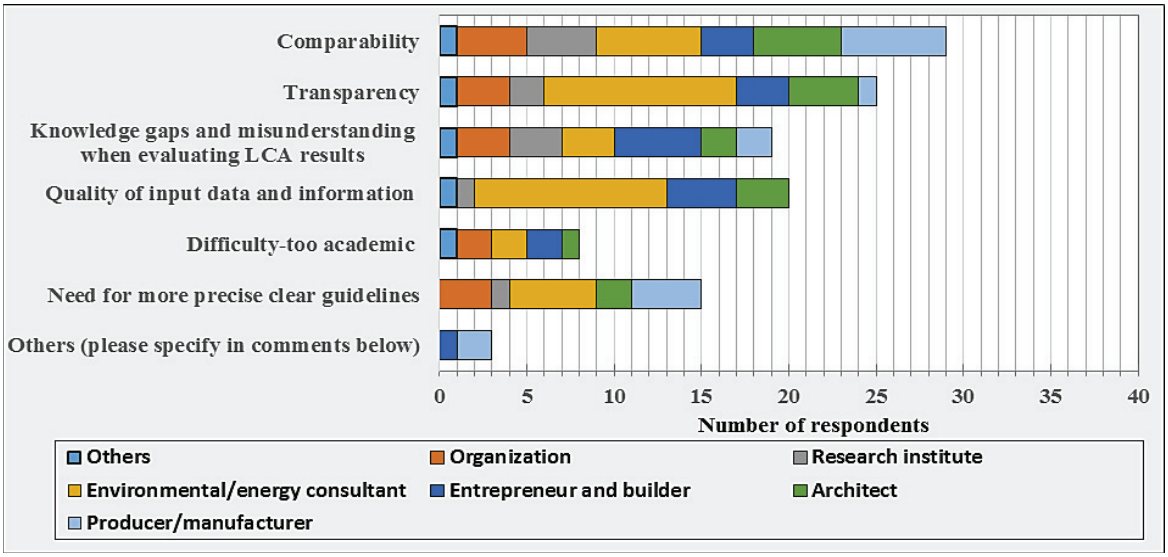

Fig. 4. Responses to the question "When using the results from an LCA, what type of problems do you see?"

For some of the respondents, mainly the respondents from Norway, their thoughts went to the EPDs, as it is a system for communicating LCA results. Quite a few commented upon digitalizing EPD data, which today is mostly based on static PDF documents. Some respondents found it difficult to use these documents in LCA tools and other applications. Some also commented on the transparency of the EPDs, saying that "The EPDs should provide the necessary background information for using the results in further LCA studies".

Some respondents called for a better understanding of the effect of methodological choices in LCA. Others called for a better understanding of the significance of identified differences when comparing alternatives. In other words, the respondents reporten to lack knowledge of what impact different methodological choices have on the results of an LCA, and they also find it difficult to compare and evaluate the results of different LCAs.

3.3. Need for collaboration between the Nordic countries

The third part of the survey contains questions about the importance of collaboration between the Nordic countries and issues benefited from the Nordic cooperation. Options ranged from very important (29 of the respondents), important (14), moderately important (9), slightly important (2), to not important (2).

Specifically, Fig. 5 shows the issues that would be benefit from Nordic cooperation from the point of view of the respondents. Every variable has a relatively high score in this survey, the highest score was the importance of creating common databases (40 of the respondents). The importance of creating new tools is lower compared to the other alternatives (9 of the respondents). Most of the respondents in the survey reported that a common Nordic environmental database and common Nordic assessment tools/guidelines would be useful or very useful. This can be seen both as a general need for availability of reliable data and a need of compatible and comparable performance criteria across the Nordic countries. Especially the database appeared to be of interest. "Maybe this can help reduce the time consumption", one respondent wrote. Some suggested that the development of common Nordic open databases for energy and transportation would be very valuable. However, quite a few of the respondents commented that an European database would be even more useful than a Nordic one.

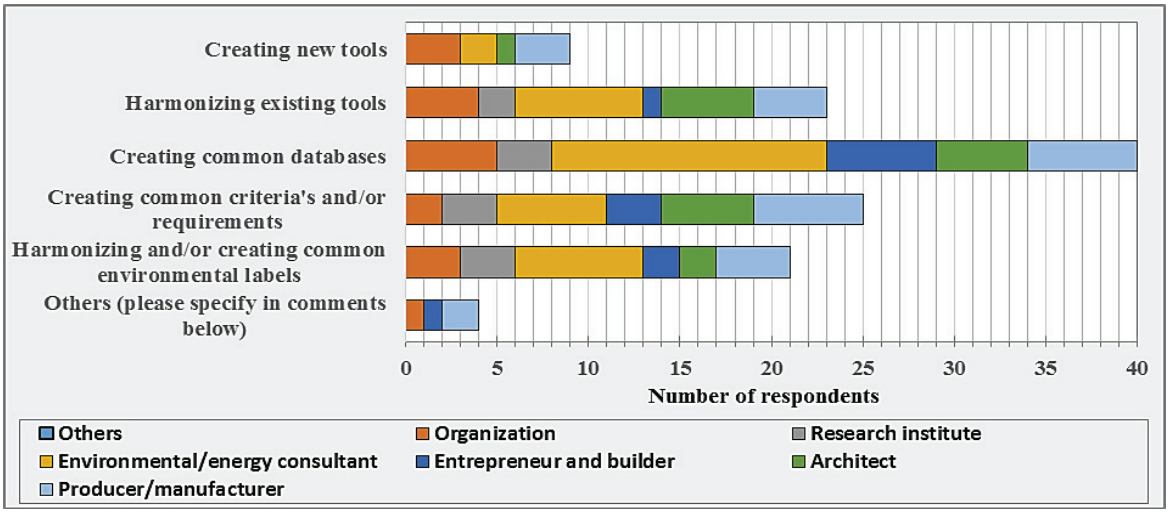

Fig. 5. Issues that would especially benefit from Nordic co-operation sharing of information.

Furthermore, the importance of harmonizing existing tools was emphasized by the respondents. One respondent wrote "There is not necessarily a need for more tools, but a methodical quality control would ease the deisgn process and improve the ability to benchmark across projects and countries". It was suggested to harmonize the rules for CO_2 factors of electricity across the countries. Harmonization of LCA methodologies and environmental labels, e.g. harmonizing EPDs and having Nordic product category rules (PCR) for EPDs across the Nordic countries, was also recommended by some respondents. However, especially the Finnish respondents said that a common database would be more important than a harmonization of tools and certification schemes.

3.4. Building information modelling (BIM) and LCA

The last part of the questionnaire includes questions about the importance of Building information modelling (BIM) in performing LCA of buildings. BIM is considered as very useful (21 of the respondents), useful (25), not needed (2) tool. Integrating BIM in LCA was described as an opportunity to do quick LCA screenings in the early designs stages, and therefore represents a potential solution to some of the challenges discovered in this study.

This question in the survey included a summary of the results from an interview of Finnish designers made by VTT. The Finnish designers mentioned the current lack of BIM in supporting the performance management of buildings, the poor availability of product information, the need for better availability of service life and maintenance-related information and smart methods for data collection. In this survey, out of 37 replies, 26 of the participants agreed with the Finnish designers point of view, 3 participants have mentioned limited or lack of experience working with BIM, whilst the remaining participants partly agreed (4), disagreed (1) or gave no comments (3). The importance of integrating information from BIM (e.g. quantity of materials and building parts) with EPD data in order to make environmentaly friendly desicion at the early design phase of building was commented. Some respondents mentioned difficulty with extracting data from BIM due to difficulty in finding information on thicknesses/amounts of products. In addition, practical difficulty of obtaining information related to the senarios for service life and maintenance was also described as a challenge. The need of developing a guideline on how to easily extract and sort the data from BIM in order to reduce the time and improve the quality of material inventory for LCA of buildings was recommended. In Norway, the Norwegian Standard comitee, the The Federation of Norwegian Construction Industries (BNL) and other partners, are currently coming together in a joint effort to clear the way for EPD-data to be integrated in BIM. The project is funded by the Norwegian State Housing bank.

4. Conclusions

The results from this study provides valuable insight in how Nordic Building Industry experiences the use of LCA and LCA-related documentation and certification schemes. The study provides awareness of the issues that are needed to be addressed and suggested solutions in order for the industry to accelerate and expand the application of LCA in the near future. The study also shows that collaboration across the Nordic countries is much valued. It is important to combine resources and capabilities to maintain and reinforce the Nordic status as a skilful actor in sustainable building and environmental assessment. Based on the results from this study, the following recommendations can be made for further work on building LCA, inside or outside the scope of the NORNET project:

- The respondents of the study described the difficulty in finding and collecting data when performing building LCA. The Nordic building industry also find building LCA time-consuming and expensive. It is likely that this is the reason for a strong interest in creating a common Nordic LCA database. This sends a strong signal to the LCA communities in the Nordic countries to cooperate, disseminate information about exisiting databases and also start building a common database. Particularly, the importance of developing common data on energy carriers, transportation and waste treatment was emphasized. For a common Nordic database to be operative, harmonization of rules are also needed. For instance, there is a need to harmonize CO_2 factors of electricity across the countries.
- The handling of the end-of-life phase of buildings in LCA was pointed out as a challenging area. The environmental benefits of recycling, reuse and energy recovery are representing an important knowledge gap in the building industry.
- The Nordic building industry find building LCA time-consuming and expensive. Common, easy-to-use tools and databases with digital data can be one solution to this issue.
- More research on efficient ways of performing LCA in the early design stages is needed. Development of default values in a data library on building parts and components for use in screening LCA in early stages would be on step. Another important step would be further work with integrating EPD data into design files of BIM can help reduce time-consumption and improve data quality in the early design phase.
- Comparability and transparency are the largest concerns when it comes to applying the results of LCA studies. EPDs are LCA results that are widely applied as a background data source in the Nordic building industries (specially in Norway and Sweden). Detailed guidelines that provides an overview to common rules and harmonized methodology used in developing EPDs is required in order to avoid trade barriers on the Nordic market. The format of the EPDs should be made more flexible, both in order to be easier to compare to each other, but also for easier access into digital tools.
- The time-aspect and the associated application of weighting factors or discount rates in building LCA should be studied in further work.
- A discussion about steering instruments for sustainable buildings in the Nordic countries should be opened - similar steering methods and harmonized environmental documentation and calculation requirements would be welcome.

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Appendix A. Questionnaire

A.1. Innovative use of LCA in the development of sustainable building and refubrishment strategies in the Nordic countrie - Research survey

Part 1: Company information

1.1 In which country is your company situated? (For multinational companies, choose the country in which your department is situated).
- □ Denmark
- □ Finland
- □ Norway
- □ Sweden

1.2 What type of company do you represent?
- □ Producer/manufacturer
- □ Architect
- □ Entrepreneur and builder
- □ Environmental/energy consultant
- □ Research institute
- □ Organization (please specify in the comments below)
- □ Other (please specify in the comments below)

1.3 Do have experience with LCA on the material level or on the building level?
- □ At material level (e.g. EPD)
- □ At building level (e.g. BREEAM, Architectural design)
- □ Other (please specify in the comments below)

Part 2: Knowledge gaps and issues in building LCA

2.1 In your opinion, what are the most important knowledge gaps in building LCA?
- □ Environmental impact waste treatment alternatives
- □ Environmental benefits of recycling and reuse and energy recovery
- □ Environmental of maintenance and repair
- □ Environmental impact of demolition and re-construction
- □ Emission factors for energy sources and electricity
- □ Other impact categories than global warming potential (CO_2)
- □ Lack of estimated default values on building parts/components for use in screening LCA
- □ Scenarios and building context
- □ Lack of data for certain product categories (please specify)
- □ Others (please specify in the comments below)
- □ Any other comments?

2.2 In your opinion, which parts of the building life cycle are missing data and guidelines?
- □ Product stage (please specify in the comments below)
- □ Transport to building site (please specify in the comments below)
- □ Construction /installation (please specify in the comments below)
- □ Use stage, e.g. maintenance, repair, replacement, refurbishment (please specify in the comments below)
- □ End-of-life, e.g. demolition, waste treatment (please specify in the comments below)
- □ Benefits beyond system boundary (e.g. benefits of recycling and reuse and energy recovery)
- □ Others (please specify in the comments below)
- □ Any other comment?

2.3 In your opinion, which issues can make building LCA difficult to apply?
- □ Time consuming and expensive (please specify in the comments below)
- □ Difficult to find and collect data
- □ Difficulty-too academic (please specify in the comments below)
- □ Others (please specify)
- □ Comments (please specify)

2.4 When using the results from an LCA, what type of problems do you see?
- □ Comparability
- □ Transparency
- □ Knowledge gaps and misunderstanding when evaluating LCA results (please specify in the comments below)
- □ Quality of input data and information (please specify in the comments below)
- □ Difficulty-too academic (please specify in the comments below)
- □ Need for more precise clear guidelines
- □ Others (please specify in the comments below)
- □ Any other comments?

Part 3: Need for Nordic collaboration

3.1 In your opinion, how important/useful would it be to have a common Nordic environmental database and common Nordic assessment tool?
- □ Very important
- □ Important
- □ Moderately important
- □ Slightly important
- □ Not important

3.2 Please, choose what kind of issues would especially benefit from Nordic co-operation sharing of information:
- □ Creating new tools
- □ Harmonizing existing tools
- □ Creating common databases
- □ Creating common criteria's and/or requirements
- □ Harmonizing and/or creating common environmental labels
- □ Others please specify in the comments below)
- □ Any other comments?

Part 4: Use of BIM for LCA

4.1 Please, choose your opinion on the usefulness of BIM for LCA
- □ Very useful
- □ Useful
- □ Not needed
- □ Others (please specify in the comments below)
- □ Any other comments?

4.2 VTT recently interviewed Finnish designers about the current lacks of BIM in supporting the performance management of buildings. Many of the interviewees addressed the poor availability of product information as an important problem. In particular, better availability of service life and maintenance-related information and smart methods for data collection would be very useful.

Do you agree with this? Please comment.

Thank you for your collaboration

Please, could you add if you have additional comments/suggestions?

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