# CHALLENGES IN EXTRACTING INSIGHTS FROM LIFE CYCLE ASSESSMENT DOCUMENTS DURING EARLY STAGE DESIGN

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## ABSTRACT

Life cycle assessment (LCA) has been established as a benchmark for design for sustainability practices. LCA provides detailed technical documents regarding a product's environmental impact, but its use is often limited to trained experts who share the knowledge with designers. Life cycle experts are highly specialized, and the typical designer faces technical barriers and time constraints in extracting information from LCA documents. This work uses knowledge transfer principles to replicate expert practices in LCA information retrieval to support designers. Life-cycle experts (n=4) were interviewed to understand practices and challenges in information retrieval for LCA documents. Interview findings were used to create a set of guidelines for effectively navigating LCA documents and then tested in a follow-up task where designers (n=16) annotated an electric toothbrush LCA using the identified guidelines. Results find designers can effectively extract information from LCA documents given provided guidelines, but need detailed support interpreting complex visual entities like charts and figures. This work is the first step toward enabling knowledge transfer from LCA documents and building a structured sustainability knowledge base.

**Keywords**: Sustainability, Knowledge management, Communication, Collaborative design

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## 1 INTRODUCTION

The UN's Sustainable Design Goal (SDG) 12 focuses on ensuring responsible consumption and production patterns as a critical objective for long-term sustainable global development. Engineering design presents a particularly important domain for this SDG: it's commonly thought that as much as eighty percent of a product's environmental impact is locked in during the early phases of the design process (McAloone and Bey (2009)). However, engineers, product managers, industrial designers, and other decision-makers in early-stage design - referred to here as "designers" for brevity - struggle to incorporate sustainability into their design work due to knowledge and experience gaps (Damen et al. (2022)). Integrating environmental principles in these early stages is critical in ensuring sustainability in product design (Vinodh and Rathod (2010)), and designers have expressed a desire for increased transparency and access to information while engaging in sustainable design. Life cycle assessment (LCA) is a method that has been well-established as a benchmark for design for sustainability. This technique produces detailed documents on a product's environmental impacts that serve as decision-making guides for many designers. However, little work has investigated how designers may directly use data-rich LCA documents to improve their own designs. Instead, life cycle experts are typically relied upon to interpret and disseminate information found in these documents, with designers facing barriers regarding technical complexity and lack of time (Le Pochat et al. (2007)). Yet, life cycle experts are not readily accessible to all designers, especially at small to medium enterprises. This work aims to enable knowledge transfer of sustainable design principles by transferring existing life cycle experts' (referred to as *experts* throughout this paper) practices to novices. In this paper, novices are represented by *designers* given they often lack formal sustainability experience. Facilitating the average designer's access to sustainable design information can directly improve the prevalence of eco-friendly products and is the ultimate goal of this project. The presented study serves as a first step toward developing a framework to facilitate knowledge transfer of sustainable design principles to designers across the entire spectrum of experience levels.

This work addresses three primary research questions:

- **RQ1.** What are the main challenges life cycle experts face when guiding designers to make design decisions based on life cycle knowledge?
- **RQ2.** How do experts interpret and extract information from LCA documents?
- **RQ3.** How can expert practices be leveraged to support designers (with little to no sustainability experience) in directly extracting information from LCA documents?

To address these questions, this work sought to first understand existing expert practices in leveraging LCA documents for sustainable product design and then explore how these existing practices could translate to designers as they interacted with LCA documents. In pursuit of the first goal, semi-structured interviews were conducted with sustainability experts from various consumer product companies (Sec. 3.1). Then, to explore whether these expert practices could be transferred to designers, findings from the interviews were used to create a set of guidelines for effectively navigating LCA documents. This set of guidelines was created with novice knowledge transfer principles in mind and subsequently tested through a follow-up task with designers. To examine if these technically complex documents could be navigated given expert-driven support, designers were asked to annotate an existing LCA with help from the provided set of guidelines (Sec. 3.2). The main contributions of this work are (1) thematic insights on areas for improvement during knowledge transfer from LCA documents to designers and (2) a set of guidelines for supporting designers in directly identifying insights from LCA documents. Overall, this work enables knowledge transfer from LCA documents to designers by serving as a first step toward a scalable sustainability knowledge base.

## 2 RELATED WORK

In this section, related works on LCA, design for sustainability, and knowledge transfer are reviewed. LCA is a common method used in design for sustainability practices, however it is often largely geared toward expert usage (Le Pochat et al. (2007)). This paper looks to incorporate elements of knowledge transfer between experts and novices into sustainable design practices, empowering individual designers to independently seek and incorporate this information into their design work.

## 2.1 Conducting life cycle assessments

Life Cycle Assessment (LCA) reports are constructed according to ISO 14040 guidelines, which specify that LCAs must include 4 phases: scoping the document, life cycle inventory analysis, life cycle impact assessment, and life cycle interpretation. However, the nature of the scoping portion of LCAs is subjective. During this phase, decision-makers decide the structure and level of detail to be included in the LCA depending on what they anticipate the expected use of the report be (Miettinen and Hämäläinen (1997)). As a result, LCAs can vary tremendously in their analysis and assessment methodologies, amount of data reported, and structure (Koj et al. (2019)). This makes direct comparison of LCA documents difficult, though there have been frameworks developed to standardize the process of reviewing an LCA (Zumsteg et al. (2012)). In an effort to save resources while still conducting valuable environmental analyses, there have been many approaches at creating simplified LCA processes, though it is agreed that these simplified LCAs still face many challenges and there is no one-size-fits-all solution (Beemsterboer et al. (2020)). Many challenges exist toward the creation of LCA documents, with even simplified LCA processes requiring expert knowledge around life cycle information and where to make simplifications (Saade et al. (2019)). This work seeks to avoid this creation barrier by allowing designers access to product LCA documents that have already been created and providing support in interpreting experts' outputs.

## 2.2 Design for sustainability tools

Various sustainable design tools exist to support analyzing product life cycles (i.e. ECODESIGN PILOT, SimaPro, EcoFaire) including the development of CAD-integrated LCA tools for geometric models. However, these tools present their own challenges, including requiring some level of environmental expertise, not being used because of resource constraints at small and medium enterprises (Le Pochat et al. (2007)), or even not providing the depth of analysis of a full LCA (Hernandez Dalmau (2015)). Recent work has even explored the successful implementation of eco-design teaching initiatives within companies through months-long lectures and assignments (Marconi and Favi (2020)), which provide rigorous but time-consuming training. Though LCAs can provide the necessary metrics to inform the direction of design choices to address environmental concerns, the current industry standard is for life cycle experts to interact with LCAs and then guide designers in their work (Millet et al. (2007)). Indeed, many outputs of LCA are not easily transferred to design decision-making or the design process as a whole (Pryshlakivsky and Searcy (2021)). In this work, existing research in sustainability tools is extended to focus on facilitating knowledge transfer of information from rich LCA sources and thereby lowering the barrier to sustainability information access that designers may face.

## 2.3 Knowledge transfer in engineering design

Knowledge transfer and management are critical factors to successful engineering design. Effective information transfer in design can occur through a variety of mediums, but primarily are characterized through discussions or face-to-face conversation, trainings, and formalized documents (Mougin et al. (2015)), making LCA reports a viable candidate for knowledge transfer. Information transfer between experts and novices primarily dedicates time to three phases: information seeking, contextual information sharing, and knowledge creation (Deken et al. (2012)). Specifically, novices have knowledge needs that fall under eleven categories, including obtaining information, terminology, tradeoffs, what issues to consider, and how to calculate (Ahmed and Wallace (2004)). By taking high-level needs of novices into account, sustainability frameworks can be build around efficiently and directly sharing this information to designers. Previous work by the authors explored the use of embedding tacit, or experiential, knowledge into searchable, scalable graphs for enabling knowledge transfer of data that may be otherwise difficult to share (Wang et al. (2023)). Using this approach could afford knowledge transfer to less-experienced designers as they make decisions that shape sustainability during early-stage design.

# 3 RESEARCH METHODOLOGY

This section describes the methodology used to gain insights from sustainability practitioners. These insights are compiled into a set of guidelines for extracting important information from LCA documents, which are subsequently put into practice during an LCA annotation activity carried out by designers.



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### 3.1 Practitioner interviews

**Interview Process:** Industry professionals who either currently or in the past worked as Life Cycle or Sustainability Experts were interviewed (n=4). These participants are referred to as *experts* from here on. Experts were recruited through LinkedIn using keyword search terms including "life cycle assessment product design" and "lca engineering design" and had a range of 6-9 years of experience working in life cycle or sustainability roles. Inclusion criteria included that participants must have worked at consumer product companies (therefore excluding those working in energy, architecture, etc.) and had been involved in improving the sustainability of designs at their respective companies. Participants worked in a range of product areas including consumer electronics, automotives, and household products. All interviews were conducted on Zoom and lasted between 30 minutes to 1 hour. Using a semi-structured interview format, these practitioners were asked about their experiences incorporating sustainable design practices into their products, leveraging data from LCA documents, and the primary challenges faced during these processes. The semi-structured format was chosen for its flexibility due to the exploratory nature of these interviews. An example subset of interview questions asked can be seen below:

1. When in the design process does your life cycle knowledge come in?
2. How do you identify the high-level priority areas on sustainability for your product?
3. Given [example LCA document], how would you navigate it? (Follow-up) Why is this information useful to you?

**Qualitative Coding and Analysis:** Interview transcripts were processed using thematic analysis to understand how experts interact with sustainability documents and then share this information with designers. After a first round of initial coding, codes were grouped into high-level themes, resulting in 9 overall themes. Toward the ultimate goal of supporting knowledge transfer between experts and novices, several of the interview themes were used to form a guide intended to capture the main areas that experts extract information from in LCA documents. This guide incorporated knowledge transfer principles for novices and was tested in an example study to identify whether designers could replicate expert processes given structured support.

### 3.2 Life cycle assessment annotation task

Designers (n=16) were recruited to complete an annotation task, with no experience in sustainable design required to participate. Designers were screened through a Google Forms survey to ensure participants had industry experience in product or industrial design. Designers who participated in the annotation task held a wide range of years of experience, from <1 year to 9 years working in a design role. Participants worked in a range of product areas including consumer electronics, automotives, aerospace, digital design, and household products.

This annotation task was intended to test the guide of expert-driven LCA categories that was compiled during the interviews. The designers were provided with the information in Table 1 and an LCA of an Oral-B electric toothbrush (Suarez). This task was carried out on the annotate.com platform, which enables collaborative annotations on a single document as well as annotation tagging, which was used to match each note with a provided category. The electric toothbrush LCA was chosen due to the product's status as a common household item. Additionally, the length of the LCA (8 pages) would not be overwhelming to designers who had never interacted with this kind of document before.

The annotation task placed participants as designers at a company tasked with improving the environmental impact of their electric toothbrush. Participants were asked to annotate an LCA document to highlight relevant design information and were told that sustainability experts had identified the provided categories as **very important** for sustainable design. Note that alongside expert-guided categories, participants could mark information as "other" to allow designers to indicate information they found interesting outside of the experts' lens. An example of an annotated page can be seen in Figure 1. Participants were asked to tag each annotation with a relevant category (Table 1) as well as an explanation for the given annotation. Participants were suggested to spend about 25 minutes on this activity. A post-task survey was distributed using Qualtrics to collect demographic information and gain insights on difficulties the participants faced during the task. Annotated portions of the document were exported to a spreadsheet along with corresponding category tags and participant comments for analysis.



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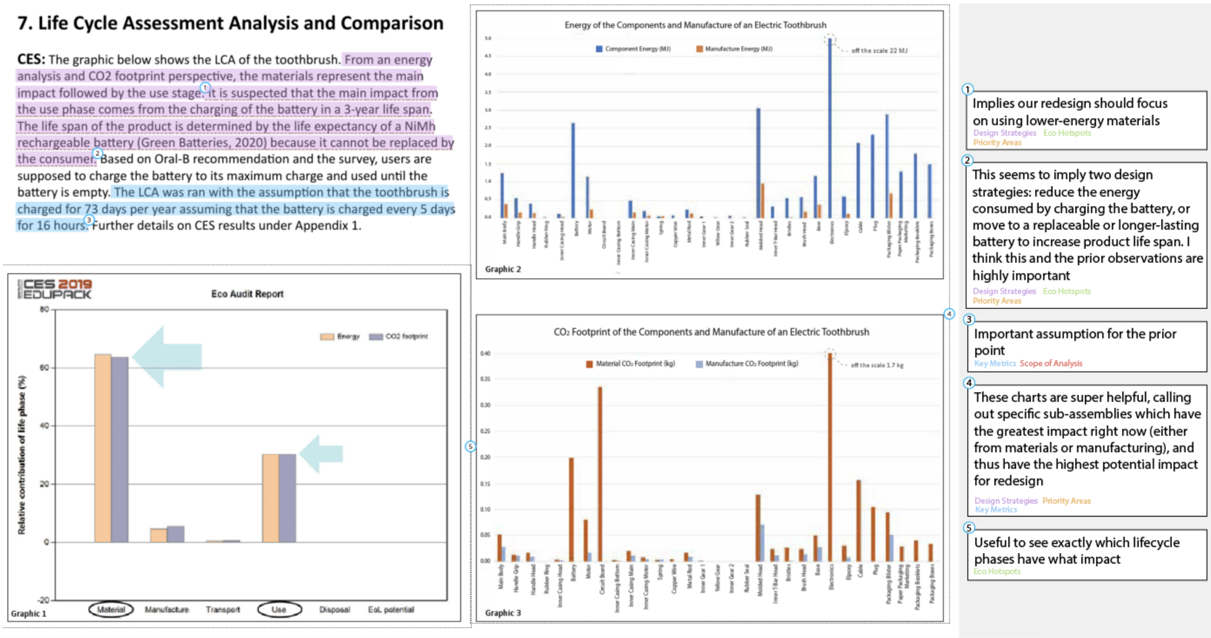


*Figure 1. Annotation task screenshot. On the left is the provided electric toothbrush LCA. On the right are designers' annotations, with each note corresponding to a numbered section on the left.*

## 4 RESULTS AND DISCUSSION

This section presents insights from the semi-structured interviews conducted with experts, primarily on insights into the process of leveraging LCA documents for support in the design process. These findings are combined with knowledge transfer principles in the creation of an LCA knowledge transfer guide. Then, results from the example annotation study are discussed. This example explored if and how designers can be supported in independently retrieving knowledge from these documents based on learning from expert techniques. Finally, challenges faced by both experts and designers during this process are presented.

### 4.1 Expert practices in interpreting and extracting information from LCA documents

During the interview process, experts were asked about how they interacted with and learned from LCA documents themselves in order to support designers' decision-making. This ultimately led to the creation of a knowledge transfer guide for novices looking to navigate LCA documents.

#### *4.1.1 The role of intuition and previous work is highly important.*

Experience and intuition play a key role in how experts can parse through documents and extract relevant information. The interviewed experts are well-versed in this field, and thus can efficiently search through LCA documents to extract key information, with all of the experts mentioning that established heuristics or rules of thumb played a role in their processes. Additionally, all experts mentioned using LCA documents of past product versions or similar products to inform and improve future iterations. The technical complexity of these documents often makes them hard to read and understand and thus can provide barriers to this information that is potentially highly relevant (Millet et al. (2007)). This work looks to be a first step toward enabling information retrieval from these documents which are data rich and could serve as valuable resources to designers if accessible.

#### *4.1.2 Identify the scope of analysis conducted.*

Understanding the scope that an LCA uses is highly important in understanding the analysis and takeaways that can be extracted, with three of the four experts highlighting its major role in contextualizing these documents. The main differences that experts identified were that LCA documents can look at different lifespans of a product (cradle-to-cradle, cradle-to-gate, etc.), they can source their materials data from particular databases, and they can consider very specific use cases in their analysis. Experts highlight that identifying an LCA document's scope is often one of the first steps taken when reading


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these documents, to situate the information that is being presented. This also accounts for identifying the assumptions going into the scope. For example, one expert outlined that understanding that a document is looking at a three-year product lifespan while another document uses a significantly shorter lifespan provides important context when interpreting the environmental impacts presented. Given its high importance in parsing through an LCA, *scope of analysis* was included as a guiding category for the follow-up annotation task, to examine if designers were able to independently find this information.

#### 4.1.3 Break the LCA down into priority components.

Breaking down a product to identify its various subsystems and components allows experts to better understand the product itself and analyze what can be changed to make a high impact. Two experts noted that this is one of the first things they do when reading an LCA document, with one beginning his description of parsing through an LCA with "I'll go through the subsystems one by one to make meaningful differences" noting the need to understand where boundaries appear within products. This allows the experts to align the design goals (i.e., decreasing emissions, meeting particular standards, minimizing environmental impact, etc.) with actionable impact areas within the product itself, providing a level of concrete understanding that can be more easily understood by designers (Hinds et al. (2001)). *Priority components* was included as one of the provided categories for the annotation task to match how designers approach reading LCA documents with expert practice.

#### 4.1.4 Recognize where environmental hotspots appear.

All experts shared that one of the primary methods used to share information from LCA documents to designers is identifying hotspots or highly important areas of carbon emissions and other important measures (energy consumption, ecotoxicity, land use, etc.). These are used to increase designer awareness and education of areas that need to be addressed in the product, analogous to many eco-design tools which are directed toward highlighting problems as opposed to directly solving them (Ritzén (2000)). To facilitate the extraction of this information for designers, this theme was divided into two categories for the annotation task: *eco hotspots* and *key metrics*. *Eco hotspots* are intended to identify specific life cycle phases where these high impacts are found, to indicate at what stage of the design any changes would need to be made. *Key metrics* highlight the numerical values of these impacts and show a quantitative measure of values that could be adjusted. Recognizing these areas in an LCA would help designers learn from other products and identify potential areas of improvement on their own designs.

#### 4.1.5 Propose design strategies for implementation.

Apart from sharing where high-impact areas appear, one of the main methods mentioned by all experts use to support their designs is proposing design strategies and best practices that increase sustainability. Common suggestions that were shared included reducing plastics or making more modular (and therefore replaceable) components. Experts seek to find high-impact areas that can still be influenced within the design, and there is often a high focus on circularity and end-of-life. It is also critical that experts share **why** these strategies are important to implement in order to encourage serious adoption, echoing knowledge transfer themes proposed by Ahmed and Wallace (2004). As this was one of the main ways experts communicate their findings to designers, *design strategies* was included as a provided category for the annotation task, encouraging designers to identify these methods.

### 4.2 Expert-driven LCA information categories

Semi-structured interviews with experts resulted in nine overall qualitative themes. Four of these themes corresponded with expert practices when interacting with and extracting information from an LCA document: identifying the scope of analysis conducted, breaking the LCA down into priority components, recognizing where environmental hotspots appear, and proposing design strategies for implementation. These themes were then transformed into a format that would allow designers to efficiently recreate the expert knowledge extraction process, specifically for LCA documents. To this end, the four themes were combined with the eleven topic categories classified by Ahmed and Wallace (2004) as *novices' knowledge needs* when learning from experts: (1) obtaining information; (2) typical value; (3) terminology; (4) trade-offs; (5) how does it work; (6) why; (7) what issues to consider; (8) when to consider issues; (9) how to calculate; (10) design process; and (11) company process.


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These topic categories were mapped to relevant themes from the interviews, with the mappings found in Table 1. For example topic 5 (*how does it work*) was mapped to breaking the LCA down into priority components, which allows the reader to examine key areas of a product. Creating a category for the guide around identifying important components of a product helps break the product down for readers and improve clarity on how it may work. The rest of the provided categories were similarly combined with novice knowledge needs to form both supportive and informative category and description pairings for the guide.

Table 1 contains the five themes presented to designers with a provided description for each, and an additional "other" category to encourage designers to indicate information they found interesting but that may fall outside of the experts' lens. These categories are put into practice in an example LCA annotation task carried out by designers in Sec. 4.3 to explore their role in supporting efficient navigation of these highly technical documents.

*Table 1. Expert-identified important categories when reading an LCA document, based on interview data, with their corresponding knowledge transfer principles from Ahmed and Wallace (2004). These categories were provided to designers in a follow-up annotation activity recreating expert knowledge transfer from these documents.*

| **Category** | **Provided Description** | **Relevant Knowledge Transfer Principles** |
|---|---|---|
| Scope of Analysis | *Establishing the boundaries of what the life cycle assessment encompasses.* | (7) what issues to consider<br>(9) how to calculate |
| Priority Components | *Components and sub-assemblies of the product that are critical or highly important to the product itself.* | (5) how does it work |
| Eco Hotspots | *Life cycle phases with high environmental impacts. Phases can include material extraction, manufacturing, transportation/distribution, use, end of life, etc.* | (8) when to consider issues<br>(10) design process |
| Key Metrics | *Numbers associated with high environmental impacts. This can include carbon emissions, energy, land use, etc.* | (2) typical values<br>(4) trade-offs |
| Design Strategies | *Overarching methods for minimizing or addressing environmental impact.* | (6) why |
| Other | *Please annotate anything you find interesting even if it may not fit the above categories.* | – |

## 4.3 Leveraging expert practices to support designers in directly extracting information from LCA documents

Once the interview insights above were compiled into a guide, the follow-up annotation task was carried out to explore if and how designers could employ expert practices in retrieving important information from LCA documents. This section presents findings from this exercise and addresses the strengths of the designers.

During the annotation task, 16 designers created a total of 508 annotations. Table 2 shows the distribution of annotations per provided category and the average number of annotations created for each category per designer. Note that designers were allowed to tag a single annotation with more than one category, so totals are higher than overall number of annotations. 75% of the annotations highlighted $\leqq$ 20 words, indicating designers were seeking specific details within the document. Only 92 annotations (18%) were in reference to a figure or image within the document.

### *4.3.1 Role of guiding categories*

Overall, designers were successful in identifying information across all expert categories (Table 2). The low number of annotations within the "other" category indicates the provided categories maintain wide



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*Table 2. Number of designer annotations per expert-provided category.*

| **Category** | Scope of Analysis | Priority Areas | Eco Hotspots | Key Metrics | Design Strategies | Other |
|---|---|---|---|---|---|---|
| **Total # of Annotations** | 76 | 105 | 154 | 80 | 155 | 39 |
| **Average # per designer** | 4.75 | 6.6 | 9.6 | 5 | 9.7 | 3.35 |

coverage of the document's perceived important features. Participants were asked in a post-task survey whether the guiding categories were useful in annotating, with almost every participant indicating they were helpful to some degree. Participants noted that greater clarity around category definitions could be helpful, and future work could add examples and more precise wording across these provided definitions. Additionally, participants were asked to identify which categories were most difficult and most simple to identify within the LCA document (Table 3). Interestingly, the *design strategies* category drew mixed reviews despite having the highest average number of annotations per person. Challenges primarily arose around the provided definition and ambiguity around design intent within the product. Participants' ability to independently identify relevant information from an LCA document confirms that these documents can be used to support sustainable design practices in a structured way, providing a foundation to conduct this task on a large-scale way given improvements around category definitions.

*Table 3. Participant ratings of difficult and simple categories to identify within the provided LCA.*

| **Category** | Scope of Analysis | Priority Areas | Eco Hotspots | Key Metrics | Design Strategies |
|---|---|---|---|---|---|
| **Simple** | 8 | 6 | 8 | 3 | 6 |
| **Difficult** | 5 | 2 | 0 | 4 | 8 |

### 4.4 Challenges faced by experts and designers when leveraging life cycle knowledge

This section presents challenges faced by both life cycle experts and designers which arose throughout this work. The expert interviews highlighted some of the primary challenges experts face in using LCA documents, with the primary insights below. To address these challenges, the barrier to access should be lowered for designers who want to interact with life cycle information, which is currently highly technical and complicated to interpret for non-experts. Additionally, the annotation task highlighted gaps where increased designer support could be provided for future work. Overall, future work should facilitate designer access to life cycle information with added context around charts and figures.

#### *4.4.1 Experts play a large role in translating sustainability information.*

Given the complexity and level of technical detail found in LCA documents and sustainability databases, experts often find themselves acting as "translators" between these documents and the designers they interact with. Three of the experts stressed the importance of communicating with all stakeholders, from designers to the marketing team to the business side, to influence sustainability priorities. Two experts reported presenting designers with information on "hotspots" and "priority areas" to help the design team focus on product areas that can bring the most sustainable impact. To help designers understand life cycle knowledge, experts mentioned techniques such as visualizing CO2 impact relative to common items (ex: cars), simplifying language around sustainability goals, and simply presenting data to increase awareness. The annotation follow-up task to these interviews is a first step that seeks to support this challenge by empowering designers to retrieve, interpret, and use this data themselves, without the need for specialized experts who are often difficult to find.

#### *4.4.2 It is impossible to directly compare information from LCA documents.*

All experts reported they extract information, such as "key metrics" and "design strategies", from other LCA reports to create baselines for sustainable practices. One of the most difficult parts of using LCA documents to extract information is the lack of standardization found among existing documents (Koj et al. (2019)). Experts shared that every LCA uses its own data sources, scope of analysis, and methods for calculating various metrics, making it "very difficult to compare apples to apples". This conflicts



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with designers' needs because they tend to need more concrete knowledge when learning new concepts as subject areas novices (Hinds et al. (2001)). Two experts reported using relative comparisons within one report for extracting key metrics. Relative comparisons help provide a quick check or measure of current practices and the state of the market. This level of abstraction provides a barrier for designers who wish to use LCA documents themselves, and thus one of the ultimate goals of this work is to create a large-scale sustainability database to provide context and concrete comparisons to designers.

#### 4.4.3 Increased support in interpreting charts and figures is needed for designers.

Through the annotation task, designers indicated through both the post-task survey and annotation explanations that they had difficulty extracting meaning from charts and figures within the LCA document, even if they could recognize that the data is important. This can also be seen in the low participant ratings for *key metrics* (Table 3), which are often contained in figures. These challenges align with novice knowledge needs around clarifying terminology and considering typical values of a measure (Ahmed and Wallace (2004)). To add context and strengthen understanding around these figures, further tools could provide background or additional data to elucidate the key takeaways from provided charts and enable designers to use this data in their own work. This work looks to use the data extracted from LCA documents to build a sustainability knowledge graph, where data is supplemented and contextualized by sources like sustainability databases and other LCAs.

## 5 FUTURE WORK AND LIMITATIONS

This work serves as a first step toward developing a framework to facilitate knowledge transfer of sustainable design principles to designers, with the ultimate goal of building an information retrieval system that provides designers with sustainable design principles in a scalable, searchable way. Though this work focused on studying how knowledge transfer principles could be combined with expert practices on LCA document information retrieval, it could be expanded in multiple ways. First, it should be noted that the number of experts interviewed is a limitation, though the data gathered was rich as it was sourced from highly trained experts who are limited in number but very experienced. Then, this work can be explored with other LCA documents to ensure findings hold across fields and report styles. Crowdsourcing methods can be employed to extract information from a large set of LCA documents and by many more participants. This can help examine annotation accuracy and consensus, both important features in building a reliable information retrieval system. Finally, further work on understanding how designers may incorporate these annotated documents into a design context would support the goal of knowledge transfer of sustainable design principles. Enabling data-driven sustainable design will allow information-rich documents like LCAs to be leveraged in future product design processes.

## 6 CONCLUSION

In this work, semi-structured interviews were conducted with life cycle and sustainability experts (n=4) to learn more about the challenges faced when extracting and sharing knowledge from life cycle assessment (LCA) documents to designers. Then, expert practices in information retrieval and sharing from LCA documents were combined with knowledge transfer principles to create guiding categories for enabling direct designer information retrieval from these documents. These categories were tested in an example LCA annotation task. Designers (with little to no sustainable design experience) (n=16) were tasked with annotating an electric toothbrush LCA with the guidance of expert-provided categories. Designers were able to successfully identify information across all critical categories but need support interpreting highly quantitative charts and figures. Primary challenges faced by experts include difficulty comparing LCA documents given a wide range of practices and the role of "translator" that these experts often play between the highly technical documents and designers. This work serves as a first step in enabling knowledge transfer from technical LCA documents to designers who wish to incorporate sustainable design practices into their process. Future work looks to improve the expert-provided categories and explore this work on a larger scale with a wide variety of LCA documents.

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