# LCA within Design: Not a Matter of “Just Doing It”

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**Abstract**

As Ecodesign becomes more popular, more and more people defend that Life Cycle Assessment (LCA) constitutes an almost necessary step within this process. However, this has provoked some level of skepticism and reluctance from industry, who sees this as a considerable investment in time and budget. But what is the cause of such divergence? LCA was initially introduced in the design workflow with very minor modifications, and does not seem to meet the requirements of designers as-is. Some problems arise in the information input for LCA, in the dynamics and specificity of the process itself and in the way in which results can affect the rest of the design process. This paper outlines some potential problems, as well as candidate solutions to ease Ecodesign, without limiting itself to the burdens of current environmental practice. Some first steps on adapting environmental evaluation to design thinking are presented, as well as an outlook of further research with this target in mind. An expected mid-term outcome is an effective integration of LCA within CAD systems, in parallel with structural or management recommendations as to integration of environmental criteria within the company.

***Keywords****: Ecodesign, Life Cycle Assessment, Information management, Creativity, Design process*

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## 1. Introduction

Our current society has seen environmental concerns become a key issue in all decision-making process. Product development does not escape this trend, and a great amount of methodologies, methods and tools have been generated due to this. These have received names such as Ecodesign, Design for Sustainability, Environmentally Sound Product Development or Green Design among others (Waage, 2007; Howarth & Hadfield, 2006; Karlsson & Luttropp, 2006; McAloone, 2003; Coulter et al, 1995).

Approaches range from vague strategies to serve as guideline to strict procedures to optimize eco-efficiency. A common ground to many of them, however, is the consideration of Life Cycle Assessment (LCA) as a standard basis to obtain environmental information about the product (Jeswiet & Hauschild, 2006; Germani et al., 2004; Nielsen & Wenzel, 2002; Erzner et al., 2001; Gertsakis et al., 1997; amongst others). Even though arguments are given against it in occasions (Millet et al., 2007; Sousa & Wallace, 2006; Erzner & Birkhofer, 2002, Jönbrink et al., 2000) it is still one of the most extended approaches for environmental assessment of products in practice (Millet et al., 2007; Collado-Ruiz, 2007; Stevels et al, 1999). Even in cases in which alternative approaches are sought (Erzner & Birkhofer, 2003; Erzner & Wimmer, 2002; Brezet & van Hemel, 1997), LCA principles still constitute the basis (Ostad-Ahmad-Ghorabi et al., 2006; Goedkoop, 2004; Goedkoop, 2001).

New approaches in the field (Karlssson & Luttropp, 2006) have defended two main strategies:

- Approach environmental considerations in the early design stages (McAloone, 2003, Lindahl, 2005).
- Integrate current evaluation methods in CAD processes (Ostad-Ahmad-Ghorabi et al., 2009, Roche, 2004, Roche, 1999).

Even though both of them are sometimes mentioned together, the authors believe that both strategies are rather divergent, since CAD tends to be used in embodiment or detailed design. In any case, implementation in practice seems to have failed up to now in implementing any of both approaches, since most considerations of environmental criteria – at least those applied in a structured way – tend to appear at later stages in the design process, and by independent tools that do not link seamlessly with CAD software.

One of the common traits in all structured approaches that have been explored by the authors is the environmental basis. All of them seem to base themselves in "improving design by considering environmental information". To some extent, most of them seem to be based in "pushing" knowledge from the environmental engineering field towards design.
Not enough attention has been put into considering the design process and the needs and availability of information in each one of the stages. The output of environmental information

into the design process also has an influence that has not been thoroughly studied in literature. Lindahl (2005) approached this topic by defining a set of criteria for Ecodesign tools for them to be successful in their application, but more studies need to be conducted in this area.

One important trait of the design process is that it contains a great number of decision-making processes, some of them explicitly stated and others more unstructured (like reactions to unexpected results). Those decision-making processes must provide with a benchmark (to assess whether the new product is doing better or worse than such an indicator), to apply to different concepts than those previously established, and to be easy to perform without distorting the rest of the processes (Ostad-Ahmad-Ghorabi et al., 2009).

The approach presented in this paper is to invert the influence and infer from the design process how LCA should relate to it, and not the other way around. In other words, the purpose would be to adapt LCA to the requirements of the design process, and most particularly to decision-making in the design process.

## 2. How much: quantifying performance instead of environmental impact

One of the main questions when defining a benchmark is to set a target as to how much environmental impact can be considered for the new model being developed. The development of new technology can be considered, as well as variations in the product. The new product being analyzed will never be extrapolation must be done.

Normally, such extrapolation can be easily done by an environmental expert with experience in the field. Nevertheless, such sort of experts is rare in the design process, and the interaction between these stakeholders can be complicated due to the high amounts of implicit information dealt with during the process.

Figure 1: Approaches in assessing products without an identical baseline product

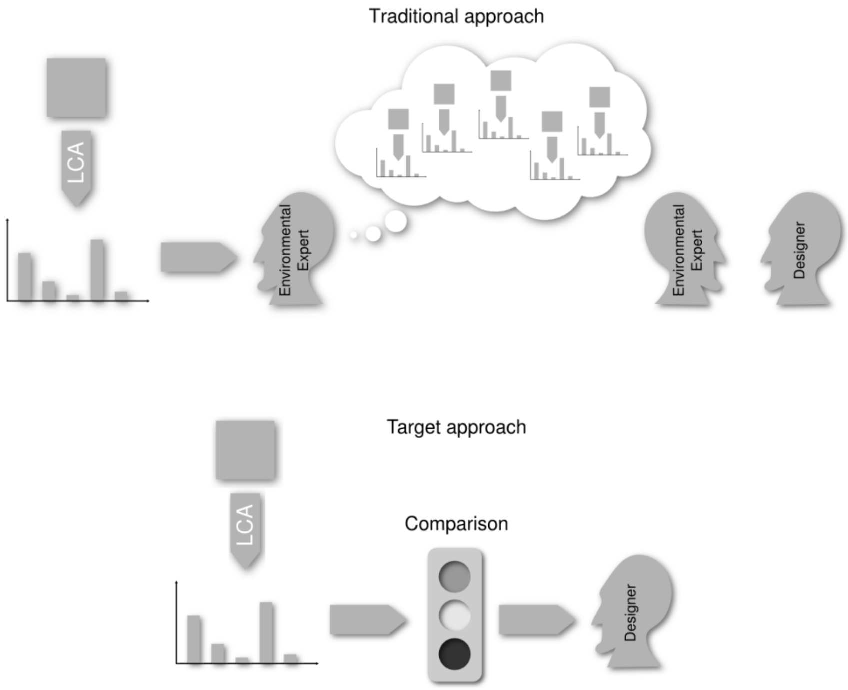



Figure 1 presents the approach that is sought in this paper. The purpose behind it is to give designers the capability to set targets and assess products in comparison to a reference performance. For that, and given a value for the environmental assessment of environmental experts can be substituted by defining a set of reference ranges that represent competing or similar products, manufactured with current technology. For that reason, the authors developed the concept of LCA Comparison Product Families (or LCP-families for short), defined as a set of products whose life cycle assessment shares a common behavior, and can therefore be compared in a practical way (Collado-Ruiz & Ostad-Ahmad-Ghorabi, 2010a).
These LCP-families group sets of products that can be defined by analogous functional units (FU), and therefore can be compared from an LCA point of view. Furthermore, these LCP-families can be put together to show which technologies and product concepts are more environmentally friendly, independently of their scale. That way, if they are grouped in the same families, designers can derive ideas for a specific product from the other family members e.g. designers of tables might take ideas out of well-performing beds, as their main functionality might be similar enough).

In order to group products and scale performances, the FU is used. This is done because products are comparable or not depending on this term (ISO, 2006). It would be expected for a 29" computer screen to have a higher environmental impact than that of a 19" screen. ISO requires every LCA practitioner to define at the start of the study such a quantified measure of the product's performance.

FUs tend to be defined rather vaguely in practice, sometimes with brief descriptions that are only quantified in their most relevant parameters. Some practitioners leave parameters out, or include text descriptions of technical solutions that do not respond to a functional nature. For that reason, the authors have introduced a concept for standardizing the phrasing of functional units. Collado-Ruiz and Ostad-Ahmad-Ghorabi (2010b) discuss the concept of functional icons (fuons), defined as an abstraction of a product, based on its essential function, it represents the whole set of products that share the parameters for its functions' flows. Through these fuons it is possible to standardize the definition of such FU's, since for a specific main function (and the flows associated with it) a set of limited parameters are presented which can be used to set up the FU. These parameters are named FU parameters (FUp's), which were further distinguished between physical parameters (FUpp's) to be used for scaling (Ostad-Ahmad-Ghorabi et al., 2008) and constraint parameters (FUpc's) to be used for selecting the LCP-family.

One important conclusion form the research conducted so far is that if performance was assessed at product level, specific environmental improvement targets were difficult to set for specific parts. For that reason the authors have been working on allocating the environmental impacts to different parts (beyond material-based indicators, which can be done almost immediately), and combining them with reference ranges (Collado-Ruiz & Ostad-Ahmad-Ghorabi, 2010a) through Ecodesign Decision Boxes (EDB, Ostad-Ahmad-Ghorabi et al., 2006).

## 3. How to do it: the influence in the design output

Another important topic that has not been considered when presenting most Ecodesign approaches is related to the effects of its result on innovation. It is generally presumed that presenting the designer with a systematic procedure to be followed sequentially is going to keep the same level of innovation – among other parameters – than an open approach. However, this process has not been profoundly studied.

There is some level of agreement on the need for innovation that leads to Factor 10 or 20 of eco-efficiency (McAloone 2003, Reijnders 1998). Creativity plays a key role in design, and as such must play it also in Ecodesign. Nevertheless, little attention has been given to the combination of creativity and the "environmentalization" of design methods. Many of the Ecodesign strategies (Brezet & van Hemel, 1997, Wimmer & Zürst, 2003) are perceived as conservative incremental approaches that limit the freedom of the designer, and eco-efficiency approaches (Lehni, 2000, Bastante-Ceca, 2006, Park & Tahara, 2008) as most generally presented optimize based on pre-set and pre-defined technologies.

Phenomena such as *fixation* (or pre-conditioning, in a more general definition) have been debated within the design field for some time already, without reaching the field of Ecodesign. The pre-conditions before the generation of ideas, such as the references that have been consulted, the nature of the design brief, or descriptions of previous models (such as that generally included in LCA results) limit to some extent the capability of generating novel solutions (Liikanen & Perttula, 2008, Purcell & Gero, 1996), and most particularly of effective or "good" ideas (Rietzschel et al. 2007). It would therefore be expectable that exposure to LCA models pre-disposes the mind into repeating the same technologies (and thus, most of the same environmental impacts) than previous models.

The nature of this phenomenon is obscure, nevertheless. For that reason, the authors carried out a set of workshops to gain understanding about these processes, both of them with groups of around 60 people with different backgrounds. The subjects were students of different studies in the Vienna University of Technology, including mechanical engineers, architects and environmental scientist among them.

The first workshop (Collado-Ruiz & Ostad-Ahmad-Ghorabi, 2010c) showed the effect of having information or not, and of having a preceding product represented by it or not. Four groups were generated (with LCA information from a preceding product, with vague information on the environmental performance of a preceding product, with an LCA of a competing product and with vague information about the environmental performance of other products in the market) and different information was given to each one of them, showing most particularly the effect of having any sort of model explicitly presented (i.e., both groups with an LCA study).

A second workshop explored the effect of different parameters in that information, be it descriptive, graphical or numerical. It also explored the effect on target-setting, since many times the final environmental performance will depend on how challenging these targets were from the start.

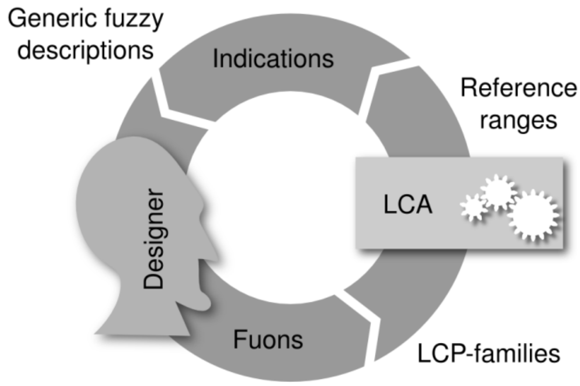
What was proven by these workshops was that exposure to information and different models of the product have an important effect on the outcome. Ecodesign up to now has neglected this fact, and this has generated some amount of skepticism amongst designers. Analyzing these factors, and considering design (and designers) in product-development-oriented environmental assessment is a strategy to solve these problems and ensure that eco-innovation becomes possible also among ecodesigners.

## 4. Outlook and outline of research

Along the research presented in this paper, it has been shown that information that is dealt with during the design process is of a fuzzy and variable nature. Most Ecodesign approaches up to now have tried to present structured approaches to infuse hard facts and rigorous results into it, in an aim of ensuring that decisions to come out of it will be of better performance.

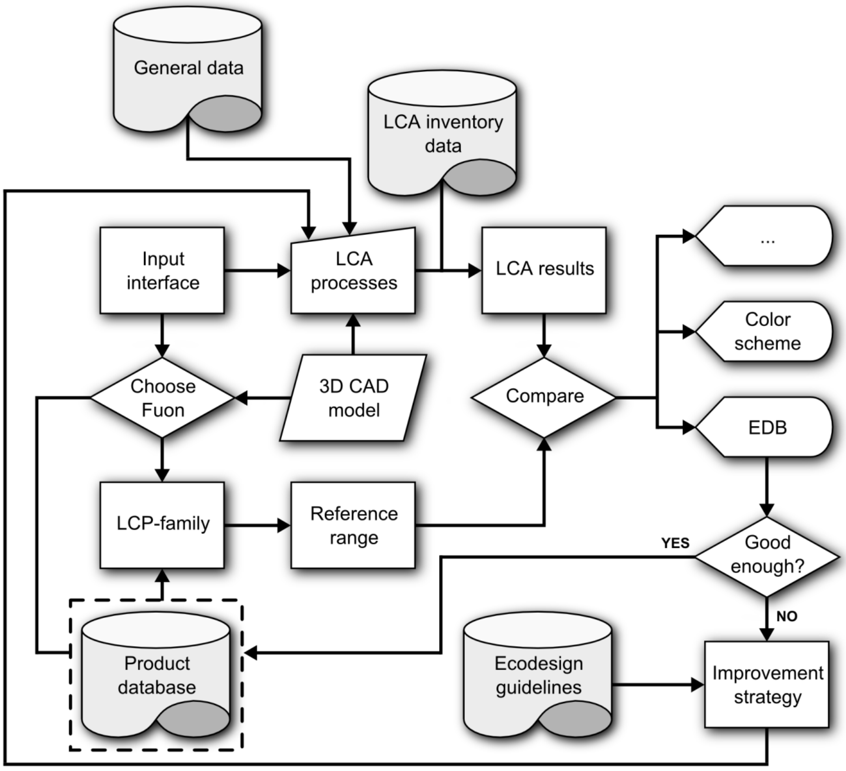
This approach and the different research lines presented deal with this information in its fuzzy nature. Modeling the product through fuons instead of heavily constrained product descriptions gives the input of information a fuzzier nature, therefore making it easier to proceed without having detailed models or pre-defined ideas. The assessment then occurs internally, out of solid LCA principles, but the output must be configured according to the conclusions of the workshops presented in section 3, i.e., it should take the form general indications and fuzzy descriptions rather than detailed models with numbers and figures. Figure 2 presents a scheme of this approach.

Figure 2: Information flow to facilitate eco-innovation




In order for this approach to be implemented into CAD systems, not only a database about environmental information of different materials (or even processes) must be implemented. For the process to be effective, a set of databases regarding input and output (fuons, modeling and strategies) should be considered additionally, as is shown in Figure 3.

Figure 3: Database structure for CAD implementation (Ostad-Ahmad-Ghorabi, 2010)




Through this database, the user always inputs “soft” or fuzzy information that can be defined at the early stages. The purpose of the system would be to autonomously to be able to output preliminary description (without detail, not to bias towards current technology), and when an LCA model is available in the CAD system, it can be benchmarked with competing models. To build the LCP-families, it is important to have a considerable amount of case studies in the databases also, so that the models built are statistically valid.

For an effective implementation, still much more work lies ahead. For this implementation to be practical, it must take much less time to model the life cycle of the product that is being developed. Most of the additional parameters in the model (e.g. consumption during use or transported distance) are based on models that repeat from LCA to LCA, or on statistical data. Such information could be stored in a database, to ensure that implementations are done in a swift way.

Furthermore, it has been said along the text that recommendations or “soft” information will be given. Even if databases with such recommendations can be set up, an effective improvement of the method is to combine it with artificial intelligence algorithms to generate recommendations that are analogous to those of environmental experts. Furthermore, having the system access to the case-study databases, it can generate recommendations from very different products, suggesting even technology changes.

This approach was presented in an expert panel with LCA, Ecodesign and Engineering Design experts from the Vienna University of Technology and from the CAD company Solidworks, with positive feedback from both of them. Solidworks has implemented in its last version a module called Design for Sustainability (Solidworks, 2010), which assesses the environmental performance of a product based on its materials and some preliminary indicators. This approach was contrasted to their current implementations, and the possible common grounds were discussed.

All in all, this line of research defines a different approach as to the role of environmental assessment in Ecodesign and/or product development. The conventional structured and rigid approach has been here substituted by analyzing the design process and inferring the constraints from it. It is important for ecodesigners of the future to still have in their assets the powerful tools and capability for innovation that designers have had for so many years.

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