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# Life Cycle Assessment Tool in Product Development: Environmental Requirements in Decision Making Process

Rossella Luglietti[a], Paolo Rosa[a], Sergio Terzi[a], Marco Taisch[a]

[a]*Politecncio di Milano, Piazza Leonardo da Vinci 32, 20156 Milano, Italy*

* Corresponding author. Tel.: +380223994822; E-mail address: rossella.luglietti@polimi.it

**Abstract**

In recent years, sustainable development has acquired a relevant position in our society. In this context, the design of modern products must consider these issues when creating eco-friendly and socially acceptable solutions, seeing sustainability as a matter of optimization in the use of available resources along the entire product lifecycle. This research aims to propose a dedicated Environmental Assessment Framework, using LCA methodology allowing designers to make environmental sustainability as an achievable and measurable requirement for developing new products. The case study presented is adapting the Life Cycle Assessment framework in the household refrigerator sector, of comparison between conventional gas-compression refrigeration and magnetic cooling system. The critical point of magnetic refrigerator is the presence of rare earths, and for this reasons a Life Cycle Assessment toll is needed to investigate the whole lifecycle.



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## 1. Introduction

In recent years, Sustainable Development, in the case the part related to environment, has acquired a relevant position on the scene and many initiatives are encouraging sustainability in our society. In this context, the design of modern products must take these issues into account when creating eco-friendly and socially acceptable solutions, seeing sustainability as a matter of optimization in the use of available resources along the entire product lifecycle. This could be achieved with the collaboration of all the involved actors (designers, engineers, managers, suppliers, customers), with the common goal of adopting sustainable practices. Being designers responsible for the system design from its early stages, they are relevant decision-makers in sustainability terms. For example, it is up to them finding solutions to create less polluting cars, engines that are more reliable, more efficient materials, innovative design and production methods, or more energy efficient products. Unfortunately, designers are often unaware of all of the impacts (both economic and environmental ones) that the product they are creating will cause during its life. This is due by the absence of adequate tools able to match different sustainability aspects (or performance indexes) and relate them to any specific choice designers are considering during their work. The eco-design directive has been extended in 2009 to all energy-related-products, like product which do not necessarily use energy, but have an impact on energy consumption (direct or indirect) and can therefore contribute to saving energy, such as windows, insulation material or bathroom devices (e.g. shower heads, taps) [1]. One of the most important topics of the Directive is the lifecycle evaluation, which wants to consider the energy consumption throughout the whole product lifecycle, from the raw materials selection to the waste production. Other standards developed for product classification including environmental aspects are the environmental labelling defined by ISO (ISO 14021, 14024 and 14025 [2] [3] [4]), which is can be applied to all product categories, and they consider the entire lifecycle with streamlined if needed.

Under this scenario, the research presented aims to develop a multi-criteria toolbox approach to be useful for designer who want to include the environmental aspects into the product development. Eco-design has been defined by Karlsson and



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Luttropp (2006) [7] in the literature as the integration of environmental considerations into product development, and that eco-design tools ought to be made available to designers during the product development process. One of the aspects taken into account is the necessity of designer to have an instrument, which can be dynamic with the prototype evolution. The toolbox will integrate the performance indexes with the environmental issues, based on the Life Cycle Assessment Criteria [5] [6].

After the methodology toolbox description, a case study application will be described. The toolbox has been implemented by considering the global domestic refrigeration sector, in particular the development of a prototype of magnetic cooling appliance. However, the again not well-defined production process together with the lack of information about the composition of many of its components (especially the magnetic ones) makes magnetic cooling technology a sort of "black box" for designers willing to implement it inside their products. Hence, a dedicated Decision support Toolbox is needed, allowing designers to make this promising refrigeration technology a more comprehensible system, and better assessing its real sustainability potentials.

## 2. State of the art of multi-criteria decision making tools

In the literature, many papers and researches, around 30 from 2010 to 2014, about qualitative and quantitative analysis including environmental aspects have been investigated, starting from Bovea and Belis (2011) [8]. In particular, the classification adopted by them has been followed to clarify the type of tools that designer may already use, and to propose a new tool overcomes limits and gaps of the others. Bovea and Belis (2011) have been classified the tools considering the follow criteria [8]:

- methods applied for the environmental assessment;
- product requirements that need to be integrated in addition to the environmental one (multi-criteria approach);
- whether the tool has a life cycle perspective (i.e. it considers all the stages of the life cycle of a product);
- the nature of the results (qualitative or quantitative);
- the stages of the conceptual design process where the tool can be applied;
- the methodology taken as a basis for such integration.

Maud *et al*. (2011) [9] investigated the related point to integrate the LCA into the design process. In particular, they analysed many instruments which use LCA during the design, i.e. DfX, materials selection. They reported an overview of these tools already implemented and used. Many authors described the Life Cycle Sustainability Assessment [10] [11], as a tool that considers the three pillar of sustainability in addition to performance requirements during the prototype development. Barberio *et al*., (2014) [12] presented a framework for combining life cycle assessment (LCA) and Risk Assessment (RA) to support the sustainability assessment of emerging technologies. They described the two different framework, with a tentative to correlate them in a single one. All the Tools discovered in the literature as the same theoretical approach combining the quantitative instruments like LCA. Only few papers have tested their framework on real application trying to use it as part of designer implementation toolbox.

## 3. Toolbox methodology approach

The literature review discovered the huge numbers of decision making frameworks developed during the last decade. The general limitation spotted is the qualitative or semi-quantitative approach, which are not directly applicable on real business. The Decision support Toolbox, is a set of computer-based tools supporting the assessment of economic and environmental information that are summarized into a calculation sheet. Physically, this research wants to develop a Toolbox able to consider all the different phases along the product lifecycle, by considering both manufacturing, use and disposal data. Such a Toolbox is needed by engineers and designers of modern companies, up to change their focus from a mere technical performance comparison to a more advanced sustainability performances comparison. This paper aims to present the methodology behind the Toolbox and the requirements, supported by the Toolbox during the early design or prototype development decision process, including the sustainable criteria. The Toolbox is divided in two different evaluators.

1) An Economic Assessment Tool: in which the typical engineering performances evaluator is supported by economic indexes. An overall economic assessment tool has been developed in order to give the possibility to designers and engineers to define how much their product configurations will cost during their whole life, before the real implementation. Within such a tool, the economic performance of the product along its life has been modelled, for example, from the point of view of materials and labor costs, commodities expenditures, etc.
2) An Environmental Assessment Tool: in which different resources consumption scenarios could be tested and compared in a virtual way. The different scenarios involving and interacting with the product along its life will be modelled and evaluated in terms of relevant performances (e.g. Endpoint indicators or Midpoint indicators).

The Decision support Toolbox may be used at different levels of the design process (for both single components and whole products) and as cross-reference tool for the comparison of different domain solutions (for both single components and whole products). Hence, it can be used to:

- Assess the economic and environmental aspects of a current component (or sub-component) before its manufacturing;
- Assess the economic and environmental aspects of a current whole product, given a pre-defined set of embedded components;