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AN APPROACH ON THE DEVELOPMENT OF SUSTAINABLE CONSTRUCTION OF PRODUCTS

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ABSTRACT

The construction sector has a pivotal role in social and economic impact on the European Union (EU), which are contributing towards work opportunities that are over 20 million directly dependent jobs). However, it is significant to take into consideration about the negative impacts of this industry, especially in relation to the environment. As an important resources consumer, the construction industry can play an active role developing new strategies for minimizing impacts on the environment throughout the life cycle of buildings and its components. The Construction Products Regulation (CPR) has contributed to set the quality standards for building products. The inclusion of 'sustainable use of natural resources' as a basic requirement in the CPR has been an important step towards the acknowledgment of environmental impacts on construction products. Assessing about the negative part in the product development at the early stages is one of the most effective methods to improve their environmental performance. The concept of eco-design has emerged as an approach to environmental management, by considering environmental aspects in the product development, without compromising other basic requirements, such as performance, quality and cost. The consideration of this approach at the early stages of construction product development contributes to the improvement of their environmental performance. Several methodologies and tools regarding an Eco-design approach have been developed over the last years. However, there are still research opportunities regarding its application within the construction industry. In this paper, a concise review of the most significant tools, methods and regulation regarding the eco-design approach on the development of sustainable construction of products is given.

Keywords: environment, development, eco-construction, eco-design, sustainability

INTRODUCTION

The construction sector has a pivotal role in social and economic impact in the European Union (EU), providing housing conditions and contributing towards job opportunities and economic growth which is having 10% of the EU's Gross Domestic Product (GDP). However, this industry is also liable for negative impacts, especially regarding the environment, that must be taken into consideration, such as depletion of natural resources day by day, energy consumption and generation of waste. There are mainly two resources for minimizing the negative impacts on the environment where first important resource is consumer which has a significant support for European economy. Secondly, the construction industry can play an active role in developing new strategies for minimizing the negative impacts on the environment. One of the strategies followed over the last years regards the concept of 'sustainability'. This term is usually used as an attempt of the construction industry to complete the sustainable development goals, which include buildings' energy efficiency and reducing waste generation through prevention, reduction, recycling and reuse.[1] In order to understand the framework of the 'sustainable building' concept, it is important to recognise the main ideas that support this definition, regarding sustainable development and the role that buildings can perform in this context. In the literature, it is possible to find many different definitions of sustainable development.[2]

The most famous one can be found in the Brundtland Report, more commonly known as 'Our Common Future': 'meeting the present needs without compromising the ability of future generation to meet their needs'.[3] It is a broad concept applied to a wide range of areas that allows drawing some different ideas to support the application of sustainability concepts in the construction sector. The first idea comes with the vision for the future and into the future, involving a high level of uncertainty in a world in constant transformation and innovation. The second is the definition of our needs. Our living requirements rely on multiple factors such as climate, social, cultural and economic context, among other external circumstances, that are expected to change in a long-term approach.[4] The different points of view for each of these aspects have been responsible for the application of different methodologies towards sustainability, especially regarding the building and construction sector. The growing issues and concerns regarding the environmental impacts in product development have raised the awareness for Eco-design. This concept has been largely studied and adopted over the last decades, particularly as an industrial design strategy. However, its application to the development of innovative and sustainable construction products is also possible and appropriate, especially at redesign or at early stages of product development, since it can contribute to the improvement of their environmental performance. This work is supported by a literature review regarding the main references on 'Eco-design' and 'sustainable construction', covering different research areas such as industrial design, engineering design, sustainable architecture and environmental management, selected from a wide range of references. Since the aim of this paper is to present a concise review on Eco design, starting from a comprehensive approach into its application to the development of sustainable construction products, the most relevant journal articles, conference papers, dissertations and technical reports were selected.

[1] Working Draft, 2015,Technical report by the Bureau of the United Nations Statistical Commission (UNSC) on the process of the development of an indicator framework for the goals and targets of the post,2015 development agenda.
[2] Hopwood, B., Mellor, M. & O'Brien, G., *Sustainable Development: Mapping Different Approaches. Sustainable Development* 38–52 (2005).
[3] World Commission on Environment and Development (WCED), Our Common Future, 1987.
[4] Berardi, U., *Clarifying the new interpretations of the concept of sustainable building. Sustainable Cities and Society* 72–78 (2013).

THE ECO-DESIGN APPROACH

Eco awareness is a clear reflection of the change in the European society. Consumers agree that the environmental impact is the third most important factor when buying, after quality and price.[5] The importance of cost and quality over environmental issues is also highlight by Luttropp and Lagerstedt [6], who considers that 'without customers prepared to pay for the function and if companies cannot make a profit, there will be no market, no matter how well the environmental issues have been addressed'. As a result, by attempting to reduce the environmental impacts of current products while considering their economic aspects and functional performance, one can move towards more competitive, innovative and sustainable solutions. This creates an opportunity to improve functional performance provided by a product over its life cycle while its environmental impacts are reduced.

In the following sections, three different parts are presented, in order to provide an organized and general understanding of the eco-design approach. The first section is focused on the Eco-design definition and the description of the design process. Next, the standards, directives and European regulations are shortly described. Finally, the main methods and tools identified are listed.

Definition

There are many terminologies used to describe the consideration of environmental impacts in products: 'Design for the Environment' (DfE), 'green design' or 'environmental design'. However, the term 'eco-' present in 'eco-design' allows relating not only with ecology but also with economic aspects of products. The word "design" has a broad meaning that expresses activities regarding design, project and planning drawing a creative path from a problem or a need towards its solution. This path has to be flexible and open to allow different approaches and methodologies to be addressed. One of the most common ways of describing a design process (such as product design, architectural design, urban design, engineering design or other different design areas) is to "see it as a chain of tasks that must be carried out for a new product". The term Eco-design emerges from these definitions, referring to a new smart and proactive design approach in line with the Bruntland report statement of sustainability. It involves the consideration of environmental issues in the product development process in order to minimize environmental impacts throughout the whole product's life cycle, without compromising other essential criteria such as performance, quality and costs. The eco-design approach widens the scope of traditional design towards a more sustainable design by learning and intending to reduce the environmental impacts of products and solutions through their entire life cycle, instead of being focused on the production and use stages. The different areas of design (architecture, engineering or industrial design) put forward important challenges to minimize the environmental impacts and develop eco-friendly products and systems, placing the environment at the same level of importance as efficiency, aesthetics, costs, ergonomics, and functionality. At an organization and management level, this approach may help to promote a competitive differential and contribute to add value to the productive chain, from raw material selection to the end of life, proving the environmental responsibility of the manufacturer.[7] It also presents a definition for eco-design as the integration of "environmental aspects into product design and development with the aim of reducing adverse environmental impacts over the lifetime of the product".[8] This definition is widely accepted and presents the required flexibility to be addressed by different design areas and

[5] Eurobarometer, Europeans' attitudes towards the issue of sustainable consumption and production, European Commission Brussels, *available at*: http://ec.europa.eu/ public_opinion/flash/fl_256_en.pdf.

[6] Uttropp, C. & Lagerstedt, J., "Ecodesign and the Ten Golden Rules: Generic Advice for Merging Environmental Aspects into Product Development"14 *Journal of Cleaner Production* 1396–1408 (2006).

[7] Karlsson, R. & Luttropp, C., EcoDesign: what's happening? an overview of the subject area of ecodesign and of the papers in this special issue. Journal of Cleaner Production, 14, p. 1291–1298 (2006).

[8] Johansson, G., Success Factors for Integration of Ecodesign in Product Development: A Review of State of the Art. Environmental Management and Health, 13 98–107 (2002).

product types. Within the design process, the Eco-design approach can be appreciated as a system of principles and rules containing the necessary tools to address a given problem, helping to drive towards smarter and more innovative solutions.

Standards and Directives

The legal and normalized framework that regulates the European market for products has become more environmental conscious and energy efficient over the last decades. This awareness is expressed in the different documents available to support the integration of environmental aspects during the product design process. The 'Eco-design Directive' was initially published in 2005 and established a framework for the setting of eco-design requirements for energy-using products within the European market.[9] In 2009 the scope of this directive was extended to 'other energy related products' where construction materials can be included, since they have a significant impact on the energy and resource consumption. The 'Eco-design Directive' outlines the conditions for the implementation of measures regulating the environmental characteristics that energy using and other energy related products need to have in order to be placed in the European market. This directive can be perceived as an important tool to increase the performance of products, especially regarding their environmental impacts, by promoting the preparation of Environmental Product Declaration (EPD) through a Life Cycle Assessment (LCA) approach. An EPD is a normalized document that expresses the assessment of environmental impacts of products was developed for evaluating the environmental impact of systems through the entire life cycle, from raw material extraction and acquisition, through energy and material production and manufacturing, to use and end of life treatment and final disposal. Through such a systematic perspective, the potential environmental burden from life cycle stages or individual processes can be identified and possibly avoided. The structure of a typical LCA comprises four different phases,[10] provides guidance for organizations on how to incorporate environmental aspects into product design and development (eco-design) within the framework of environment management systems and quality management systems. It does not give details on how to carry out eco-design at the design.

The 'Eco-design Directive'

It was initially published in 2005 and established a framework for the setting of eco-design requirements for energy-using products within the European market. In 2009 the scope of this directive was extended to 'other energy related products' where construction materials can be included, since they have a significant impact on the energy and resource consumption.[11] The 'Eco-design Directive' outlines the conditions for the implementation of measures regulating the environmental characteristics that energyusing and other energy related products need to have in order to be placed in the European market. This directive can be perceived as an important tool to increase the performance of products, especially regarding their environmental impacts, by promoting the preparation of Environmental Product Declaration (EPD) through a Life Cycle Assessment (LCA) approach. An EPD is a normalized document that expresses the assessment of environmental impacts of products, in compliance with ISO. [12] This LCA approach, presented in ISO,[13] was developed for evaluating the environmental impact of systems through the entire life cycle, from raw material extraction and

[9] International Organization for Standardization - Environmental Management - Integrating Environmental Aspects into Product Design and Development, 2002.
[10] International Organization for Standardization, Environmental management systems - Guidelines for incorporating ecodesign,2011
[11] International Organization for Standardization, ISO/TR 14062:2002 - Environmental management - integrating environmental aspects into product design and development, 2002.
[12] International Organization for Standardization, ISO 14025:2006 - Environmental labels and declarations - Type III environmental declarations - Principles and procedures, 2006.
[13] International Organization for Standardization, ISO 14040:2006 - Environmental management: Life Cycle Assessment - Principles and framework, 2006.

acquisition, through energy and material production and manufacturing, to use and end of life treatment and final disposal. Through such a systematic perspective, the potential environmental burden from life cycle stages or individual processes can be identified and possibly avoided. The structure of a typical LCA comprises four different phases provides guidance for organizations on how to incorporate environmental aspects into product design and development (eco-design) within the framework of environment management systems and quality management systems. It does not give details on how to carry out eco-design at the design level but provides specific guidance on how to address the environmental impacts of products or services within the context of the environmental management system. However, this standard provides generic principles and guidelines that must be considered through eco-design activities in product design and development presents a design and development strategy based on a life cycle approach that 'aims to provide people directly involved in the design and development phase with a systematic program for predicting and identifying the possible effects their future products could have on the environment, and for making effective decisions in the design and development of these products in order to improve their environmental performance.[14] According to this reference, the integration of the environmental aspects within the design and development of products, at an organisational level, must comply with the following principles:

Early integration: once the product has been fully developed or marketed, the attempts to improve the environmental performance will be more limited; • 'Life cycle approach': the consideration of all the life cycle stages is essential to grow a valid awareness on how products can affect the environment;

Functionality thinking: the focus must be on identified needs and performance requirements; • 'Multi-criteria concept': the design approach must be developed allowing the combination of different criteria, such as quality, costs and environment; • 'Trade-offs': an integrated Perspective can help you find a balance between requirements, advantages, and needs. The balance of different parts of the eco-design approach may alter depending on the individual products, kind of organization, and set aims. Recognizing the risks and trade-offs associated with techniques adopted during the design process is critical for conducting an accurate evaluation of product environmental performance.

The defining of product-related objectives is also an essential step in integrating environmental factors and taking into account environmental consequences such as resource conservation, recycling, and energy recovery, as well as pollution, waste, and other negative impacts prevention. The product life cycle's various inputs and outputs establish these objectives. The integration of environmental issues occurs in six unique phases during the product design and development process, each with its own set of environmental integration possibilities. The sequence of the various stages allows for continual process improvement by building an iterative model to evaluate results against environmental targets and reference products. Recognizing the complexity of LCA tools has resulted in the creation of simpler rules and checklists that make it easier for designers to make decisions, particularly during the early stages of product development.[15] The MET matrix, published by Brezet and van Hemel is a unique analysis tool that provides both qualitative and quantitative evaluations of a product. This matrix focuses on three components of a product: materials, energy, and toxicity, as well as their inputs and outputs during the course of five major stages of the product life cycle.[16]
The final output is a table with five rows and three columns that allows the design team to see the inputs and outputs at each stage of the product life cycle. This matrix is simple to create and may quickly highlight the

[14] International Organization for Standardization, ISO/TR 14062:2002 - Environmental management - integrating environmental aspects into product design and development, 2002.
[15] Pigosso, D., McAloone, T.C. & Rozenfeld, H., Characterization of the State-of-the-art and identification of main trends for ecodesign tools and methods: classifying three decades of research and implementation. Journal of the Indian Institute of Science, 95(4), pp. 405–427, 2015
[16] Brezet, H. & van Hemel, C., Ecodesign: a promising approach to sustainable production and consumption, UNEP, 1997.

major environmental elements to consider throughout the design phase. It is not particular to the end of life of the product and can be used throughout its life cycle. The assessment of environmental factors must be linked with other fundamental areas of product design (technical and economic, for example), necessitating a multidisciplinary team. Its execution is straightforward and quick, but it may result in subjective outcomes, making it difficult to compare different items, depending on the

Checklists are another simple way to eco-design that enables for a quick assessment of a product's environmental footprint. These tools are typically used for certain business tasks during the first design stages, such as Fast Five Phillips[17] and Volvo's Black, White, and Grey List.[18] Regardless of the product's complexity, it is possible to develop a specialized checklist to handle significant challenges during the design phase. Checklists are widely regarded as being beneficial, simple to comprehend, and implement, and are frequently used as the initial tool when beginning an eco-design approach. The usage of guidelines provides wide support, which may include specific aspects of the product development process or the entire life cycle. The design and development approach given in ISO serves as a systematic guidance tool for the entire product life cycle. The guideline "Eco-design and 10 golden rules"[19] is a highly basic guideline designed to serve as a starting point for developing more specialized and customized guidelines based on product type and performance criteria. The benefits of these streamlined approaches are based on a quick evaluation of the product's environmental profile, which allows for easier assessment of improvement measures during the product development process. However, team experience is required to create specialized checklists and recommendations, insert essential information, and interpret the results of these tools.

The Eco-Design Strategy for the Construction Industry

The Construction items Regulation governs how construction items are marketed in Europe. This document includes technical indicators for assessing product performance that allow for comparisons between products. The inclusion of 'sustainable use of natural resources' as a new basic requirement for establishing building product quality standards has been a significant step toward recognizing environmental impacts and improving functional and environmental performance for construction projects.[20] This criterion encourages the reuse or recyclability of building materials and parts after demolition, the longevity of construction projects, and the use of environmentally friendly raw and secondary resources. Aside from technical information about the product's performance, the 'Declaration of Performance' should include information about the presence of hazardous substances in the construction product, in order to improve the possibilities of sustainable construction and enable the development of eco-friendly products. Buildings account for a considerable portion of energy consumption and CO2 emissions in the EU. The Energy Performance of Buildings Directive[21], which aims to reduce building energy consumption, encourages the improvement of building energy performance within the EU while taking into account local climatic conditions, indoor climate requirements, and cost-effectiveness. One of the most important requirements outlined in this regulation is that all new buildings be nearly zero energy by December 2020, with public buildings meeting this criterion by December 2018. These regulations are having a significant impact on the construction industry, requiring improvements to the energy performance of building envelope elements in the case of new constructions,

[17] Meinders, H., Point of no return - Philips EcoDesign Guidelines, Eindhoven, 1997.

[18] Nordkil, T., Volvos Vita Lista - Volvo Corporate Standard, Sweden, 1998

[19] Luttropp, C. & Lagerstedt, J., Ecodesign and the ten golden rules: generic advice for merging environmental aspects into product development. Journal of Cleaner Production, 14, pp. 1396–1408, 2006.

[20] Regulation (EU) No 305/2011, Construction Products Regulation. Official Journal of the European Union.

[21] Directive 2010/31/EU, Energy Performance of Buildings Directive, 2010.

conservation measures, or large restorations. In line with the EPBD, the 2009 extension of the scope of the 'Eco-design Directive' to 'other energy-related products'[22] allows for the consideration of construction products, such as building elements that form part of the building envelope, because these construction elements have a significant impact on the overall energy performance of the building. The European regulatory framework encourages the incorporation of environmental factors into building systems and construction goods, which can then be translated into an eco-design approach in the construction industry. The consideration of eco-design in the building and construction sector refers to 'processes which are environmentally responsible and resource efficient throughout a building life cycle' by considering different aspects such as building and products design, materials, equipment, energy generation and services.[23] Regarding the sustainability of building construction products, international standard provides the principles and requirements for EPD of building products. As previously mentioned, an EPD is a declaration providing quantitative environmental data by defining parameters and other relevant environmental information, if relevant.[24] This document can be a significant tool for assessing the environmental implications of products after they have been designed, making it more suitable for product improvement via redesign processes. Building architectural design, including overall aesthetics, material selection, geometry, and details, influences numerous functional performance criteria, such as durability and energy usage. An eco-designed building must be a smart and efficient building, or a 'well-designed system', in order to ensure enough durability, good environmental and energy performance, and reasonable costs, without sacrificing other important factors, such as desired aesthetics and safety. In response to these concerns, the International Union of Architects published a 'Manifesto for Responsible Architecture' that outlined the architects' commitment to the future environment. This document was published at the UN Climate Change Conference (COP21) in November 2015[25] and establishes design criteria for a more sustainable architecture, allowing the use of eco-design principles at the design stage through six main principles:

• Encourage innovative proposals: The goal is to make better use of resources during the design of new structures or refurbishment operations, as well as to encourage innovative solutions that favor shared and adapted spaces and facilities;

• Value design studies: the consideration of a building's environmental performance should be directly related to architectural solutions, regarding the building orientation, geometry, and the thermal performance of materials and systems.

• Encourage the use of local resources and solutions for construction: using endogenous resources shortens supply chains, greatly reducing the building's carbon footprint, and focuses on locally proven technical solutions; The goal is to use resources more rationally during the design of new buildings or refurbishment operations, as well as to encourage innovative solutions that favor shared and adapted spaces and facilities;

• Value design studies: the assessment of a building's environmental performance should be directly related to architectural solutions, regarding the building orientation, geometry, and thermal performance of materials and systems. • Encourage the use of local resources and construction solutions: using endogenous resources shortens supply chains, drastically lowering the building's carbon footprint, and focuses on locally proven technical solutions;

[22] Directive 2009/125/EC, Ecodesign Directive, 2009.

[23] Annunziata, E., Testa, F., Iraldo, F. & Frey, M., Environmental responsibility in building design: an Italian regional study. Journal of Cleaner Production, 112, pp. 639–648, 2015.

[24] International Organization for Standardization, ISO 21930:2007 - Sustainability in building construction: Environmental declaration of building products, 2007.

[25] International Union of Architects (UIA), Manifesto for responsible architecture, 2015.

These documents describe several methodologies, methods, and guidelines for assessing and reducing the environmental implications of current building systems, goods, and solutions. Starting with this understanding, one can begin to comprehend how to progress beyond present solutions and toward more innovative and sustainable ones.

4 CONCLUSIONS The defining of product goals and specifications at the start of the design process is an important phase, and it is also the best moment to include eco-design concepts into the product development process. Throughout this phase, there are numerous possibilities to properly incorporate environmental factors into product design. This can result in significant savings in natural resource use, the avoidance of harmful components, minimal energy consumption during use, and planning for re-use, recycling, or final disposal from the early life cycle stage. The fundamental difficulty is to create a product that meets functionality, efficiency, aesthetics, and other needs while being economically and environmentally responsible. Achieving a balance between environmental costs and functional income is critical for sustainable development. These notions can be applied to the construction industry, which views buildings as a complex system with various levels of design. Given the existing framework discussed in this paper, applying an eco-design approach to the development of sustainable construction products is not only feasible, but also desirable, as it can contribute to sustainability, energy efficiency, economic competitiveness, and an environmentally friendly building stock and cities. Methods and Tools To implement an Eco-Design strategy, environmental problems and their causes must be assessed in order to affect product design, material selection, production, use, reuse, recycling, and final disposal. This evaluation can be conducted using a variety of tools and methodologies. Baumann et al. [14] found around 150 eco-design tools. Considering the eco-design aim, the most appropriate tools can be chosen based on the type of evaluation and outputs, suitability, and stage of the eco-design [15]. This section provides a quick overview of the most often referenced tools. According to the taxonomy suggested by Knight and Jenkins [16], the tools are grouped into three basic categories: analytical tools, checklists, and As previously stated in this paper, LCA is a methodology for evaluating the environmental performance of systems over their service life and producing quantitative data as a result of the assessment. LCA has been recognized as an efficient method for determining environmental consequences, and it is used in various software programs. However, this methodology requires a huge amount of information, which is still not fully quantifiable at the early phases of the design process. As a result, the evaluation is more effective when used as an assessment tool in the advanced stages of product design or during redesign procedures. At these stages, it is also feasible to find areas for improvement in the product being developed. A simplified version of LCA can also be employed, albeit the assessment results may be more ambiguous.