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# Life Cycle Design and efficiency principles for membrane architecture: towards a new set of eco-design strategies

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**Abstract**

The typical membranes for building are polymer-based materials, which have origin from fossil fuel. Nevertheless, they are supposed to become very lightweight building components, compared with other typical ones, and, due to their lightness, involve fewer stiffening structural materials (bio-based or not) than other traditional massive components. The need of understanding their real potentials and limits in terms of eco-efficiency is declared. The paper presents the research results about the eco-efficiency principles in the field of membrane architecture, based on the application of Life Cycle Assessment methodology to membrane structures. The paper presents a systematic review of the state of the art, with the aim to demonstrate the advantages of the Life Cycle Design strategy answering to the environmental sustainability. A comparison matrix about existing environmental data on membranes (environmental impacts, EPD, Recycling and up-cycling processes) and the LCA studies are part of the shown research output. On the need of harmonization of the research about the availability of LCA data for membranes and on the basis of the collected information, a first set of eco-design principles for membranes structures is proposed. Concluding, the authors reveal the current gap between the research studies and the real praxis in architectural design referred to a specific context and envisage further improvements of the application of the eco-efficiency principles starting from the early design phases.



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*Keywords:* Membrane skins; Eco-efficiency; Time; Environmental Impacts; Life Cycle Assessment, Lightweight Buildings

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## 1. Introduction

Designers more and more appreciate membrane materials: they are increasingly using them both for aesthetical purposes, and for retrofitting or refurbishment, as ultra lightweight wrapping envelope or façade cladding systems into permanent buildings (fig.1). Targeting their environmental efficiency, the organic shape, the minimum weight, the high flexibility, the translucency, the fast installation and low maintenance are pivotal aspects to be considered and assessed. They exploit minimal amounts of material to cover a space, compared to the common covering materials, thanks also to the ability to be tensioned, by shaping themselves to the forces ways, without additional components.

European interest in lightweight textile structures is clearly evinced by the explicit reference [1] to possible uses of advanced textiles in the coordinated calls for proposals on the cross-cutting themes of nanotechnologies (NMP) and the energy efficiency of buildings (E2B), where new lightweight building solutions are examined as potential replacements for the current accepted options that only seek energy efficiency through mass. Moreover the information, the research advances and the knowledge about membranes is somewhat fragmented and still sporadic. A powerful effort to outmatch the fragmentation is on-going by the activity of the TensiNet [2] and by the exchange and sharing of research's, companies' and firms' experiences into the COST Action TU 1303 – '*Novel structural skins: Improving sustainability and efficiency through new structural textile materials and designs*' [3]. These activities aim to harmonize the research on membrane and foil structural skins, to standardise testing and analysis approaches within Europe, and, by sharing the state of the art, to orientate the innovation and development of new and energy efficient structural skin products and applications.

Academic research activities are focusing several topics, in which structural membranes and advanced textiles are the pivotal elements of the eco-innovation processes. First of all, the eco-efficiency of membrane structures has been investigated, achieving the awareness of the generated embodied energy for lightweight materials and building systems during the design phase: most of the scientific results strongly underline to focus on the final eco-performance properties rather than on the individual material one [4] [5]. When increasing the level of energy performance of buildings in the operational phase, embodied energy in materials may represent a high percentage of the energy spent in the whole life cycle of a building. This means that the environmental quality of the products does not necessarily correspond to their eco-efficiency into a specific construction. Therefore designers and suppliers need to know the environmental profile of the products, together with thermal, acoustic, resistance performances, as a choice factor in the design phase. Consequently the producers and suppliers of membranes and the relative building components and structures are driving in this direction, developing new products, bio-based polymers and building components, designing lightweight structures, closing the production chain, controlling the (less or more) hazardous emissions looking for 'nearly zero dangerous emissions', pushing the improvement of the technologies for the recycling of materials and outputted substances and for closed production environments [6] [7] [8] [9].

## 2. Aim of the paper

The paper presents the research results on the eco-efficiency principles in the field of membrane architecture; it offers the collected information on the state of the art on the eco-efficiency and Life Cycle Assessment methodology applied to the membrane structures. The state of the art was organized by the categories of their application in construction. The aim of this research is to elaborate those concepts and to systematize the actual obtained results, demonstrating the advantages of the Life Cycle Design strategy answering to the environmental sustainability. A comparison matrix about existing environmental data on membranes (environmental impacts, EPD, Recycling and up-cycling processes) and the LCA studies are part of the shown research output. On the need of harmonization of the research about the availability of LCA data for membranes and on the basis of the collected information, a first draft of eco-design principles for membranes structures is proposed.