Intelligent Human Systems Integration (IHSI 2024), Vol. 119, 2024, 541–547
https://doi.org/10.54941/ahfe1004519

Design Process for Technological and Meaningful Innovation: A Case Study of Light Solar Design Lab

Stefania Camplone[1], Alessio D'Onofrio[2], Antonio Marano[2], and Ivo Spitilli[2]

[1]Department of Engineering and Geology, University of Chieti-Pescara, Italy
[2]Department of Architecture, University of Chieti-Pescara, Italy

ABSTRACT

In the scenario of contemporary project culture, technological innovation applied to Intelligent Light Solutions does not always align with the evolution of language and the new and potential utilitarian, symbolic, and emotional meanings that products of Light Solar Design could assume to enhance the décor of urban and territorial landscapes. This theme has been addressed as an educational and design research experience, based on a multidisciplinary approach of Design Driven Innovation, utilizing methodologies, tools, and guidelines from Solar Design and Life Cycle Design (LCD). The paper proposes a critical discussion on the methods, tools, and project outcomes.

Keywords: Light solar design, Design driven innovation, Technology innovation, Meaning innovation

INTRODUCTION

In urban and territorial contexts, the growing demand for the aesthetics of industrial products and the rapid development of Intelligent Light Solutions and renewable energy require a Design Driven Innovation approach (Verganti, 2009) to initiate a process of research and experimental application on technological and meaningful innovation. In alignment with this strategic orientation, the Eco Product Design laboratory, an integral part of the Master's Degree program in Eco Inclusive Design at the Department of Architecture, University of Chieti-Pescara, undertook a research project focused on Light Solar Design. The objective was to make the scene of collective outdoor spaces more visible and attractive, to achieve sustainable, efficient, and aesthetically appealing products, to define the role of materials in the pursuit of eco-efficiency, and in the representation of the aesthetic-communicative value of Light Solar Design products, conceived as works beyond anonymity.

ECO PRODUCT DESIGN LAB

In the context of contemporary urban and territorial culture, technological innovation in the field of Intelligent Light Solutions and renewable energy enables the networking of all the components of a system and the transmission of information and services for safety, monitoring and control of environmental conditions, as well as the flow of people, goods, and energy. Presently, technological innovation in the evolution of the concept of highly energy-autonomous intelligent lighting does not seem to simultaneously inspire an evolution in language and new utilitarian, symbolic, and emotional meanings (Verganti, 2018). Such innovations are crucial for addressing the pervasive degradation of urban spaces, including cities, historic centers, green areas, and water bodies. In the Eco Product Design laboratory, our research has focused on the theme of enhancing outdoor spaces within urban and territorial landscapes. The primary objective has been to identify, as key areas of application, the most promising innovation topics within the Core Function of Energy Lighting. This includes applications in diverse settings such as coastal and water landscapes, urban and mountain parks, areas of urban mobility and safety, agricultural cultivation and urban gardens, art cities, prestigious locations, historic centers, and potential uses in Arctic regions and sites suitable for amateur astronomical observation.

Figure 1: 'IComet', an eco-product for amateur astronomical observation sites: the 'iSun' signaling system and 'iSpot' positioning system for lighting, charging, and 'light pollution' monitoring. Concept design by Davide Galieri (2023).

The design process has been two-pronged: On one side, it involved contextual research, encompassing an analysis of constraints, regulations, case studies, current market trends, and available technologies. On the other side, it included exploratory research into potential scenarios and innovation opportunities, focusing on new interpretations of light, emerging urban and territorial narratives, and the aspirations for a more inclusive social life. The metadesign research phase further integrated an examination of the atmospheres, culture, forms, stratifications, and objects of different places, delving into both the tangible and intangible values of the Genius loci. This investigation also covered the distinct functionalities between Core Function (C.F.) for lighting and renewable energy, basic functionalities (F.B.) for monitoring and control (including security, microclimate, mobility, and the flow of people, objects, and energy), and value-added functionalities (F.V.A.) aimed at enhancing people's lives, such as information, interactivity, data collection, Wi-Fi access, physical, sensory, and emotional well-being, and facilities for resting, socializing, and charging electronic devices like bicycles and cars. The outcomes of the contextual and exploratory research phases have been compiled into 'Knowledge and Constraints Dossiers', which detail the system of constraints and are later integrated into project development, and 'Vision Dossiers', which offer a collection of suggestions and themes to guide the conceptual design activity. To ensure the efficiency and feasibility of these proposed solutions, concept development was conducted through an educational laboratory framework, primarily via a series of intensive workshops. These workshops involved collaboration with companies such as i.Guzzini, a leader in innovative lighting systems, and Matrec, a consulting and research firm specializing in material sustainability and circularity.

LCD TOOLS AND METHODS

To steer the design process toward new environmentally sustainable solutions, the Life Cycle Design (LCD) tool is employed. Utilizing LCD in the early stages of ideation and conceptualization significantly enhances the likelihood of developing innovative, eco-efficient designs. The fundamental aim of LCD is to reduce both the input of materials and energy and the output in terms of waste and emissions, encompassing the entire life cycle of the product, from pre-production, production, and distribution to its usage, eventual disposal, and the potential recycling of its constituent resources.

LCD implements design strategies and guidelines centered on resource minimization, the adoption of low-impact resources and processes, optimization of product life, extension of material lifespan, and facilitation of disassembly (Vezzoli, 2007). Within the Eco Product Design laboratory, the strategies found to be most effective for innovating Light Solar Design proposals included minimizing material usage, selecting renewable energy sources, and incorporating Design for Disassembly principles. Pertaining to specific LCD strategies, the focus was primarily on enhancing product maintainability, upgradability, and reparability. This was achieved through developing solutions that simplify assembly and disassembly processes, particularly by employing easily removable connections.

Regarding the strategies aimed at minimizing material and energy expenditure, guidelines were followed that encouraged the design of functionally efficient systems, wherein hypothesized production methods facilitated material reduction (primarily via the use of structural ribs to stiffen and thin out materials). Furthermore, these guidelines directed the creation of eco-efficient products that promote sustainable consumption patterns, chiefly during their operational phase, and ensure minimal environmental impact through the integration of renewable energy sources, such as photovoltaic panels. Additionally, the proposed solutions adhered to guidelines advocating the use of renewable or recycled materials that are not in danger of depletion, while concurrently aiming to reduce harmful emissions by considering the processes of material transformation, production, distribution, and disposal treatments.

SOLAR LIGHT DESIGN

Solar Design defines the scope of designing industrial products that utilize photovoltaic technology. The photovoltaic system consists of a set of electrical components (photovoltaic module, inverter, battery, charge controller) which collectively convert solar energy into electrical energy. Achieving maximal efficiency in this conversion necessitates accounting for optimal solar irradiation conditions, which are influenced by factors like the geographical location's tilt angle, the orientation's azimuth angle, and varying conditions based on the latitude where the product will be installed.

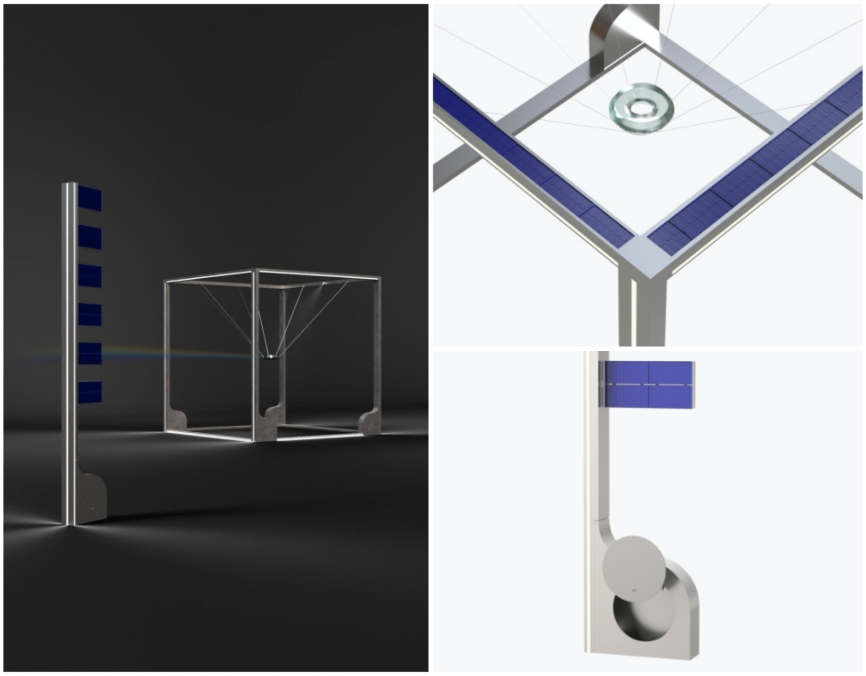

Figure 2: 'Genderlight', an eco-product for urban safety: information-communicative installation and flag-mounted solar panel streetlight. Concept design by Lara Pulcina (2022).

In the market, the prevalent types of photovoltaic cells are monocrystalline, polycrystalline, and amorphous (thin-film) cells, each differing in efficiency, structural design, and aesthetic. The design process in the Eco-Product Design laboratory involved a meticulous assessment of the appropriate photovoltaic cell type, considering the morphological characteristics of the product surfaces, irradiation conditions, and the system's energy requirements. In optimizing the efficiency of Solar Light products (Marano, 2013), the design strategy primarily focused on embedding photovoltaic cells in the most sun-exposed upper sections of the lighting fixtures. For certain applications, broader surfaces positioned vertically were utilized, integrating sails or grids laden with photovoltaic cells. When the available surface area was insufficient for the required energy output, more efficient monocrystalline silicon cells were chosen over their amorphous counterparts. In designs featuring curved surfaces, amorphous silicon photovoltaic cells with a thin, semi-flexible film were employed, adaptable to various curvatures. Conversely, for products with circular, irregular, or complex shapes, thin-film amorphous silicon cells, capable of conforming to any form to comprehensively cover the surface, were used. In some instances, polycrystalline silicon cells, customizable into optimal shapes for the specific surface, were selected. The design development phase benefited significantly from the collaboration and consultancy with iGuzzini, a firm specializing in advancing Intelligent Light Solutions. This partnership facilitated the integration and networking of all system components, the employment of smartphone-based light management technologies (Smart Light Control), and the delivery of information and services directly from the lighting installations (Smart Services).

MATERIALS AND TECHNOLOGIES FOR ECO-DESIGN

In addressing environmental issues, materials assume a crucial role in both advancing product eco-efficiency and in representing their aesthetic-communicative value. Within the context of Life Cycle Design (LCD) strategies, materials play a decisive role in: choosing materials with low environmental impact (reduced waste production and CO2 emissions during both production and the product's end-of-life phase); exploring circular economy solutions; selecting durable and high-quality materials (extending product lifespan and consequently delaying waste generation while indirectly reducing the need for new resources); using non-toxic or bio-based materials; adopting secondary raw materials as substitutes for traditional materials; adopting secondary raw materials as alternatives to conventional ones; Allowing the possibility of material reuse in the product's end-of-life phase.

However, materials also directly influence the appearance and sensory perception of products. Materials directly related to nature, such as wood, stone, or glass, can give the product a more organic appearance, while materials like steel or aluminum may convey a colder, yet more technologically efficient aspect.

Emerging materials, including bio-composites and, more recently, biodegradable eco-plastics (Pellizzari, 2017), not only embody new socio-ethical values but also enable the creation of complex morphologies and innovative aesthetic, expressive, and sensory qualities. For companies, embracing sustainability is not just a response to increasing environmental consciousness among consumers; it is an opportunity for innovation and competitive repositioning in the market.

Specifically, in the realm of Light Solar Design products, a central concern is energy consumption reduction via renewable resource utilization. This strategic approach gains further significance when integrated with other LCD strategic priorities based on the conscious and appropriate selection of materials.

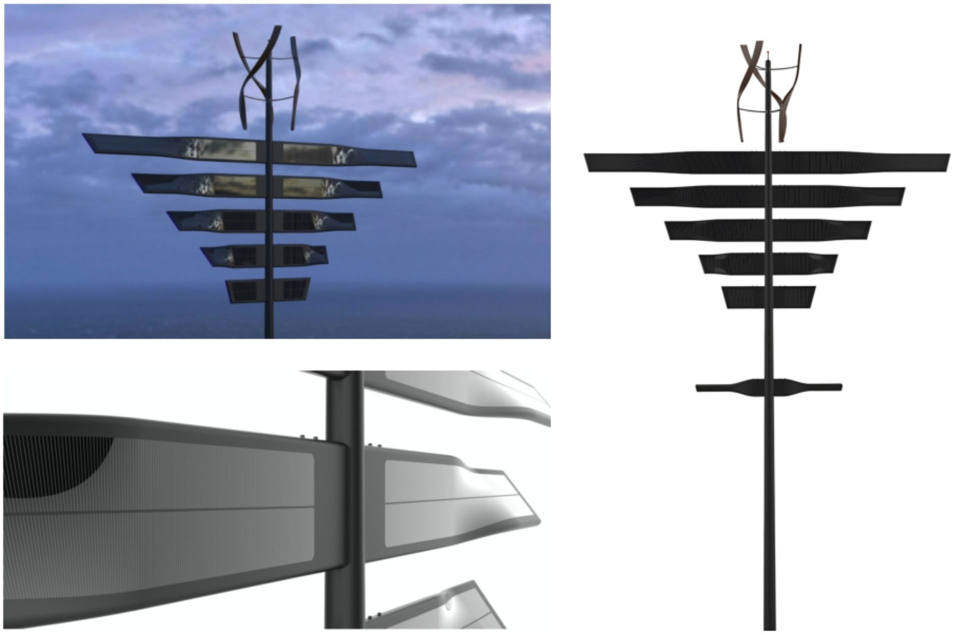

Figure 3: 'Light Solar Eolic Design', an eco-product for Arctic countries: smart integrated lighting and eolic system. Concept design by Simone Giancaspero (2022).

In the concept development processes undertaken in the Eco-Product Design Laboratory, a comprehensive evaluation of the selected materials' physical, chemical, and mechanical properties (such as optical, thermal, magnetic, and electrical attributes) and their eco-compatibility aspects (including recyclability, renewability, biodegradability, and compostability) was conducted. Moreover, each design underwent a thorough analysis, breaking down the product into subsystems and components, with a detailed examination of connections aimed at reducing their quantity and variety, thereby simplifying disassembly operations. Additionally, the analysis and optimization of production processes, in line with eco-efficiency strategies, were enhanced through the use of the Matrec Databases, a research and consulting firm specializing in the measurement of product circularity.

CONCLUSION

The Eco Product Design laboratory has initiated a thoughtful exploration into the environmental aspects of design culture, along with a research endeavor in Design Driven Innovation specific to the Light Solar Design sector.

This case study accentuates the significance of the theme 'Living in Outdoor Spaces in Urban and Territorial Landscapes,' and sheds light on the most promising innovation themes within the Core Function of Lighting Energy.

It delineates the selection of Life Cycle Design (LCD) strategies and guidelines optimal for achieving product eco-efficiency, explores potential applications of Solar Design, and examines the role of materials both in achieving eco-efficiency and in conveying the aesthetic and communicative value of Light Solar Design products.

Through an in-depth analysis of the tools and methodologies employed in the Design Process, along with a succinct overview of the resultant design solutions, this paper endeavors to make a meaningful contribution to the ongoing discourse in technological innovation and the evolution of significance in Light Solar Design.

ACKNOWLEDGMENT

The different sections of this paper are the result of collaborative discussions and joint reviews among the authors. Specifically, the composition of the various sections is credited to: S. Camplone (Materials and Technologies for Eco-design), A. D'Onofrio (Solar Light Design), A. Marano (Introduction, Eco Product Design Lab, Conclusion), I. Spitilli (LCD Tools and Methods).

REFERENCES

Marano, A. (2013). Design solare. Roma: Gangemi editore.

Pellizzari, A. Genovesi, E. (2017). NeoMateriali nell'economia circolare. Milano: Edizioni Ambiente.

Verganti, R. (2009). Design-Driven Innovation. Milano: Rizzoli Etas.

Verganti, R. (2018). Overcrowed. Milano: Hoepli.

Vezzoli, C. (2007). Design per la sostenibilità ambientale. Bologna: Zanichelli.