Building Integrated Photovoltaics (BIPV): system application guidelines and albedo aspects

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ABSTRACT

The integration of renewable energy systems into design and architectural projects is a topic and prevalent theme that presents opportunities for innovative approaches. Since the process combines energetic, structural, design characteristics and also the context in which the project is inserted, there are important variables to be considered in a Building Integrated Photovoltaics (BIPV). The goal of this article is to classify them in order to support designers, architects and engineers closer by means of guidelines for good practices in BIPV design. The realization of this study is justified by the fact that there is a disinformation and a cultural thought that photovoltaic systems depreciate de project design, which characterizes the lack of incorporation of such elements.

Key Words: Design project, Building Integrated Photovoltaics, BIPV, Guidelines, Albedo

1. INTRODUCTION

Photovoltaic technology is able to convert solar radiation directly into electric energy. It can be used exactly where energy is consumed ('on-site') and provide any kind of building energy request (thermal and electrical). As a great differential to other renewable energies, "photovoltaics can be easily integrated anywhere into the building envelope, for a number of functions: on/in rooftops, opaque and semi-transparent envelope surfaces, having a structural function as well as sun shading and cladding function, and enabling also a construction costs reduction"(SCOGNAMIGLIO; RØSTVIK, 2013). In this context, Building Integrated Photovoltaics (BIPV) are projects in which photovoltaic modules become an integral part of the building envelope, replacing roofing, facades, or other constructive elements, while Building Applied Photovoltaics (BAPV) systems are installed in a structure parallel to an existing building, superimposed on the roof or facade. The great difference between the two models lies in the fact BIPV is conceived integrally and indispensable to the architectural project as a constructive piece, while BAPV is a later addition to the already finished project, often hindering the integration and development of quality architectural projects.

As a focus of increasing global interest, Building Integrated Photovoltaics are considered to be essential tools for the diffusion of photovoltaic technology and to achieve the worldwide goal of Zero Energy in buildings, defended by Shukla, Sudhakar and Baredar (2016, p.100), as energetically self-sufficient buildings, with Zero Net Energy. To achieve this goal, the Strategic Design for Environmental Sustainability supported by Marseglia (2017 p.1727), claims that within a design project (product, service or system integrated development) should approach interrelationships with the environment, cultural, technological and social aspects to reach a good result. These relationships are essential in creating quality BIPV projects and emphasize the fact that in Brazil this technology was known more like a market process than a public policy, highlighting the fact that some aspects are not contemplated and are faulty for its effective implementation. Besides that, there are important barriers to be transposed.

Those barriers include the use of photovoltaic technology on unsatisfactory architectural projects, a low social acceptance, the fact that information about the technology is scattered and uncorrelated and disinformation "as education is seen as one of the barriers for BIPV deployment" (TABAKOVIC et al.,2017). In addition, Santos and Rüther (2014, p.116) discuss that architects are often reluctant to adopt photovoltaic technology because of lack of training and information about the performance potential of non-ideally oriented and inclined photovoltaic modules. There is a false perception among these professionals that solar modules should only be installed on ideally oriented and inclined surfaces, leading to the lack of incorporation of BIPV systems in buildings, the poor quality of architectural projects or non-adoption of photovoltaic systems, problems that justify this research development.

In response to the problems raised, some guidelines for BIPV projects were developed with the purpose to summarize the information and with the intention of being improved in future work. The goal is to present the important variables to be considered in a BIPV project in order to bring architects, designers and engineers closer to the presented reality, with an interdisciplinary vision. For this reason, subjects like albedo, usually discussed in research articles which are distant from design and architecture but of great importance, were studied and makes part of the discussion.

2. RESEARCH METHODOLOGY

The main data source of this study is the Swiss research center BIPV ISAAC-DACD-SUPSI, focusing on development of architecturally integrated PV systems. To complement the data source of this article, a literature review was made, including bibliography about design, BIPV, albedo and solar energy. These data are from qualified journals on the subject.

3. BIPV SYSTEMS GUIDELINES

When applying the concept of Building Integrated Photovoltaics (BIPV), it is essential to classify the variables that must be taken into account when a BIPV project needs to be done. The literature review allowed the knowledge of principles and implementation points that were transformed into guid… s as show…

Principle	Guideline	Implementation
Budget	Determine the economic plan	Paytime
		Available investment ($)
Market	What is the market in which you are inserted	Stakeholders
		State incentive policies
Scale and type of the project	Scale determines how to work and insert the technology *Single building or cluster of buildings	Furniture design
		Architecture*
		Landscaping
		Urbanism
Energy demand	The energy needed as an input for design	Building energy demand
		Passive and active strategies
		connected to the urban network
		Batteries
Building footprint	Space requirements for energy self-sufficiency	Relation between energy and form
		Building envelope area requirements
		Energy generation 'on-site'
Technology	The technology chosen as a relation between efficiency, area to be used and desired integration effect	Crystalline cells
		Thin-film cells
		Organic photovoltaic cells
Photovoltaic Module Design	Module design properties as a important factor to achieve certain integration objectives *Quality, strength, structure, coating, colour, tinted glass, etc. **such as insulated glazing	Module Size
		Module shape
		Covering glass*
		Cell background or reverse side of module
		Semi-transparency
		Arrangement of solar cells in the module
		Interconnections
		Multi-layered superstructures**
Fixation System	How the system will be integrated into the envelope and what role it will play in the building (roof, facade, window, outdoor partitions, etc) *Modular fixation, not adaptable and not always have a role in the water-tightness functionality **balconies, parapets, outdoor partitions, shading systems and several other elements	Mounting systems (partially integrated)*
		Full Roof solution (totally integrated)
		Prefab systems
		Solar tiles
		Lightweight systems
		Skylight/Solar glazing
		Curtain wall
		Rain-screen façade
		Accessories**
Context in which the building is inserted	The context will directly affect the efficiency of the system and the presence of the PV modules will affect the building surroundings	Shadow
		Dazzle
		Albedo
		Urban density
Aesthetics	Aesthetics directly related to the level of integration and social acceptance	Integration into the building's skin
		Project quality
		Social sustainability
		Social acceptance

The authors (2019)

The principles considered are: budget, market, scale and project type, energy demand, building footprint, technology, photovoltaic module design, fixation system, the context in which the building is inserted and aesthetics. Data have been collected from the catalog developed by the SUPSI-SEAC report 2017, the Manual for BIPV projects publicated by Odersun (still in use despite the deactivation of the company) and articles published in relevant journals.

These variables are usually analysed separately and without being related to each other, what causes unilateral decision-making when in fact the design process is complex and holistic. Besides that, because the solar energy study field is extremely interdisciplinary, communication is not facilitated and the incorporation of technology into design projects is impaired. Overall, here we present the sketch beginning of the tool that articulates the different points to be taken into account in BIPV project and that facilitates communication within the different study fields of solar energy.

4. THE IMPORTANCE OF ALBEDO FOR SOLAR BUILDING SKINS

As most projects and related articles do not consider albedo as an important factor for the design project, it was chosen to create an item that explains the relation between albedo, the photovoltaic system, the surroundings and how they affect each other. Albedo, or reflectance, can be understood as a light reflected by a surface or, according to the Oxford dictionary, "the proportion of the incident light or radiation that is reflected by a surface". Using these definitions in a photovoltaic energy context, Brennan et al. (2014) affirm that "Albedo irradiation changes the spectral distribution of the incident irradiation on the surface of the PV device, which in turn affects system output".

In this context, the project process considering albedo may become improved since the amount of light reflected by the surface can increase the efficiency of the system, and most surfaces surrounding the PV modules are the result of design choices. For instance, if the surroundings (a wall or ground next to the building, for example) of a photovoltaic facade are white, the indirect light reflected to the photovoltaic facade will be more intense than if such surfaces are black and this relation changes the system efficiency. In this context, Brennan et al. (2014) discourse the significant contributions from albedo in different topologies. The authors used systems with a large tilt angle relative to the ground as an example that can have large albedo contribution. In addition, Andrews and Pearce (2013) include that vertical PV systems (for example BIPV facades) are severely impacted by albedo.

Some authors calculated the albedo factor by grass, snow, water and reflective surfaces, for example Andrews and Pierce (2013) make a comparison between grass albedo (0.23) and snow albedo (0.78), when 0.00 configures no reflection and 1.00 total reflection. Otherwise these authors comprehend snow albedo as a transition, because the thickness changes reflection index. Considering that, Andrews and Pierce (2013) say that when the surrounding irradiance is high, albedo can provide a large effect on the performance of photovoltaics systems. When these systems receive more reflected irradiation the energy production is improved. For example, the BIPV project Monte Rosa Hut, made by Bearth & Deplazes Architekten (image 1), is directly affected by snow albedo in winter periods, when the energy demand is increased.

Besides the albedo influence, the implementation of a BIPV project can affect the surroundings producing increased heat, dazzle and visual impact. This variables need to be considered and taken into account before the system application. For instance, when dealing with historic regions the visual impact of a Building Integrated Photovoltaics project can cause damages, or when the project is situated in a street with a big flow of people and cars the dazzle caused by a photovoltaic facade can be discomforting. Therefore, the social acceptance and sustainability is extremely important to the system implementation and should be considered, as mentioned by Marseglia about the Strategic Design for Environmental Sustainability.

Summarizing, when one decides for a photovoltaic system, the project needs to include surrounding data for understanding albedo and improving the solar energy generation. In addition, the designer always has to remember that the building and the surroundings affect each other and some extra care has to be taken to maintain the balance between them.

[Figure 1] *Monte Rosa Hut, Switzerland. Surroundings with and without snow.*

Tonatiuh Ambrosett (2009)

5. CONCLUSIONS

As discussed in this study, BIPV and BAPV projects are important for disseminating the use of solar energy and achieving the worldwide goal of Zero Energy in buildings. The users involved in this process still do not consider energy as an input for design, a work that designers and architects are responsible for. The energy we use should be seen as "a variable able to relate itself to the form of our buildings (or clusters of buildings or even cities and landscapes) instead of being seen as a kind of abstract variable that design cannot deal with" (SCOGNAMIGLIO; RØSTVIK, 2013). To facilitate this implementation, the creation of guidelines helps to recommend good practices in BIPV projects, makes connections between interdisciplinary variables and are a sketch beginning of the tool that will be improved in future work.

For that, some principles like budget, market, energy demand, building footprint, scale, project type, technology, photovoltaic module design, fixation, aesthetics and the context in which the building is inserted, needs to be considered. Moreover, albedo - which is usually not linked to the architectural integration of photovoltaic systems - should be included to optimize the efficiency of the modules in non-ideal orientations. These principles characterize a change of thought about the way buildings are designed. This re-think need is corroborated by the fact that in Europe starting from the end of 2020, all new buildings will have to be Nearly Zero Energy Buildings (Nearly ZEBs - ED2010/31/EU recast) and demonstrate a paradigm change.

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