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The Importance of Zenithal Lighting Systems for Natural Light Gains and for Local Energy Generation in Brazil

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Abstract**—**This paper presents an approach on the advantages of using adequate coverage in the zenithal lighting typology in various areas of architectural production, while at the same time to encourage to the design concerns inherent in this choice of roofing in Brazil. Understanding that sustainability needs to cover several aspects, a roofing system such as zenithal lighting system can contribute to the provision of better quality natural light for the interior of the building, which is related to the good health and welfare; it will also be able to contribute for the sustainable aspects and environmental needs, when it allows the generation of energy in semitransparent or opacity photovoltaic solutions and economize the artificial lightning. When the energy balance in the building is positive, that is, when the building generates more energy than it consumes, it may fit into the Net Zero Energy Building concept. The zenithal lighting systems could be an important ally in Brazil, when solved the burden of heat gains, participate in the set of pro-efficiency actions in search of "zero energy buildings". The paper presents comparative three cases of buildings that have used this feature in search of better environmental performance, both in light comfort and sustainability as a whole. Two of these buildings are examples in Europe: the Notley Green School in the UK and the Isofóton factory in Spain. The third building with these principles of shed´s roof is located in Brazil: the Ipel´s factory in São Paulo.

Keywords**—**Natural lightning, net zero energy building, sheds, semi-transparent photovoltaics.

I. Introduction

THE growing need for technological solutions in architecture to mitigate the environmental impacts of architectural interventions has opened the field for the creation of energy´s economizers systems and energy generators in the different phases of the building's useful life: implantation, construction, operation and maintenance. However, the attendance to the technical questions to attend to the environmental accounts needs to be accompanied by the attention to the lightning and visual human comfort, in the intent to amplify its purposes.

The human relationship with sunlight is a relevant factor besides being essential life to the life on Earth, but it is also responsible for some physiological and psychological human's aspects, influencing the visual perception of the environment. The appropriate using of the natural light by the architecture is fundamental for the experience lived inside the buildings.

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Another relevant aspect is the search for energy efficiency in the built environment. The economy in the use of artificial systems of lighting needs to be one of the premises of a more efficient project and the use of natural light is the first strategy to be considered. According to Corbella,"If the lighting project is well designed, it will result in a great saving of electric power, both in artificial lighting and in air conditioning. Remember that all the electric energy used to illuminate converts to thermal energy at the end of the transformation process, which contributes to increase the internal temperature" [4].

The optimized use of natural lighting, whether zenith or coming through the glass façades and windows, contributes to the conservation of energy in buildings by avoiding the use of artificial lighting unnecessarily and to favoring the visual perception, raising the project from the point of the view of design quality.

According to Acselrad [1], one of the discursive matrices of sustainability is self-sufficiency, which is related to the proposals for preservation and construction of self-sustaining conditions, such as sustainable communities. Another discursive matrix would be efficiency.

The goals of sustainability in the civil construction have advanced of conservation of energy and self-sufficiency to the local generation solutions with return of surplus to the energy official grid. It is a conceptual change that turns to the relation of the building with the city and the region. It means that it is not enough just to be self-sufficient; it needs to be participatory in the mesh of urban space.

Net Zero Energy Building concepts are the buildings producing annually more than its energy needs, with the energy balance positive.

In Latin America, the city of Bogotá already has two representatives of the Net Zero Energy Building concept, certified by two different global initiatives. The Cosmas and Damian Foundation Bone Bank is certified by Mission Net Zero, and CIAT (International Center for Tropical Agriculture) is certified by The Living Building Challenge, also reaching LEED Platina.

New buildings are being designed within this "zero energy" concept in the voluntary way in Brazil. In the United States and Europe, some aim at the positive annual energy balance of the new buildings over the years.

Brazil has favorable conditions of solar radiation in practically all of its territory (see Fig. 1 below). This condition contributes to two advantageous strategies for energy efficiency and also to achieving the goals of Zero Energy Building. One is the good availability of natural light, and the other is the huge possibility of solar power generation.

The roof has special emphasis for these strategies, considering that, due to the solar trajectories in the latitudes of the Brazilian territory; the horizontal surfaces are highlighted in the arrival of the radiation.

The best performance of natural light in general results in a greater contribution to the Net Zero Energy Building concept.

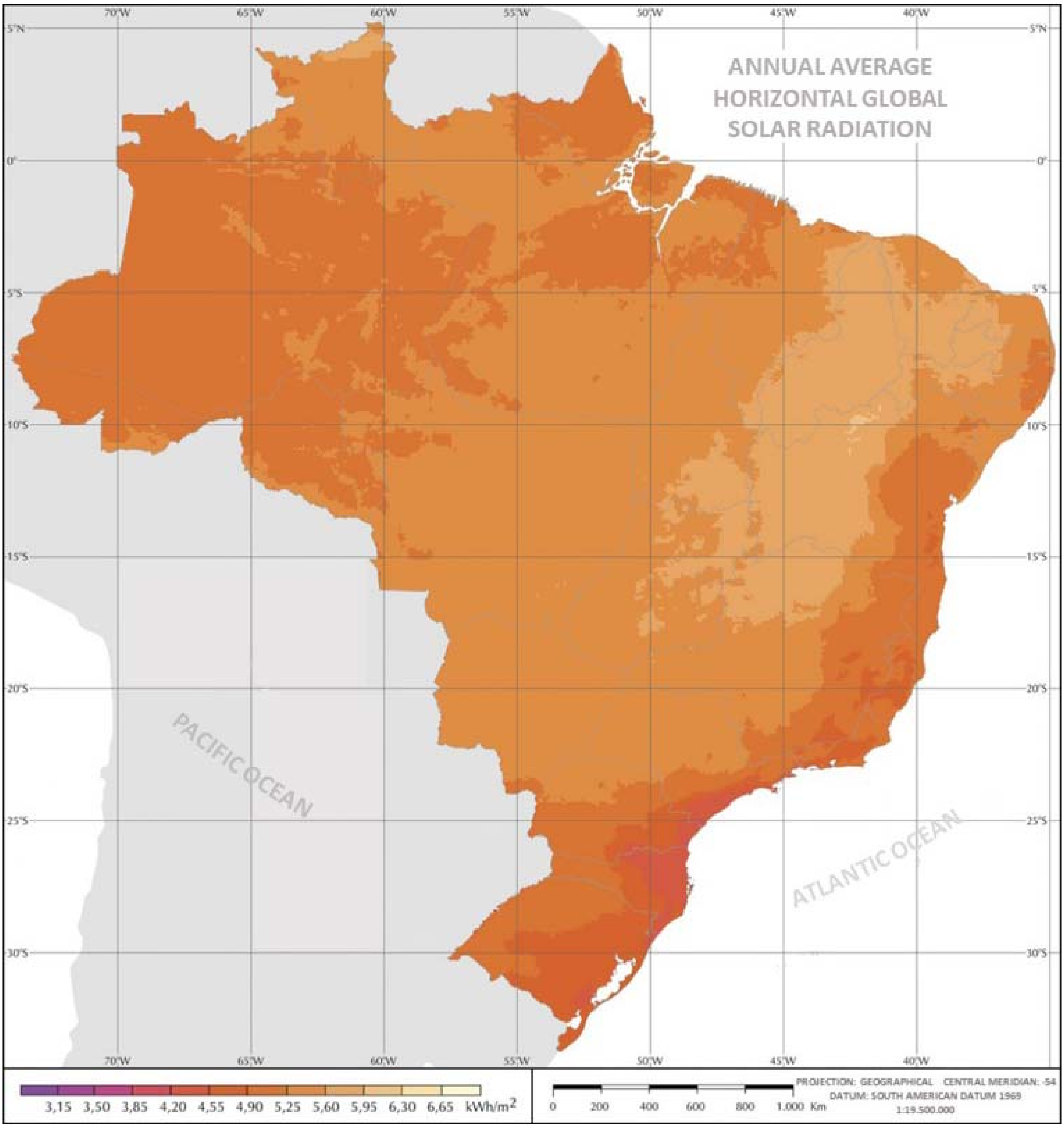

Fig. 1 Solar radiation ‘map in the average annual inclined plane in Brazil [12]

The present article follows with the presentation of applied zenith light resources, with emphasis on the shed system in projects known to be energy efficient.

The study of architectural elements, including component elements of the envelope and its contribution to the Net Zero Building, is relevant for reducing environmental impacts and conserving resources, especially because, according to Debeir et al.:

> "Establishing accurate energy balances can certainly highlight some of the great features of energy utilization mechanisms in contemporary societies: from this point of view, energy analysis is an irreplaceable instrument for good management of natural resources" [5].

The following projects will be presented with their zenith light resources. The Notley Green School in the UK associates sheds and green roof, and results had inspired the application of these resources in other schools of the region. Another project presented is located in Malaga, Spain and has a repetition of natural light roof´s elements, not being sheds elements as the theme of the article, but the design had turned possible the photovoltaic arrangement of generation of solar energy from panels of cover with sufficient transparency for gains in the illuminance of the inner courtyard by natural light.

The third project presented is a Brazilian representative, the Ipel plant in São Paulo, with a large coverage in curved sheds and other natural light use features at the top of the building.

II. The Shed System, Light Gains and Power Generation: Data and Examples

For a suitable project with the use of natural light, one must take into account a set of variables, as explained in the norm NBR 15215-3, 2004:

> "Availability of natural light (variable quantity and distribution relative to local atmospheric conditions), external obstructions, size, orientation, position and design details of the apertures, optical characteristics of the glazing, size and geometry of the environment and the reflectivity of the internal surfaces" [2].

Natural lighting is more uniform and has greater range than the lateral light features when using some element such as a distribution atrium.

The term "sheds" means the coverage elements for natural light access on one side and usually is repeated along the roof.

The better orientation of this resource to the South in the latitudes comprised between 24º and 32º S, which is in the location of Brazil. Following this orientation, the glazed part will allow the diffused light to enter most of the day. However, one must be aware of the sun's rays with a lower slope (especially those of the late afternoon) that can cause glare. This is based on the definitions of Corbella when he states that

> "the design of zenith elements must be done respecting the local solar trajectories, so that there is no direct solar radiation. Thus, the sheds should be designed with south orientation and in order to obtain a mask in the solar trajectory diagram that hides all trajectories" [4].

The sheds facing the South can not only favor the access of indirect natural light, which does not prevent unwanted heating, but also allows the generation of energy directed to the North (see Fig. 2), a more favorable orientation for the reception of solar radiation directly on the photovoltaic panels.

The face to the North can be an opaque material that receives the traditional modules or can be semi-transparent photovoltaic modules. This partial transparency is obtained from so-called photovoltaic films or films and can also be interesting applications in atrium buildings with solar light.

It should be emphasized that the North orientation will receive the greatest heat heating load by direct solar radiation throughout the days of the year, which will require an energy analysis before its specification to avoid undue overheating.

In computational simulations developed by Didoné et al. [6], the application of several photovoltaic technologies in different parts of the envelope allowed the evaluation of its potential when applied in different slopes and orientations. Most of the energy was generated by the photovoltaics applied in the roof, being responsible for 35% of the energy generated in the simulated prototype in Florianopolis Brazilian city and 38% in Fortaleza, respectively.

Therefore, roof is the surface the best option for the generation of energy from a photovoltaic arrangement, as long as there are elements of the immediate surroundings generating shading.

In addition, the slope of the North face of the shed that intends to generate energy should follow, according to Santos,

> "the slope of a module at an angle equal to the local latitude and oriented to the north (in the Southern Hemisphere) making possible the greater use of solar energy, this is caused by the slope of the Earth's axis in relation to the solar orbit" [8].

In this way, the shed can become an important element in the photovoltaic integration in the building, because it brings together energy efficiency and natural light of quality.

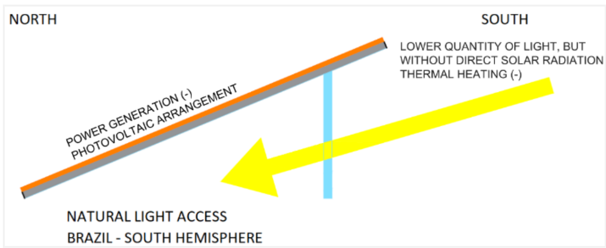

Fig. 2 Coverage scheme with higher performance of energy generation

A. The Notley Green, in United Kingdom

The school was designed by the Allford Hall Monaghan Morris UK office with emphasis in the passive solar energy and energy savings, which has inspired other projects and schools across the county.

The percentage of glassed area was studied in a software in order to obtain the maximum natural light, reducing the losses: the vegetation cover rises to form a shed that allows the entrance of light from the north (ideal orientation in the Northern Hemisphere) in classrooms, internal courtyard and hall and reduce the need for artificial light.

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B. Isofóton, Spain

The Isofóton factory, with more than 28,000m^2, is located in the Technological Park of Andalusia. The building uses the photovoltaic technology that they manufacture.

The coverage includes photovoltaic modules connected to the grid and the project also featured special photovoltaic modules in grids that were integrated into the exterior walls.

The European Renewable Energy Association gave an award to this project called Solarolar Projects award from Eurosolar in 2008.

Fig. 3 Covered with green roof and accesses of natural light [7]

Fig. 4 Inside view of sheds [7]

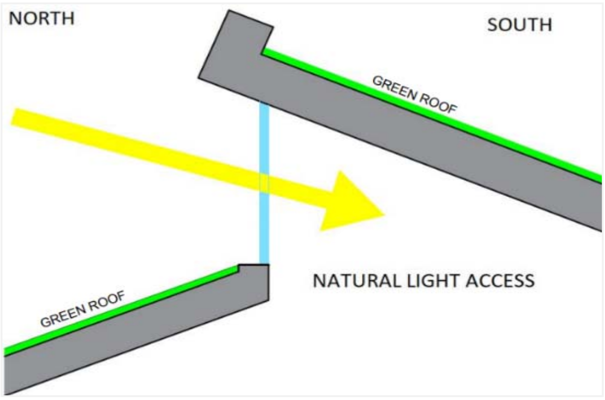

Fig. 5 Scheme of Notley Green School coverage

In Figs. 3-5, the zenithal illumination used can be noted, where the glass cover has an applied photovoltaic lamina, allowing the access of natural light and taking advantage of its potential in the local generation of energy.

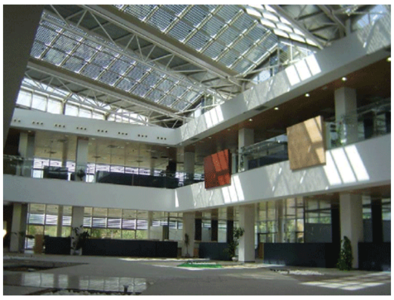

Fig. 6 Isofóton Headquarters, Malaga - Interior view of the atrium with elements with monocrystalline cell modules [3]

Fig. 7 Isofóton, Spain. Detail of the monocrystalline cell modules [10]

Fig. 8 Isofóton, Spain. Top view of the factory [10]

In the following diagram, based on the project analysis, it is possible to verify that Isofóton is an important example to analyze the possibility of natural light passing through the use of semitransparent modules of photovoltaic energy generation, which potentiates the use of zenith light resources in the energy efficiency scenario.

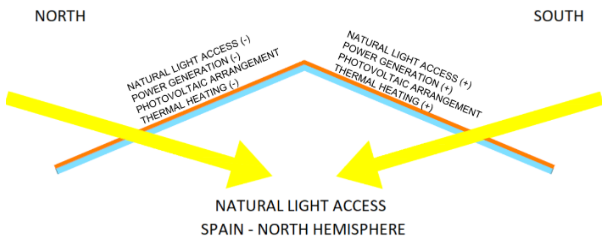

Fig. 9 Isofóton coverage scheme

Following is the Brazilian example of a manufacturing system of sheds.

C. Ipel Factory, Brazil

The Ipel headquarters, designed by Sidônio Porto, are located in an industrial condominium in Cajamar, São Paulo. The factory counts on a metallic coverage curved of great spans, composed by a succession of sheds uniting the administrative and production sectors.

Fig. 10 Ipel Factory [11]

The sheds have metal tiles with thermoacoustic insulation, with laminated glass facing the south face of the terrain, which provide excellent levels of natural light. According to the project´s author:

> "Natural lighting is a resource that we seek to exploit to the fullest, bringing luminosity and lightness to the work environment, but the idea was to explore indirect light, avoiding annoyances caused by exposure to excessive brightness, which was achieved with employment of wide eaves, that direct the clarity for an indirect incidence, besides providing an adequate solution of cover in days of rain, without breaking the harmony of the drawing " [11].

Laterally the sheds also have openings with laminated glass, as can be seen in Fig. 7. It is possible to note the project´s care with the East and West orientations of these glazing because Sidônio Porto makes use of large eaves for shading. The schematic below summarizes the detail of one of the factory coverage sheds.

Fig. 11 Ipel Factory, Brazil [9]

Fig. 12 Ipel Factory, Brazil [9]

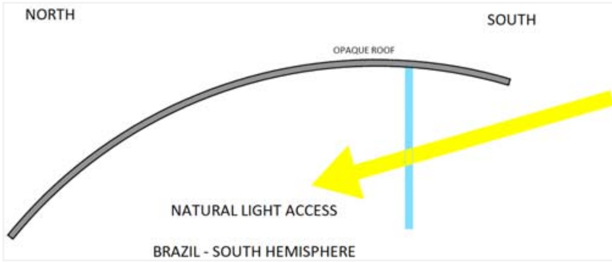

Fig. 13 Ipel Factory, Brazil

III. Conclusion

The zenith lighting element called shed was presented in different applications in Brazil and Europe, in different approaches, which shows the flexibility of formats, materials and solutions possible with this type of resource.

The roof shed performance in Brazil is adequate when it comes to the South orientation and it can be concluded that it can be an ally when it endures the maximum energy efficiency in the building with the use of energy generation in its face opposite to the natural light, especially when it is a Net Zero Building which is one of the goals of the project.

The green roof option as seen in the example of Notley Green School would also apply to several Brazilian bioclimatic zones as a pro-efficiency and thermal comfort feature.

In order to correctly design zenithal light systems from the environmental point of view and comfort to the user, it is necessary to encourage research and studies aimed at its design, energy calculations and assessment of thermal and visual comfort standards, in this way element can contribute considerably to the quality of the project as a whole, with a positive environmental interrelation.

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