

Economical analysis of a natural lighting system, through a prismatic domus, in a shed in the Manaus industrial district

Marcia Gabriela Fernandes da Silva¹, Joci Jane Santos de Souza², Hudson Diogo Araújo Marques Diogo³, Fabiana Rocha Pinto⁴, Thiago Costa de Lima⁵

¹Graduating in Electrical Engineering at FAMETRO Amazonas, Brazil

Email: marciagabyfs@gmail.com

²Eletrotecnichs Tecnicist at FUCAPI Amazonas, Brazil

Email: jocijane@yahoo.com.br

³Eletrotecnichs Tecnicist at FUCAPI Amazonas, Brazil

Email: hudsondiogohd2@gmail.com

⁴Dr. Teacher and Advisor of the Corse of Bachelor degree in Environment Engineer and Renewable Energies at FAMETRO Amazonas, Brazil

Email: Fabiana.floresta@gmail.com

⁵Eletrotecnichs Tecnicist at FUCAPI Amazonas, Brazil

Email: Thiago.t1lima@gmail.com

Abstract— The prismatic Domus is a technology presented to show an economic analysis referring to the use of natural lighting, where the sun is an efficient and safe source of energy. Relate this technology to the environment, considering the impacts and use of natural resources and the thermal comfort of the employees working in the area of the shed, considering its length, width, right foot and total area, in addition, showing the need for preventive maintenance and corrective technology, as well as the investment values, with their respective investment returns. The objective of this study is to demonstrate an economic analysis based on the use of the Prismatic Domus, which is a source of natural energy capture, in an industrial center company in Manaus, AM, as a renewable energy source instead of fossil fuel. The object of this analysis was a shed in the industrial pole located in the city of Manaus, where the dimensions of the building's shed were measured, regarding width, length and height. Thus, it started by collecting measures from the shed, which obtained 45 x 53 x 11m, respectively. Based on NBR 5413, which deals with the interior's illuminance and the data collection related to the shed, recorded in the dimensions of 45 x 53 x 11m respectively, a luminometrically study was carried out, where software, such as softlux in it is free version, are normally used, available to download free of charge, where you can record the information in each step of a total of 04 steps and choose from the pre-established options that meets the needs of each project. The data presented show that in the use of prismatic domus technology, the reduction with electricity consumption is 70.52% compared to the use of a lighting system that uses the utility energy. With the use of this system, using the prismatic domus, there is no concentration of light in a single point (hot spot effect), has ease of cleaning and low maintenance.

Keywords— Economy, Energy efficiency Urbanization.

I. INTRODUCTION

Artificial lighting has transformed the lives of human beings, especially with regard to human well-being related to their comfort, as well as the emergence of technologies that use fossil resources for electric energy as a generating source, introducing a new model to improve human life. Energy efficiency and resource use by these systems. However, the price that is paid for this scenario of comfort

and technological development to be implemented results in environmental impacts and degradation [1].

Artificial light follows the human trajectory, where over time, new products have emerged linked to this process of energy generation, among them, the lamp, which in turn emits heat with other elements, contributing directly to the heating which has been causing climate change, posing risks to human life and the environment, and may limit habitat and its resources for future generations [1].

The concern of using less and less fossil fuels as a source of energy and minimizing environmental impacts has become a challenge for scientists, where in times of awareness of the rational use of electricity and the cost of charging the local permit holder, including the appeal for sustainability, arises in Brazil as an alternative to traditional systems, from natural lighting using prismatic polycarbonate, being characterized as renewable energy source [2].

As long as there is no awareness, sustainability and the need to migrate to renewable energy sources, the planet and man will suffer the consequences given the scarcity of their natural resources [2].

Economic analysis focused on natural lighting using prismatic polycarbonate, therefore, seeks to demonstrate that we can obtain satisfactory results when compared with commonly implemented technologies [3].

Given the developed capitalist model, time has become synonymous with money, so technologies need to minimize the use of the technical workers required for preventive and/or corrective maintenance, in addition to the advantages considering the economic bias, such as the thermal comfort of employees in the workplace. Concerning the so-called "Sealed Building Syndrome", which are projects that do not interact with the external environment, where they are neglected for this reason, a single window receives a huge amount of energy during the day. An example that can be extended to the upper coverage area of this shed making it energy efficient and improving the quality of life of employees [4].

From this analysis, it is possible to opt for a more energy efficient technological innovation project that does not transmit heat to the environment, ensuring the return on investment in a minimum time, which can attract investors, or even in the construction of new buildings, which can already implement these renewable energy solutions [4].

Natural lighting system

There are rules for various activities, environments and standards, but when it comes to natural lighting, meeting the standards is not enough, because in addition to the rules, you need to meet other related factors that are visual discomfort, glare, tiredness, exposure to ultraviolet rays, inherent factors that for those who work daily in an environment given these changes becomes increasingly detrimental to humans and can cause headaches, nausea for lack of excess lighting, where a good distribution of light and color is essential [6].

The daylighting system can be a variant, depending on the type of material used for sunlight transmission, where the study focuses on polymers used in engineering applications, such as polycarbonate and its variations, seeking to disseminate their energy efficiency, flexibility,

comfort, safety, durability, ultraviolet resistance and heat retention [6] (Figure 1 and 2).



Fig.1: Installation of Prismatic Domus in the outside area.

Source: [6]



Fig.2 – Installation of prismatic domus in the inside area of the company.

Source: [6]

Prismatic elements were developed for obstructed environments, such as basements, sheds in order to redirect sunlight towards the environmental background. Thus, the prismatic panels are positioned at the roof level to capture sunlight and direct it into the environment in all directions, managing to become a receiver of the sun's rays and fragment them into "micro rays" sending back to the atmosphere 75% of the heat transmitted by infrared rays, where the big heat transmitting villains, allow only the passing of visible light, with 100% Color Reproduction Index (IRC), by diffraction action, and the illumination scattered evenly in the environment [4].

Prismatic domus is a term used to refer to a group of transparent and amorphous plastics, considered a material resistant and lightweight with a high degree of transparency and high impact resistance. Because of these properties, as is the case of blocking ultraviolet light (UV), it is widely used in roofing protecting those in the

environment from this radiation providing higher thermal quality, since ultraviolet radiation is a major responsible for the heat coming from solar light. It is also a good heat-resistant, electrical insulator, self-extinguishing not spreading flames, has dimensions of 1.3 x 1.3m; 1.3 x 2.5m; 1.6 x 1.9m, thermoformed sheet, with the highest concentration of micro prisms approximately 40,000 per m² [6].

The refraction is based on one of Newton's experiments with prisms, noting that when light enters the prism, it undergoes refraction with the same effect on prism output. Underlining the Snell-Descartes Law, it's stated that the deviation that light undergoes in this process of entering or leaving the prism depends on the refractive indices of the prism material and air. However, when light travels through the prism glass, it has the scattering effect, so each frequency of light feels a different refractive index and, when exiting the prism, suffers a different deviation [6].

For each frequency of the visible spectrum of light we associate a color, where because of this phenomenon it is observed the formation of this color gradient at the exit of the prism. In the phenomenon of refraction, there is a change in the speed of propagation of light through a deviation from the original direction, that is, the light undergoes an angular deviation from the normal line, so that it passes from one transparent medium to another transparent one [7].

Thus, if the incidence of light in the way is normal, that is, it has an incidence angle equal zero, the light will not deviate and, therefore, its refracted angle will be null [7]. On the other hand, when the incidence of light causes an oblique deviation, the light ray will come closer to the normal line, leading to the deviation in the light path, i.e., the phenomenon of refraction.

The objective of this study is to demonstrate an economic analysis based on the use of the Prismatic Domus, which is a source of natural energy capture, in an industrial center company in Manaus, AM, as a renewable energy source instead of fossil fuel.

II. METHODOLOGY

The research methods of this analysis start from field research, considering its accomplishment from obtained data on the spot [8]; bibliographic, where it is necessary to consult articles, norms, books and manuals; and descriptive aiming to describe the characteristics of certain populations or phenomena [9].

The object of this analysis was a shed in the industrial pole located in the city of Manaus, where the dimensions of the

building's shed were measured, regarding width, length and height. Thus, it started by collecting measures from the shed, which obtained 45 x 53 x 11m, respectively.

For the installation of the prismatic plate, one has to consider that one of its faces facing the inside of the shed contains thousands of microprisms, for the diffusion of natural light, generating a behavior of "scattering" of light throughout the environment, in a single point "hot spots" and light tracing as the sun's position varies [10].

For projects using prismatic domus as material, useful utilization percentages are required, taxed from 2 to 3.5% of the total coverage area, considering the Brazilian Standard 5413 [11] which deals with Interior Illuminance, indicating the amount of lux suitable for the shed (area of analysis) from 300 to 500 lux, following the same criteria of a lighting design [11].

III. RESULTS AND DISCUSSION

Based on NBR 5413, which deals with the interior's illuminance and the data collection related to the shed, recorded in the dimensions of 45 x 53 x 11m respectively, a luminometrically study was carried out, where software, such as softlux in its free version, are normally used, available to download free of charge, where you can record the information in each step of a total of 04 steps and choose from the pre-established options that meets the needs of each project.

The breakdown is initially (step 1) from data such as: a. inserting the name of the environment; b. the dimensions the building imputing the width, the length, the right foot, choosing the colors/reflectance; c. the environmental conditions regarding the cleaning requirement and the type of activity in the shed.

In step 2 it is specific to the choice of luminaire, where one finds for each choice their respective characteristics, such as: a. technical specification; b. Photograph; c. drawing; d. photometry; e. illuminance; f. utilization factor and zonal flow.

In step 3, you will find a field to specify illuminance (lux) for the project area. Already in the last phase (step 4) based on the calculations of the last three steps, we obtain as a result: a. amount of average, minimum and maximum lux; b. the number of luminaires needed for the area; c. the distances between each other, beyond the row numbers. Still in this step, a layout can be obtained specifying the location of the luminaire and its lux, being in point-to-point formats, both color and black and white illuminance using the colors visually to identify the maximum, medium and minimum lux (Figures 3, 4, 5 and 6).

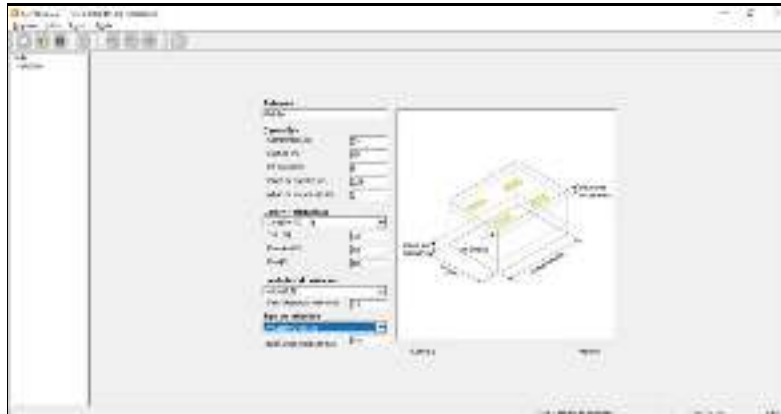


Fig.3: Entering the environment data.
Source: [12]



Fig.4: Luminarie selection
Source: [12]

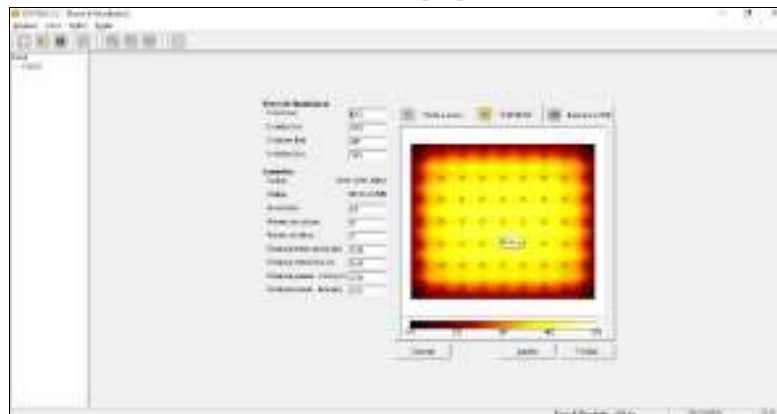


Fig.5: Luminarie Distribution.
Source: [12]

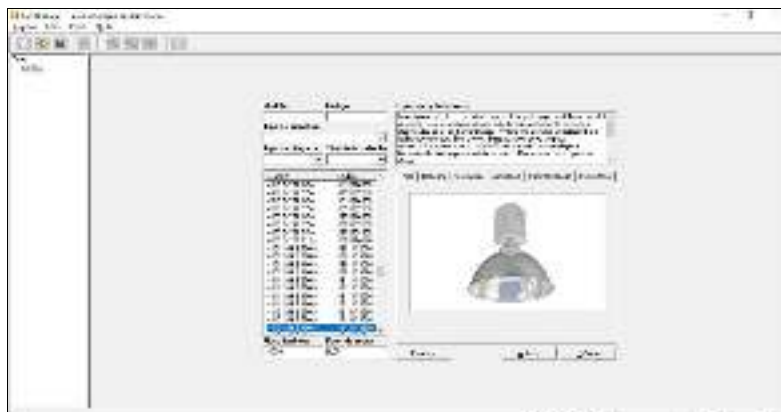


Fig.6: Lux measurement at each luminarie location point

Source: [12]

Through the obtained data, it is observed the quantity of 63 luminaires to be installed in this shed, with power of 400W each luminaire, which considers the working regime of the shed of 17h, on the days covering from Monday to Saturday. For this analysis, the average kWh value considered to be R \$ 0.52, obtained by the average monthly tariff between peak and off-peak consumption (Table 1).

Table 1: Luminaries operation data

Description	Power	R\$		Quantity
		Average media kWh	Operation (h)	
Overlap lamp	400	0,52	17	63

Source: Own authorship, 2019.

This way, approximate values were obtained, having a daily expense of R \$ 222.77, totaling monthly expenses of approximately R \$ 5,791.97, where, if we consider the 26 days in the month, excluding Sundays only, one reaches an annual electricity use in the amount of R \$ 69,503.62, in this area only.

Evaluating the installation of the prismatic Domus for this same area, the following specifications are used: a roof using galvanized trapezoid tiles, with thickness of 0.40mm, 7.0m in length, and 1.0m in width; In addition to the useful percentage of utilization taxed at 3%, it may reach a total area of 2,385m² at the end, in which only the use of approximately 72m² will be necessary for the installation of the prismatic domus. The choice of dimensions of the prismatic domus is 1.60 x 1.90m, in this area a quantity of approximately 24 plates should be installed.

From the working regime practiced in this shed, of 17 hours daily, Monday to Saturday and with the use of

the natural lighting system of 12 hours daily, it can be concluded that the values will be reduced. (Table 2).

Table 2: Prismatic domus application in reducing of electricity consumption.

Description	Power	R\$		Quantity
		Average media kWh	Operation (h)	
Overlap lamp	400	0,52	5	63

Source: Own authorship, 2019.

It is observed that the operating hours will reach 5h daily, resulting in a daily cost reduction of R\$ 65.52, considering 26 days a subsidy of R\$ 1,703.52 and a decrease of R \$ 20,442 annually, 24 in the lighting system.

Therefore, Table 3 shows a reduction in the amount paid with electricity, considering the use of prismatic domus.

Table 3: Reduction of electricity use

Operation (h)	R\$		
	daily	monthly	Yearly
17	222,77	5.791,97	69.503,62
5	65,52	1.703,52	20.442,24

Reduction de 70,52%

Source: Own authorship, 2019.

Thus, it is observed that the prismatic domus can offer numerous advantages, such as energy reduction and consequent reduction in financial expense, high durability and mechanical resistance, lower thermal transmission, ultraviolet filtering, 100% color rendering index, excellent performance on cloudy days, zero eye glare, increased lamp life of the artificial lighting system, low amount of equipment to illuminate large environments,

ease of cleaning and low maintenance making the system with the use of prismatic domus an excellent The choice of short, medium and long term, in addition to implementing sustainability, much more than economy, with this choice helps to protect the planet, turning off the lights illuminates a new possibility to preserve the environment.

IV. CONCLUSIONS

The data presented show that in the use of prismatic domus technology, the reduction with electricity consumption is 70.52% compared to the use of a lighting system that uses the utility energy.

With the use of this system, using the prismatic domus, there is no concentration of light in a single point (hot spot effect), has ease of cleaning and low maintenance.

When the lamps are turned off, a new possibility is lit to preserve the environment, considering the natural use of lighting with sunlight, besides the reduction of costs, there is an interaction with the external environment, especially in terms of improvement of the environment. Work environment, performance, and productivity of its employees.

REFERENCES

- [1] FARIA, Ana Carolina de. Sustainable lighting The benefits of using led technology in lighting projects. Dissertation (Master in and ecology and sustainable production). Pontifical Catholic Univ. Goiás, 2014.
- [2] FREITAS, G.C.; DATHEIN, R. Renewable energies in Brazil: an assessment of the implications of socioeconomic and environmental development. Nexos Econ. magazine, v. 7, n. 1, p. 71-94, 2013.
- [3] MB group. Available in: <https://grupomb.ind.br/mbobras/economia-de-energia/polycarbonato-prismatico-na-iluminacao-natural-qual-a-vantagem/>. Accessed in set 17, 2019.
- [4] Construction Forum. Available in: <http://www.forumdaconstrucao.com.br/conteudo.php?a=4&Cod=122> Accessed set 13, de 2019.
- [5] AECweb. Available in: https://www.aecweb.com.br/prod/e/domus-prismaticos_12130_16611. Accessed in set, 16 2019.
- [6] Basic Astronomy. Available in: <https://www.apolo11.com/espectro.php>. Accessed in set 14 2019.
- [7] Available in: <https://www.todamateria.com.br/refracao-da-luz/>. Accessed in set 16, 2019.
- [8] RODRIGUES, Auro de Jesus. Scientific methodology . São Paulo: Avercamp, 2006.
- [9] GIL, Antonio Carlos. "How to design research projects". São Paulo: Atlas, 2008. pp. 4.
- [10] ENGEPOLI. Prismatic Domus System for natural lighting. Available in: https://www.aecweb.com.br/emp/contm/sistema-de-domus-prismatico-para-iluminacao-natural_9197_12450. Accessed set 13, 2019.
- [11] NBR 5413, ABNT - Brazilian association of technical standards .Interior lighting. Rio de Janeiro. 1992.
- [12] Lighting sizing software. Available in: <https://softlux1.software.informer.com/download/>. Accessed in set 16, 2019.