

Bioclimatic criteria in the AMOF building to reduce the emission of Carbon Dioxide (CO₂) - Lima - Peru 2021

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Abstract. This research aims to analyze the influence of the application of bioclimatic criteria, to obtain integral well-being, energy efficiency and reduction of carbon dioxide (CO₂) to the environment. The growing trend for the use of sun-exposed glass in buildings, which causes the greenhouse effect, increases the interior temperature of the building and causes glare, promoting artificial cooling by inefficiently using energy, heating a room naturally and then cooling it artificially is a bad practice and stimulates the closing of the curtains, which causes the lighting of luminaires; with which the building emits carbon dioxide (CO₂) to the medium, contributing to global warming. It has been developed, with a methodological approach based on the principles of bioclimatic architecture, the analysis of the variables that allow to study this influence, in the office buildings in Miraflores, considering the AMOF Building under adverse thermal and light conditions. With the results obtained, it is verified that the solution with solar geometry proposed for the AMOF building solves problems of thermal wellbeing, lighting and decreases the emission of carbon dioxide (CO₂) by 74.07 %. Therefore, it is concluded, that these considerations not taken into account, influence the conditions of habitability and well-being of users, making the window the weakest point of the building to achieve human well-being, energy efficiency and pollutes the environment.

Keywords: Bioclimatic Architecture, Integral Well-being, Solar Geometry, Energy Efficiency, Carbon Dioxide (CO₂).

1. Introduction

The situation of energy consumption worldwide and Peruvian has been in constant growth, modern life depends on energy, energy is needed for appliances at home, to move from one place to another, to perform the tasks of work, etc., a major energy-intensive sector is the residential, commercial and industrial sector which ranks second in energy consumption in the country [1].

Within this sector are the office buildings, which in recent years have increased their construction in Lima, there is an average growth of 3.0% in recent years [2], especially in districts such as Miraflores, this type of building has become a major energy consumer due to its architectural approach. Construction is responsible for about half of all U.S. greenhouse gas (GHG) emissions. annually [3], the same occurs in Peru, a product of the design outside the conditions of the local climate and sun [4].

Because of this, architectural solutions have been developed that have no natural comfort conditions in office buildings, in recent years the proposals are artificially air-conditioned (air conditioning, heating and artificial light), architectural solutions have been standardized, which has promoted the misuse of energy, forgetting that buildings can be heated naturally, taking advantage of the advantages and controlling the disadvantages offered by the local climate (See figures 1 and 2).



Figure 1. Platinum and Strip Mall Buildings in Miraflores



Figure 2. Leuro and Cantuarias Buildings in Miraflores

This situation motivated the concern to study these topics and to be able to do an investigation on The Design of Windows. Analysis in relation to Human Well-being and Energy Efficiency in Office Buildings in the District of Miraflores. March 2013-March 2014 [5], work from which the current research is derived, also chosen, after the analysis of several buildings, the AMOF building as a case study because it presents adverse conditions in terms of thermal and lighting well-being. Considering the principles of the methodology of the bioclimatic architecture, to propose a solution that improves the negative conditions found, thus verifying the proposed improvements, achieving energy efficiency and reducing carbon dioxide (CO₂) emissions.

The issue of energy saving is a global need, to reduce extra spending on poorly used energy and avoid environmental pollution, that is why efforts have been made with work and research in the development of passive technologies (natural air conditioning of buildings), in order to achieve a new society that thinks about non-polluting, applies the energy efficiency and seeks the improvement of the quality of life.

"Architecture must materialize so that it can respond not only to the dynamics of the environment that hosts it, living side by side with it in a synergistic way, but must also be in concomitance with the cultural and economic diversity of today's society" [6], that is, to work for environmental sustainability.

Perú is a tropical country, located in the Tropic of Capricorn, has an incidence of solar rays with a tendency to perpendicularity, determining a very high intensity, with average solar radiation of 5 kWh/m² [7]. The tropical zone has the largest solar radiation in the world and has great energy potential [8].

On the other hand, of the 32 types of climates on Earth, in Peru there are 28 [9], meaning that the country is a natural laboratory for the exercise of architecture, because it possesses a large climatic variety that must mean various ways of facing the architectural design problem.

In Perú, little theoretical work has been done in this regard, but they have not focused on how the design with bioclimatic criteria appropriate to the local environment improves the comfort conditions, avoiding energy consumption and reducing emissions.

In recent years, the residential, commercial and public sector ranked second in the country's energy consumption [1]. The buildings have had large energy consumption to be air conditioned artificially and to need artificial light during the day to be able to carry out the activities inside the building, product of the deficit of integral well-being in the buildings, promoting the emission of carbon dioxide (CO₂).

It also ranks third in terms of emissions of carbon dioxide (CO₂) and methane (CH₄) [1], which shows the negative influence of buildings that are not adequately resolved.

The work is part of the area of environmental conditioning for buildings [10], research is carried out to improve the conditions of thermal comfort, lighting of the offices and by means of the bioclimatic solution, take care of the environment. Demonstrating that the proposal of passive architecture achieves improvements in terms of heat, light and reduction of carbon dioxide (CO₂) emissions

2. Literature review

2.1. *Arquitectura Bioclimática*

The research is theoretically based on the fundamental principles of bioclimatic architecture, that is, that which has as premise to be designed with the climate, taking advantage of the solar movement for the well-being [11] getting environmental comfort, energy efficiency and no pollution of the environment.

Energy consumption should be limited, it is essential to consider the local climate, the orientation of the venue, the choice of the form and finally address the appropriate choice of the enclosure [12].

Passive bioclimatic design seeks to integrate form, matter and energy; and this is the great challenge that the current situation of scarcity and rising fuel costs poses to the designer [13].

This theoretical foundation is the basis for making the built habitat more friendly to the natural habitat. What is possible with the criteria of the bioclimatic architecture, with the management of the physical processes of conduction, convection and radiation, that allow to avoid inadequate energy consumption. Exploiting natural resources is the fundamental premise for developing proposals with passive solutions [14]. This good practice reduces carbon dioxide (CO₂) emissions from buildings.

On the other hand, with the methodology based on the analysis developed in three well-defined parts, bioclimatic criteria can be developed [15]:

- Climatology of buildings (analyzes human thermal well-being and design according to the orientation of the place).
- The materials (the thermophysical conditions of the materials).
- The architectural design.

Bioclimatic architecture should not be copied or standardized, it should be understood that each place has its peculiarities. It is necessary to think globally, but to act locally; each place must be studied, in its natural physical characteristics (Climate, solar geometry, comfort conditions) to obtain architectural responses that are specific to each region, the universal model does not exist. Bioclimatic architecture is the basis of energy efficiency in buildings.

In conclusion, the bioclimatic principle is based on building with the climate, that the architecture is the element that this between exterior climate and the interior well-being, developing spaces that satisfy the architectural functionality and the integral well-being.

2.2. *Solar geometry*

The development of the bioclimatic architectural proposals has as an important component the analysis of the apparent movement of the sun, which depends on the geographical location of the place, since the latitude determines the inclination of the sun. The sun is therefore a fundamental part of architectural design.

"The apparent movement of the sun should always be one of the determining aspects in the conception of buildings and cities, The energy performance, the conditions of habitability and the compositional qualities of the same will be closely related to the way in which direct solar radiation affects them in the different moments of the year and in the different hours of the day. These statements are all the more important in view of the ever-increasing demands for thermal and lighting comfort in the face of an urgent need to reconsider the aspect of energy efficiency, which in turn means saving money and protecting the environment" [16].

The development of a proposal with solar geometry and climate considerations, the basis of bioclimatic architecture [17], makes it possible to propose a proposal that takes advantage of the advantages and can mitigate the disadvantages of the sun, according to climatic conditions.

With the solar geometry the celestial coordinates, azimuth angles and solar height are obtained, with the solar graphics or with solar calculators, to with this information, to analyze the facades of the buildings and to be able to determine the relevance of the proposed solutions. The solar analysis must be done in parallel with the climate analysis in order to properly evaluate the application of bioclimatic criteria in the architectural proposal (See Figure 3).

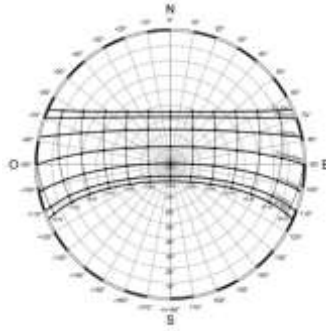


Figure 3. Equidistant polar solar chart

The knowledge of the solar movement is essential to be able to carry out the design process in the architecture, with the analysis of orientations, because it is the sun that will significantly influence the interior environmental conditions of the building. It is clear that solar radiation and its apparent movement are what allow to achieve the right comfort conditions, as long as you take advantage of the advantages and control the disadvantages offered by the sun, with a volumetry that also goes according to the climate variable.

2.3. Energy efficiency

With the passive solution, buildings that mitigate the emission of carbon dioxide (CO₂) to the environment are achieved, since the bioclimatic architecture is the basis of energy efficiency [18] and with the rational use of energy emissions are reduced [19].

Bioclimatic architecture as a fundamental part for energy saving in buildings [20], demonstrates the existence of a parallel concern for the issue of the energy consumption of buildings, because today, the construction sector with the buildings as it is developing, have a high energy consumption, reason why energy assessments are made to be able to plan more optimal solutions with lower energy consumption.

Approximately half of the energy generated in the world is used for the operation of buildings. If you add the movements to and from the buildings, it is verified that the designers of the built environment control and are responsible for 75% of the global energy consumption, generating a lot of CO₂ emissions to the environment [12].

Therefore, as a first possibility to achieve energy efficiency, local conditions and bioclimatic criteria are taken into consideration, understood as basic technical foundations that allow to contribute in the architecture to achieve energy savings, pollution to the environment and promoting the principles of sustainability.

The entire literature review aims to determine how bioclimatic considerations improve the conditions of well-being, energy efficiency and contribute to reduce carbon dioxide (CO₂) emissions, there is a concern, increasingly, to develop solutions to existing problems that are appropriate to the place where one works.

3. Methodology

The research is of applied and correlational type, since the analysis of the AMOF building is developed in its current state, it was the building that had the worst bioclimatic performance in the research: The Design of Windows. Analysis in relation to Human Well-being and Energy Efficiency in Office Buildings in the District of Miraflores, which is the basis of this work, carrying out the study of the variables:

- Orientation of facades and windows.
- Thermal Comfort (Definition of Thermal Balance inside the building)
- Lighting comfort (Definition of luxes inside the building)
- Solar protection (Solar penetration inside the building)
- Energy consumption.
- Emission of carbon dioxide (CO₂).

Confronting the elements evaluated, it was found that the building presented problems of thermal well-being, lighting, energy efficiency and carbon dioxide (CO₂) emissions to the environment. Therefore, an architectural solution is proposed, with application of bioclimatic criteria based on solar geometry to solve the conditions found.

The bioclimatic proposal, which was adapted to the place of study, improves the condition of the building, providing well-being

(thermal and light), to achieve as a result, energy efficiency and reduction of carbon dioxide (CO₂) emissions. The same analysis was carried out for the building in its current state. Then a correlational analysis is performed, the current state is confronted with the proposal. Finally, to check the benefits of the proposed proposal for the AMOF building.

The research work is developed with an evaluation based on the methodology of the bioclimatic architecture for energy saving [20], that is, calculations were made so that quantitative information could be obtained, no subjective aspects of users were evaluated. Thus, perform an analysis in relation to the variables in a correlational way and get the support of the proposed proposal.

The foundation was to study the situation of the current state of the AMOF building, the thermal, lighting and emission aspects of carbon dioxide (CO₂) to the environment were analyzed based on relevant calculation methods and as a result the rating of the same is obtained.

To solve the problems of the building (current situation), a solution was proposed based on the theoretical principles of bioclimatic architecture, applying solar geometry, with a passive proposal on the facade that mitigates the problems encountered, which is evaluated in the same way as was done to the building in its current condition, checking the solution to the problem.

The research has two important foundations, providing welfare to the users of the building and reducing the environmental pollution caused by the current state of the building. The natural habitat is cared for with bioclimatic architecture with energy efficiency and reduction of emissions, contributing to environmental sustainability [21].

3.1 Design and type of research

The work is carried out with the study of the current situation of the AMOF building (east facade), for which the architectural survey was done and evaluated using the simulators Ecotect Analysis 2011, Autodesk Revit and Archicad 14 the behavior of the facade with respect to heat gain, natural lighting conditions, thermal comfort and carbon dioxide (CO₂) emissions.

The simulators were loaded with the information of the place, creating a climate file WEA, likewise, placed the library of materials to analyze, the number of users and equipment in the interior environment. With this data is calculated by determining the problems of the building in its current state. The bioclimatic proposal was developed with solar geometry, the proposal was analyzed, as it was done with the current state, finally, the comparison of the current form is made against the window proposal that achieves solutions of integral comfort.

4. Results

The results of the analysis of the AMOF building are presented, in its current state and with the implementation of the proposal with bioclimatic criteria. These analyses will test the benefits of applying bioclimatic criteria in the building to reduce carbon dioxide (CO₂) emissions.

4.1. Study current status building AMOF

The analysis of the study of the AMOF building allowed to verify the existence of problems of thermal comfort, lighting and emission of carbon dioxide (CO₂), which will be presented below.

The AMOF building, was analyzed in its current state, is located at Av. Jorge Chávez 180, Miraflores: (See Figure 4)

EDIFICIO Nº1	AMOF ESTE
DIRECCION	AV. JORGE CHÁVEZ 180, MIRAFLORES
PROYECTISTAS	ARQ. MESTANZA ZUÑIGA, ENRIQUE ARQ. GARCIA RIVERA, MIGUEL
ORIENTACION	ESTE
USO	EDIFICIO DE OFICINAS
MATERIAL DE LA VENTANA	VIDRIO TEMPLADO 10mm TRANSPARENTE CON LAMINA INSULADA VERDE
PROTECCION SOLAR	NO
ALTURA	6 PISOS



Figure 4. AMOF building in Miraflores

For the evaluation of the AMOF building, in its current situation, east side (facade evaluated), the analysis was carried out by making calculations with the information obtained, studying the interrelation of dimensions and indicators, for the independent variable, bioclimatic criteria, orientation (from the facade and windows), thermal comfort (definition of the comfort zone and analysis of thermal balance inside the building), lighting comfort (definition of luxes inside the building), solar protection (Solar penetration to the interior of the building), materials (Of the windows); for the dependent variable, the emission of CO₂, with the analysis of energy consumption was evaluated with the factor of emission of CO₂ the behavior of the building.

For the software used, in the analysis for the thermal, energy and carbon dioxide (CO₂) emissions part, the Archicad 14 software was used, for the light analysis the Autodesk Revit 2020 software was used with the complement Insight; the following information was placed on them: Location data (latitude, longitude, altitude above sea level), comfort zone of Miraflores, architecture, materials, climate information of Miraflores, quantity of equipment and luminaires with hours of use, capacity of materials, climate information of Miraflores, quantity of equipment and luminaires with hours of use, capacity of persons, with hours of assistance.

Determined the comfort zone of Miraflores, the analysis was done annually, the average of the final analysis is shown, indicates that the east side receives incidence of direct sun for six hours, which causes heating that harms the interior well-being, forces to use curtains to avoid the sun. This causes the luminaires to be turned on during the day and the artificial air conditioning equipment, making a bad practice and increasing heat load. Thermal conditions outside the thermal well-being zone were obtained, the warmer day indicates a temperature difference between the indoor and outdoor temperature of 7.5°C, causing more heat inside the building than outside, which is wrong and outside the comfort zone (area bounded by red lines from 20.10°C to 27.50°C) (See Figure 5).

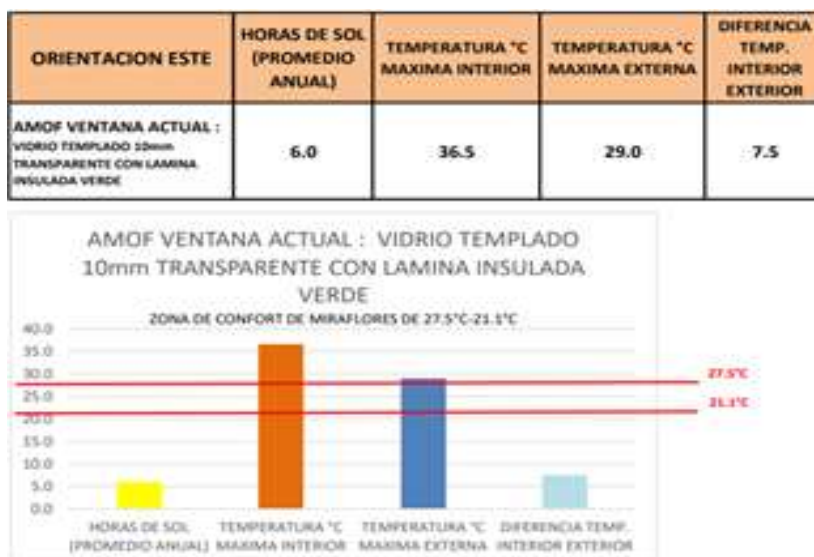


Figure 5. Thermal result. AMOF-Current State Building, Miraflores

Light analysis was also carried out in the current state of the AMOF building (east facade). Determined the lighting comfort zone, we proceeded to do the analysis on an annual basis, we show the average of the final analysis, showing that the east side is with problems of glare at the edge of the windows and penumbra at the bottom of the environments, damaging the well-being of the users, it forces to use curtains to avoid the sun, which decreases the natural lighting inside the environments.

This causes the lights to be turned on during the day, bad practice is to turn on the day lights, the analysis determined that there was a glare zone near the window and another in penumbra at the bottom of the environment with average values of 1500 luxes to 300 luxes, outside the lighting comfort zone (from 500 luxes to 750 luxes for office work) (See Figure 6).

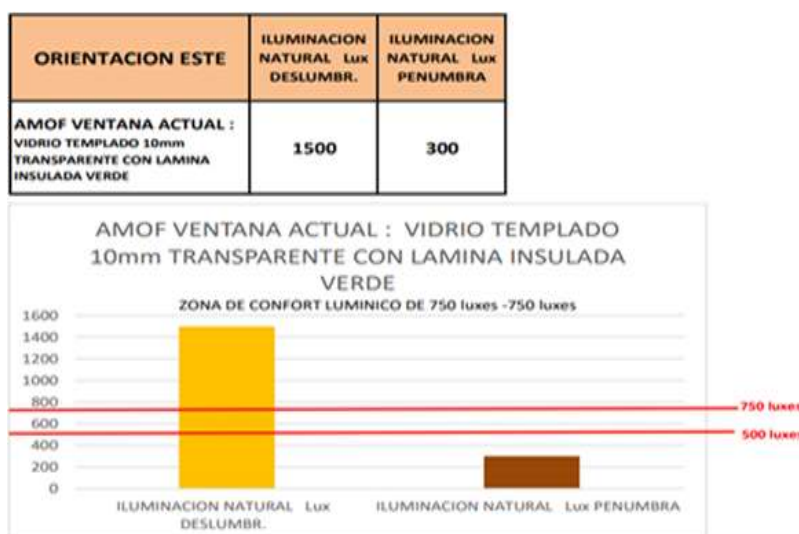


Figure 6. Lighting result. AMOF-Current State Building, Miraflores.

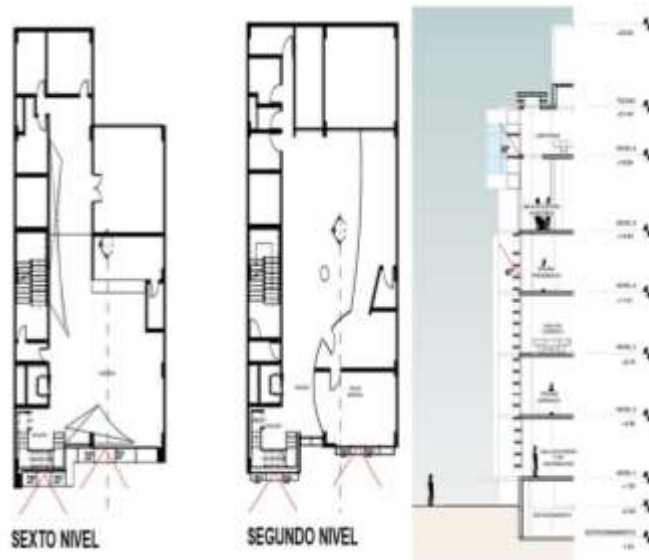


Figure 9. AMOF Building - Proposal with solar control (Plants-Cut), Miraflores

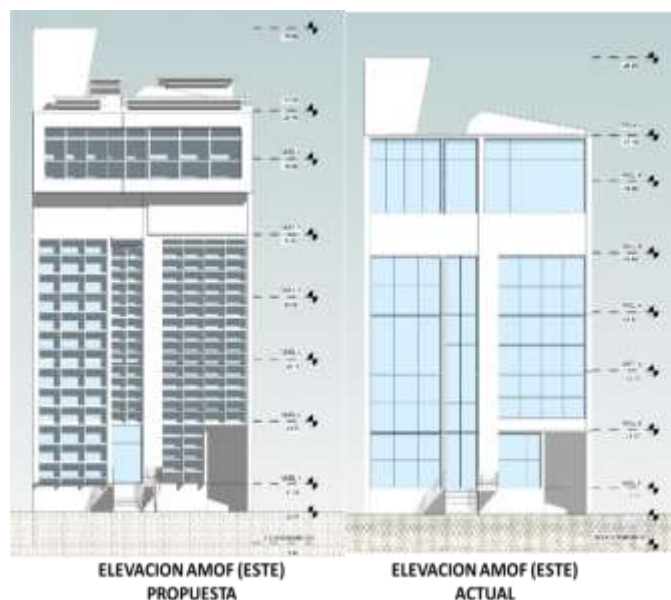


Figure 10. AMOF Building - Proposal and Current (Facades), Miraflores

The proposal reduced the impact of the sun, which allowed shading windows by the protection system, avoids glare due to excess solar input, therefore, there was rational use of energy, reducing carbon dioxide (CO₂) emissions to the environment, using the same 10 mm Green Tempered Glass with thermal transmittance coefficient $U= 5.0 \text{ W/m}^2 \cdot \text{K}$.

Analysis of the proposal of the AMOF building was carried out, taking the same parameters that were used in the evaluation of the current state of the AMOF building (east facade), showing that bioclimatic criteria reduce carbon dioxide (CO₂) emissions.

The average of the final analysis is shown, indicating that the incidence of direct sun decreases to two hours, causing a decrease in solar heating, improving the well-being of users and controlling glare.

Therefore, there is no need to turn on the luminaires during the day and there is no need to turn on the artificial air conditioning equipment, achieving a good practice when lighting naturally taking advantage of solar control, thus improving the thermal and lighting performance of the AMOF building, thermal conditions within the thermal well-being zone were achieved, the warmer day a difference in indoor and outdoor temperature of -2 was obtained, 5°C , the exterior being warmer than the interior, as it should be, leaving the interior temperature within the comfort zone (zone delimited by the red lines of 20.10°C to 27.50°C) due to the proposal implemented in the facade (See Figure 11).

The proposal reduced the impact of the sun, which allowed shading windows by the protection system, avoids glare due to excess

solar input, therefore, there was rational use of energy, reducing carbon dioxide (CO₂) emissions to the environment, using the same 10 mm Green Tempered Glass with thermal transmittance coefficient U=5W/m². K.

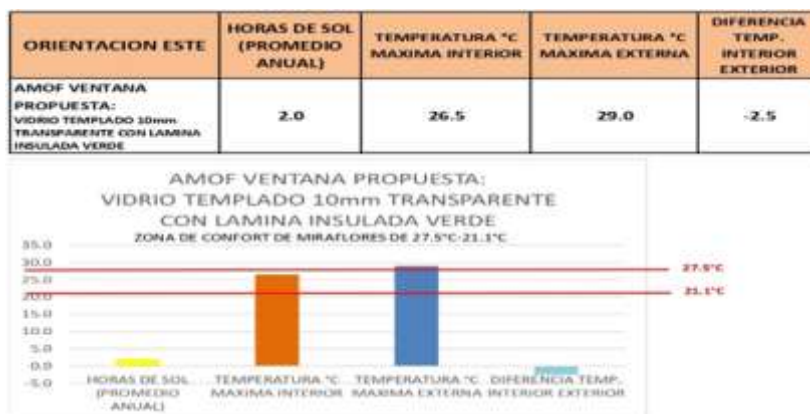


Figure 11. Thermal result. AMOF building- Proposal, Miraflores.

Also, the lighting comfort zone was determined, the analysis was done annually, the average of the final analysis is shown, indicates that the glare detected at the edge of the windows is controlled and the light is diffused better to the background of the environments, It is not necessary to use curtains to avoid the sun.

Therefore, it is not required to turn on the luminaires during the day, the analysis showed the natural lighting with better light distribution, with average values from 700 luxes to 500 luxes, within the lighting comfort zone (from 500 luxes to 750 luxes for work in offices) (See Figure 12).



Figure 12. Lighting result. AMOF building- Proposal, Miraflores

The energy consumption and carbon dioxide (CO₂) emissions of the AMOF building were evaluated with the proposal with bioclimatic criteria, With the analysis of the information, an annual energy consumption of the environments of the east façade was obtained with the implementation of the bioclimatic proposal of 9,422.6 kWh/a, which is equivalent to an expenditure of S/. 3,137.00 soles.

With the energy consumption (kWh) and using the carbon dioxide emission factor (Kg CO₂ eq/kWh=0.385), a result of 3.627 kg/a (3.63 ton/a) of carbon dioxide (CO₂) emission was obtained, comparing with the current state of the AMOF building there is a reduction that demonstrates the importance of the application of bioclimatic criteria for thermal well-being, lighting, energy efficiency and environmental nonpollution (See Figure 13).

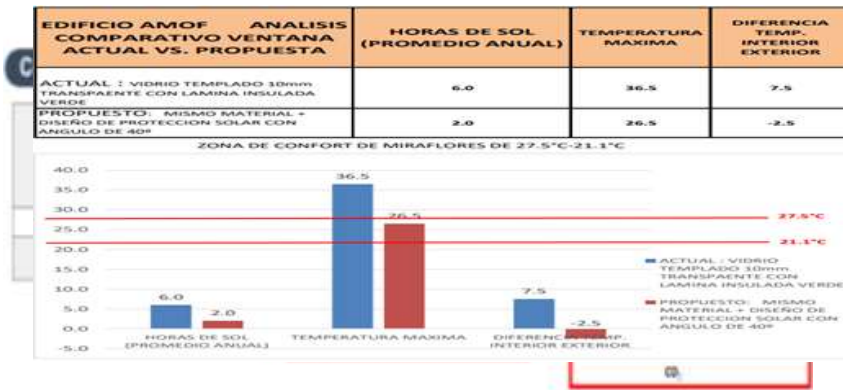


Figure 13. Result CO2 emission. AMOF-Proposal Building, Miraflores

In the summary table of the analysis of the bioclimatic proposal for the AMOF building, it can be seen that thermal and lighting well-being is achieved and the emission of carbon dioxide (CO2) is reduced.

For the proposed façade in the AMOF Building (east façade). The analysis showed that it had, adequate lighting levels for office work, near the window of 700 luxes average, decreased the solar incidence in the glass to only two hours (from 6.00 am to 8.00 am), which allowed solar control and working hours an average temperature of 24.80°C average with a peak of 26.50°C on the warmest day in the offices, temperature within the limits of the comfort zone and with the decrease in energy consumption obtain 3.63 Ton/a of carbon dioxide (CO2) emissions (See Figure 14).

EDIFICIO	VENTANA TIPICA OFICINA (PROPUESTA)											
	ANCHO	ALTO	MATERIAL	PROTECCION SOLAR	ORIENTACION	HORAS DE SOL (PROMEDIO ANUAL)	TEMPERATURA MAXIMA INTERNA	DIFERENCIA TEMP. INTERIOR EXTERIOR	ILUMINACION NATURAL DESLUMBR. / PENUMBRA		EVALUACION	EMISION CO2
AMOF SOLUCION	6.1	2.4	VIDRIO TEMPLADO 10mm TRANSPARENTE CON LAMINA INSULADA VERDE	DISEÑO DE PROTECCION SOLAR CON ANGULO DE 40°	ESTE	2.0	26.5° C	-2.5	700	500	DENTRO DE CONFORT TERMICO Y LUMINICO	3.63 Ton/a

Figure 14. Thermal, light and CO2 emission results. AMOF Building - Proposal, Miraflores.

From the analysis carried out, the thermal and lighting comfort conditions of the AMOF building with the bioclimatic proposal, achieve with the implementation of the passive solar protection system to obtain indicators within conditions of thermal and lighting well-being.

Finally, a comparative analysis was made between the current state of the AMOF building and AMOF with the bioclimatic proposal, in Figure 15, it is clearly seen as the proposal (passive system of solar protection appropriate to the climate and sun of the place) was efficient and achieved indoor temperature results that were found within the thermal comfort zone for Miraflores (area delimited by red lines between 20.1°C to 27.5°C), while the building in its current state is outside the thermal comfort zone.

Figure 15. Comparative Thermal Analysis. AMOF Building Current Status -AMOF Building Proposal, Miraflores.

Figure 16 shows how the proposal, with solar protection systems calculated and diffusing light (the horizontal and vertical elements of solar protection function as diffusers of natural light), was more efficient and managed to obtain results of natural lighting that are within the comfort zone of light for Miraflores, (from 500 to 750 luxes for work in offices), while the building in its current state is outside.

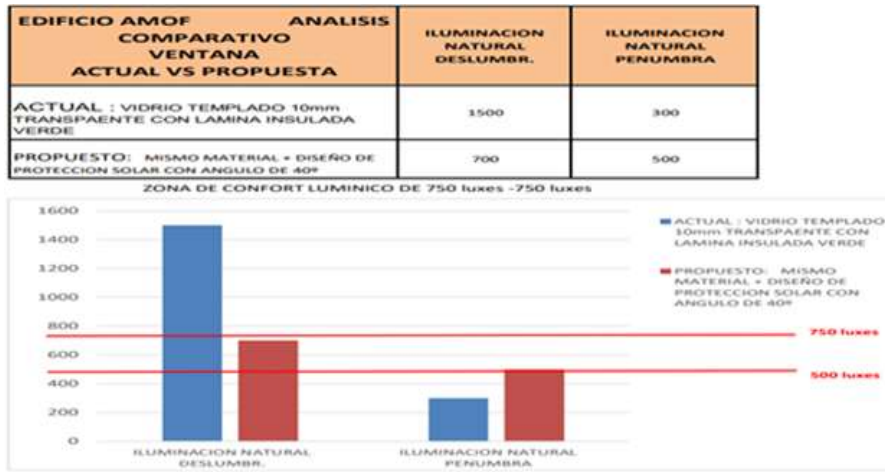


Figure 16. Comparative Light Analysis. AMOF Building Current Status - AMOF Building Proposal, Miraflores.

The data obtained was submitted to the MINITAB software to perform the correlational analysis with a T-test of two samples (See image 17), to develop an analysis with scientific statistics, giving as results the following data run.

Prueba T e IC de dos muestras: AMOF INSIDE (ACTUAL), AMOF INSIDE (PROPUESTA)				
EDIFICIO	N	MEDIA	DESVIACION ESTÁNDAR	ERROR ESTÁNDAR DE LA MEDIA
AMOF INSIDE (ACTUAL)	24	27.37	5.96	1.2
AMOF INSIDE (PROPUESTA)	24	25.16	1.12	0.23
Diferencia = μ (AMOF INSIDE (ACTUAL)) - μ (AMOF INSIDE (PROPUESTA))				
Estimado de la diferencia = 2.21				
IC de 95% para la diferencia = 2.21				
Prueba T de diferencia = 0 (vs. no =): Valor T= 1.78 Valor P= 0.087 GL= 24				

Figure 17. Data for correlational analysis. AMOF Building Current Status - AMOF Building Proposal, Miraflores.

This analysis has a Confidence Index of 95%, which allowed to check the work, because it is within the confidence interval, likewise, developed the graphs of individual values between the two samples AMOF Inside (Current) and AMOF Inside (Proposal) to demonstrate the best behavior of the proposal (See Figures 18 and 19).

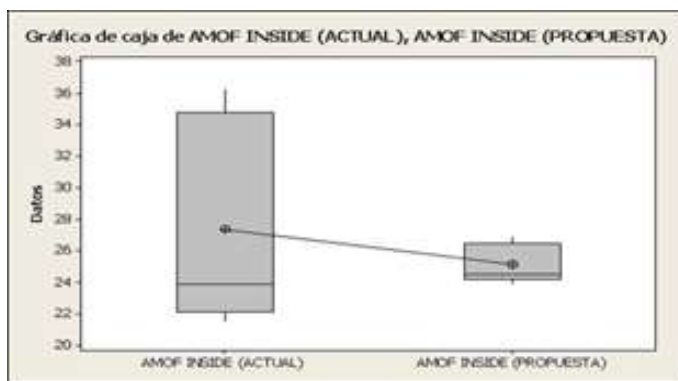


Figure 18. Comparative Analysis Chart Box. AMOF Inside (Current)-AMOF Inside (Proposal).

The advantages of the proposal with bioclimatic criteria, applying a passive solar protection system, in the district of Miraflores are:

-The proposed solar protection system promoted the shading of the façade (Passive cooling) and diffusion of natural light inside the offices (Passive natural lighting). It was not necessary to change the type of glass.

-It did not negatively impact the environment by avoiding artificial systems, achieving efficiency and energy savings, reducing carbon dioxide (CO₂) emissions, thereby taking care of the environment and the environmental sustainability of the city.

-The bioclimatic architecture was the basis of the energy efficiency in the proposal, this was verified by achieving the levels of thermal and lighting comfort suitable for the development of work processes.

-The methodology of bioclimatic architecture is replicable, because the principle of application is to adapt to the place, with which, the solutions must be appropriate to each area of study and can improve the environmental conditions of cities.

Apply the bioclimatic criteria, it is important to be able to generate energy savings, avoid environmental pollution and obtain comprehensive comfort, with the proposal it was possible to make the AMOF building a vector of no pollution by achieving energy efficiency, by reducing the emission of carbon dioxide (CO₂), it was achieved that the building is environmentally friendly.

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