congreso internacional arquitectura y urbanismo

Entrópico
REVISTA DE ARQUITECTURA Y URBANISMO

Artículo

Bioclimatic criteria in the AMOF building to reduce the emission of Carbon Dioxide (CO_2) - Lima - Peru 2021

Criterios bioclimáticos en el edificio AMOF para reducir la emisión de Dióxido de Carbono (CO_2) - Lima - Perú 2021

Alejandro Enrique Gómez Río[1] | Stefany Marjorie Vilchez Yupanqui[2]

[1] Arquitecto por la Universidad Ricardo Palma, Maestro en Ecología y Gestión Ambiental por la Universidad Ricardo Palma; Doctor en Medio Ambiente y Desarrollo Sostenible por la Universidad Nacional Federico Villarreal; Postdoctorado en Ciencias Aplicadas al Medio Ambiente por la Universidad Centro Panamericano de Estudios Superiores (México). Docente por 27 años en la Universidad Ricardo. Creador, coordinador y docente del Diplomado de Arquitectura Bioclimática con Eficiencia Energética y del Programa de Especialización en Diseño Ambiental (FAU-URP). Jefe del Laboratorio de Acondicionamiento Ambiental de la Facultad de Arquitectura y Urbanismo URP. 2009 a la fecha. Especializado en arquitectura ambiental. Correo electrónico agomez@urp.edu.pe.

[2] Bachiller en Arquitectura por la Universidad Ricardo Palma, Especializada en Diseño Ambiental por el Programa de Especialización de la Universidad Ricardo Palma. Asistente del Laboratorio de Acondicionamiento Ambiental FAU-URP. Asistente del proyecto Universidad Ecológica URP. Arquitecta junior de Alejandro Gómez Arquitectos, Augusto de Cossío Restauraciones SAC, TRU Arquitectos Concretos y Gestión de Proyectos Pilares SAC. Con experiencia en proyectos sostenibles, retail y restauración, especializada en diseño ambiental. Destaco por mi capacidad para gestionar equipos, coordinar proyectos y aplicar metodologías ágiles. Correo electrónico stefany.vilchez@urp.edu.pe.

Resumen: Esta investigación tiene como objetivo analizar la influencia de la aplicación de criterios bioclimáticos en las edificaciones para la obtención de bienestar integral, eficiencia energética y reducción de dióxido de carbono (CO_2) al medio ambiente. La creciente tendencia al uso de vidrios expuestos al sol en los edificios, que provocan el efecto invernadero, aumentan la temperatura interior del edificio y provocan deslumbramientos, promoviendo el enfriamiento artificial mediante un uso ineficiente de la energía; calentar una habitación de forma natural y luego enfriarla artificialmente es una mala práctica y estimula el cierre de las cortinas, lo que provoca el encendido de las luminarias; con lo que el edificio emite dióxido de carbono (CO_2) al medio ambiente, contribuyendo al calentamiento global. Se ha desarrollado, con un enfoque metodológico basado en los principios de la arquitectura bioclimática, el análisis de las variables que permiten estudiar esta influencia, en los edificios de oficinas de Miraflores (Lima, Perú), considerando el edificio AMOF bajo condiciones térmicas y lumínicas adversas. condiciones. Con los resultados obtenidos se comprueba que la solución con geometría solar propuesta para el edificio AMOF soluciona problemas de bienestar térmico, iluminación y disminuye la emisión de dióxido de carbono (CO_2) en un 74,07 %. Por lo tanto, se concluye, que estas consideraciones que no fueron consideradas, influyen en las condiciones de habitabilidad y bienestar de los usuarios, haciendo de la ventana el punto más débil del edificio para lograr el bienestar humano, la eficiencia energética y la reducción de la contaminación al medio ambiente. ambiente.

Palabras clave: Arquitectura Bioclimática, Bienestar Integral, Geometría Solar, Eficiencia Energética, Dióxido de Carbono (CO_2)

Abstract: This research aims to analyze the influence of the application of bioclimatic criteria in buildings to obtain integral well-being, energy efficiency and reduction of carbon dioxide (CO_2) 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 (CO_2) to the environment, 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

Citación: Gómez Río, A. E.; Vilchez Yupanqui, S. M. Bioclimatic criteria in the AMOF building to reduce the emission of Carbon Dioxide (CO_2) - Lima - Peru 2021. *Congreso internacional de arquitectura y urbanismo.* 2024, *2*, 2. https://doi.org/10.33413/eau.2024.358.

Editor académico: Heidi De Moya Simó y Gilkauris Rojas Cortorreal.

Recibido: 18/06/2024
Aceptado: 14/10/2024
Publicado: 01/11/2024

in Miraflores (Lima, Peru), 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 (CO_2) by 74.07 %. Therefore, it is concluded, that these considerations that were not regarded, 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 reduction of pollution to the environment.

Keywords: Bioclimatic Architecture, Integral Well-being, Solar Geometry, Energy Efficiency, Carbon Dioxide (CO_2)

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 (Ministerio de Energía y Minas, 2019).

Within this sector are the office buildings, which in recent years have increased their construction in Lima (Peru), there is an average growth of 3.0% in recent years (Binswanger Perú, 2015), especially in districts from Lima city such as Miraflores, where 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 (Mazria & Kershner, 2008), the same occurs in Peru, a product of the design outside the conditions of the local climate and sun (Serra, 2004).

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).

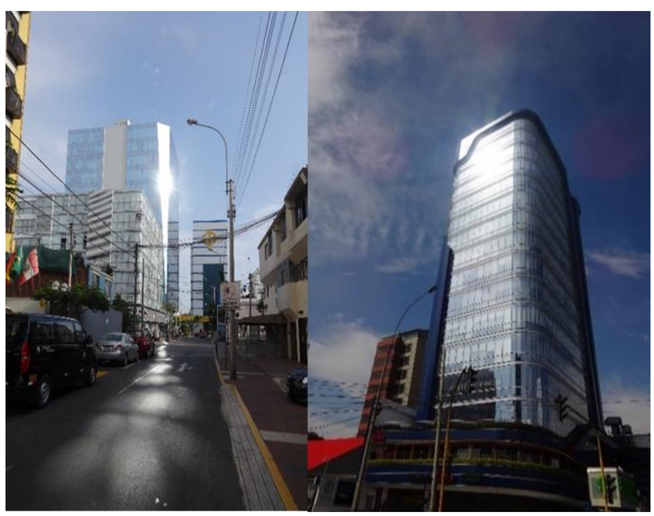

Figure 1. Platinum and Strip Mall Buildings in Miraflores. Photo Dr. Alejandro Gómez Ríos.

Figure 2. Leuro and Cantuarias Buildings in Miraflores. Photo Dr. Alejandro Gómez Ríos.

Peru 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 (Ministerio de Energía y Minas, 2003). The tropical zone has the largest solar radiation in the world and has great energy potential (Gómez, 2013).

On the other hand, Peru has 28 of the 32 types of climates that exist in the world (Ministerio del Ambiente, 2009), meaning that the country is a natural laboratory for the exercise of architecture, because it has a great climatic variety that must imply various ways to face the architectural design.

In Peru, little theoretical work has been done in this regard, but they haven't 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 sectors ranked second in energy consumption in the country (Ministerio de Energía y Minas, 2019). 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 (CO_2).

It also ranks third in terms of emissions of carbon dioxide (CO_2) and methane (CH4) (Ministerio de Energía y Minas, 2019), which shows the negative influence of buildings that are not adequately resolved.

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 (Gómez, 2013), 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 (CO_2) 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), 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" (Rosales et. Al, 2016), that is, to work for environmental sustainability.

The work is part of the area of environmental conditioning for buildings (Serra & Coch, 1995), 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 (CO_2) emissions.

It was determined that it is possible to achieve energy efficiency, reduction of pollution emissions and improvement of welfare conditions in the AMOF building through bioclimatic criteria based on solar geometry, showing the importance of architecture on environmental sustainability and habitability conditions.

2. Development

2.1. Literature review

2.1.1. Bioclimatic Architecture

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 (Vélez, 2012) 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 (Heywood, 2017).

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 (Gonzalo, 2007).

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 (Lacomba, 2012). This good practice reduces carbon dioxide (CO_2) 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 (Givoni, 1998):

- 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, 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.

2.1.2. Bioclimatic Architecture

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" (Wieser, 2010)

The development of a proposal with solar geometry and climate considerations, the basis of bioclimatic architecture (Olgyay, 1999), 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).

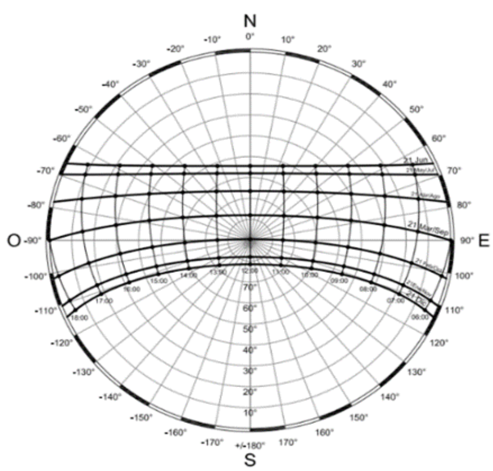

Figure 3. Equidistant polar solar chart. Source: Geometría solar para arquitectos M. Wieser (2010).

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.

2.1.3. Energy Efficiency

With the passive solution, buildings that mitigate the emission of carbon dioxide (CO_2) to the environment are achieved, since the bioclimatic architecture is the basis of energy efficiency (Heras Celemín, 2004) and with the rational use of energy emissions are reduced (Villar-Burke et al., 2014).

Bioclimatic architecture as a fundamental part for energy saving in buildings (Heras Celemín, 1990), 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 CO_2 emissions to the environment (Heywood, 2017).

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 (CO_2) emissions, there is a concern, increasingly, to develop solutions to existing problems that are appropriate to the place where one works.

2.2. Methodology

2.2.1. 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 (CO_2) 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.

3. 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 (CO_2) emissions.

3.1. Study current status of AMOF building

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 (CO_2), 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).

BUILDING	AMOF EAST ORIENTATION
ADDRESS	AV. JORGE CHÁVEZ 180, MIRAFLORES
DESIGNERS	ARCH. MESTANZA ZUÑIGA, ENRIQUE ARCH. GARCIA RIVERA , MIGUEL
ORIENTATION	EAST
USE	OFFICE BUILDING
WINDOW MATERIAL	TEMPERED GLASS 10mm TRANSPARENT WITH GREEN INSULATED SHEET
SUN PROTECTION	NO
HEIGHT	6 FLOORS

Figure 4. AMOF building in Miraflores. Photo Dr. Alejandro Gómez Ríos.

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 CO_2, with the analysis of energy consumption was evaluated with the factor of emission of CO_2 the behavior of the building.

For the software used, in the analysis for the thermal, energy and carbon dioxide (CO_2) 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).

EAST ORIENTATION	HOURS OF SUN (ANNUAL AVERAGE)	MAXIMUM INDOOR TEMPERATURE °C (ANNUAL AVERAGE)	MAXIMUM OUTDOOR TEMPERATURE °C (ANNUAL AVERAGE)	TEMPERATURE DIFFERENCE INDOOR OUTDOOR
AMOF CURRENT WINDOW: TEMPERED GLASS 10mm TRANSPARENT WITH GREEN INSULATED SHEET	6.0	36.5	29.0	7.5

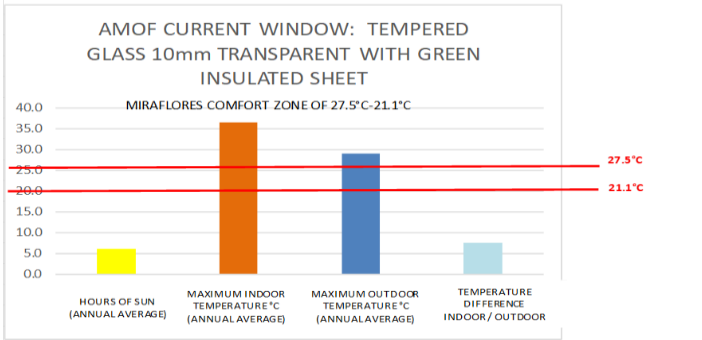

Figure 5. Thermal result. AMOF-Current State Building, Miraflores. Based on Archicad 14 software. Own preparation.

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).

EAST ORIENTATION	NATURAL LIGHTING Lux GLARE	NATURAL LIGHTING Lux GLOOM
AMOF CURRENT WINDOW: TEMPERED GLASS 10mm TRANSPARENT WITH	1500	300

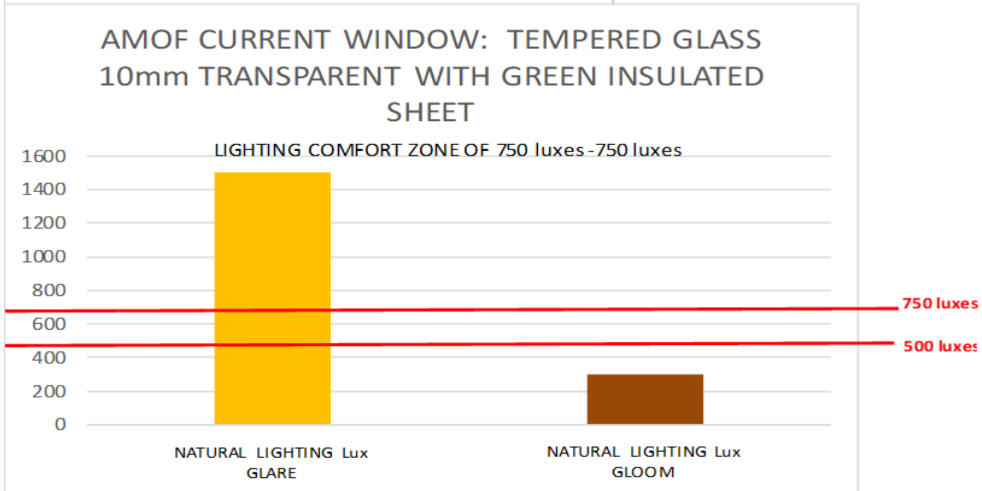

Figure 6. Lighting result. AMOF-Current State Building, Miraflores.
Based on Autodesk Revit 2020 software with the Insight plugin. Own Preparation.

The energy consumption and carbon dioxide (CO_2) emissions of the current state of the AMOF building were evaluated, with the analysis of the information obtained as a result an annual energy consumption of the environments of the east façade of 36,548 kWh/a, which is equivalent to an expenditure of S/. 12,060.00 soles.

With the energy consumption (kWh) and using the carbon dioxide emission factor (Kg of CO_2 eq/kWh=0.385), an annual result of 14,071 kg/a (14 ton/a) of carbon dioxide (CO_2) emission was obtained, demonstrating the pollution emitted by the building (See Figure 7).

AMOF BUILDING CURRENT STATE					
ENERGY CONSUMPTION BY SOURCES					
ENERGY					CO2 EMISSION
SOURCE TYPE	NAME OF ORIGIN	AMOUNT MWh/a	PRIMARY MWh/a	COST Soles/a	CO2 EMISSION Kg/a
SECONDARY	ELECTRICITY	36	109	12060	14071
TOTAL		36	109	12060	**14071**
		LIGHTING AND EQUIPMENT 36548.2 KwH/a	36548.2 ENERGY CONSUMPTION	x 0.385 CO2 EMISSION COEFFICIENT	= 14071 kg/a (14 Ton) ANNUAL KILOS

Figure 7. Result CO_2 emission. AMOF-Current State Building, Miraflores.
Based on Autodesk Archicad 14 software. Own preparation.

In the summary table of the analysis of the current state of the AMOF building, we can see the problems it has in thermal non-conformity, lighting and carbon dioxide (CO_2) emissions. The analysis shows, great glare with levels near the window of 1500 luxes average, six hours of solar incidence in facade which determines in working hours an average temperature of 33.79ºC, with peak of 36.50ºC on the warmest day in the offices, temperature outside the comfort limits, which made an environment totally unsuitable to develop work activities and based on the high energy consumption emit 14.0 Ton /a carbon dioxide (CO_2) emissions per year. (See Figure 8).

BUILDING	TYPICAL OFFICE WINDOW (CURRENT STATE)											
	WIDE	HIGH	MATERIAL	SUN PROTECTION	ORIENTATION	HOURS OF SUN (ANNUAL AVERAGE)	MAXIMUM TEMPERATURE (AVERAGE)	TEMPERATURE DIFFERENCE INSIDE OUTSIDE	INATURAL LIGHTING GLARE	GLOOM	ASSESMENT	CO2 EMISSION
AMOF CURRENT STATE	6.1	2.4	TEMPERED GLASS 10mm TRANSPARENT WITH GREEN INSULATED SHEET	WITHOUT SUN PROTECTION	ESTE	6.0	36.5° C	7.5° C	1500	300	OUT OF THERMAL AND LIGHTING COMFORT	14.0 Ton/a

Figure 8. Thermal, light and CO_2 emission results. AMOF-Current State Building, Miraflores. Based on Autodesk Archicad 14 and Autodesk Revit 2020 software. Own preparation.

Having verified the existence of the problems in the current state of the AMOF building (east facade), we proceeded to make a bioclimatic proposal, to mitigate the problems detected.

3.2. Study proposed of AMOF building

The study was prepared to solve the problems detected in the AMOF building, with a proposal with bioclimatic criteria, which consisted of developing a solar protection system with design angle of 40º height (analyzed in architectural cut) and 35° azimuth (analyzed in architectural plant), to control the solar path based on the analysis that was made with the solar angles that were determined with the Celestial Coordinates (azimuth and solar height) of the solar graphics of Miraflores, in this way, to avoid problems of glare, overheating of the building and therefore to reduce energy consumption, which allows as a consequence of the application of the bioclimatic criteria the reduction of carbon dioxide (CO_2) emission to the environment. (See Figures 9 and 10).

Figure 9. AMOF Building - Proposal with solar control (Plants-Cut), Miraflores.
Based on Autodesk Revit 2020 software. Own preparation.

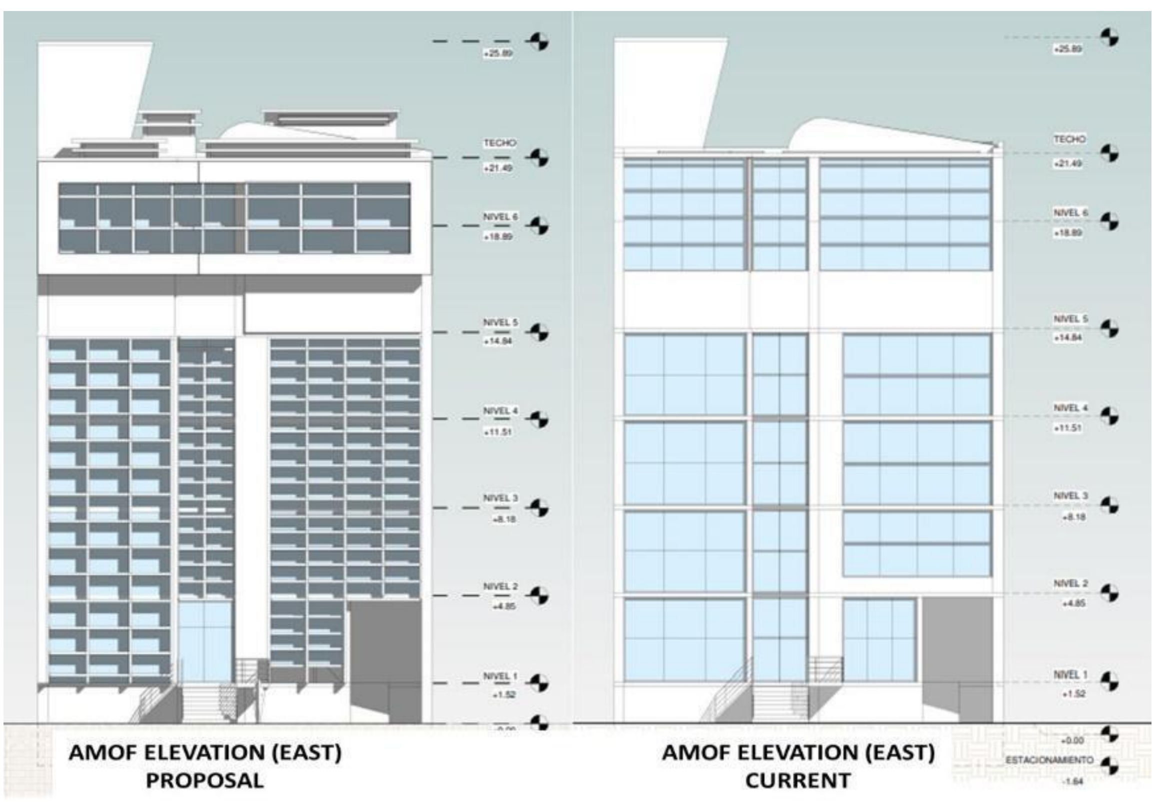

Figure 10. AMOF Building - Proposal and Current (Facades), Miraflores.
Based on Autodesk Revit 2020 software. Own preparation.

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 (CO_2) emissions to the environment, using the same 10 mm Green Tempered Glass with thermal transmittance coefficient U= 5.0 W/m2. 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 (CO_2) 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 (CO_2) emissions to the environment, using the same 10 mm Green Tempered Glass with thermal transmittance coefficient U=5W/m2. K.

EAST ORIENTATION	HOURS OF SUN (ANNUAL AVERAGE)	MAXIMUM INDOOR TEMPERATURE °C (ANNUAL AVERAGE)	MAXIMUM OUTDOOR TEMPERATURE °C (ANNUAL AVERAGE)	TEMPERATURE DIFFERENCE INDOOR OUTDOOR
AMOF PROPOSED WINDOW: TEMPERED GLASS 10mm TRANSPARENT WITH GREEN INSULATED SHEET	2.0	26.5	29.0	-2.5

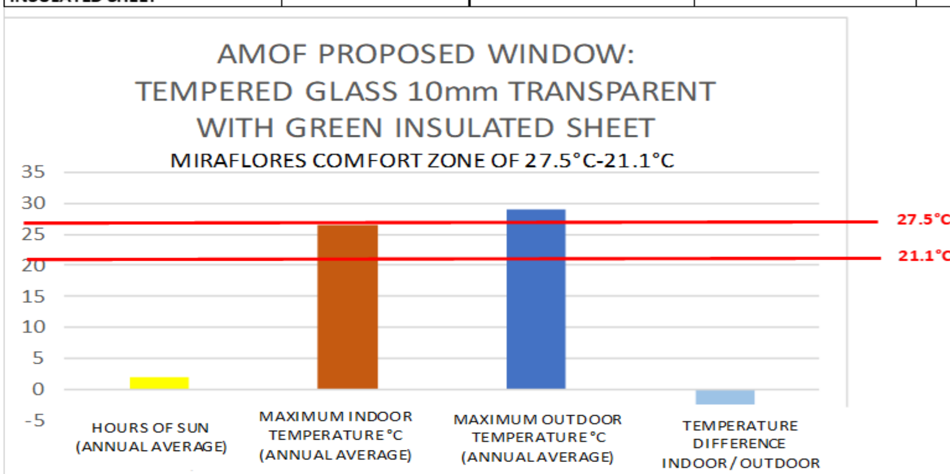

Figure 11. Thermal result. AMOF building- Proposal, Miraflores.
Based on Archicad 14 software. Own preparation.

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).

EAST ORIENTATION	**NATURAL LIGHTING Lux GLARE**	**NATURAL LIGHTING Lux GLOOM**
AMOF PROPOSED WINDOW: TEMPERED GLASS 10mm TRANSPARENT WITH GREEN INSULATED SHEET	**700**	**500**

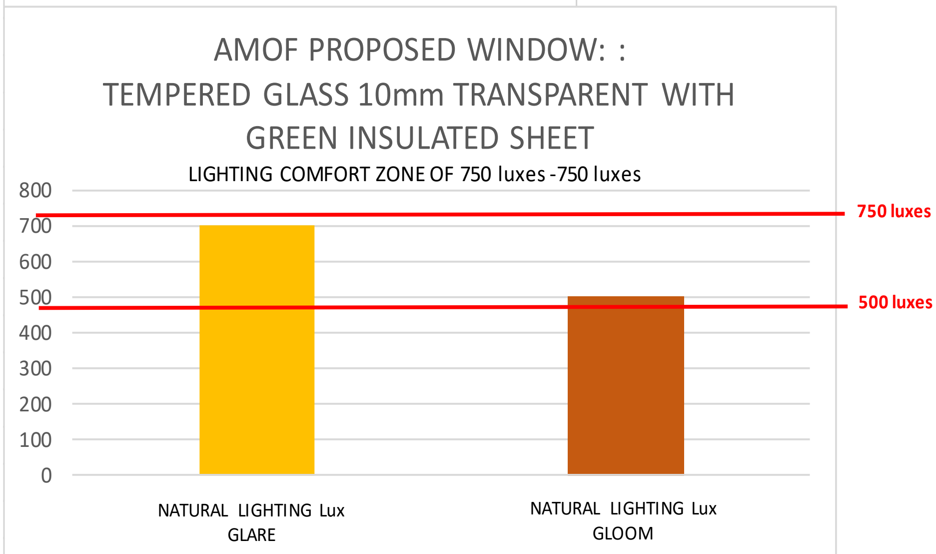

Figure 12. Lighting result. AMOF building- Proposal, Miraflores
Based on Autodesk Revit 2020 software with the Insight plugin. Own Preparation.

The energy consumption and carbon dioxide (CO_2) 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 CO_2 eq/kWh=0.385), a result of 3.627 kg/a (3.63 ton/a) of carbon dioxide (CO_2) 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).

AMOF BUILDING WITH PROPOSAL					
ENERGY CONSUMPTION BY SOURCES					
ENERGY					CO2 EMISSION
SOURCE TYPE	NAME OF ORIGIN	AMOUNT MWh/a	PRIMARY MWh/a	COST Soles/a	CO2 EMISSION Kg/a
SECONDARY	ELECTRICITY	9	28	3137	3627
TOTAL		9	28	3137	**3627**
		LIGHTING AND EQUIPMENT 36548.2 KwH/a	9422.6 x 0.385 = 3627 kg/a (14 Ton) ENERGY CONSUMPTION / CO2 EMISSION COEFFICIENT / ANNUAL KILOS		

Figure 13. Result CO_2 emission. AMOF-Proposal Building, Miraflores.
Based on Autodesk Archicad 14 software. Own preparation.

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 (CO_2) 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 24.80ºC average with a peak of 26.50ºC 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 (CO_2) emissions (See Figure 14).

BUILDING	TYPICAL OFFICE WINDOW (PROPOSED)											
	WIDE	HIGH	MATERIAL	SUN PROTECTION	ORIENTATION	HOURS OF SUN (ANNUAL AVERAGE)	MAXIMUM TEMPERATURE (AVERAGE)	TEMPERATURE DIFFERENCE INSIDE OUTSIDE	INATURAL LIGHTING GLARE	GLOOM	ASSESMENT	CO2 EMISSION
AMOF SOLUTION	6.1	2.4	TEMPERED GLASS 10mm TRANSPARENT WITH GREEN INSULATED SHEET	SUN PROTECTION DESIGN WITH 40° ANGLE	ESTE	2.0	26.5° C	-2.5	700	500	WITHIN THERMAL AND LIGHT COMFORT	3.63 Ton/a

Figure 14. Thermal, light and CO_2 emission results. AMOF Building - Proposal, Miraflores. Based on Autodesk Archicad 14 and Autodesk Revit 2020 software. Own preparation.

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 20.1ºC to 27.5ºC), while the building in its current state is outside the thermal comfort zone.

AMOF BUILDING COMPARATIVE ANALYSIS CURRENT WINDOW VS. PROPOSAL	HOURS OF SUN (ANNUAL AVERAGE)	MAXIMUM INDOOR TEMPERATURE °C (ANNUAL AVERAGE)	TEMPERATURE DIFFERENCE INDOOR OUTDOOR
CURRENT: TEMPERED GLASS 10mm TRANSPARENT WITH GREEN INSULATED SHEET	6.0	36.5	7.5
PROPOSAL: SAME MATERIAL + SUN PROTECTION DESIGN WITH 40º ANGLE	2.0	26.5	-2.5

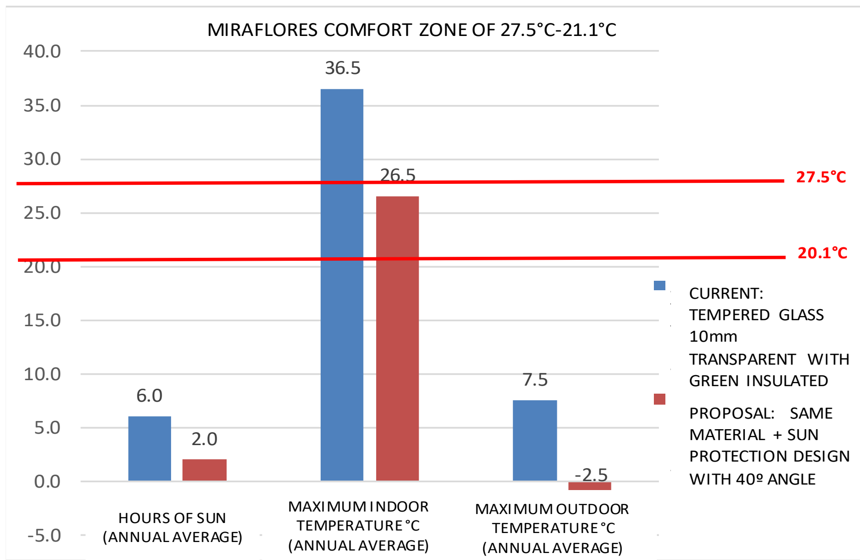

Figure 15. Comparative Thermal Analysis. AMOF Building Current Status -AMOF Building Proposal, Miraflores. Based on Archicad 14 software. Own preparation.

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.

AMOF BUILDING COMPARATIVE ANALYSIS CURRENT WINDOW VS. PROPOSAL	NATURAL LIGHTING Lux GLARE	NATURAL LIGHTING Lux GLOOM
CURRENT: TEMPERED GLASS 10mm TRANSPARENT WITH GREEN INSULATED SHEET	1500	300
PROPOSAL: SAME MATERIAL + SUN PROTECTION DESIGN WITH 40º ANGLE	700	500

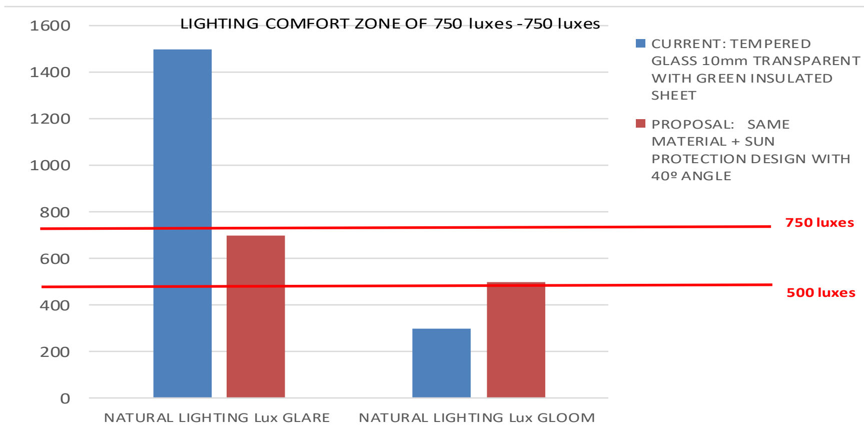

Figure 16. Comparative Light Analysis. AMOF Building Current Status - AMOF Building Proposal, Miraflores. Based on Revit 2020 software with the Insight plugin. Own Preparation.

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.

Two-Sample TE IC Test for AMOF INSIDE (CURRENT) vs. AMOF INSIDE (PROPOSAL)				
BUILDING	N	AVERAGE	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN
AMOF INSIDE (CURRENT)	24	27.37	5.96	1.2
AMOF INSIDE (PROPOSAL)	24	25.16	1.12	0.23
Difference = mu [AMOF INSIDE (CURRENT)] - mu [AMOF I SIDE (PROPOSAL)]				
Estimate of the difference= 2.21				
95% IC for the difference = (-0.35, 4.76)				
Difference T test = 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. Based on MINITAB software. Own Preparation.

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).

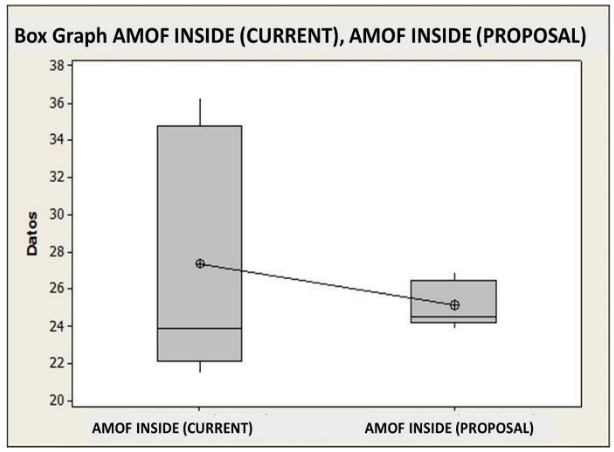

Figure 18. Comparative Analysis Chart Box. AMOF Inside (Current)-AMOF Inside (Proposal). Based on MINITAB software. Own Preparation.

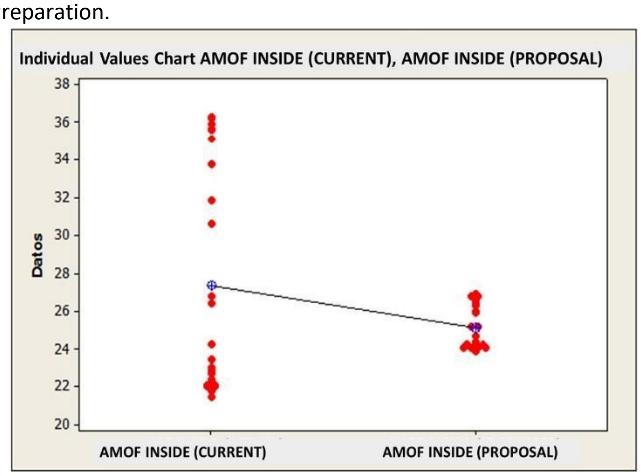

Figure 19. Comparative analysis Graph of individual values. AMOF Inside (Current) AMOF Inside (Proposal). Based on MINITAB software. Own Preparation.

4. Discussion

The work shows that the application of bioclimatic criteria in the AMOF building allows improving the conditions of thermal and light non-conformity found in the case of study, as well as significantly reducing the emission of carbon dioxide (CO_2).

Figure 16 shows that the application of solar geometry, decreased from 6 to 2 hours the solar capture in the facade, 66.66% less solar gain, which allowed to avoid glare, which is indicated in Figure 17, that from 1500 luxes, was reduced to 700 luxes with solar control, light range suitable normatively for office use, achieving a reduction of 46.66%.

In the same way, by reducing the solar gain (see Figure 16), the interior temperature is reduced from 36.5°C, on the warmest day, to 26°C, achieving the temperature within the comfort zone for Miraflores, which is 20.10°C to 27.5°C.

As a result of the application of the bioclimatic criteria, the annual energy consumption was reduced from 36,546 kWh/to 9,422 kWh/a, which means a 74.22% reduction in energy consumption, also shows the reduction of carbon dioxide (CO_2) emissions from 14.0 Ton/a to 3.63 Ton/a, resulting in a 74.07% reduction in emissions. All of which verifies the benefits of the implemented proposal.

Currently, buildings account for about 40% of energy use, naturally constituting potential scenarios for energy savings and emissions (Yang & Wang, 2013) (Pérez-Lombard et al., 2008) (Moroşan et al., 2010) (Dueñas Del Río, 2013) in addition, human beings have an occupation of 80% to 90% of their time in built spaces (Van Hoof et al., 2010), which promotes an intense energy consumption.

It should be noted that energy efficiency can be conditioned to the architectural form (Zhovkva, 2020), also, bioclimatic architecture is fundamental to energy efficiency (Guerra, 2013), that is why the methodology of the bioclimatic architecture applied in the work, with its theoretical bases of use of the climatic and solar conditions of the place, verify that the proposal proposed with bioclimatic criteria offers conditions of thermal and lighting comfort, within the permissible parameters, which allowed efficiency and energy savings, achieving the reduction of carbon dioxide (CO_2) emissions to the environment.

5. Conclusions

The development of standardized design concepts, which have been repeated in all places, or in all buildings in the same place, regardless of dimensions, materials and orientations, have promoted that the buildings do not meet the conditions of well-being, as well as, have become vectors of environmental pollution, harming environmental sustainability and habitability conditions.

The analysis showed that the AMOF building in its current state, having a standard architectural solution, obtains bad indoor conditions of thermal well-being, lighting, as a result, an inefficient use of energy and emits carbon dioxide (CO_2).

The scientific contribution of the research lies in the proposal of bioclimatic criteria, developed based on solar geometry. The implementation of the proposal verifies the improvement of welfare conditions, the achievement of energy efficiency and the reduction of pollution emissions. It demonstrates the importance of architecture for energy efficiency and the direct relationship between energy consumption and pollution emissions.

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 (CO_2) 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 application principle 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 (CO_2), it was achieved that the building is environmentally friendly.

Funding: This research did not receive external funding.

Data availability statement: The information is at the link: https://drive.google.com/drive/folders/1Vr5nY321DRq6E7vO5iztEhm7SmaBbYwS?usp=drive_link

Acknowledgements: Thanks to Architect Carol Aguirre for her support in developing the evaluations with the software to check the current status and improvements with the proposal.

Conflicts of interest: The authors declare that they have no conflict of interest.

References

Binswanger Perú (2015). *Market insight. Lima 1T 2015.* Lima, Perú: Binswanger Perú. Retrieved from https://fdocuments.es/document/market-insight-oficinas-2015-2t-binswanger-peru.html

Dueñas del Río, Alejandra (2013). Reflexiones sobre la arquitectura sustentable en México. *Revista Legado de Arquitectura y Diseño*, Vol. 14, 77-91.

Givoni, B. (1998). *Climate considerations in building and urban design*. USA: Van Nostrand Reinhold.

Gómez, A. (2016). *El diseño de ventanas. Análisis en relación al bienestar humano y la eficiencia energética en las edificaciones de oficinas en el distrito de Miraflores. Marzo 2013-Marzo*. (Tesis de doctorado). Universidad Nacional Federico Villarreal, Lima.

Gómez, A. (2013). El sol y la arquitectura. *Revista Par Proyecto Arquitectónico*. Lima: Iakob Comunicadores & editores S.A.C, Vol. 7, 68-69.

Gonzalo, G. (2007). Manual de Arquitectura Bioclimática. Buenos Aires: Editorial Nobuko.

Guerra Menjívar, M. (2013) Arquitectura Bioclimática como parte fundamental para el ahorro de energía en edificaciones. *Ing-novación. Revista semestral de ingeniería e innovación de la Facultad de Ingeniería, Universidad Don Bosco*. Año 3, Vol. 5, 123-133

Heras Celemín, M. (2004). Ahorro y Eficiencia Energética. Edificios sostenibles. Física y sociedad. *Revista del colegio oficial de Físicos*. Madrid: Roelma Producción Gráfica. Vol.15, 22-25

Heras Celemín, M. y Montoro, J. (1990). *Comportamiento energético de edificios solares pasivos*. CIEMAT (Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas).

Heywood, H. (2017). *101 Reglas básicas para una arquitectura de bajo consumo energético*. Barcelona: Gustavo Gili

Lacomba, Ruth (Ed.) et al., (2012), *Manual de Arquitectura Solar y Sustentabilidad*. México D.F.: Editorial Trillas.

Mazria E. & Kershner K. (2008) *Meeting the 2030 Challenge Through Building Codes, Architecture 2030*. Retrieved from http://www.architecture2030.org/pdfs/2030Challenge_Codes_WP.pdf

Ministerio del Ambiente (2009). *Política Nacional del Ambiente*. Lima:Aleph Soluciones Gráficas. Retrieved from https://www.minam.gob.pe/ wp-content/uploads/2013/08/Política-Nacional-del-Ambiente.pdf

Ministerio de Energía y Minas (2019*). Balance Nacional de Energía (MINEM).* Retrieved from https://hdl.handle.net/20.500.12542/343.

Ministerio de Energía y Minas, Servicio Nacional de Meteorologia del Perú (2003). *Atlas de Radiación Solar del Perú. (SENAMHI).* Retrieved from https://hdl.handle.net/20.500.12542/343

Olgyay, V. (1999). *Arquitectura y Clima. Manual de diseño bioclimático para arquitectos y urbanistas*. Barcelona: Gustavo Gili (Original book published in 1963).

Rosales, María Alejandra, & Rincón, Francisco José, & Millán, Luis Hilario (2016). Relación entre Arquitectura - Ambiente y los principios de la Sustentabilidad. *Multiciencias*, Vol.16 (3),259-266. Retrieved from https://www.redalyc.org/articulo.oa?id=90453464004

Serra, R. (2004). *Arquitectura y Climas.* Barcelona: Editorial Gustavo Gili.

Serra, R y Coch, H. (1995). Arquitectura y Energía Natural. Barcelona: Ediciones UPC.

Van Hoof, Joost; Mazej, Mitja y Hensen, Jan LM (2010) Thermal comfort: research and practice. *Frontiers in Bioscience*. Vol. 15, 2, 765-788.

Vélez, R. (2012). *La Ecología en el Diseño Arquitectónico.* México D.F.: Editorial Trillas

Villar-Burke, R., Jiménez-González, D, Larrumbide, E., Tenorio, J.A. (2014). Impacto energético y emisiones de CO_2 del edificio con soluciones alternativas de fachada. *Informes de la Construcción*, Vol.66 (535): e030, DOI: http://dx.doi. org/10.3989/ic.12.085.

Wieser, M. (2010). *Geometría solar para arquitectos*. Lima: Editorial Universidad Ricardo Palma.

Yang, Rui, & Wang, Lingfeng (2013) Development of multi-agent system for building energy and comfort management based on occupant behaviors. *Energy and Buildings*. Vol. 56, pp 1-7.

Zhovkva, O. (2020). Los principios de eficiencia energética y respeto al medio ambiente para complejos multifuncionales. *Revista Ingeniería de construcción*, Vol.35 (3), 308-320. DOI: https://dx.doi.org/10.4067/S0718-50732020000300308