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Research Paper

A Solar energy, to the test of the great glass stage in contemporary Architecture in Saharan environment

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A B S T R A C T

Currently, the façades of the desert buildings have witnessed and remarkably widespread use of glass. But, without any regard to the lowest harsh climate data. However, this exaggerated use of glass in the contemporary facades of the buildings may cause many problems, especially at the level of thermal comfort of the user. Hence, the excessive energy consumption resulting from heat exchange through the glass. With the current technological developments and the development of new and advanced building materials of glass, who can be used to reduce excessive energy consumption. Among these, materials are insulating glass and energy-producing at the same time. However, how effective is this type of glass in contemporary desert architecture? What is their efficiency at the level of thermal performance inside the building and even on the level of user comfort (heat exchange, production, and energy-saving)? To find out, a comparative study was conducted between four types of glazing materials used in contemporary architecture, Simple Glazing (i), Double Glazing (ii), Semi-Transparent Photovoltaic (STPV) (iii), and the Vacuum Photovoltaic Insulated Glass Unit (VPV IGU) (iv). Before the simulation, an overview of the history of the use of glass in contemporary buildings in Algeria in general and in desert regions, in particular, was presented. After that, the most important results of the comparison study are presented according to the simulation software TRNSYS.

1 Introduction

In the last century, excessive energy consumption often comes up in the talk of all the times, to express great dissatisfaction with the ever-increasing use of electric coolers in summer and heating in winter in the workplace, where we spend the majority of our time throughout the day, specifically in regions where the climate is difficult to live with. Even more predominant in an architecture almost designed in glass, the capacity of resistance to shocks and applied loads are very low, hence the discomfort in the workspaces. The development of technology and the evolution of the standard of living,

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encourage more the consumption of energy, which becomes more and more worrying. According to several studies conducted in the EU, the building sector (the most energy-intensive in the world) represents 40 to 45% of total energy demand, expected to increase by 34% in 2035 (BP Energy Outlook | Energy economics | BP) [1].

Specifically, solar energy is considered to be the most productive since it is able to provide an electrical power of 1.8 × 1011 MW compared to other renewable energy resources [2]. And since fossil energy resources are not a long-term solution, it is imperative to change the type of energy supply. The sun plays a prominent role in this supply. The integration of Photovoltaics (PV) in buildings is now the concern of researchers in the field of solar energy. By integrating them into the facades of buildings, PV panels make it possible to produce electricity. This principle takes the name of Building Integrated PV (BIPV). This is a multi-functional intelligent system made up of solar modules that collect the sun's rays and convert them into light green electricity. The (BIPV) can be integrated at the level of facades, roofs, windows, etc [3] and [4]. Technological progress has made (BIPV) an aesthetic, architectural expression, in proportions, colors and textures [5]. This is in addition to their interest in the proliferation of thermal comfort mainly in work spaces [6-7], worked on the technical feasibility and integration methods of (BIPV) in commercial public buildings in the Mediterranean climate. The study [8] depicts the state of the (BIPV) market today. It presents the advantages and disadvantages of the installation and maintenance of (BIPV).

Global interest in (BIPV) has increased following forecasts of a compound annual growth rate of 18.7% and a total of 5.4 GW installed worldwide from 2013 to 2019 [9]. [10] carried out an integrated technical and economic analysis. The assessment tool, which is designed to assist architects and engineers, decision-makers, and investors, identifies the most suitable PV installation areas in urban areas. It has been shown that there is a 19% and 6% rate of increase in energy production and an internal rate of return in the walls to the south. The economic analysis of [11] has shown that with the social and environmental benefits of the applied system, replacing traditional building materials for facades and roofs with units (BIPV) will be more economical and feasible. Windows (BIPV) have shown great potential for energy savings, for example, around 12-21% annual energy savings and 14-26% for peak cooling demand [12]. The annual analysis in [13] shows that the PV potential of roofs and facades exceeds the local PV potential can contribute to 50 to 75% of total electricity demand. In addition, economic analysis shows that recovery times of less than 10 years can only be obtained with photovoltaic systems on roofs, while a recovery rate of 50/50. The combination of the two would result in a 15-year payback period.

The (BIPV) has experienced unprecedented expansion in recent years [14-15]. By integrating it into the envelope of buildings, such as facades, roofs, this makes it possible to produce electricity directly on buildings and to cover their electricity needs. The systems (BIPV) pride themselves in their ecological contribution, economic benefits (concede to save the cost of construction), as well as the aesthetic aspect that they give to facades. In addition, the plates (BIPV) exalt a high energy yield [16]. There are many types of applications (BIPV) like (STPV) for Semi-Transparent Photovoltaic windows which allow the partial penetration of daylight inside the building. [17] This insinuates the penetration of natural light to the depth of the interior space of the building without resorting to artificial lighting. Another type of PV window shines through an innovative form of photovoltaic insulating glass (IGU). Cost is relatively low, with good thermal performance, this technique comprising, a panel (STPV) and a sheet of glass with an air space is used in new and modern buildings. The installation methods for the (IGU) are generally easy and uncomplicated. In addition, Miyazaki, Akisawa, & Kashiwagi analyzed the effects of solar cell transmission and window-to-wall ratio (RFP) on the energy performance of PV IGUs. The results of this study demonstrated that the permeability of solar cells was assumed to be between 10% and 80%. But it was found that the optimal permeability of solar cells was confined between 40% and 50% (WWR) [18].

Wang et al. Evaluated the energy performance of insulating glazing (a-Si) via digital simulations with experimental tests. It emerged from this study that the capacity for improving the energy efficiency of PV (PV-IGU) exceeded 25.3%, while energy efficiency was only 10.7% for a single transparent glass. According to them, PV-DSF has better performance and better thermal insulation than PV-IGU in reducing solar heat gains. For them, the PV-DSF has an energy-saving potential of 28.4%, compared to the (PV-IGU) which goes up to 30%. These authors confirmed that the yield of PV-IGU was 2% higher than that of PV-DSF, but it was after its breakdown [19]. In addition, the authors in [20] studied the degree of influence of different building design standards on the nature of the choice of optimal visual characteristics of (STPV) glazed windows. In this study, the researchers showed that (STPV) windows had a visual penetration (visible transmittance) of 10%. Thus, they were able to conclude that (STPV) has the best energy-saving potential of a renewable natural origin.

Most of the previous studies were limited to the thermal behavior and energy efficiency of the various (STPV) and (PV-IGU) only in buildings in cold areas. While, Unfortunately, an almost complete absence of this type of study was observed in areas with a hot desert environment. Hence our choice for this type of studies came, as our study aims to conduct comparative studies (ordinary and double glazing, units (STPV) and (PV-IGU) between thermal performance and energy performance between different proportions and types of glass used in contemporary buildings covered with glass Entirely in the Algerian desert. Where the summer temperature often exceeds 50 °C.

2 Materials and method

2.1 Glass as a material in contemporary architecture

Since ancient times, man has maintained his integration with and coexistence with his natural environment. However, with the passage of time and with the developments that touched all the magazines of his life, especially the field of construction. He became Each region has unique designs and buildings with an identity that distinguishes it from other places. According to [21], the beginnings of modernity appeared at the turn of the nineteenth century, when demoted the revival and annihilation of interest in the study of history, thus saying that each era is capable of creating its own values.

Nowadays, a new type of modern and contemporary buildings has recently spread throughout the world. These buildings were characterized by transparent facades completely covered with glass. And became a global trend in all regions of the world without paying attention to or take into account the indicators and standards (climate - environment - identity - customs and traditions) prevailing in each region. This led to the emergence of standard and similar buildings with unified designs, despite the different characteristics of the natural, social and cultural environment in each region. Architect [22] has always been an advocate of the idea of designing in this context, he specifies that "Architecture is not a search for a form by the eye. He is first and foremost to seek maximum agreement with the climate, which is permanent and with living conditions that are constantly changing".

2.1.1 Status of glass in contemporary architecture in Algeria.

After independence, the Algerian government, like all other countries in the world, decided to keep pace with modernity and to construct new and contemporary buildings in line with the modern developments that the world has known. In addition, new transparent building materials such as glass appeared, as it became easy to construct attractive and skyscraper transparent buildings. As these materials can reflect the modern aesthetics of buildings, and allow the celebration to express contemporary and sophisticated in Algeria. Therefore, the Algerian authority at that time opened the door for dialogue with many of the most famous architects at the international level for the purpose of constructing the best buildings in the world.

Like architect Oscar Niemeyer, who designed the University of Bab Ezzouar in 1974 and this building is still witnessed its distinction and elegance until today (see Fig.1). Although the architect used glass predominantly, it is still a distinctive architecture in line with the climatic data of the region. As the sun protection systems are present in most of his work. In addition, transparent interfaces are present everywhere with the aim of making the most of daylight. However, this transparency is often accompanied by useful prominent surfaces that reflect direct sunlight.

(a) Main façade. ***(b) Exterior view.*** ***(c) Interior view.***

Fig. 1 – Houari-Boumedienne University of Science and Technology, Bab-Ezzouar, Alger, 1974, Oscar Niemeye.

In the last years, architectural design has become the most demanding transparent (trendy fashion). Where this design was adopted in many sectors of contemporary international architecture, then it becomes like a model and tendencies that symbolizes development and modernity.

As well, the same is true for Algeria and is no exception, especially in recent years, as more modern designs of glass buildings in Algeria have become uniform conception in the north, like the south. That is, whether in the cold coastal areas or in the hot desert areas. Where these contemporary buildings were characterized by the presence of a glass curtain covering the facades of all the external facades of the building.

So, this makes these designs standard and lacks the identity and history of the region. With no respect for the type and nature of the project (the type of service). This is what led to the emergence of problems in the excessive energy consumption resulting from the architect's indifference to climatic data (the effect of poor resistance to glass on the comfort of the descendent), see figure below.

(a) Ministry of Finance, North of Algeria. ***(b) Hotel Annaba, Est of Algeria.*** ***(c) Hotel Oran, West of Algeria.***

Fig. 2 – A contemporary architecture in Algeria.

2.1.2 What about contemporary architecture in Saharan environments: the city of Béchar as a specimen

As in many Algerian cities, many buildings have recently sprouted, whether built or under construction using modern building materials and construction techniques, such as the appearance of transparent facades in most of these buildings, despite the difficult climate, which is characterized by being very hot and very dry in this region. This design gave a new image in the region that is different from most of the old desert styles and architectural styles previously adopted in this city. The glass covers most of the facades of modern buildings in this desert region.

In the Saharan city Bechar where the climate is hot and dried, the climatic factor is an element of essential in the morpho-genesis of these cities, indeed the human who lives in this context has always sought to adapt its living conditions to the climate. This can be found in present in the form of a series of finely detailed urban and architectural strategies hierarchical, from urban morphology to constructive details. At the level of the urban fabric, the building is compact, the streets are narrow and covered. [23], explains that the building is the result of the interaction between the human being, his nature, his needs, the available techniques and the nature in which the climatic factor plays a decisive role in the creation of the built form. Also, as for the envelope of the construction, the composition of the pieces is around a patio (introverted architecture), the walls are massive with an earth color (50 to 70cm), openings drilled to the outside are generally of small dimensions protected by occults (Claustral, Moucharabieh,...) (c.f., Figure.3) for climatic and sociologic reasons (of intimacy). This shows that although the man in this Saharan environment has found solutions that adapt to the rigor of the climate to protect himself to ensure his comfort through sustainable solutions.

Contemporary architecture in the Sahara has seen new forms and designs, which do not resemble traditional forms. Indeed, like modern architecture, this new Saharan architecture, is often characterized by the use of large windows on the facade, the strip window, and the canopy. Their effectiveness for comfort is being questioned. "This recent architectural trend, mainly driven by a desire for transparency in the building offers completely glazed façades, free of any need for their bearing function and reduced to the role of an envelope" [24]. So, the architects of this trend have contributed to the production of an architecture that is perfectly indifferent to the Saharan climate and largely energy-intensive.

The city of Bechar, like all Saharan cities in Algeria, has a number of important tertiary equipment of which office buildings are an important part. The external aspect of the architecture of these contemporary buildings is strongly glazed in order to express an aesthetic aspect of transparency while using curtain wall techniques and the large glass surfaces on the façade.

(a) The Béchar bank, Béchar.

(b) Trade Department, Béchar.

(c) Public Works Department, Béchar.

(d) Education department, Béchar.

(e) Direction of work, Béchar.

(f) The bus station, Béchar.

Fig. 3 – A contemporary architecture in Saharan region of Béchar.

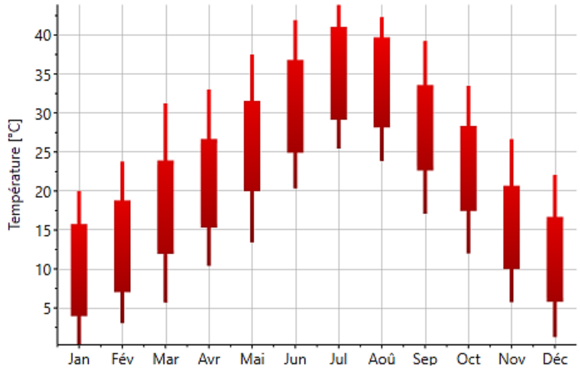
2.2 Case study

2.2.1 Climate data at the city of the Case Study in Béchar

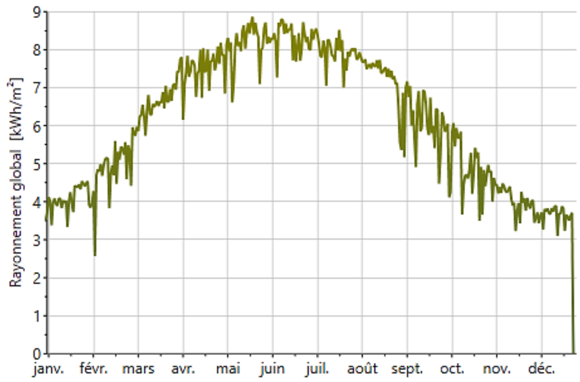
Every architect must adhere to the climatic data of any area in which he wants to build. Especially regarding temperature, humidity, nature of precipitation, sunlight, wind direction... so that it can design buildings that are more comfortable and less energy-intensive. Béchar is characterized by a somewhat mild climate in winter. As for summer, the weather is hot and dry, as heating in winter is not a big problem as it is in summer, because winter in this region is not long, as it does not exceed three months in tongues. Therefore, the architect must design buildings, according to smart and more efficient methods that cover the requirements of the architecture, from the appropriate thermal relaxation, especially in the summer, especially since the climate in this region is very hot.

In most cases, the coolers are not sufficient to cool the interior spaces, and therefore do not guarantee thermal comfort inside the buildings, which results in excessive consumption of energy.

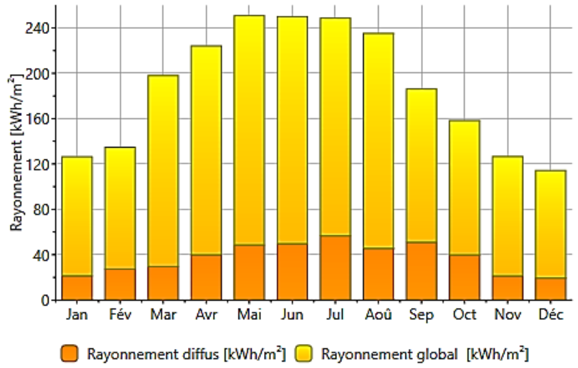
In summer, the temperature in Bashar exceeds 47° C under the shade (c.f., Fig.4a), while the humidity remains somewhat low, ranging between (4% to 20%) due to the scarcity of rainfall and its irregularity throughout the year as it remains low between 11 mm to 16 mm (c.f., Fig.4e). On the other hand, the temperature may drop below zero degrees Celsius sometimes. Add to this the presence of intense hot winds and often accompanied by violent sandstorms, which may reach speeds of 100 km / h. By analysing these data for climatic data, Bashar has a very harsh climate throughout the year. It singled out and that the summer period is six months (April - September), but what is known about the desert region in Algeria, in general, is that it enjoys a significant insolation capacity, which often exceeds 3500 hours per year. Exceeding 9 kWh / m² (c.f., Fig.4b), direct solar radiation that can reach to 250 kW / m² at the horizontal level (see Figure 4c). The second duration of sunlight is limited to 10/14 hours a day throughout the year (c.f., Fig.4d).



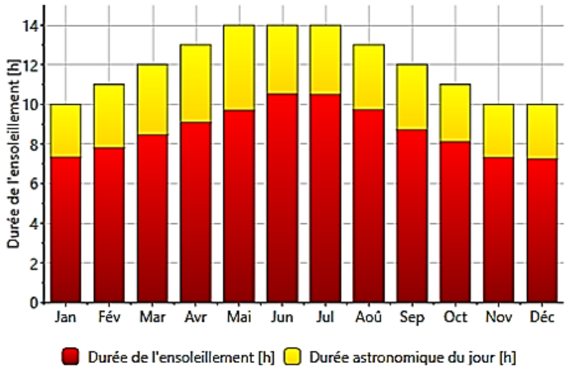
(a) Temperature.



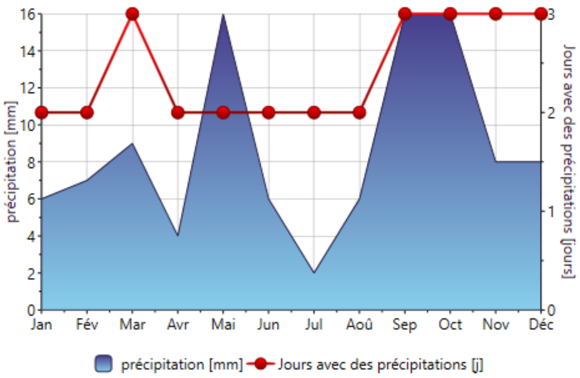
(b) Global Radiation.



(c) Radiation.



(d) Duration of sunshine.



(e) Precipitation.

Fig. 4 – Monthly weather data of Béchar.

2.2.2 Contemporary architecture facing the energy efficiency of (BIPV) in the Saharan environment

Contemporary glass-covered buildings have enjoyable openside views, especially if the building overlooks a picturesque outdoor landscape. These transparent interfaces also allow natural lighting to be provided in the building's internal space, which reduces the consumption of electrical energy allocated to artificial lighting within the building's interior. Moreover, the psychological comfort of the workers and the percentage of their productivity at work is related to the type and nature of the office's internal space, whether positively or negatively (lighting type, moderate temperature). Since transparent facades often have a weak thermal resistance compared to opaque walls and ceilings, this may allow sunlight to enter the interior spaces. So, high temperatures cause greater warming in the building in the summer [25].

Thus, the excessive use of glass as contemporary facades in the desert environment may cause many problems, harassment, and difficulty. The most important of them is the high temperature of the building in the summer and the increase in air conditioning loads, the lack of visual amenities such as intense glow, and the extreme cold in the winter. The outer walls of the buildings are responsible for separating the spaces between the interior and the outside and are therefore a protective cover that protects them from all external hazards (such as the impact of climate change). The design of building facades differs from building to building depending on the climate. This makes each region its own design, nature, the building materials used in it, and even the glass window areas. Because all of these factors have a degree of significant impact on the comfort of the user inside the building (visual comfort, psychological comfort, and thermal comfort). So, the architect must be very careful to choose the building materials most resistant to external climatic conditions. This is because the glass façade of contemporary buildings is responsible for energy loss which may reach between 71% in the summer, while the rate of energy loss exceeds 48% in the winter, according to a study by [26].

For reference, the value (U_{value}) expresses the temperature loss through the glass and is calculated by structural elements, measured in Watts per square meter Kelvin W/m^2K. (The lower the (U_{value}) the better the thermal performance of the glass.). It forms part of the daily specifications and construction, according to building regulations, especially when environmental laws are more stringent and stricter in order to develop buildings and raise more than their energy efficiency. This heat exchange is a result of the high heat transfer coefficient (U_{value}) of the glass technology most often used in buildings today. Therefore, uniformity of glass resistance and low (U_{value}) are very essential to achieving high-energy efficiency in future building in hot areas such as the desert.

The type of glass used in windows, the size of the windows, and the number of layers of glass affect the degree of solar heat gain. The heat flows from the warmer side to the cooler side (the overall heat flow from the warmer side to the cooler), meaning the inner face of the window from input to Outside in the winter, and opposite in the summer. Thus, the definition of energy performance in windows is the ability to control solar heat gain through glazing. Access to solar energy through windows is also a major factor in determining the cooling load of many modern glass buildings. The values of (U_{value}) and (SHGC) are the Coefficients of Solar Thermal Gain, as general indicators are more effective by which we can evaluate the degree of strength and resistance of the glass used on the facades.

The second primary property that contributes to the energy performance of windows is the ability to control solar heat gain through glazing. As the acquisition of solar heat through windows is an important factor in determining the value of the cooling load for many commercial buildings. The origin of solar heat gain is from direct and diffuse radiation from the sun and the sky (or reflected from Earth and other surfaces). Some radiation passes directly into the building through glazing, while some may be absorbed from the glazing tip, which is indirectly introduced into the inner space. As for the rest of the radiation absorbed by the frame, which will also contribute to the solar heat gain factor for the window.

(SHGC) indicates the percentage of solar radiation (across the entire spectrum) on a glass group (window or skylight) ending inside a building as thermal energy (heat). In other words, SHGC represents the ability of the glass collector (including the glass and the frame) to resist heat gain from solar radiation. (SHGC) express in a percentage and therefore they are dimensional, as this ratio can generally range from 0 to 1, but in reality, the ratio of products usually ranges between 0.2 and 0.9. In other words, (SHGC) expresses the value of each of the heat generated by the solar radiation traveling through the glass, in addition to the heat energy that is absorbed and transferred inward through the glass and frame.

To calculate (SHGC), it is essential to calculate the difference in the net heat gain between the state with and without the existing solar radiation ratio. Therefore, the (U_{value}) and (SHGC) values can be expressed as follows: See equation (1) and (2) [27].

$$U_{value} = \frac{Q_{in} - Q_{in,no-sun}}{T_i - T_o} \tag{1}$$

$$SHGC = \frac{Q_{in,no-sun}}{I_s} \tag{2}$$

where Q_{in}: It is the global heat transfer through the glazing zone in the situation with solar radiation; $Q_{in,no-sun}$: It is the total heat transfer through the glazing zone in the situation without solar radiation, (W/m²); T_i: It is the air temperature ambient of inside, (C°); T_o : It is the air temperature ambient of outside, (C°) and I_s : It is the total incident solar radiation on the covering zone of glass, (W/m²).

2.2.3 Advantages of BIPV in contemporary architecture

The supply of solar radiation received within one hour in the world is sufficient to cover a full year of global energy demand entirely [2]. This makes it free, renewable, available, unlimited, and long-term energy. Therefore, it is time to re-struggle in changing the type of non-renewable energy supplies and replacing them with clean green energy, in order to protect the earth from pollution resulting from the excessive consumption of this energy (Oil and gas).

Among the latest technologies that are most effective in the field of developing the energy use and manufacturing industry, especially in the field of construction and architecture, is the photoelectric technology manufactured for usable electric energy starting from solar radiation. This process is called an electrical conversion process, where green renewable electricity is generated using solar radiation, without waste, noise, or environmental pollution.

The great technological progress in the field of building materials technology led to the development of new building materials called (BIPV) installed on the building's outer shell (these materials help in the production and use of renewable solar energy). BIPV has become an innovative solution that has many advantages at all levels, starting with energy manufacture and protecting the environmental and ecological side, to the effect of enriching the architectural aesthetic aspect. Among the most important advantages of (BIPV) and multifunctional systems include:

- The effect of the (BIPV) incorporated in the building as a thermal resistance (Thermal insulation). The integration of the system in the building facades increases the resistance of the walls and prevents the occurrence of heat exchange between the two media, and thus (BIPV) is used as thermal insulation between the interior and the external environment. This avoids energy loss and thus maintains a moderate temperature inside the building's interior [8; 28-31].

- Flexibility, renovation, attractivity and sustainability [32], the (BIPV) panels are light, easy, aesthetic materials, and quick to install and set up. Add to that the integration of a system in the facades of buildings increases the attractiveness and distinction of the building, with its availability in different colors, materials, and size [33]. In addition, systems (BIPV) can be a versatile tool to offer an aesthetic, with a design that renovates the value of a building [34-35].

- The ecological footprint advantage of (BIPV), green energy is a means of protection against the dangers of pollution. Due to the misuse of harmful and nonrenewable energies such as petroleum, coal, and natural gas, the production and consumption of fossil energy resources lead to emissions of polluting gases such as carbon. But with the use of renewable alternative energies such as solar energy and above all (BIPV), we effectively contribute to the protection of the environment and the preservation of the ecosystem [36-38].

- The design of semi-transparent PV glass permits in addition to daylight to benefit from natural daytime lighting an optimal balance of natural lighting and visual comfort [39]. The choice of transparent or semi-transparent facades allows light transmission and contact with the outside [40].

- Acoustic and visual comfort due to the behavior of multifunctional facades. Solar facades are multi-purpose architectural components, which can generate both heat and energy by using sunlight [41].

2.3 Materials

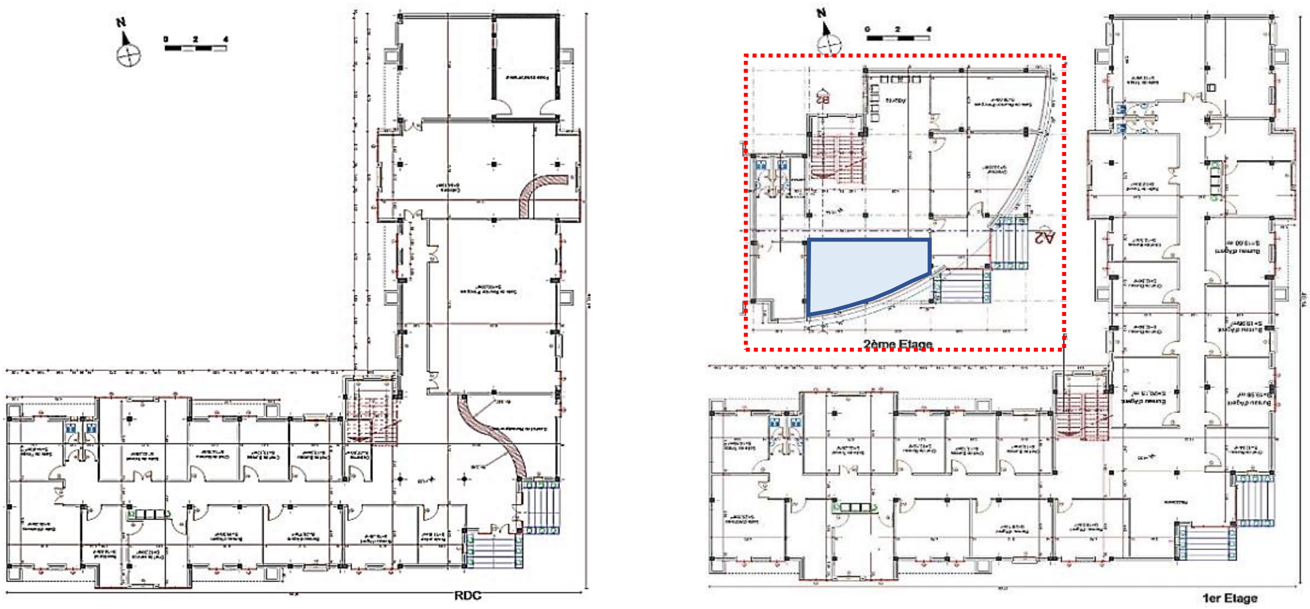
2.3.1 Description model of the case study

2.3.1.1 Architecture condition

This study aims to measure the effect of the ratio and the type of glass used in contemporary buildings on the thermal performance of the building (Simple Glass, Double Glass, STPV glass, and VPV IGU glass), and also aims to determine the optimum percentage of glazing (type and dimensions) in contemporary desert buildings. In addition, the energy efficiency of each type of glass was measured (The electrical energy produced). Note that the study was conducted on a contemporary building, of the Directorate of City Planning Architecture and Building (DUAC), as this building is located in the city center of Bechar, where it is characterized by a very hot and dry desert climate (c.f., Fig.4a). Built-in 2009, this building is the first glazed, transparent, and contemporary building to be built in Bechar (c.f., Fig.4b).

The total area of the building on the land is 690 m², and it is two floors. This building is positioned in the shape of an L, resulting from the intersection of two rectangles, the first linked in the southern direction, and the second in the east. In the middle of it is a cylindrical model. This building has a contemporary transparent architectural façade with curtain wall systems for typical commercial buildings covering 65% of the total wall area. This is what makes this building attractive, dynamic, and more oriented and exposed to solar radiation, compared to facades with flat surfaces (c.f., Fig.4c).

(a) Situation of case study. *(b) South and south-west facade of case study.*



(c) The Architectural Case Study Plan.

Fig. 5 – Architectural information of case study.

2.3.1.2 Geometric descriptions of case studies and Building modeling

An office was chosen as an example of a simulation procedure (Case study to evaluate energy efficiency). This space is on the upper floor, and the office has a transparent south-facing interface (Windows). Three different types of glazing ratios were identified in this office (see Table 1), and four different types of physical properties were tried (see Table 2).

Finally, each type of glass type was compared to the thermal comfort of office users (the thermal performance of each type of glass), as well as the energy performance for it (Energy production and consumption), then examined the performance of the building's natural daylight. Consequently, the work methodology has been divided as follows: (i) The thermal equilibrium model, (ii) The internal energy generation and building consumption model, and (iii) The daylight model.

Table 1 - Description of geometry of cases studies.

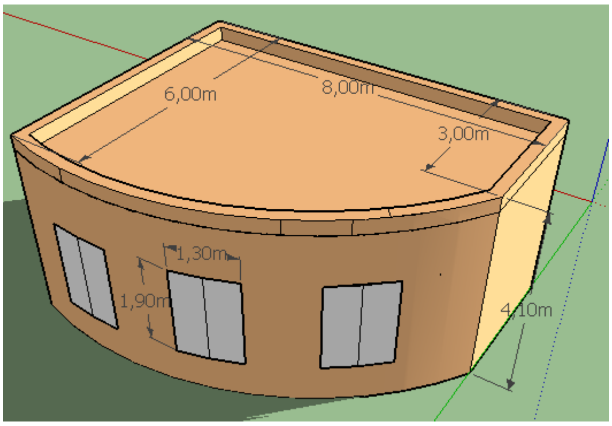
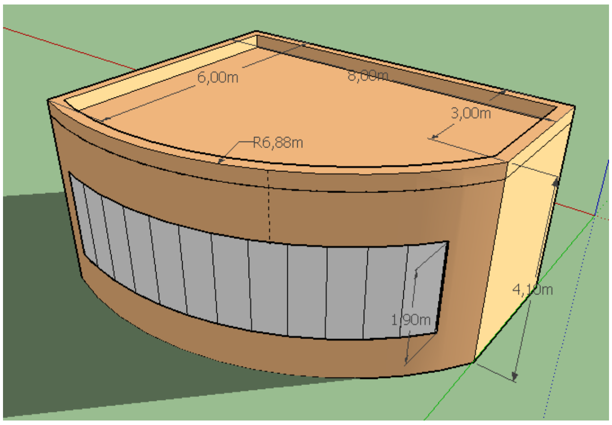
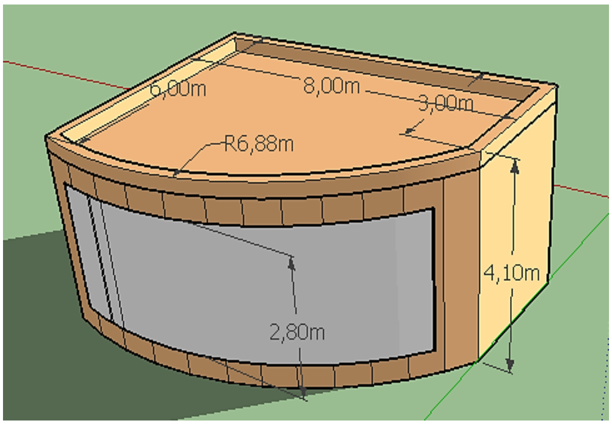
Geometry and typology of the modelled building.	
The typical layout of the Generic office.	**Orientation and sizing windows.**
 **1st case study (A).**	03 windows of the same size, (facing south-west). $Height = 1.9\,m\,;\; Width = 1.3\,m$ **Total areas of one window:** $1.9\,m \times 1.3\,m = 2.4\,m^2$ **Total areas of three window:** $2.4\,m^2 \times 3 = 7.2\,m^2$ **Total area of outside envelope (South -West façade):** $Height\;4.1\,m \times Ray\;Length\;6.88\,m = 28.2\,m^2$ **Ratio (Proportion Surface Opening, Envelope):** $\frac{7.2\,m^2}{28.2\,m^2} = 0.25\;\; so\;\; 25\%$
 **2nd case study (B).**	Transparency façade, (facing south-west). $Height = 1.9\,m\,;\; Ray\;Length = 6.88\,m$ **Total areas of three window:** $1.9\,m \times 6.88\,m = 14.1\,m^2$ **Total area of outside envelope (South -West façade):** $Height\;4.1\,m \times Ray\;Length\;6.88\,m = 28.2\,m^2$ **Ratio (Proportion Surface Opening, Envelope):** $\frac{14.1\,m^2}{28.2\,m^2} = 0.5\;\; so\;\; 50\%$
 **3rd case study (C).**	Transparency façade, (facing south-west). $Height = 2.8\,m\,;\; Ray\;Length = 6.88\,m$ **Total areas of three window:** $2.8\,m \times 6.88\,m = 20\,m^2$ **Total area of outside envelope (South -West façade):** $Height\;4.1\,m \times Ray\;Length\;6.88\,m = 28.2\,m^2$ **Ratio (Proportion Surface Opening, Envelope):** $\frac{20\,m^2}{28.2\,m^2} = 0.75\;\; so\;\; 75\%$

Table 2 - Key Properties of different glazing of Simulated.

Type of glazing	Thickness (mm)	Visible Transmission	Factor Ug (W/ (m².K)	Solar Transmission Coefficient %	SHGC (Solar Heat Gain Coefficient)
Clear and simple glazing	5.7	0.884	5.54	0.771	0.817
Clear and double glazing	24.1	0.786	2.63	0.607	0.703
Semi-Transparent Photovoltaic (STPV)	25.7	0.136	0.497	0.195	0.471
Vacuum Photovoltaic Insulated Glass unit (VPV IGU)	20.8	0.12	0.557	0.076	0.143

2.4 Methods used

2.4.1 Methodology

To find the objectives of the study, a model was accomplished to several operations of simulations in the desktop space equipped with transparent windows with different glazing ratios. In order to study the degree of their effect for each (Individual Clear Glass, Double Insulating glass, Semi-Transparent cells (STPV), Glass Unit Vacuum Photoelectric Isolator (VPV IGU), annually.

First, the total energy from the office's electricity consumed in the refrigeration, lighting, and office equipment process was evaluated. For an evaluation of the performance of windows of different sizes and different types of glass, see the methodological scheme below (see Figure 6) which describes the methodology used in detail in this work.

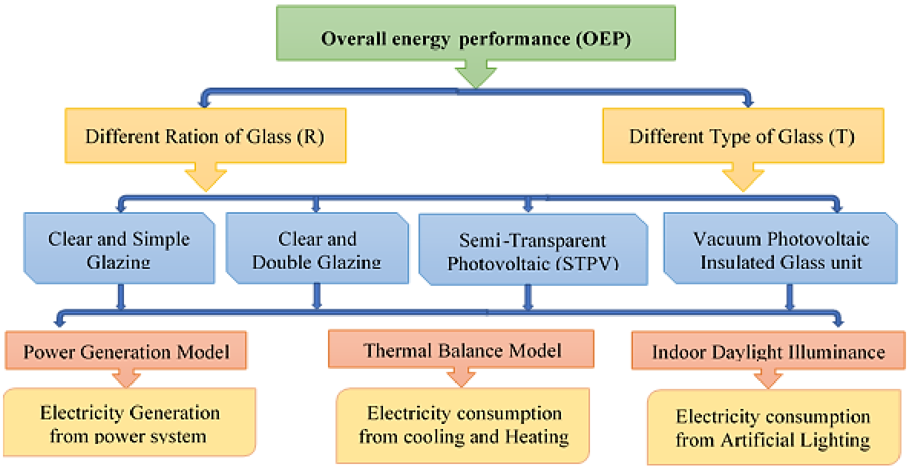


Fig. 6 – Flowchart of method.

- **The first case (I),** a three-dimensional office stereoscope was designed and modeled in the simulation program with the specification of each of the techniques, properties of the building materials used, and the orientation of the building as well as the dimensions of the windows, the direction, window ratios. The above table shows a detailed description of each case studied using three types of window ratios whose characteristics are summarized.
- **The second case (II),** evaluation of the comparison of the total energy performance of each case (the power generation model, the thermal balance model, the internal daytime lighting model), by expressing the total energy performance by the percentage of electricity profits managed during the year.

- **The Third case (III),** evaluation of the electricity produced (energy) for each system, in addition to calculating the rate of coverage of this produced electricity for the office's need for electricity oriented to the air conditioning and heating system. Also, the amount of electricity consumed in artificial lighting was determined. Finally, simulations were performed to assess the degree of resistance of each glass type, thus determining the effect of the Ratio of the solar cell area (R) on the thermal performance within the office.

2.4.2 Simulation tools: In the TRNSYS and TRN Build environment

Currently, many software applications applied to simulation are building and energy development. Where these programs differ from each other, both in the algorithms that use them, through their limits and the user interface, as well as through the methodology of work in them and the areas of their application and even their limits and Its disadvantages.

To develop our simulation model in this work, we chose to work in dynamic simulation first on a TRANSY program, and this program allows us to model both thermal and energy systems and express them by some graphing. Moreover, we have used the TRNBuild tool (type 56) to enter both weather data (Bashar meteorological data) and the engineering and physical properties of the building materials used.

The architectural properties are intended to determine the sizes and dimensions of the glass, the position of spaces, and their spatial orientation. While the physical properties of the building materials used are intended to determine the type of wall building materials and types of glass (its thickness, thermal resistance, energy production capacity …) (c.f., Fig.7, and Fig.8).

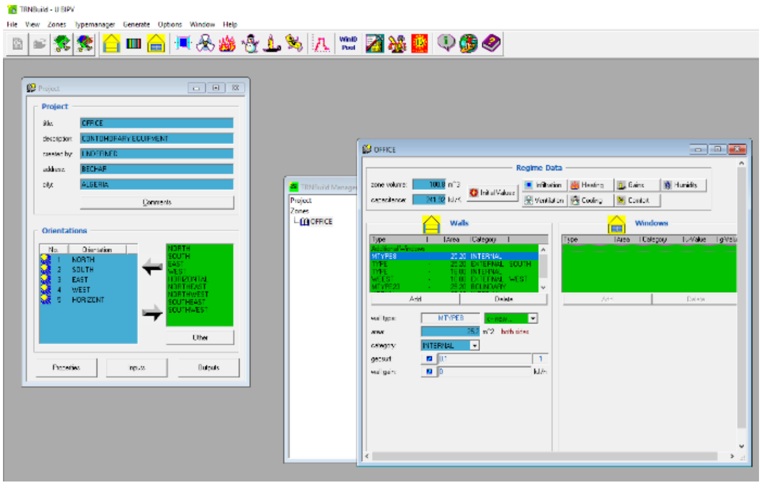


Fig. 7 – Window for assembling the project in TRNBuild Simulation studio

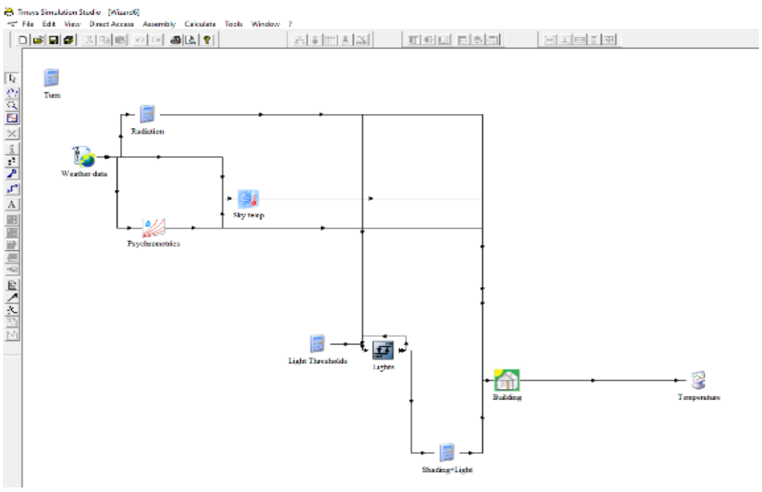


Fig. 8 – Window for assembling the project in TRNSYS simulation studio

2.4.3 Simulation parameters

2.4.3.1 Constant simulation parameters

It relates to meteorological data, in addition to the patterns of use (the nature and type of work performed in space, the number of people occupying each space, and temperature instructions according to the activity of the human body). As for temperature instructions, according to the technical and regulatory document that is used in Algeria, the comfortable temperatures for heating and air conditioning in offices are respectively (20° C in winter, 26° C in summer).

Table 3 - Constant parameters of Simulated.

The components of TRNSYS	• Time varies: (08 :00h - 17:00h). • Occupancy rate :(03 people per office). • Lighting power and various equipment: (Computers - lamps - Air conditioning ….). • Temperature instructions and the operation of the heating and air conditioning system.
The effects of thermal inertia	• The effects of natural ventilation. • Thermal zones: The thermal exchanges between the internal and external zones (by convection, conduction, and radiation). • Assembly with systems: BIPV solar systems, electricity production).
Meteorological data (Metronom); Corresponding	• The effects of natural ventilation. • Thermal zones: The thermal exchanges between the internal and external zones (by convection, conduction, and radiation). • Assembly with systems: (BIPV solar systems, electricity production). • The temperature. • Wind speed and direction. • Moisture and Solar radiation.
Building materials	• The construction materials used in the construction of the tourist facility used in the simulation are described in detail in the table below (Table 4).

Table 4 - Detailed characteristics of building materials used in the tourist center (case study).

The constant parameters of the simulation in the case study

Exterior Wall: (Cement plaster, 15cm brick, air gap, 10cm brick, plaster).

Interior Wall: (Plaster coating, Cement coating, 10 cm brick, cement coating, plaster coating).

Slab: (Hedge, floating slabs, cement mortar, floor slab).

Roof: (Plaster coating, cement coating, hollow body, compression tile, cement mortar, floor slab).

Thermal characteristics of the materials used in the base case

Materials	Thermal Conductivity $(KJ/h\ m\ K)$	Heat specific $(KJ/kg\ K)$	Density (kg/m^3)	Thickness (m)
Hollow brick-1-	1.7	0.79	720	0.20
Hollow brick-2-	1.8	0.79	720	0.15
Coating outside	4.15	1	1700	0.02
Coating plaster	1.26	1	1500	0.02
Mortar	4.15	0.84	2000	0.02
Tiling	6.14	0.7	2300	/
Concrete	7.56	0.8	2400	0.20
Hordes	4.801	0.65	1300	0.20

2.4.3.2 Variant parameters of the simulation

Table 5 shows the various characteristics of the four models of glazing for the studies that have been developed, including the thermal balance model, the electricity production model, the energy consumption model consumed by the cooling and heating systems. Then the determination of the amount of energy directed to the consumption resulting from artificial lighting in the office. With four different types of glazing and three different ratios, they are as follows: 25%, 50%, and 75%.

- Comparing various thermal equilibria, and determining the total energy efficiency of the Semi-Transparent PV system (STPV) in typical office buildings in the Saharan environment of Bechar.
- Estimation of the ratio of the influence of the thermal performance of the solar cell area R (VPV IGU). Under the same conditions (In the same office).
- Finally, comparative studies have been made between thermal performance between different types of simulated glass (1) Clear and Simple Glass, (2) Transparent and Double Glazing, (3) the Unit of Semi-Transparent Photovoltaic cells (STPV), (4) Vacuum Photovoltaic Insulated Glass Unit (VPV IGU). By determining the percentage of energy coverage produced for each system (the difference between the energy consumed and the electrical energy produced).

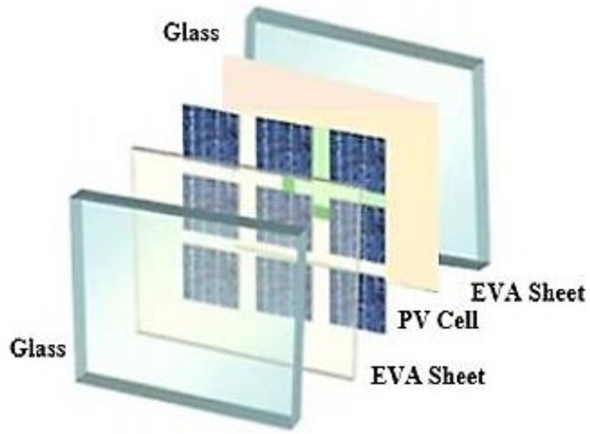


Fig. 9 – A simplified diagram of a of (STPV) structure

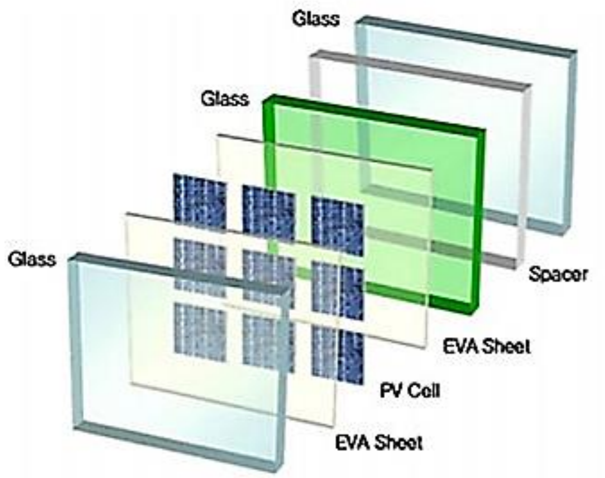


Fig. 10 –Schematic diagram of the (VPV IGU) structure.

Table 5 - The parameters varying from the simulation.

Characteristics of deferment types of simulated glasses.	**(1) Single and clear glazing (Transparent):** Clear single-glazed glass was introduced as a basic prototype.
	(2) Double glazing: It is currently widely used in the world, because of its resistance and efficiency in reducing energy loss compared to single glazing. The double glazing is composed of two single sheets of 6 mm thick transparent glass sheets with a 13 mm air cavity, with an insulating gas.
	(3) The Semi-transparent Photovoltaic Building (STPV): Solar energy production technologies and materials have recently spread. So, architects have encouraged and called for the utilization of semi-transparent units (STPV) and the replacement of conventional energy-consuming and unproductive glass This is because (STPV) is smart green material and adds an aesthetic touch to the buildings. It also contributes to the efficient use of green solar energy and converts it into electrical energy. This type of PV modules often consists of two layers of highly transparent glass panels, they are centred on a series of opaque solar cells compressed between these two transparent glass panels. This allows it at the same time to enter daylight into the transparent area between the solar cells. Figure 9 shows a simplified diagram of a (STPV) outline.
	(4) Vacuum Photovoltaic Insulated Glass Unit (VPV IGU): For the manufacture of VPV IGU material, the vacuum glazing unit is integrated with PV module, in one integrated and homogeneous glass unit. As shown in detail in Figure 10, as the outer panel layer is a translucent Si-PV filtered glass allows light transmittance of 20%. The inner layer is a vacuum in the middle of insulated glass with two layers of glass and an evacuated gap. The outer layer of PV laminated glass adheres to the inner vacuum glass with a layer of polyvinyl butyral (PVB). The contemporary and compact building facade of (VPV IGU) can absorb a significant proportion of natural solar radiation by Si cell layers in Si. In addition, there is the natural solar radiation reflected, where the remaining solar radiation penetrates deep inside the room to provide natural daylight. The solar cell converts sunlight into electrical energy, while unused solar energy travels into lost heat entering the interior space of the building. As the (VPV IGU) is one of the best products with great thermal resistance and insulation, its inner layer of vacuum glass reduces the heat gain and loss across the window. In the summer, the passage and entry of lost heat from the solar radiation from the outside into the interior can be discouraged by absorbing the solar cells from the enclosed spaces. While in winter, it can reduce the loss of heat from the inner medium to the outer medium. Radiation is the only way to transfer heat to the interior and the vacuum gap does not affect the interruption of the passage of this passage. To reduce the total heat transfer of this radiation, the plant has placed a low E layer with the emission of 0.040 was placed on the inner surface (outwards) of the vacuum glazing to reduce the total heat transfer.

3 Results and discussion

3.1 Power performance

Figure 11 shows the total annual electricity consumed for cooling inside an office with different types and proportions of glazing. The simulation results showed the thermal efficiency, as when (VPV IGU) using in the main interface of the office, it has the most thermal efficiency among all the case studies. Thus, the compound (VPV IGU) allowed reducing the cooling energy consumption significantly, due to the fact that the amount of U (VPV IGU) and the value (SHGC) is small. As shown in Table 4. The lower the value of both U and SHGC, the better the thermal insulation of the glass. Meaning, it is very resistant to the passage of solar radiation and prevents its penetration into the interior.

3.1.1 Aannual electricity consumption of cooling

The largest decrease in the total heat passing through the wall is due to the absorption of solar photovoltaic modules of the solar heat, thus reducing the passage of these heat through an exterior wall (from the outside inward). Consequently, the units of solar PV cells installed on the wall play two roles, the first being an insulator that prevents the passage of heat and the second absorbs the sun's rays and convert them into electrical energy. Hence, solar cells have a direct effect on the amount of absorption and excretion of heat between the inner and outer media (wall resistance).

- **In the first case study**, with 25% of the windows, the office consumed about 998.64 kWh annually using clear and simple glass, while it needed 961.38 kWh of electricity annually when replacing the ordinary glass with double glass. Which reduced consumption up by about 4%. Whereas, when using STPV, the building's need for direct electricity to cool the building was about 935.19 kWh annually. As for after using (VPV IGU), the building's need for electricity decreases to 835.56 kWh annually, and the rate of consumption decrease of electricity in the office between the use of simple glass and glass (VPV IGU) is estimated to reach 16% (see case A in Figure 11).
- **In the second case study,** In the second case study, with 50% of glazing, the office consumes approximately 1163,34 kWh annually directed for cooling with the use of clear and simple glass. While the amount of total energy consumed annually decreased by 10% when it was used a double transparent glass to become 1048.41 kWh annually. Then, the total energy consumed decreases to 1004.76 kWh annually, then to 985.59 kWh annually. When using glass (STPV) and (VPV IGU), respectively (see case B in Figure 11).
- **In the third case study,** with a 75% ratio of windows, the office consumes about 1258.38 kWh per year in the case of using the clear and simple glazing. When replaced with clear and double glazing, which was approximately 7%. The office with this type of glass consumes about 1172.43 kWh. The energy-saving was 13 %, and 14.5% compared with the cooling consumption of the office with double-clear glazing, (STPV), and (VPV IGU), respectively. The amount of annual energy expended estimated by 1172.43 kWh per year in case of using double glazing. Decreased to 1091.25 kWh per year when using the system (STPV) and reached to 1077.03 kWh when using the system (VPV IGU) (See case C in Fig.11).

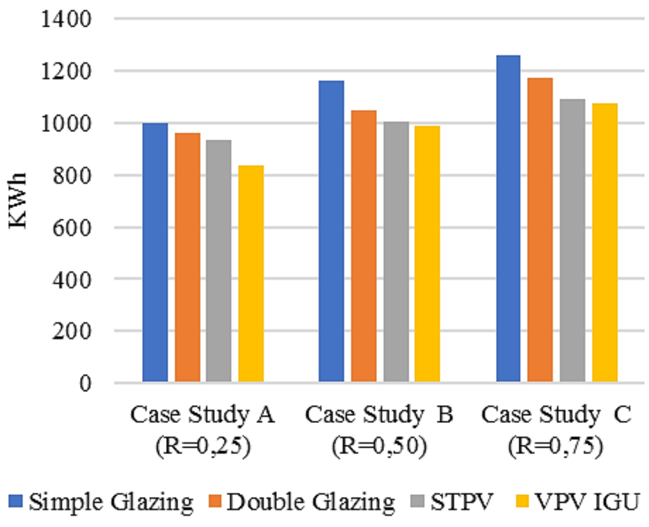


Fig. 11 – Annual consumption of cooling electricity.

3.1.2 Annual consumption electricity of heating

For the evaluation of winter energy performance, i.e. annual electricity consumed for heating, with a measure of the effect of different types of glass used in the simulation (Different sizes of windows). It has been found that:

- **In the first case study**, and with a glazing ratio of (R = 0.25), the office consumes about 560.07- kWh per year of winter heating energy when using clear and simple glass. While this energy consumed decreased, when replacing simple and transparent glass to double transparent glass, it will reach 497.79 kWh annually. In other words, a decrease in energy consumption of 12% is observed. And to increase the resistance of the wall, the units (STPV) and then (VPV IGU) were combined into the building's main façades, leaving the electricity consumed 396,63kWh and 351.72 kWh annually for energy, respectively. That is, the rate of annual energy consumption decreases for cooling reached 38% between the use of simple and transparent glass and the use and integration of (VPV IGU) units that are most resistant to heat exchange between the inner and outer spaces (see case A in Figure 12).

- **In the second case and with (R = 0.5),** when using simple and transparent glass in the contemporary office, the energy consumed in heating in one year is estimated at 621 kWh per year. But after replacing it with clear and double glass, the annual heating energy consumption is reduced. This decrease is estimated at 63 kilowatt-hours, which means that it decreases thereafter to become 558.18 kWh per year. When using STPV glass in a clear and double-glazing place, the annual energy consumption for heating decreased to 486 kWh per year or 12%. Then this energy, decreased to 421.29 kWh per year, and this decrease was estimated at 32% using (VPV IGU) compared to the use of simple transparent glass (see Case B in Figure 12). It has recently spread to Bechar, many buildings with modern and contemporary architectural styles. It is characterized by contemporary facades entirely covered with glass in the administrative buildings in particular. And even neglected the social, economic and climatic aspect that is consistent with the climate situation in the region. This type of architecture causes excessive energy consumption both in summer and winter, especially when using ordinary non-insulating glass. So, our main goal of this work is to find the most suitable solution that satisfies all parties of engineers, authority, and users, which provides rich architecture from the artistic side to produce clean energy and thermally insulated and meet all conditions of comfort and luxury. And this by using the system of (VPV IGU) glazing. Where this study shows us the importance of its applications in contemporary façades of architecture in hot areas.
- **In the third case study,** 75% of the windows (R = 0.75) when using clear and simple glass, the office consumes about 675 kWh annually. When replacing it with double and transparent glass, the annual reduction in heating energy is reduced to 612 kWh annually. Then to 549.9 kWh annually, and 495 kWh annually. With the integrated units of (STPV) and (VPV IGU), respectively (See case C in Figure 12). The difference between the maximum and minimum annual consumption of energy for heating was estimated at 27% between the use of clear and simple glass and (VPV IGU). (See case C in Figure 12).

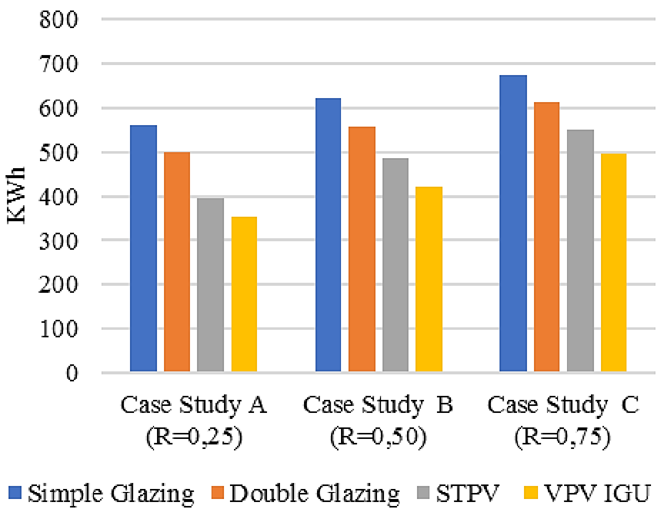


Fig. 12 – Annual consumption of heating electricity.

3.2 Thermal performance

The U value of building materials used plays an essential and effective role in their thermal performance, the higher this value. The lower its thermal performance. Thus, windows and facades are one of the most important primary factors affecting building energy consumption. The rise in temperature inside the glazed space is mainly due to the flow of a large amount of sunlight derived from solar radiation. Whether direct or indirect or as a result of the transmission of this radiation and their absorption through the glass of windows. The transmission of heat through conduction often depends on the temperature difference between the two mediums, the cold and the hot medium. The temperature resistance of the glass varies from one type to another, and it is according to the physical and chemical properties of each type. In order to find out the role of each type of glass in the resistance to heat in summer (i), and the cold resistance in winter (ii), simulations was performed in three cases of different window glazing measurements with four types of glass (see Table 5).

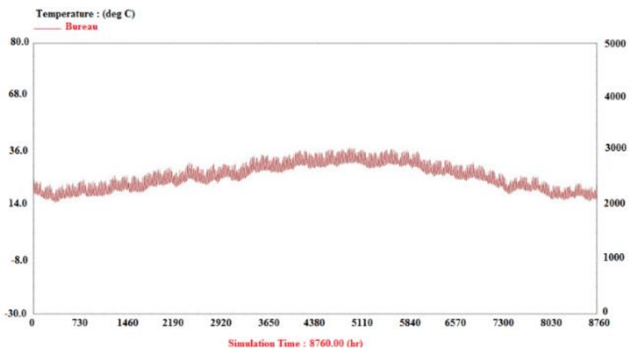
3.2.1 The maximum and minimum air temperature inside an office building with different types of glazing (In the summer and winter).

i. In the first case study (Case A), (R = 0.25),

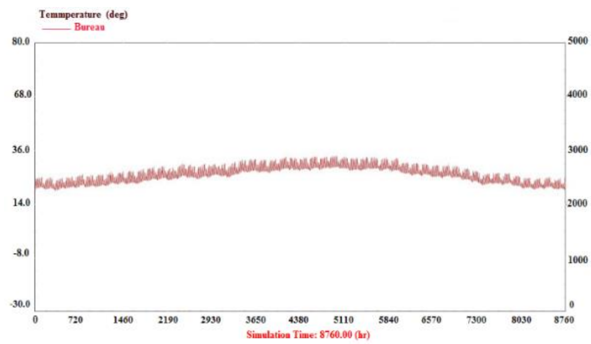
- **In summer season**

The temperature in the office ranged between 37.03 (° C), when using clear and simple glass. Then it drops to 31.36 (° C) when integrating transparent and double glazing.

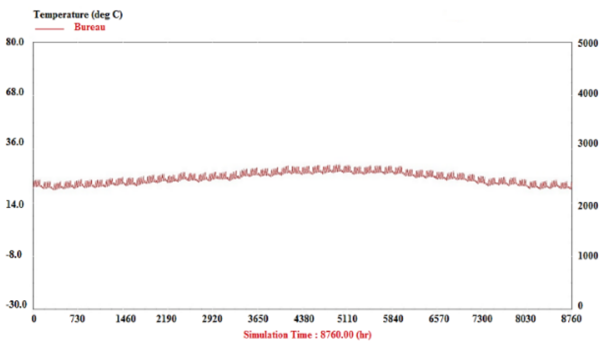
Meanwhile, a decrease in temperature was recorded to 29.5 (°C) after using the STPV system in windows and with 0.25 servings of glass. And, the temperature reached 26.85 (°C) after using the (VPV IGU) Vacuum Insulated Glass Unit system. From this, it allowed to reduce the temperature inside the office to 10.18 (°C). compared to the use of simple transparent glass, in the same dimensional conditions (See Figure 13).



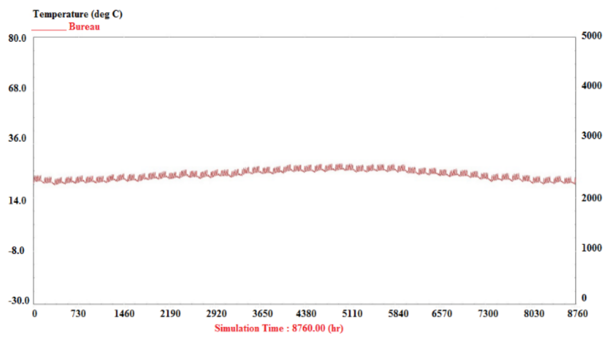
***(a)** In case of using the clear and simple glazing (Maximum and minimum annual temperature between 15.48 C° - 37.03C°).*



***(b)** In case of using the clear and double glazing (Maximum and minimum annual temperature between 19.89C° - 31.36C°).*



***(c)** In case of using the Semi-transparent photovoltaic (STPV). (Maximum and minimum annual temperature between 21.16 C° -28.9C°).*



***(d)** In case of using the Vacuum Photovoltaic Insulated Glass Unit system (VPV IGU). (Maximum and minimum annual temperature between 21.75 C° - 26.85 C°).*

Fig. 13 – The temperature inside an office building with different types of glazing (Case study -A- With R=0.25).

- **As for the winter season**

In the windows, with 0.25 portions of glass, and when using clear and simple glass, we recorded the temperature in the office that exceeded 15.48 (°C) as a maximum, meaning that the office is somewhat cold. But as the glass was replaced by another glass more resistant, the degree of coldness inside the office decreased to 19.89 (°C). The glazing system (STPV) also contributed to a decrease in the degree of coldness in the office by about 1.27 (°C) compared to the use of double glazing, where the temperature became more moderate by a degree of 21.16 (°C). And since the system of insulated glass unit (VPV IGU) has great resistance, this contributed to providing a mild climate in the winter, after it was 15.48 (°C) when using simple and transparent glass, it became 21.75 (°C) after using for (VPV IGU) insulated glass unit. That is a clear difference and exceeding 6,27 (°C).

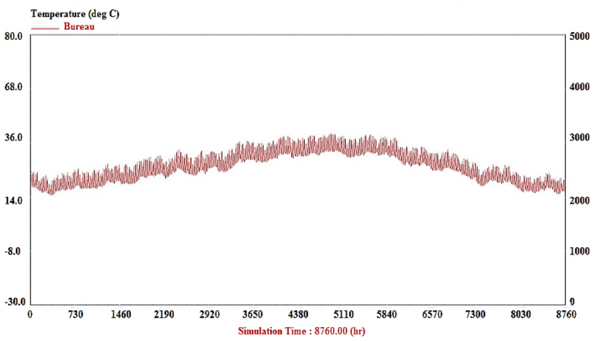
Therefore, according to temperature data at the office in the winter that appears below (see Figure 13). The temperature problem can be addressed by changing the type of glass. Currently, the construction of buildings with contemporary glass-covered facades in desert areas is no longer a major problem. The temperature inside the office has always been found in the case of C (see Figure 15), and with glazing (VPV IGU) the interior temperature of the office in the case of A is approaching the temperature of the office when using clear and double glazing. Despite the difference between the glazing ratio, between different study cases (R=0.25 and R=0.75).

ii. In the second case of the study (Case B), (R = 0.5),

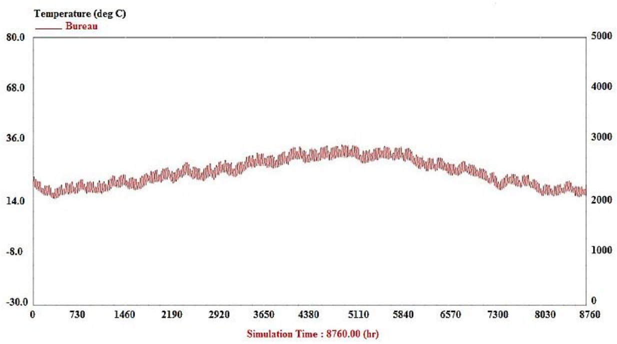
- **In summer season**

The temperature inside the office varies greatly, depending on the type of glass used in the windows. Where the temperature exceeded 39.29 (°C) when using clear and simple glazing, while it decreased by 3.82 (°C), becoming 35.47 (°C) when combining clear and double-glazing units. However, after incorporating semi-transparent photovoltaic panels (STPV) and (VPV IGU) Vacuum Insulated Glass Unit. A temperature of 31.45 °C and 28.02 (°C) were recorded, respectively.

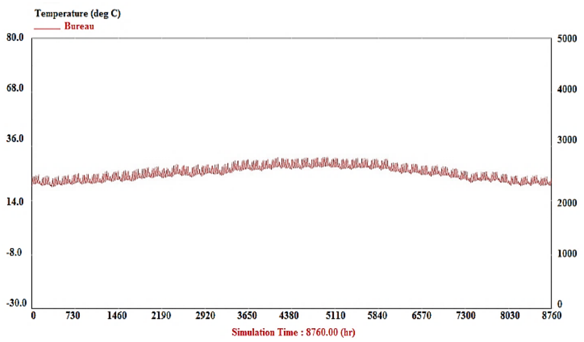
So, the temperature range between the maximum and the lowest in the office was estimated at 11.27 (°C). That is, a clear effect of the type of glass used in windows has been recorded on the temperature inside the office, between the use of ordinary transparent glass units and the incorporation of the (VPV IGU) Vacuum Insulated Glass Unit (see case B in Figure 14).



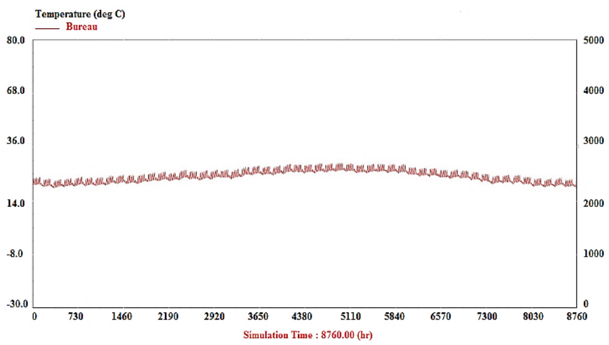
***(a)** In case of using the clear and simple glazing (Maximum and minimum annual temperature between 13.93C° - 39.29 C°).*



***(b)** In case of using the clear and double glazing (Maximum and minimum annual temperature between 18.40 C° - 35.47 C°).*



***(c)** In case of using the Semi-transparent photovoltaic (STPV). (Maximum and minimum annual temperature between (19.01 C° -31.45 C°).*



***(d)** In case of using the Vacuum Photovoltaic Insulated Glass Unit system (VPV IGU). (Maximum and minimum annual temperature between 20.77 C° - 28.02 C°).*

Fig. 14 – The temperature inside an office building with different types of glazing (Case study -B- With R=0.50).

- **As for the winter season**

As for the winter, the office temperature has reached 13.93 (°C) when using clear and simple glass, while the degree of coldness decreased by 4.47 (°C), to 18.40 °(°C) when combining double and transparent glass units in this contemporary office building.

However, with the use of semi-transparent photovoltaic panels (STPV) and vacuum insulated glass unit (VPV IGU), moderate temperature somehow. while it has reached 19.01(°C) and 20.77 °C respectively. A significant difference of up to 6.84(°C) between the use of normal clear glass units and the incorporation of a (VPV IGU) vacuum insulated glass unit (See Case B in Figure 14).

The temperature inside the office in case B when we use (VPV IGU) approximates the internal temperature of the office in case A when we use (STPV). From this, we conclude that the (VPV IGU) system is a rather successful solution, we can rely on it as a solution to provide energy and natural lighting in hot areas. Thus, compared with conventional single-glazed PV glazing and clear and double glazing, the structure of (VPV IGU) can help decrease the cooling load and recover the indoor thermal comfort. A novel (VPV IGU) has been presented. Power generation and thermal performances of the (VPV IGU) have been studied via simulation studies. Owing to the combination of PV stratifies and vacuum glass, the (VPV IGU) can not only produce electricity but also reduce air conditioning load as well as recover the indoor thermal comfort.

iii. In the third case study (Case C), (R = 0.75),

- **As for the summer season**

After performing a temperature simulation to see the effect of simple glass with Ug factor = 5.54 W / m². Where a significant increase in the internal temperature of the office, which exceeded 47.92 (°C). But after replacing that glass with double and transparent glass, the temperature decreased, in this case by 5.53 (°C), meaning that the temperature became 42.39 °C. The glass factor (STPV) is estimated at Ug = 2.584 W / m². As for the VPV IGU, it is estimated Ug = 5.557 W / m². When prevented the heat from entering the office (Preventing the heat exchange process between the two spaces). After we recorded 37.37 (°C) when using STPV glass. Then the degree of interior space temperature is 33.02 (°C) after the glass units (VPV IGU) are installed in the modern office window, i.e. a difference of 4.35 (°C) between the two types of glasses, (see case C in Figure 15).

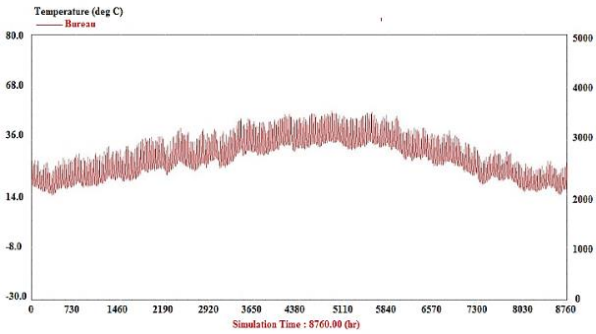
PV vacuum glazing has the lowest transmission direct solar energy than 0.10 which can be beneficial for thermal insulation when the solar radiation is strong. These results from the diagrams, determine the penetration of solar heat through. The PV glazing vacuum can be retained at a very low level. Therefore, the alternation of the indoor temperature is generously more stable compared to the building envelope by using other fenestration products when the solar irradiation is absolutely inverted. The (VPV IGU) can maintain the indoor environment at a relatively low temperature due to its excellent thermal insulation performance in summer.

- **As for the winter season**

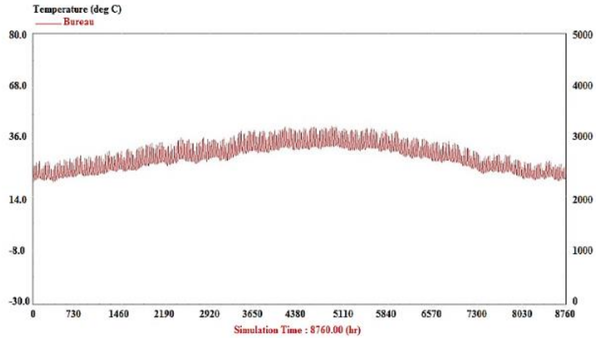
In the third case, using 75 % of the glazing in the contemporary facade of the building. A severe cold was recorded inside the office in the winter, which could cause a severe problem on the level of thermal comfort for workers. The temperature in the office exceeded 12.93 (°C) when using simple glass. But after our unremitting attempts to improve the temperature and reduce the intense coldness (reducing the energy consumption directed to heating the office). We replaced it with more resistant glass to prevent cold from entering through this simple glass inward, where a significant decrease in the degree of coldness reached -2.92 degrees Celsius. As the office temperature became a 15.85 (°C).

And when we wanted to confirm or deny the research hypothesis, which response to its problem and related to the possibility of using transparent interfaces for contemporary architecture in desert areas, but with the use of units (VPV IGU). Because this is the last, multi-role, the first of which is insulating and resistant to the passage of heat into the interior of the building. Secondly, producing electricity after converting it into the solar radiation into an electric current that contributes to covering the needs of office from electricity. Third, the attractive architecture side of this advanced technological material.

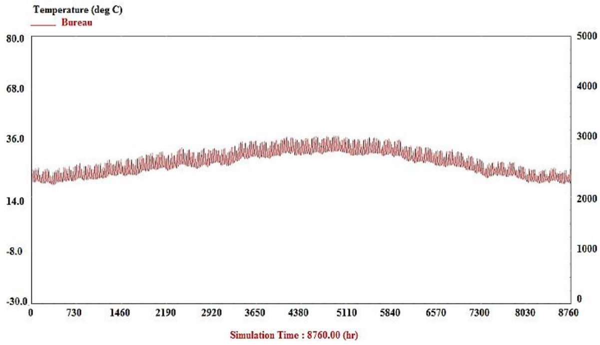
After incorporating the (STPV) into the facades, the temperature inside the office improved, where 18.2 (°C) was recorded in the winter. However, the temperature approached to 20.1 (°C) when using the VPV IGU units. That is, we recorded a fairly acceptable temperature compared to what it was when using clear and transparent glass and (VPV IGU), where we recorded an estimated variation in 7.17 (°C) between the maximum and lower temperatures and in the same dimensions of the glass (R = 0.75).



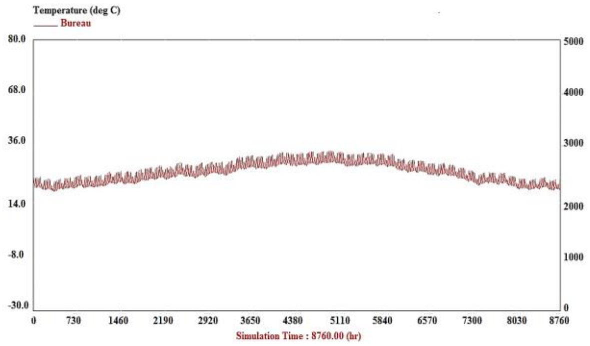
***(a)** In case of using the clear and simple glazing (Maximum and minimum annual temperature between 12.93C°- 47.92C°).*



***(b)** In case of using the clear and double glazing (Maximum and minimum annual temperature between 15.85 C°- 42.39C°).*



***(c)** In case of using the Semi-transparent photovoltaic (STPV). (Maximum and minimum annual temperature between 18.2 C°- 37.73C°)*



***(d)** In case of using the Vacuum Photovoltaic Insulated Glass Unit system (VPV IGU). (Maximum and minimum annual temperature between 20.10 C°- 33.02C°).*

Fig. 15 – The temperature inside an office building with different types of glazing (Case study -B- With R=0.75).

3.3 Power generation by the PV window system

Solar radiation reflected on the surface of the STPV and VPV IGU units consists of three sections:

The first part (i) is reflected outward. While the second part (ii) of this radiation crosses the glazing unit and is converted into direct solar heat. The other part (iii) is absorbed from these solar units and is partially converted either to electrical energy as well as thermal energy. As the percentage of production of electric energy manufactured and transferred by solar cells is mainly related to the efficiency of the electricity conversion of the cell.

Figure 16 shows the annual production of electricity produced by (STPV) and (VPV IGU) systems for different window dimensions (Ration). In this case, after performing the simulation process taking into consideration the following variables (orientations - Window Dimensions - Climatic Data). The amount of energy produced is estimated annually, for each of (STPV) solar system and (VPV IGU). Where we found that the (STPV) system produces an estimated 351.72 *kW*, 828 *kW*, and 1638 *kW* of electrical energy annually. And this amount of energy is mainly related to the dimensions of the window or the so-called glazing ratios, which were 0.25%, 0.5%, and 0.75%, respectively.

While this is a small amount compared to the annual quantities of energy produced by the (VPV IGU) system, which was estimated at 486 *kWh* for a window with a glazing rate of 0.25%, and 1035 *kWh* for a window with a glazing rate of 0.50%. While the highest amount of electric energy produced was from the share of the window with 0.75% of glazing rates. and was the amount of energy produced estimated at 1938.24 *kWh*. In other hand, we did not record any energy production in all cases, whether when using single clear glass, the same for double clear glass. From this, we strongly advocate the need to remove all the ordinary glass used in the façade of contemporary buildings and replace it with more resistant glass (VPV

IGU system). As the latter guarantees great electrical productivity for energy, and it is characterized by high thermal efficiency throughout the year.

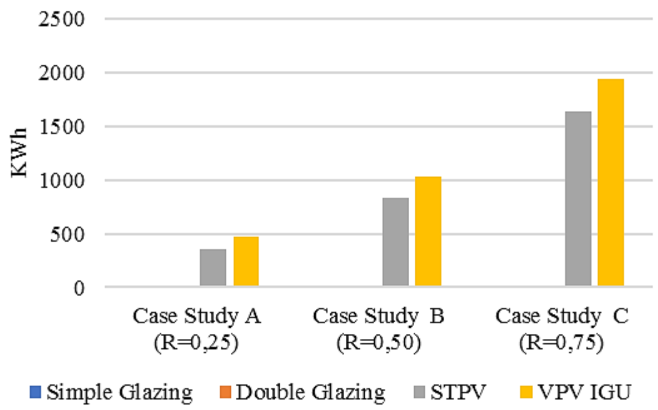


Fig.16 – Annual electricity production (kWh).

3.4 Daylighting performance

Windows are of great importance and a great role in the natural lighting and ventilation of air renewal, but it is necessary to choose the type of glass used in the window in a professional and thoughtful manner. Because this will also affect the degree of energy consumption in the building, either negatively or positively.

The figure below shows the total quantities of electricity consumed for office lighting for a year. The simulation was performed on four types of glazing used in office windows (same case study), but with the change in the dimensions and proportion of glazing in the window at a time (0.25, 0.50, 0.75). Since the greater the dimensions of the window, the lower the amount of electrical energy directed to artificial lighting.

Therefore, it may not need to turn on artificial lighting only rarely, and thus help us reduce the level of energy consumption directed to artificial lighting. Especially if the glass is transparent and colorless. Through our study and taking a glazing rate of 0.75, the office may not need to use artificial lighting, which is noted in the case C.

With the use of clear and simple glass, a decrease in the consumption of electrical energy was allocated to the lighting compared to the use of (VPV IGU). But with the use of ordinary glass in contemporary buildings it may cause a great glow to the user, which may negatively affect the visual comfort of it.

i. In the case of A and when R= 0.25,

A gradual increase in the amount of annual electrical energy consumption, after we recorded 12.24 *kWh* when using a single clear glass. Then 12.69 kWh after replacing it with double and clear glass. Which percentage of electrical consumption increased by 3.54%.

However, with the use of STPV and then the (VPV IGU) units there has been a relatively high percentage of annual electrical consumption of 13.41 *kWh* and 14.22 *kWh*, respectively. That is, the difference in energy consumption between them is approximately 5.69 %.

The difference in the energy consumption between the simple and transparent glass and (VPV IGU) reached 13.92%. However, compared to the effect of the simple and transparent glass on the annual electricity consumption directed to the cooling, this percentage is very small (c.f., case A in Fig.17).

ii. In the case of A and when R= 0.50,

After increasing the proportion of glass in the contemporary facade of the office, and its multiples to 50 %. A gradual decrease in the annual directed consumption of lighting. After using glass (VPV IGU), energy consumption recorded 12.24 *kWh*, but this consumption decreased by 3.67%, to become 11.79 *kWh*. This was after this glass was replaced by (STPV) glass.

The percentage of this consumption was increased gradually, to 11.34 *kWh*, then 10.62 *kW*. This is after using double glazing and normal clear glass, respectively. Finally, the decrease between the minimum (STPV) and the maximum (VPV IGU) for the annual directed electrical consumption of the lighting was estimated at 6.34% (c.f., case B in Fig.17).

iii. In the case of A and when R= 0.75,

When the glazing rate reached 75% in the façades of the contemporary building, the electricity used in the lighting decreased significantly. Especially when using single and clear glass, the space needed for electricity was only 7.83 *kWh*. Whereas when it was replaced by clear and double glass, the consumption increased to 11.33%. Meaning, this architectural office space needed 8.82 *kWh*.

However, after simulating the (STPV) system, then (VPV IGU), the electricity consumption used in lighting was recorded, 9.09 *kWh*, then 9.81 *kWh*, respectively. That is, the rate of this increase between them is estimated at 7.33%. While the percentage difference in the annual energy consumption increase in the artificial lighting between the clear glass and the one and (VPV IGU) was estimated at 20% (c.f., case C in Fig.17).

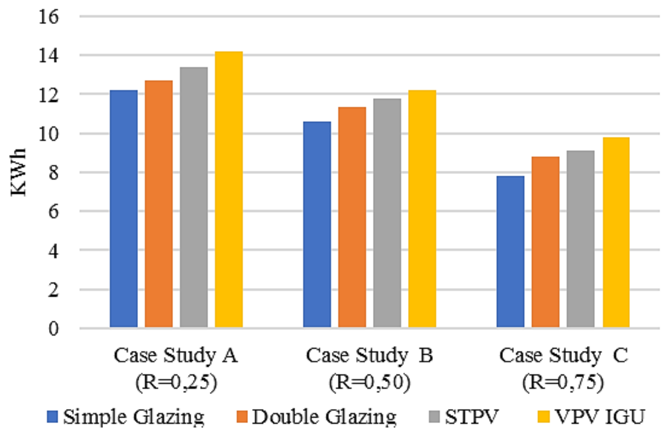


Fig.17 – Annual electricity consumption of artificial lighting.

3.5 Overall energy performance

The figure below shows comparative results of the annual total energy performance (total benefits of electricity), between different types of glazing (clear and single glazing; clear and double glazing; (STPV); (VPV IGU) with different dimensions of window glazing (Case A, R = 0.25), (Case B, R = 0.50), and (Case C, R = 0.75).

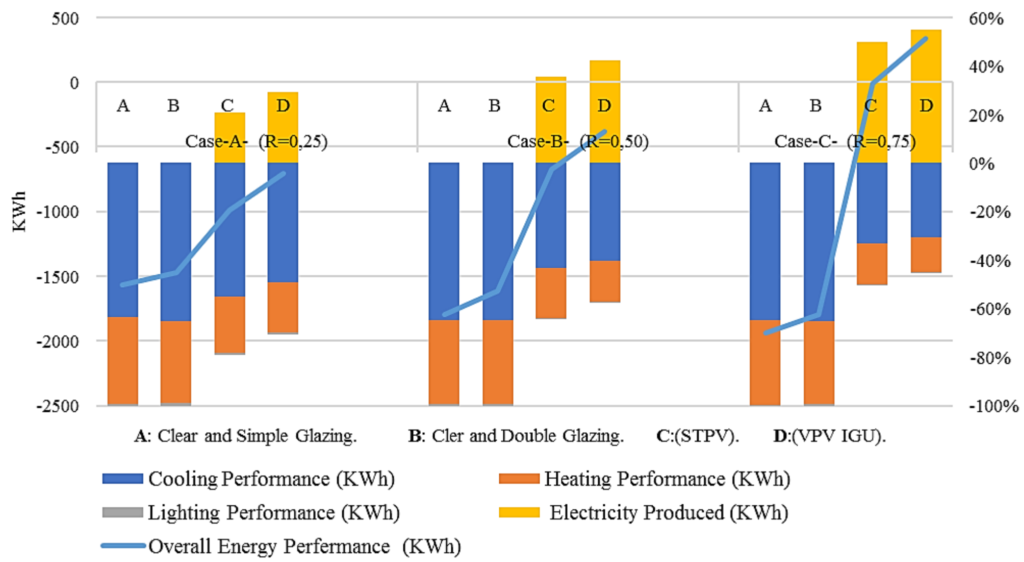


Fig.18 – Annual overall electricity benefits for different types and different Ration of system glazing (kWh).

The aim of this study is to choose the best quality glass from among these proportions while determining the most effective system. This is in order to contribute to finding a solution to the problem of excessive consumption of electrical energy and the problem of thermal comfort in contemporary architecture constructed in hot desert areas such as Bechar.

To calculate the total energy performance of the system, the total energy consumed in cooling is calculated (for cooling - heating - lighting). To know whether the system used is effective or not, it is necessary to calculate the difference between the total energy consumed (for cooling - heating - lighting), and the total green energy produced by the glazing system (solar energy).

- If the result of the difference is negative: in the sense that the system did not cover all the office's electrical energy needs, i.e. the glazing system used is a consuming system that is not produced. Or, it is a product of a weak degree that is not sufficient to cover all the office needs of electricity within a year.
- While the result of the difference is positive: this indicates that the vitrification system is characterized by excellent energy efficiency, i.e. the vitrification system used is a product system that is not consumed.

In other words, this system is a product of electrical energy to a large extent, which may suffice even to cover most or all of the office's electricity needs within a year. The excess (Unused) electrical energy produced can also be stored in dedicated batteries, for later use when needed. And in the case of low energy efficiency due to climatic influences such as high summer temperatures and low sunning in the winter season.

In the first case (R = 0.25), when using clear glass, the total energy consumed in the office is estimated at (Heating, cooling, and lighting) at 1570.95 kWh. However, when replacing this glass with double clear glass, it recorded a decrease in this office energy consumed to 1471.86 kWh and an estimated decrease of 6.3%. To improve the overall energy performance, a study was made of another type of energy-resistant, green glass, of (STPV) and (VPV IGU) units. So that after using (STPV) glass, the energy consumption decreased to become 994 kWh, and from that, the percentage decrease was estimated at 36.8% compared to transparent glass. The reason is primarily due to the production capacity of this glass (green electrical energy production), which contributed relatively to the office's electricity needs.

Where this system was able to provide about 351.72 kWh of the total energy needed by the office annually (heating, cooling, and lighting), which was estimated at 1345.23 kWh. So, this system was able to cover about a quarter of the total energy consumed. Whereas, after replacing this glass with a glazing unit (VPV IGU), this system produced electrical energy estimated at 495 kWh, increasing the coverage rate of the office's electricity needs and becoming 37%. The amount of energy required by the office annually (heating, cooling, and lighting) was estimated at 1335 kWh, it decreased to 706.5 kWh. This is mainly due to the fact that this glass (VPV IGU) is a producer of green electrical energy, which covered part of the energy needed by the office.

And after raising the ratio of the total area of the glass used in the interface to R = 0.75. By comparing its overall energy performance with the overall energy performance of the glazing ratio R = 0.50, an overall energy consumption increases of 7.53% and 9.77% has been recorded, respectively. That is, the amount of energy consumption became 1941.21 for one clear glass and 1793.25 kWh for double clear glass. On the other hand, the electrical power produced of the system (STPV) exceeded 828 kWh and 1638 kWh for the Ratio of transparency dimensions for windows R = 0.50 and R = 0.75, respectively. As for the glass (VPV IGU), this system was able to produce approximately 1125kWh and 1938.24kWh of energy, with respect to the following glazing ratios R = 0.50 and R = 0.75, respectively.

In the case of R = 0.50, both the glazing system (STPV) and (VPV IGU) contributed significantly to the overall energy performance, as they were relatively able to cover the office's energy needs. In addition, the glazing system (STPV) contributed to the provision of electrical energy estimated at 828 kilowatt-hours per year annually, after the total energy needed in the office (annually) was 1502,82 kWh per year.

Then it decreased to 674.82 kWh per year, and from it, we conclude that the glazing system (STPV) contributed to providing electrical energy in the office estimated at 55%. The Glazing System (VPV IGU) also managed to produce about 1035 kWh of office power, which reduced the amount of office energy consumed by 68.87%. After the office needed a total electricity capacity of 1258.38 kWh per year, it became in need of 384,12 kWh per year, only.

With increased transparency in the contemporary facade of the building by R = 0.75. And the Glazing System (STPV) covered about 99% of the total office power needed. This total energy (of cooling, heating, and custom lighting) is estimated at 1650.24 kWh. Whereas, this system produced an estimated 1638 kWh of energy.

Finally, the total electricity required for the office is only 12.24 kWh per year. As the office's total electric energy needs were 1597,14 kWh per year, and its total productive energy capacity (Glazing System (VPV IGU) is 1938.24 kWh per year, in this case, it was able to cover 100% of the office's energy needs. In addition, 341.1 kWh of excess capacity is stored (Stored in batteries).

4 Conclusion

In this paper, a case study was selected for a model office in a contemporary building with transparent and glazed façades, in a hot, dry desert climate such as Bashar. In order to evaluate the total energy performance (energy efficiency) of different types of glazing and compare them (clear glass and one; clear and double glass (STPV); (VPV IGU). In addition to that, the main objective of this is to compare the thermal performance (heating and cooling), daylight performance, and the degree of energy consumption and production (energy efficiency). This is for a contemporary office (case study) with windows with glazing of different proportions (R = 0.22, R = 0.20, R = 0,86). And by simulation software of (TRNSYS).

As the results of this comparison confirmed, the new glazing system (VPV IGU) is a unique and high-performance technology for development, and it has a great thermal insulation feature while providing high transparency in the facade of contemporary buildings. Moreover, new designs for building materials technologies (VPV IGU), an energy-efficient, low cost, and environmentally friendly solution for all types of buildings. After comparing the thermal performance of different types and ratios of glazing, and the annual consumption of electricity used for cooling. He found that VPV IGU-equipped office interfaces had the best thermal performance because VPV IGU had (U_{value}) and SHGC much lower than other glazing types of windows.

This is what made us record a noticeable decrease in the energy consumption used for office refrigeration with the (VPV IGU) system installed in the facade. Because it has Low glass with its low E coating, made it offer the best thermal performance and as an insulating building material and thus it is more resistant. And it shows its role in particular, in areas with a high level of solar radiation concentration, as well as for very hot desert climatic regions.

i. Firstly, after simulation studies, we estimated the energy consumed in the first case (R = 0.25), when using transparent and double glazing is 1570.95KWh. However, when replacing this glass with transparent double glass, we recorded a decrease in the energy consumed by heating, cooling, and lighting in the office to 1471,86 kWh, and this percentage decreased by 6.3%.

After using the STPV glazing system at the front of the office, we recorded a decrease in the energy consumed and estimated this decrease by 63.24% compared to the single and transparent glass. As this system was able to provide approximately 351.72 *kWh* of the total power required by the office, which was estimated at 1344.96 *kWh*. That is, the system was able to cover 26% of the total energy consumed within a year.

The (VPV IGU) glazing system produced 495 kWh of electric power, which is 29% better than the (STPV) in energy production (in the same conditions). (VPV IGU) Glass was able to cover the office's electricity needs by 41.2%. After the office's need for electricity was 1201.5 kWh, it became 706.5 kWh.

ii. Secondly, in the second stage of studies and with an increase in transparency in the contemporary facade of the building by R = 0.50. When using glazing (unproductive energy), the annual energy consumption in the office was estimated at 1794.96 *kWh*. When we use clear and only glass; But after the use of clear and double glass, the amount of energy consumed in the office decreased to 1617.93 *kWh*, and the amount of this drop was estimated at 177.03 *kWh*, i.e. the rate of decrease to 10%.

In addition, the (STPV) system reduced the amount of energy consumed in the office by 55.4%, meaning that the office needed only 674.82 kWh of energy annually. The (VPV IGU) system also managed to reduce the amount of energy consumed in the office more, by 70%, meaning that the office only needs 384.12 *kWh*.

iii. Third, in the last stage of studies, and with an increase in the percentage of transparency in the contemporary facade of the building, by R = 0.75. We recorded an increase in the amount of electrical energy consumed in the office to 1941,21 kWh when using single clear glass, and 1793.25 kWh when using double clear glass. That is, it decreased by 147.96 kWh, and we estimated this percentage by 7.62%.

(STPV) was able to cover 99.75% of the total office requirement, estimated at 1650,24 *kWh*. It (Dedicated energy for cooling, heating, and lighting), when this system produced 1647 *kWh* of energy. After that, we found that the total electrical energy needed by the Electricity Office became only 14.94 *kWh* annually. While the UGI VPV system was able to cover 100% of the office's energy needs, which was estimated at 1938,24 *kWh*, in addition to 341,1 *kWh* of extra power (stored in the batteries).

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