

Energy Efficiency in Building Based on the BIPV Panels System Used as a Double Skin Envelop in a Hot Arid Region

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Abstract –This paper aims to solve one of the energy issues using specific new building designs using the building-integrated photovoltaic (BIPV) panels as a double skin envelope. The BIPV system can be an innovative material for the building envelope during the design process as a: frame component, curtain wall or shading device. In addition to its power generation, the use of the BIPV can be an integrated part of the design of future envelopes and in the energy renovation of old buildings; these systems can produce renewable energy, minimize energy consumption, provide adequate indoor comfort and have less impact on the environment. As an external envelope of the buildings and a source of energy, the BIPV systems can represent the architectural appearance and aesthetic arrangements of the future building. Our investigation is based on an Energy report in many existing office buildings in a hot arid region of Algeria in order to assess their energy consumption, thereafter; calculate the energy yield after the BIPV hypothetical use in building architecture. The important result shows that the BIPV system enhances energy consumption with different percentages of the total energy consumption per year (Building sample 1: 50%, Building sample 2: 30% and Building sample 3: 65%) this is due to many architectural elements; such as: envelop form, shading devices, opening ratio, and environment masks. The major conclusion of the research reveals that The BIPV systems can preserve the architectural aesthetic appearance as well as enhancement of energy consumption.

Keywords –Building-Integrated Photovoltaic (BIPV); Double Skin Envelop; Energy Efficiency; Energy Report; Hot Arid Region.

I. INTRODUCTION

Much of the research and development into energy efficiency and renewable energy was sparked by the oil crisis of the 1970s. The design and construction of new buildings have benefited from government initiatives that promote and reward energy performance. However, growing living standards, economic development, and an increase in population have all resulted in higher energy usage and higher emissions. About 30% of energy use and 50% of electricity use are attributed to the building industry [1]. For the environment and human health, CO₂ emissions associated with

the use of this energy are becoming increasingly concerning. Buildings use at least 50% of the energy they use for space heating and cooling, and only about 10% of the energy is used for household hot water heating [2]. A development in this area could lower the energy consumption of buildings and the pollutants that contribute to pollution.

The integration of photovoltaic systems in architectural design processes, particularly at the facade level, continues to provide challenges in the present. Building integrated photovoltaic (BIPV)-vacuum systems hold promise for improved window applications because they can manage solar heat admission, limit heat transfer, and



produce environmentally friendly power [3]. The PV system could be utilized in part to charge an electric vehicle and supply extra electricity to the national grid [4]. Despite technological advancements in the solar panel sector, its incorporation as a component of building facades lacks credibility. Architectural styles like "high-tech" make it simple to incorporate this new energy producing technology. This trend's components are uniform, much as those in the photovoltaic sector. The PVs have primarily been used on rooftops, but because the entire roof area is insufficient, photovoltaic integration on building façades is also necessary [5]. The energy efficiency of a building for lighting, heating, ventilation, etc. is successful due to the huge external surfaces made available from the envelope once used and studied as the optimum approach to incorporate photovoltaic systems. This will allow for the energy-efficient performance of PV systems to be adjusted to the shape of the building [6].

II. PRESENTATION OF THE CASE STUDY

A. Selected Buildings

The experiment's chosen buildings had double-walls with air grape. The chosen building conditions are displayed in table 1 below.

Table 1. Buildings selected for the study

Building 1	Building 2
	

Both buildings share some geometric similarities such as: number of storeys, extroverted form, façade and wall regularity, windows size... etc.

B. The selected building conditions

The first building is a 4-story courtyard structure with a double-skin façade made of concrete (CPA, or communal popular assembly).

The second building is an enclosed structure with a large courtyard; it is a five-story office building with a concrete skin façade.

C. The measurement instrumentations

The study's setting is the city of Biskra in southern Algeria, which is located at an altitude of 34°48'north and a longitude of 5°44'east. It ascends 86 meters in height. This city has a hot, dry environment, and the temperature varies greatly throughout the day, night, and seasons. Keep in mind that there is significant thermal amplitude between the monthly maximum and minimum temperatures. The warm season is also marked by extremely high temperatures, which have an impact on the comfort of the users as well as the building's thermal behaviour.

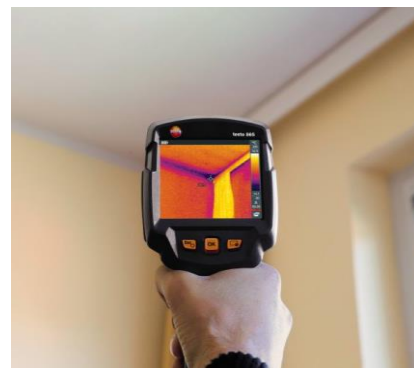


Fig. 1 Thermal camera "Testo 865".

III. MEASUREMENT RESULT DISCUSSION

Figure 2 displays the measurements for the double concrete wall in Building 1, the double wall built of glaze in Building 2, and a simple concrete interior wall. We measured for both building the outdoor air temperature (T_{ext}) and the internal surface temperature.

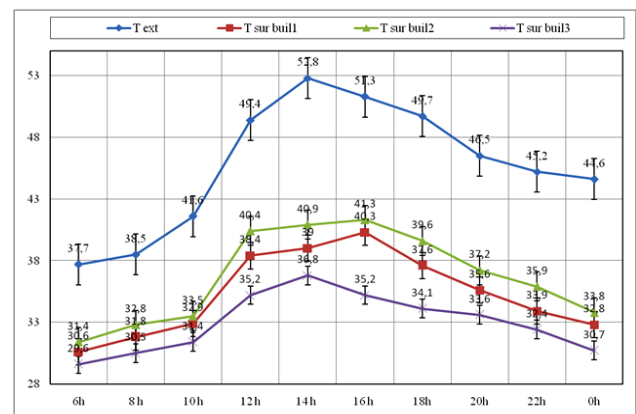


Fig. 2 External/interior surface temperatures of the external walls.

The (T_{ext}) is found to be high throughout the day, but notably after 12 am (at noon), when the

temperature reaches its peak of more than 50 °C. The interior surface temperatures of the double skin facade (T_{sur}-DSF) greatly outweigh the external temperatures when solar radiation is present, on the other hand. Although the metal's thermal properties seem improper for a hot environment, they have less of an effect in the real world. Buildings 1 and 2 with deep courtyards appear to improve the indoor thermal environment on hot summer days. The maximum value recorded is 52.7 °C at 2 pm, a difference of 13.6 °C (an increase of 25.8%) from the outside temperature, which has a significant impact on the thermal behaviour of the facade.

IV. PV PANELS' ENERGY POTENTIAL

Facades are now at the core of energy issues, and an early design process is now necessary as the integration of PV systems into buildings becomes a primary goal of achieving near-zero energy. Environmental issues can be solved by using clever adaptable modular PV facades that balance daylight and shadow [7] [8].

According to VSR, SSE, and RAS indices, table 2 below displays the energy potential derived from the investigated structures.

Table 2. Energy potential for the PV panels use in the selected buildings

	VSR (%)	SSE (m ²)	RAS (m ²)
B1	9	672,25	920
B2	13	813,33	897

VSR (volume/surface rapport (%))
 SSE(surface solar exposur (m²))
 RAS(roof available surface (m²))

Insulation lasts longer in hot, dry climates than in other climate types. Therefore, during the lengthy summer day, the PV module's efficiency may be higher. The fluctuation in temperatures, which lowers PV production, is a drawback of utilizing PV in hot weather [1] [9]. PV modules should typically have a cell temperature of no more than 25 °C for best performance (not the ambient temperature). According to a general rule, one module loses 0.5% efficiency for every degree Celsius that the cell temperature raises beyond 60 °C [10]. As a result, the PV should not be operating, leaving a space between the structures. Particularly in warmer climates, this gap shouldn't be less than 15 cm.

V. PV PANELS USE AS A STICK-SYSTEM CURTAIN WALLS

The facade's installation resembles the contour of the city. PV can be used to cover a huge area with high efficiency [6]. The verticality of the facade, which is typically oriented poorly and decreases efficiency, is the main challenge. The installation of photovoltaic panels on building facades has further benefits, as the panels can shield the structure from excessive solar radiation and serve as an alternative to the pricey coatings found on renowned structures [11]. However, it is possible to install the PV on an incline facade or to install the modules to increase their output [12].

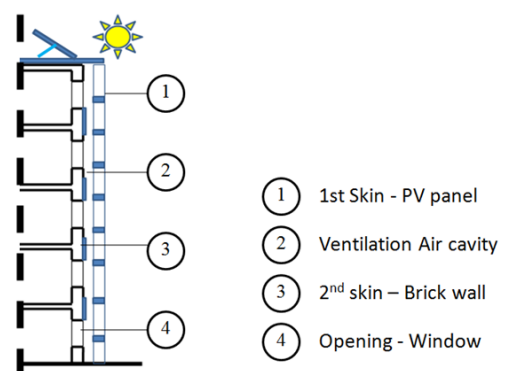


Fig. 3 Details of PV panels use as a stick-system curtain walls.

VI. ELECTRICITY OUTPUT GENERATED BY THE PHOTOVOLTAIC SYSTEM SUGGESTED

In order to determine the annual energy output of a photovoltaic solar plant (E); we have opted to calculate how much electricity a photovoltaic system will generate globally, using the following equation:

$$E = A * r * H * PR \dots \quad (1)$$

E = Energy (kWh)
 A = Total solar panel Area (m²)
 r = Solar panel yield or efficiency (%)
 H = Annual average solar radiation on tilted panels (shadings not included)
 PR = Performance ratio, coefficient for losses (range between 0.5 and 0.9, default value = 0.75)

The solar panel yield (r) is calculated by dividing the electrical power (in kWp) of one solar panel by the panel's surface area. As an illustration, the solar panel yield of a 250 Wp PV module with a 1.6 m² area is 15.6%. Remember that this nominal ratio is provided for standard test conditions (STC), which

include the following: radiation = 1000 W/m², cell temperature = 25 °C, wind speed = 1 m/s, and AM = 1.5. In these circumstances, the solar panel's nominal power is measured in "Watt-peak" (Wp or kWp=1000 Wp or MWp=1000000 Wp).

On tilted panels, the (H) represents the yearly average sun radiation. In Saudi Arabia, it ranges from 2600 kWh/m²/y to 200 kWh/m²/y in Norway. This worldwide radiation value is available (Solar radiation databases). The various E values for the building under study are displayed in table 3 below.

Table 3. Efficient rate and envelope available area values of the studied building

	A (m ²)	r (%)	E (kWh)
B1	324	31,59	199585,62
B2	542	52,84	558465,96

The figure 4 that follows contrasts the actual building 2 energy consumption with the monthly PV energy output of a photovoltaic solar plant (E).

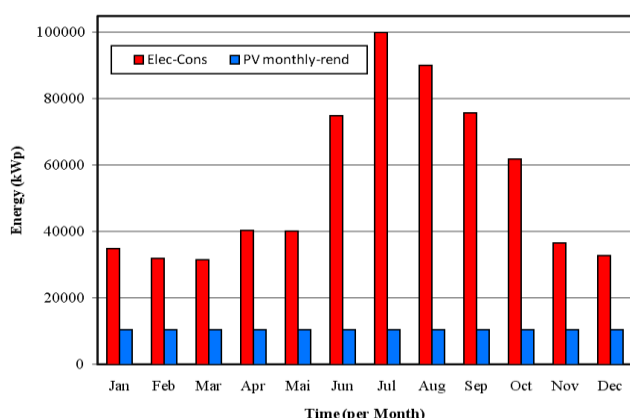


Fig. 4 PV yield decrease in the annual electric consumption (Building 2).

A growing demand for shade systems created with architectural goals is being driven by the current architecture's increased usage of wide window openings and curtain walls (fig. 6). Different-shaped PV modules can be employed as window shading elements or as a component of a suspended glazing framework [13]. The building's structural load shouldn't increase as a result of the use of photovoltaic blinds [14]. A growing synergy effect lowers the overall cost of such installations and adds value to the photovoltaic system, the building, and shading system. Unidirectional trackers are another option for PV shading systems that can be used to tilt the PV setup for optimal

power while offering various levels of shading. Our integrated ecosystem enables the integration of numerous PV application types into various building components.

VII. CONCLUSION

The major findings of an in situ study based on an empirical inquiry in existing buildings are presented in this publication. The study's objective is to assess how employing a courtyard and a double-skinned façade might improve inside comfort and energy consumption. After that, it looks into the usage of PV panels on the building's exterior to improve its energy efficiency. The findings show that integrated PV panels can be used in building envelopes in hot, arid locations to reduce energy consumption. Adding a courtyard can also improve the inner spaces' passive thermal comfort. As an external envelop, a sufficient system of integrated PV panels is advantageous for heat protection. This study opens up a number of avenues for further research into the potential for future energy rehabilitation of existing buildings, particularly those relating to the impact of the double skin facade's material choice on thermal comfort and energy efficiency.

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