PRESENTING AN ENERGY-EFFICIENT MODEL FOR THE ENVELOPE OF HIGH-RISE OFFICE BUILDINGS CASE STUDY: COLD AND DRY CLIMATE

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ABSTRACT

The expansion of high-rise buildings and vertical cities has made room for a significant potential for large areas in the envelope (façade) of buildings to produce the required energy. This opens the opportunity to conduct research about the city of Mashhad-Iran. This study aims to provide an optimal model of the envelope of an office building and maximum utilization of sunlight in providing energy and indoor lighting in cold and dry climates. DesignBuilder software, version 6.1.0.006, to simulate the building and Energy plus 8.9 simulator engine was used to compare the amount of energy consumed, and electricity generated. We evaluated the data by the analytical-comparative method. The results showed that ,in one year, the energy produced by model number one (#1) (27.6%) and model number two (#2) (18.7%), among other simulated models with 15% efficiency (base efficiency rate) regarding all solar factors used in them, the amount of the electricity generated manifests a significant difference from the total electricity consumption of the building studied, assuming that the percentage of electricity supply with the actual efficiency of the proposed solar factors, are 17.99% and 17.88%, in model (#1) and model (#2). Once compared the given results of the models used for the photovoltaic panels, photovoltaic solar glasses, and the occupied area by them, a direct impact on the efficiency and energy generation of the building model envelope was seen. So, this study paves the road for further use of new technologies of building-integrated photovoltaic (BIPV) for locations that have similar climate.

Contribution/Originality: This study documents that a rarely designed optimal model can be applied for the envelope of office high-rise buildings through integrated photovoltaic (BIPV) systems to optimize indoor daylighting and energy efficiency in Iran's cold and dry climate in order to enhance occupants' health, well-being and productivity towards a sustainable future.

1. INTRODUCTION

It is the abundance, cleanliness and availability of solar energy that makes it a long-lasting source of energy, also known as the most promising alternative, specifically for the Global Renewable (Sustainability) Plan (Siddiqui et al., 2017; Wang et al., 2018). Electricity can be considered as the heart of modern economies that offers an

increasing share of energy services. Due to increasing currents of electricity, transportation, heating, and a dramatic demand growth for digital communication gadgets, as well as air conditioning, electricity has become the utmost priority in humans' list of needs. Renewable energy here plays a principal role in providing electricity for everyone.

Buildings can be ranked among the leading consumers of energy and CO_2 emitters (Chen et al., 2012). High-rise buildings are large consumers of energy. They account for the dominant elements in urban architecture on account of their scale and purpose and therefore, environmentally friendly designs must be spotlighted. Many architects, engineers, and designers believe that properly designed and constructed buildings in large and dense cities can be a representation of sustainability progress and green architecture. Evidently, this belief has led them to minimize adverse factors affecting the environment to maintain the health and wellbeing of residents (Nouhi, 2000). Given the fact that the major part of sustainable development happens in the building sector, countless economic activities could be done to reduce greenhouse gas emissions in this sector (Borbon-Almada, Rodriguez-Muñoz, & Najera-Trejo, 2019). In case a solution is proposed, as long as it is economically viable and well-integrated into the existing architecture, we can expect a reasonable process of energy consumption. With the rapid decline in natural resources, the utilization of renewable energy solar for instance, is being the number-one alternative on the boil (Norton et al., 2011).

Based on IRENA analysis, solar PV power installations could grow almost six-fold over the next ten years, reaching a cumulative capacity of 2 840 GW globally by 2030 and rising to 8 519 GW by 2050. This implies that the total installed capacity of PV in 2050 will almost be eighteen times higher than it was in 2018 (IRENA, 2019). The use of photovoltaic (PV) panels or glass for PV facades has shown that it has a profound effect on the overall energy consumption of buildings, particularly through its efficacy on PV electricity generation, lighting, cooling, and heating (Jiang, Zhou, Lu, Han, & Wang, 2008; Miyazaki, Akisawa, & Kashiwagi, 2005).

Seemingly, a myriad of technologies now offers ways and alternatives for the very sake of reducing energy consumption in buildings and different forms of environmental pollution. A viable item among various developing technologies, building-integrated photovoltaics (BIPV) can play a role in reducing destructive environmental effects by converting sunlight into electricity (Chae, Jeehwan, Park, & Byungha, 2014). This system is one of the most effective methods for generating energy from the Sun (Radwan & Osama, 2016). Photovoltaic panels integrated with buildings not only generate electricity but are also part of the building (Eiffert, 2000).

In BIPV systems, PV cells replace conventional building materials and convert them into active elements (Henemann, 2008). BIPV systems replace some common building materials and components in building envelopes, such as roofs and facades. According to Peng, Huang, and Wu (2011) BIPV systems are either considered to be a functional part of building structure or architecturally integrated into building design (Peng et al., 2011). Hence, the BIPV system acts as a type of building material and envelope while simultaneously generating power (Strong, 2016). Building-integrated Photovoltaics (BIPV) is the integration of photovoltaic cells into different parts of a building. PV modules have double functions; they are both an alternative to the materials used in the building facade and an energy generator for the premises. Photovoltaic panels are integrated into the building to provide the following: solar protection, weather protection, sunlight modulation, thermal insulation, sound insulation, and security (Debbarma, Sudhakar, & Baredar, 2017). Figure 1 shows a global market point of view of integrated photovoltaic technology.

Predominantly, most building surfaces can fit for being integrated with photovoltaic modules. And they can be classified into four main categories: 1) index photovoltaics (including curtain wall products, spandrel panels, etc.), 2) ceiling photovoltaics (including tiles, skylights, etc.), 3) window photovoltaics (including glass laminates) -Glass, transparent thin films, etc.) And 4) photovoltaic awnings (including panels, louvers, curtains, etc.) (Maturi & Adami, 2018; Pester & Crick, 2013; Sonnenenergie, 2008; Stamatakis, Mandalaki, & Tsoutsos, 2016).
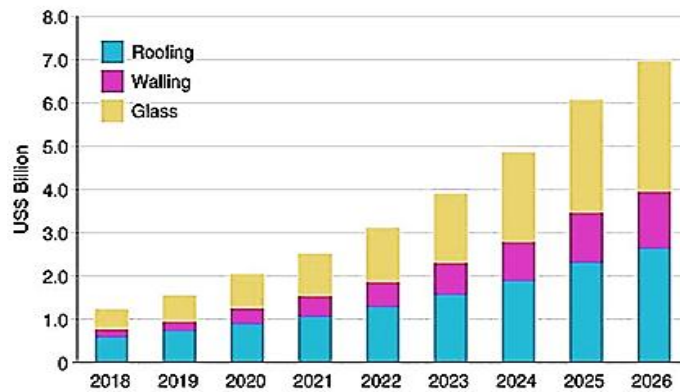
Figure-1. Global Market Outlook (2018-2026) About integrated thinking for photovoltaics in buildings.
Source: Ballif, Perret-Aebi, Lufkin, and Rey (2018).

Since the boundary is between the interior and exterior spaces of the building envelope, which plays an important role in the building's energy consumption, the building's covering studies report that half of the building's energy consumption is related to its cooling and heating (World Energy Resources, 2013). As for the sustainable design, the building envelope is evolving towards ecological and environmental compatibility and dynamic adjustability (Norton et al., 2011; Zawidzki, 2015).

Facade is the main component of a building and so defines its appearance. It acts as a barrier between the interior and the exterior space. The facade is a shield against sun exposure and reduces heating/cooling loads, therefore, enhances daylight distribution (EU, 2010; Nagy et al., 2016). The building's facade separates the interior from the exterior part. Yet, that must also transmit reasonable light to the inside and create an efficacious connection between the two spaces (Debbarma., Sudhakar, & Baredar, 2017).

Appling BIPV to urban areas facilitates the absorption and conversion of solar energy via buildings' envelope for integrating with the photovoltaic module. The use of BIPV in the facade of modern buildings has become common in countries with higher latitudes (Jiang et al., 2008; Lam, Li, & Cheung, 2003). Although solar radiation in vertical surfaces is much lower than horizontal ones (Khoo et al., 2013) applying roof installations are limited (Xu, Reed, & Reindl, 2016) and facade installations should be used as a means of generating electricity from renewable energy sources (Hachem, Athienitis, & Fazio, 2014). Hence, the BIPV system acts as a type of building material and shell which generates power at the same time (Strong, 2016).

Accordingly, high-rise buildings -the main consumers of energy in urban areas- should serve as a site for solar PV. The facade of high-rise buildings offers an excellent opportunity to use solar PV (Aseem, Sharma, & Kothari, 2017). Solar PV facade is aesthetically pleasing, generates electricity, and contributes to better building energy performance. Transparency in solar PV facades has been seen by distances between solar cells or through thin-film solar cells. Light works can also create beautiful patterns in this context (Agrawal & Tiware, 2010; Sombsthay et al., 2019; Vats & Tiwari, 2012). To see or receive daylight, integrated transparent and semi-transparent solar photovoltaic glasses could be replaced with ordinary windows (Munari et al., 2013). Office buildings are more suitable for BIPV applications because the panels generate electricity at approximately the same activity hours as the building (Lam et al., 2003).

Building-integrated photovoltaics contain many benefits, one of which is a cutback on construction and labor costs, compared to a building where photovoltaic cells were installed after the construction. The growing interest in BIPV is thanks to the fact that many countries today have turned to achieve near-zero buildings with no energy consumption. For BIPV systems to be versatile, several factors must be taken into consideration, including the temperature of the photovoltaic modules, the shade, the installation angle, and the rotation angle. Among these

factors, the most important is the radiation and the temperature of the photovoltaic, because both, depending on the installation location, affect the electrical efficiency of the BIPV system and the energy performance of the building (Peng et al., 2011). Figure 2 shows an example of a BIPV facade of a high-rise building.

Figure-2. BIPV façade.
Source: Debbarma et al. (2017).

In this study, maximum sunlight efficiency to generate electricity and provide indoor illumination by using outdoor daylight in cold and dry climates, were simulated models for the envelope of a high-rise office building. The aesthetic dimension and use of new technologies with the minimum changes in the current structure of the existing building was considered, too.

2. RESEARCH BACKGROUND

In recent years, demand for new sources of sustainable energy has become one of the most challenging topics in global research (Chu & Majumdar, 2012; Eslami, Gholami, Bakhtiari, Zandi, & Noorollahi, 2019). That is due to the growing energy consumption worldwide. Industrialization and rapid growth of the global population have accelerated the search for applied renewable energy sources, with finding alternatives for fossil fuels as its ultimate goal (Kılkıs et al., 2019; Whiting, Carmona, Carrasco, & Sousa, 2017). However, the multiplying demand from all over the world has led to a global pressure regarding energy consumption, suggesting that fossil fuels and sources must be replaced by low-cost, renewable ones by the means of fresh technologies in this domain (Kotilainen, Saari, Mäkinen, & Ringle, 2019; Ostergaard, Duic, Noorollahi, Mikulcic, & Kalogirou, 2020). Owing to a lack of land resources, urban areas are witnessing the growth of high-rise buildings. These crowded buildings are the leading consumers of energy (Aseem et al., 2017) so the need for local clean energy production is high (Poder, 2018).

For years, active solar technologies were merely being used as mechanical systems for electricity generation installed on buildings. Although some proposed solutions to create comfort in interior areas, hardly any attention was paid to their design and their combination with the architecture of buildings (Cappelletti, Nelli, & Reatti, 2018). Since an adaptive facade is not a new issue for building skin sustainability, they have gone through various stages since the beginning of the 20th century (Tabadkani, Valinejad Shoubi, Soflaei, & Banihashemi, 2019).

Radwan and Osama (2016) concluded that management of building envelope design and materials leads to a significant decrease in energy consumption Radwan and Osama (2016). Heinstein, Ballif, and Perret-Aebi (2013) examined BIPV and solar panels as a typical cladding system for an integrated curtain wall and monolithic façade and articulated its advantages as an intelligent method (Heinstein et al., 2013). Semi-transparent and transparent PV in double or triple glazed elements have been used for building integration in the form of windows' photovoltaic glasses, which in addition to electricity generation, could let daylight into the building (Munari et al., 2013).

Springer et al. simulated the power generation in a building integrated with photovoltaics systems. Their study showed that the result of that integration as a component of thermal insulation in building coating as the electrical

generation characteristics of the photovoltaic systems is well understood (Sprenger, Wilson, & Kuhn, 2016). Yang and Burnett (2000) simulated and showed that by replacing a traditional wall with a BIPV wall, the cooling load could be reduced from 33 to 50% (Yang & Burnett, 2000). Norton et al. mentioned that the net cost of installing such a system is much lower than a conventional photovoltaic system (Norton et al., 2011).

Lu and Law investigated the overall energy performance of a PV window, and the result showed that the proposed window was able to reduce the heat gain by 65% (Lu & Law, 2013). Ng, Mithraratne, and Kua (2013) studied the energy-saving potential of BIPV was achieved with different BIPV and gained an energy-saving potential of 16.7–41.3% technologies (Ng et al., 2013). Miyazaki et al. investigated that amorphous silicon (a-Si) double-glazed PV windows in their optimal configuration (40% solar cell transfer and 50% window-to-wall ratio) could reduce total building electricity consumption by 55% compared to single-glazed windows (Miyazaki et al., 2005). Didoné and Wagner (2013) Performed extensive simulation to estimate the available annual daylight and the energetic performance of various window systems. Generally, the PV window offers the best energy performance for all facades, except for those with less solar radiation (Didoné & Wagner, 2013). Li et al, studied daylight, solar radiation, and energy consumption fora-Si transparent photovoltaic, and showed a decrease in electric lighting and cooling energy requirements (12% per year) and an increase in environmental benefits such as CO_2 reduction as results., SO_2, NO_x) (Li, Lam, Chan, & Mak, 2009). Also, the results of Karamenis and Skandalos's study showed that translucent photovoltaics effectively reduce energy consumption in buildings (Skandalos & Karamanis, 2015). Debbarma. et al. (2017) investigated that the use of transparent amorphous silicon (a-Si) thin film and its integration with the building in the windows that cover the front part of the building by changing the location of the building in terms of azimuth and reducing shadows revealed an up to 47% efficiency and improved energy production (Debbarma et al., 2017). Mirshojaeian, Saradj, Maddahi, and Ghobadian (2020) simulated building façades and compared the result of the window-to-wall ratio, building materials, and façade thickness between traditional-indigenous and modern building façades (Mirshojaeian et al., 2020).

According to a study conducted by Mirshojaeian et al. (2020) in Iran, the construction sector has a large share in energy consumption, meaning that the use of cheap energy and lack of proper thermal insulation for buildings, which leads to energy loss. It is of utmost importance to pay attention to this critical issue and find solutions for envelope design to reduce energy loss. The basic parameters in the performance of the outer shell of buildings are heat flow, air and humidity movement, air infiltration, solar energy, and natural illumination (Mirshojaeian et al., 2020).

The main research questions posed in this paper are as follows:

- How to provide maximum efficiency of sunlight in providing energy and interior lighting by an optimized model of an office building envelope?
- What feature in modern solar technologies, increases the focus on their use in high-rise buildings envelope to benefit from sunlight?

Based on the hypothesis set in this paper, it seems that by presenting an optimal model for the exterior shell of a high-rise office building, with the efficiency of renewable sources and reduction of environmental pollutants, it is possible to generate electricity while reducing artificial light consumption by using daylight.

On the other hand, assuming the efficiency of new solar technologies for producing electrical energy and maximum use of the facade area of today's high-rise buildings, without the view and landscape being limited, more efficiency of daylight and decrease in energy consumption can be seen.

Since Mashhad is a city situated in Iran, at latitude of 56 18 36 N and 34 59 E, cold and dry climate, and with average daylight hours during a year respectively 4.8 hours and 11.6 hours, this study aimed to optimize the facade of the YAS administrative-commercial tower in Mashhad, its daylight efficiency, and hence, electricity generation. Figures 3, and 4 show the south façade and azimuth of YAS Tower as the research case building.
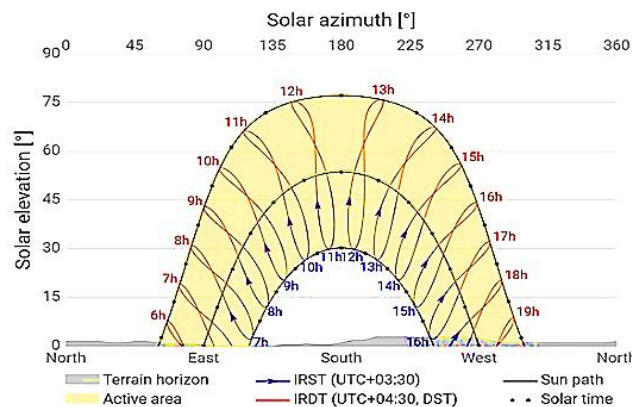
Figure-3. South facade of YAS Tower

Source: http://www.ghaffari-trade.com

Figure-4. Azimuth of YAS Tower.

Source: https://globalsolaratlas.info/map.

3. RESEARCH METHODOLOGY

This research has been conducted based on high-rise office building envelopes in the cold and dry climate of Mashhad, Iran. The research method was an analytical comparative approach by the printed sources found in the library, reliable internet scientific sources, and reviewing similar research. The geographical location of the case study suggests that the southern view is more suitable for benefitting from solar technology. In addition, two models were applied for the south facade of the business-office tower simulation by Design Builder software version 6.1.0.006, with the Energy plus 8.9 simulator engine. The models were proposed based on the applying transparent photovoltaic glasses and monocrystalline photovoltaic. Also, minimum changes and degradation in the existing building were considered. Models were proposed based on the use of transparent photovoltaic glasses and monocrystalline photovoltaic. Also, minimum changes and degradation in the appearance of the existing building were taken into consideration. This simulation has been performed assuming that the solar system is passive and on-grid, as well as all integrated photovoltaics, have equal efficiency (15% efficiency). Energy consumption and electricity generation in the building were measured and calculated over a one-year period.

Then, based on the type and area of photovoltaics integrated with different parts of the building, efficiencies have undergone calculation for each model. Following that, through creating a proportionality between the data obtained from the electricity amount produced by each model in DesignBuilder software (with 15% efficiency) and the actual efficiency calculated by the same models, based on the efficiency of the proposed photovoltaics, the electricity generation amount for each was obtained and the results were evaluated.

4. DISCUSSION

4.1. Model Hypotheses

This research has been conducted in cold and dry climates to investigate the electricity generation and efficiency of daylight in the photovoltaic facade. The DesignBuilder software has been used to evaluate the performance of the photovoltaic system in electricity generation. The cooling and heating system of the fan coil building has two pipes. The engine room equipment included a condensing boiler and a compression chiller. The thermal and refrigeration terminals of the building are ceiling fans with a water flow control valve in each room. Therefore, the temperature of each room can be controlled specifically. In the simulation of the building, the number of people, equipment, lighting system, as well as their performance is set by the template thanks to the Design Builder software standards. The heat transference Coefficient for the outer layer is 0.714 W/m. K and for the ceiling is 0.674 W/m. K.

4.2. Solar Materials

4.2.1 Low-E Photovoltaic glass

In this research, Low-E photovoltaic glass with 20% transparency, an efficiency of 3.4%, and maximum energy generation of 34W/m. K has been employed because of the importance of internal daylight and maintaining the view of windows and curtain walls. The configuration and technical specification of the photovoltaic glass with 20% transparency have been defined.

4.2.1.1. Configuration and the Standard Thickness of the 20% Low-E Photovoltaic Glass

Thickness Configuration (mm): 6T+3.2F+0.76a-Si+0.76P+6T/12Argon/6T LOW-E

Total Thickness: 16.72 mm

SHGC (%): 12%

U value m^2 (W/m^2K): 1.2

U value ft^2 (Btu/ft^2 F): 0.21

External Light Reflection (%): 7.3%

Transparency (%): 20.0%

Peak Power (Wp/m^2): 34

4.2.2. Monocrystalline Photovoltaic

In some spots of the building where internal daylight is not of much importance, the main alternatives like curtain wall frame, sealing, rooftop side of the pool wall and window O.K.B are the means suggested for the simulation models for the efficiency of the solar light. Monocrystalline panels with maximum energy generation of 500 Wp/m2 and maximum efficiency of 20.7% were used. Below, monocrystalline silicon photovoltaics, technical specifications have been shown

4.2.2.1. Technical Specifications of Monocrystalline Photovoltaic Panels

Peak Power Watts-P_{MAX} (Wp): 500

Power Tolerance-P_{MAX} (W): 0 ∼ +5

Maximum Power Voltage-V_{MPP} (V): 43.4

Maximum Power Current-I_{MPP} (A): 11.53

Open Circuit Voltage-V_{OC} (V): 51.5

Short Circuit Current-I_{SC} (A): 12.13

Module Efficiency η_m (%): 20.7

4.3. Suggested Models for Integrated BIPV in Cold and Dry Climate

Tables 1, 2 and Figure 5 have rounded up the information of similar sections in both models that were covered with LOW-E solar photovoltaic glass with 20% transparency and monocrystalline photovoltaics.

Table-1. Information about southern facade and the area covered with LOW-E photovoltaic glass with 20% transparency in both models.

Place of the LOW-E photovoltaic glass with 20% transparency	Area (m²)
Small windows at right and left arm of the southern facade	824.166
Suspended windows in the middle of the southern facade	118.656
Both senary glassy parts in both low sides of the pool	52.08
Both parts are individually glassed, at the top and both sides of the pool	17.228
Vertical and horizontal part of the curtain wall	672.055
South view of the pool wall	244.7

Table 2. Numbers of monocrystalline photovoltaic Panels in common with two models.

Specified part to monocrystalline photovoltaic panel	Numbers of used panels
Pool ceiling	160
South view of the pool wall	57
Horizontal curtain wall frame	81
Vertical curtain wall frame	108

4.3.1. Equations for Calculating the Efficiency of Models

Total efficiency percentage equation of models:

$$E\% = \frac{P_t\ (W)}{A_t\ (m^2) \times 10}$$

Area monocrystalline photovoltaic panels' equation for models:

$$N_P \times A_p\ (m^2) = A_{tmp}\ (m^2)$$

Total power generated by the monocrystalline photovoltaic panels' equation for models:

$$N_P \times P_m\ (Wp/m^2) = P_{mp}\ (Wp/m^2)$$

Equation Power generated by the LOW-E photovoltaic glass with 20% transparency in each model:

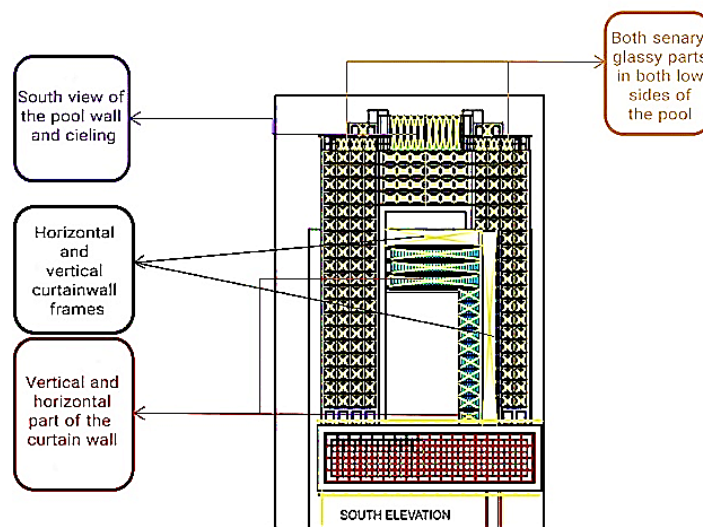$$A_{tpg}\ (m^2) \times P_m\ (Wp/m^2) = P_{pg}\ (Wp/m^2)$$

Figure-5. Model (#1).

92

4.3.2. Model Number One (#1)

LOW-E photovoltaic glasses with 20% transparency has been opted for windows in the southern facade of the "YAS" tower to use the most of solar energy and lower energy consumption and artificial light for internal illumination. The allocated sections to solar factors are identified with a cross mark (×) in Figure 5, and the details are in Tables 3 and 4.

Table 3. Areas of the dedicated parts to the model (#1) solar factors.

Dedicated parts to the monocrystalline photovoltaic panel	Numbers of the used panels
Pool ceiling	160
South view of the pool wall	57
Horizontal curtain wall frame	81
Vertical curtain wall frame	108
Total panels	406

Table-4. Area of the dedicated sections to the solar factors in model (#1).

Dedicated sections to each solar factor	Area (m²)
Total sections dedicated to LOW-E photovoltaic glass 20%	1684.185
Total sections dedicated to monocrystalline photovoltaic panels	978.46

The simulation results in DesignBuilder show that this building is using 162118 cubic meters of gas and 2785353 kWh of electricity power with the model number one envelope, for one year. By using the numbers of photovoltaic panels mentioned in the table with 15% efficiency, we can generate 769084 kWh of electricity annually. In this case, 27.6% of the building's power consumption can be supplied with the photovoltaic system Table 5.

Table-5. Summary of results KWh with 15% efficiency of model (#1).

Months	Generated electricity	Received radiation	Heating system energy	Cooling system energy	Total energy of the heating and cooling systems
Jan	62062	108245	530811	0	530811
Feb	58578	110793	302232	0	302232
Mar	61155	131206	143743	0	143743
Apr	61119	148813	0	73604	73604
May	60174	175030	0	216190	216190
Jun	58813	184208	0	325333	325333
Jul	63839	193059	0	401366	401366
Aug	72644	189833	0	344154	344154
Sep	79445	174979	0	225907	225907
Oct	73255	144186	0	91961	91961
Nov	59055	106955	244639	0	244639
Dec	58944	100419	464601	0	464601
Total year	769084	1767726	1686025	1678515	3364540

Power generated by the allocated section to the LOW-E photovoltaic panel with 20% transparency with 3.4% efficiency and 34 Wp/m² maximum power generation is:

$1684.185 \times 34 = 57262.29$ Wp/m²

The area of the photovoltaic panel in model number One is:

$406 \times 2.41 = 978.46$ m²

Power generated by the allocated section to the LOW-E photovoltaic panel with 20% transparency, with 20.7% efficiency, and 500 Wp/m² maximum power generation is:

$406 \times 500 = 203000$ Wp/m²

Calculation of the total efficiency for model number One is:

$$\text{Model one efficiency \%} = \frac{2602.29(W)}{2662.645(m^2) \times 10} = 9.87\%$$

The amount of the generated electricity by model (#1) is annually 501442.768 KWh with making an electrical analogy with 15% efficiency (due to the panel type) and the suggested photovoltaic glass with 9.78% real efficiency within the simulation.

4.3.3. Model Number Two (#2)

Model (#2) is the same as model (#1). The left and right wings of the building are the only difference. For O.K.B, monocrystalline photovoltaic is used in two wings, also their windows glasses are not photovoltaic. The dedicated sections to solar factors are identified with a cross mark (×) in Figure 6 and detail in Tables 6 and 7.
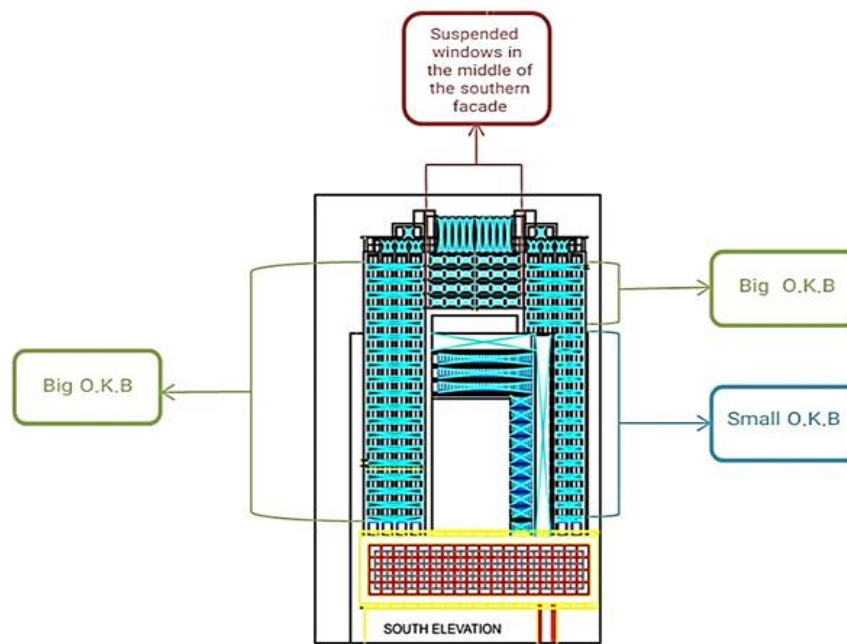

Figure-6. Model (#2)

Table-6. Areas of the dedicated parts to the model #2 solar factors.

Dedicated sections to each solar part	Area (m²)
Total section dedicated to LOW-E photovoltaic glass with 20% transparency	860.019
Total section dedicated to monocrystalline photovoltaic panel	1484.54

Table-7. Dedicated section to monocrystalline photovoltaic panel and their number in model (#2).

Dedicated parts to the monocrystalline photovoltaic panel	Numbers of the used panels
Pool ceiling	160
Pool side wall	57
Horizontal curtain wall frame	81
Vertical curtain wall frame	108
Big and small O.K.B in right and left arms of the southern facade	210
Total panels	616

The results given by simulation for model (#2) envelope are 162118 cubic meters of gas use and 2785370 kWh electricity used annually. By using these many panels with 15% efficiency, we can generate 521814 kWh electricity annually. In this case, 18.7% of this electricity can be generated with the photovoltaic system Table 8.

Table-8. Summary of the KWh results with15% efficiency for model (#2).

Months	Generated electricity	Received radiation	Heating system energy	Cooling system energy	Total energy of the heating and cooling systems
Jan	37935	108245	530811	0	530811
Feb	36837	110793	302231	0	302231
Mar	40728	131206	143742	0	143742
Apr	42826	148814	0	73605	73605
May	45390	175030	0	216193	216193
Jun	45965	184209	0	325336	325336
Jul	48843	193059	0	401369	401369
Agu	51970	189833	0	344157	344157
Sep	52589	174980	0	225910	225910
Oct	46482	144186	0	91962	91962
Nov	36519	106955	244639	0	244639
Dec	35729	100419	464601	0	464601
Total year	521814	1767729	1686025	1678532	3364557

Calculation of the total efficiency for model number Two:

$$\text{Model two efficiency \%} = \frac{337240.646(W)}{2344.559(m^2) \times 10} = 9.87\%$$

The amount of the generated electricity by model (#2) is annually 499202.06 KWh with making an electrical analogy with 15% efficiency (due to the panel type) and the suggested photovoltaic glass with 14.38% real efficiency within the simulation.

5. RESULTS

As per Table 9 of Figure 7, the comparison of the results obtained from the two proposed models with the same efficiency for both models, which is 15%, the highest generation of electricity is feasible with model (#1), with generated electricity amount of 769084 kWh. After that, model (#2) comes in line, with generated electricity, 521814 kWh per year.

Table-9. Summary results of the amount of electricity Generated with 15% efficiency.

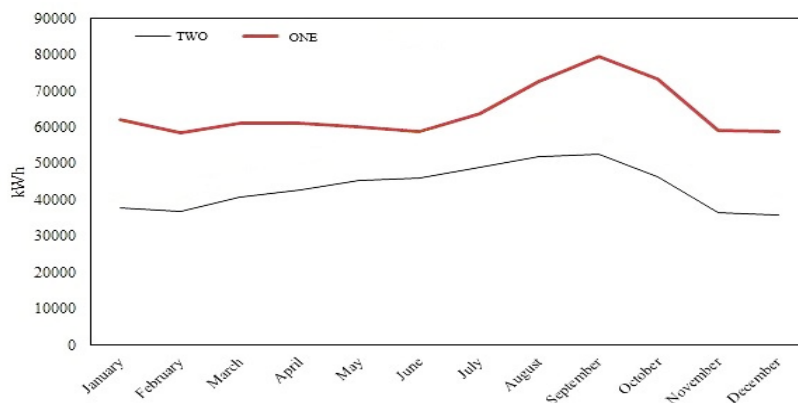| Model	Generated electricity KWh	Percentage of electricity supply of total KWh
One	769084	27.6
Two	52181	18.7

Figure-7. Comparison of electricity generation results of Proposed models with 15% efficiency.

According to Table 10 and Figure 8, the comparison of the results obtained from the two proposed models with different calculated efficiencies showed that the highest generation of electricity happens with model (#1), with generated electricity amount of 768/501442 kWh. After that, model (#2) is in line, with generated electricity amounting to 4999,062 kWh annually.

Table-10. Summary results of the amount of electricity generated with the calculated efficiency.

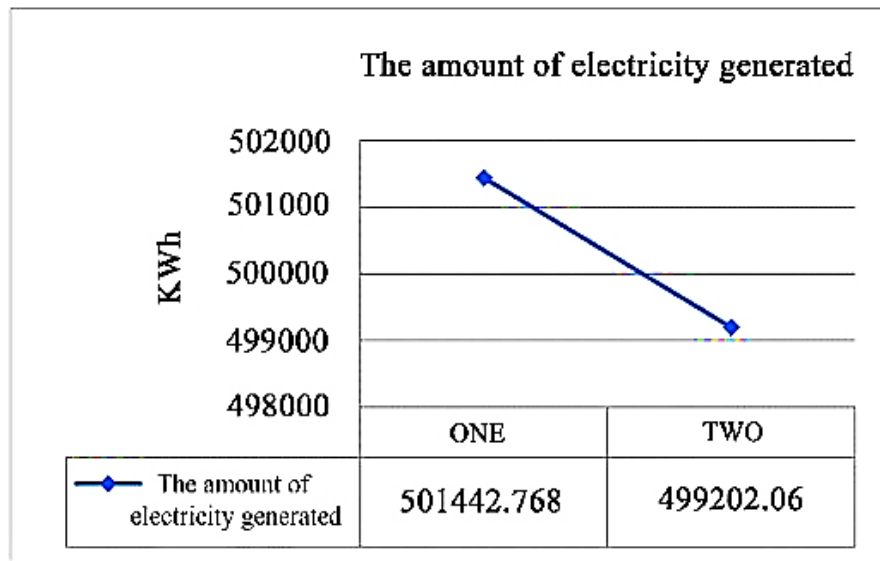| Model	Generated electricity KWh	Percentage of electricity supply of total KWh	Efficiency
One	501442.768	17.99	9.78%
Two	499202.06	17.88	14.38%

Figure-8. Comparison of electricity generation results of Proposed models with calculated efficiency.

6. CONCLUSIONS

The transition to zero-energy buildings to reduce macro and micro-climate changes, can be realized only when advanced steps are taken in building materials, using renewable energy instead of fossil fuel energy sources. In this context, cooling and lighting loads have gone down significantly, while generating electricity, and energy-saving potentials have increased.

Consequently, PV systems can be a good choice. The results of examining the models with 15% efficiency and the calculated efficiency based on the type of photovoltaic glass and photovoltaic panels, showed that, in both cases, model (#1) generates the largest amount of electricity. However, the observed difference in electricity generation for model (#1) and model (#2) with the same efficiency (15%) triumphs over those with calculated efficiency.

Therefore, in addition to climatic factors, the angle of radiation, the intensity of sunlight, shading of adjacent buildings, and keeping the panels clean, the following three factors in the amount of electricity generated by the building that the envelope is effective for utilizing daylight and generating electricity with coated photovoltaic panels are as such:

1) The total area allocated to panels and solar agents to generate electricity.
2) Type and efficiency of panels.
3) The area in which each type of panel, with its efficiency, occupies the total area of the envelope.

Based on our findings for the question put by this research, we can declare that a vast variety of options come at hand once the optimal model presented and new generation photovoltaics are used, compared to their installation and application in the envelope of the building.

Invariably, the results suggest that by using new technologies and combining solar photovoltaics with transparency and double-glazed capabilities -which cause low heat transfer and prevent the penetration of harmful solar radiation (Infrared and Ultraviolet rays) -with monocrystalline photovoltaics and also, appropriate design for their placement in the envelope of high-rise office buildings, even built, and existing buildings, caused the envelope to be optimized.

And still, it performed maximum efficiency of daylight with the supply of electrical energy. Finally, it reduced energy consumption by applying minimal changes to the existing structure of buildings. Likewise, this may allow us to go further in the domain of promoting new solar technologies application in similar geographical locations and cold and dry climates by reducing installation and implementation costs.

Abbreviations

E%	Efficiency percentage (W)	PV	Photovoltaic
NP	Numbers of panels	BIPV	Building-Integrated Photovoltaics
Ap	Area of each panel (m2)	O.K.B	Ocopenci Kingstone Benchmark
Atpg	Area of the total photovoltaic glasses with 20% transparency (m2)	LOW-E	Low Emissivity
Ppg	Power generated by the photovoltaic glasses (Wp/ m2)	T	Tempered Glass
		F	Float Glass
Pm	Maximum generated power (Wp/m2)	P	PVB (Polyvinyl Butyral) Foils
Pt	Total power of the photovoltaic glass and panels used for each model	a-Si	Amorphous Silicon Thin Film Solar Cells
Pmp	Power generated by monocrystalline panel (Wp/m2)	SHGC	Solar Heat Gain Coefficient

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