PV-glass Interfaces for the Syndicate of Engineers Building in Latakia

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Abstract

Building Integrated Photovoltaics (BIPVs) systems are a promising and innovative technology that has gained significant attention in the last decade. These systems aid buildings in meeting their energy demands, thereby addressing the rising energy needs. This case study was conducted on the Engineers Association Branch in Latakia.The experimental method was used to calculate the needed electrical loads, it was found that replacing 74m² of south-facing traditional glass windows of the Syndicate of Engineers building, with polycrystalline photovoltaic windows (P-Si), will produce 59.2 kilowatts, which is a sufficient amount to cover the total electrical load for the lighting and the operating office equipment, this mean to have a zero-energy building over a period of 30 to 35 years, in addition to save 65000kg of CO2 for the 30 later years. This study is particularly important in Syria's reconstruction phase, which will involve the construction of numerous tower buildings with large glass facades, where space for installing solar panels may be limited on the roofs, Therefore, the integration of solar panels in the facades is the ideal solution to cover the needed loads.

Keywords: Building Integrated Photovoltaics (BIPVs); Polycrystalline; Photovoltaic windows; Solar energy; Renewable energy; Zero energy-building; CO2 emissions; BIM; Sustainability

1. Introduction

Among all renewable energy sources, solar energy is regarded as the most promising candidate and is expected to be the foundation of a sustainable energy economy, as sunlight is the most abundant renewable energy resource [1,2,3]. The solar photovoltaic (PV) systems might be superior to other renewable energy types, because they produced no noise [4], and only a little operation and maintenance needs [5], with no direct pollution or depletion of resources. Thus solar power is growing more rapidly than any other form of the renewable sources technologies [6,7].

Buildings take nearly 40% among total energy consumption [8,9]. For buildings, energy exchange through windows accounts for over 50% by means of conduction, convection, and radiation. To reduce energy consumption, new structures should be developed for glass surfaces to enhance their

Doi: https://doi.org/10.54216/IJBES.060202
Received: October 18, 2022 Revised: December 25, 2022 Accepted: March 12, 2023

thermal insulation properties [10]. Glass windows played a central role in creating both thermal and light environment inside the buildings. Various strategies tried to improve the thermal and optical performance of the glass windows, thus instead of working on isolating windows and reducing their heat transfer coefficient, it would be better to work on transferring the windows into energy-producing windows [11], relying on renewable energy sources.

Building Integrated Photovoltaics (BIPVs) systems represent a new and promising technology [12] [13]. An increasing interest in this systems have been noticed in the past decade(A key review of building integrated photovoltaic (BIPV) systems [14], as they are considered one of the best ways to harness solar power.

Building Information Modeling (BIM) is a technology based on exchange of digital mock-up between construction project actors for buildings lifecycle management [15]. BIM is considered as an innovative way of addressing the many problems that arise in the design, construction and maintenance of buildings. It can be utilized in all phases across the project life cycle [16]. It also improves the project's performance and efficiency [17,18]. It aids with the validation of building processes and solving complex problems [19]. The significant barriers to adopters and non-adopters are: Lack of standardization and protocols, Lack of expertise, Lack of additional project finance to support BIM, Lack of government policy, and Lack of collaboration among stakeholders. On the other hand, the common and most significant drivers to adopters and non-adopters are: Availability of trained professionals to handle the tools, Proof of cost savings by its adoption, Awareness of the technology among industry stakeholders [20,21]. Research has shown that BIM is rarely adopted in the developing country [22]. In the current circumstances of the construction industry in Syria, it is very difficult to implement the entire system, but it can be implemented in stages, such as the design stage, especially in the reconstruction phase, which requires great engineering effort and cooperation among all stakeholders [23]. The Architectural, engineering, and construction (AEC) industry projects in Syria struggled with myriad problems. However, Building Information Modeling (BIM) technology worldwide proves its capability to solve these issues [24]. That's why Syrian educational bodies need to allocate more time and effort to qualify engineers and help them keep up to date with the latest [25,26]. Syrian (AEC) industry is witnessing the transformation from CAD to BIM so it must be encouraged by the government and other related firms and individual expertise to spread it as much as possible in order to keep up with the ever-evolving world of technology [27]. To conduct risk management considering BIM technology, The management system should review the conventional risk assessment procedures, and developed criteria must be introduced and become an everyday practice of all construction projects [28]. Using BIM with partnering agreements improves stakeholder behavior in Construction Mega-Projects. enhancing stakeholder relationships reduces disputes, eliminates conflict of interest, and allows sharing of knowledge [29]. Information exchange (IE) needs to be planned from the beginning of the process, agreed upon between different parties, tested, and verified [30]. A new plan ″which is expected to prepare a new generation of architects who are High-tech qualified and fully aware of BIM and its general ideas″ was developed, it makes it easier for these architects to emerge within the job market and fulfill AEC firms' requirements [31]. A six-step methodology to implement BIM namely; raising awareness; perceived benefits; AEC industry readiness, and organizations' capability; identifying the barriers; removing the barriers; and defining the key factors influencing the implementation [17]. The importance of BIM also appears in energy projects, where BIM has been used to evaluate the thermal effect of passive solar heating in dwellings [22], and skylights were designed using Revit, It turns out that The skylight system improves the energy efficiency and life cycle of the building only if certain parameters of design are considered [32]. Moreover, the importance of BIM has emerged in other sectors, It is considered a revolution that has transformed the way in which engineering facilities and infrastructures are designed, analyzed, constructed and managed [33]. One more benefit of BIM is the integrations between BIM and nanofibers , BIM has shown that there is a positive relationship between the needle diameter and the diameter of electrospun PVDF nanofibers [34].

The importance of BIM in energy modeling appears in the design stage, as it works to control consumption and sometimes reach zero consumption by balancing what will be consumed in the building, and what will be produced from renewable energy production sources.

Doi: https://doi.org/10.54216/IJBES.060202
Received: October 18, 2022 Revised: December 25, 2022 Accepted: March 12, 2023

2. Related Work

This study aims to use (BIPVs) systems for the sake of reaching a zero-energy building, by studying the possibility of replacing the traditional glass windows of the Engineers Syndicate building - Latakian branch, with photovoltaic windows in order to cover the needed electrical loads through these windows.

Despite the large spread of solar energy as a good solution to the wide blackout in Syria, towers still suffer from the lack of sufficient space to install solar panels to secure the required capacity that covers the total electrical loads, so (BIPVs) will be the best choice to take advantage of the large spaces occupied by windows in buildings.

A novel (BIPVs) mounting structure has been designed to solve issues related to maintenance and replacement of PV components. It was concluded that function, cost, technology and aesthetics are more important than high integration. It was also mentioned that due to the lower lifetime of PVs compared to the lifetime of buildings (50 years), easy maintenance and replacement of PV modules are more important than just extending its life [35].

The potential of BIPV technologies was assessed for six different PV technologies, namely m-Si, P-Si, amorphous silicon, cadmium telluride, copper indium diselenide (CID) and heterojunction with intrinsic thin layer, were considered. The results showed that total annual energy generation amounts were between 42.6 MWh and 144.5 MWh [36].

Solar irradiation potential for different type of surfaces (façades, roofs, etc.) was assessed. 78 cities were studied and only in 8 of them the optimum tilt angle was found to be equal to the latitude. Considering the roofs, it was shown that at least 85% of the maximum solar irradiation was available for an optimally tilted system facing north or west, while that of south facing roofs was found to be at least 66%. When façades were considered it was shown that a maximum of 60% of the irradiation was reachable. Therefore, it was concluded that BIPV systems could be considered not only for the roofs, but also on façades at low latitudes [37].

3. Research methodology and data collection:

The experimental method was used to calculate the electrical loads needed for the building, and this included collecting data about the building's use of electricity, such as the number and types of devices used, and the number of operating hours, determining the electrical loads, and designing a solar system that can meet the building's energy needs. This involves selecting the appropriate solar panels, inverters, batteries, and other components based on the building's location, orientation, and energy requirements.

To assess changes in energy consumption, a comparative analytical approach was employed to compare the building's energy usage pre and post the installation of photovoltaic windows. The building of the Syndicate branch in Lattakia was visited and architectural sketches were used to calculate room areas and glass facades. Additionally, employees provided information on daily operating hours and existing office equipment.

3.1. Mathematical equations:

The capacity of photovoltaic panels is calculated as in the equation:

$$P = \frac{E}{PSH} \qquad (1)$$

Whereas:

P: solar panel capacity

PSH: The number of solar radiation hours per day

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- **Battery system calculation:**

$$\text{Hour-amp}=\frac{E}{\text{system voltage}}$$

To find the required battery capacity, divide the result by:
1- DOD = 0.8
2- We consider that temperature can drop in winter to 0°C, therefore we also divide by 0.7

$$Ah_{(bank)} = \frac{hour - amp}{DOD \times 0.7} \tag{2}$$

Whereas:
$Ah_{(bank)}$: total capacity of the battery system
DOD: depth of discharge

$$N_{(batteries)} = \frac{Ah_{(bank)}}{Ah_{(battery)}} \tag{3}$$

Whereas:
: number of batteries$N_{(batteries)}$
: Selected battery capacity$Ah_{(battery)}$

- **The inverter capacity calculation:**

$$VA_{INV} = Total\ Power \times CF \tag{4}$$

Whereas:
VA_{INV}: inverter capacity in volt-amps

CF: correction factor

4. Case study:

This study was carried out in the building of the Engineers Syndicate branch in Lattakia. The building consists of six floors in which the Syndicate occupies the fifth and sixth floors. It is the candidate for the application of photovoltaic solar window technology because of the presence of glass facades along its southern and western facades.

4.1. Total load in the building

Electricity is consumed in studied building during the day from 08:00 am to 03:00 pm as shown in Table (1).

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Table 1 : The building electrical loads

type of electrical load	number of electrical loads	capacity of each load	total capacity	Operating hours	Total capacity per day
120 cm fluorescent lamp	69	38 w	2622	2	5244 wh
Desktop computer	12	170 w	2040	6	12240 wh
Printer	13	40 w	520	3	1560 wh

According to the solar atlas, Its location is characterized by suitable solar radiation during various days of the year [38], Figure (1).

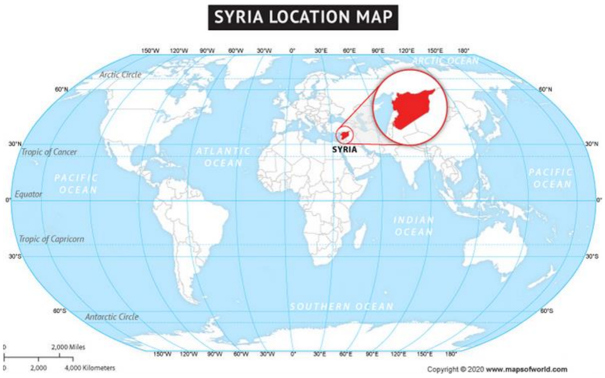

Figure 1 : The location of Syria on the world map [38]

The daily consumption of electrical energy is calculated on the basis of the daily working hours which is estimated at 6 working hours per day over 5 days a week. Figure (2) shows a photo of the building in which the study was conducted.

Figure 2 : The building of the Engineers Syndicate branch in Lattakia

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4.2. Photovoltaic solar windows technology

Due to the great spread of large glass facades in buildings, an increase in energy consumption was noticed. To take advantage of the large facade areas, photovoltaic windows have been used in order to convert solar energy into electricity to cover the electrical load of buildings.

There are three main types of photovoltaic windows available now:

1- Photovoltaic films.
2- Double glazing units.

3- Windows integrated with solar energy [39].

4.3. Transferring the glass windows of the building into Photovoltaic windows

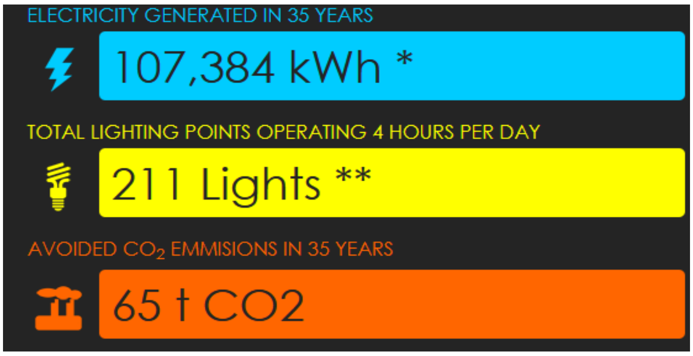
In this section, we will focus on the southern facades, owing to the fact that in the northern hemisphere, solar panels are oriented directly towards the south, in order to obtain the best possible productivity of solar cells.

There are three 6m^2 windows in the fifth floor facing the south, which make total area = 6×3 = 18m^2.
There are five 8m^2 windows in the sixth floor, in addition to a 16m^2 one, which make the total area = (8×5) + 16 = 56 m^2
The total area of the southern facades = 18 + 56 = 74m^2
Using polycrystalline glass windows will be taken into consideration, these windows have many desirable physical and chemical properties such as abundance, low toxicity, stability, in addition to low manufacturing costs [40]. They have an output capacity of 160 w/m^2 [41].

The total power generated of 1 m^2 of polycrystalline window per hour is 74 × 160 = 11840 w.
The total power generated per day is 1840 × 5 = 59200 w.

4.4. Modeling and calculating the expected output of this technology using ONYX solar website

ONYX solar website was used in order to calculate the expected capacity of the photovoltaic solar windows according to the total area of the facades that can be replaced. Results were calculated based on the total area of the glass interfaces that can be replaced in the building, geographical location, type of the used windows, their area in square meters, and window orientation. Type of polycrystalline was chosen, with a 74m^2 area, the windows were directed towards the south, Figure (3) shows the results of the modeling performed on the building. Table (3) shows the Simulink results.



ELECTRICITY GENERATED IN 35 YEARS

107,384 kWh *

TOTAL LIGHTING POINTS OPERATING 4 HOURS PER DAY

211 Lights **

AVOIDED CO$_2$ EMMISIONS IN 35 YEARS

65 t CO2

Figure 3: the results of the modeling performed on the building.

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Table 2 : the results of the modeling performed on the building

Electricity generated in 35 years	107,384 kwh
Total lighting points operating 4 hours per day	211 lights
Avoided CO2 emissions in 35 years	65 ton

5. Results and discussion

- Total electricity consumption per hour: depending on table (3):

$$2622 + 2040 + 520 = 5182 \text{ W}$$

- Total electrical load required per day E: depending on table (3):

$$E = (2622 \times 2) + (2040 \times 6) + (520 \times 3) = 5244 + 12240 + 1560 = 19044 \text{ WH}$$

- The value of total power generated from 1 m^2 of polycrystalline window per hour is

$$74 \times 160 = 11840 \text{ w}$$

- The value of total power generated per day = 11840 × 5 = 59200 w.

The total electrical load required per day was multiplied by a correction factor of (20 - 30%) in order to compensate any energy losses [42].

$$E = 19044 \times 1.25 = 23805$$

The number of the useful sun hours per day in Syria is: PSH = 5 h.

$$P = \frac{23805}{5} = 4761 \text{ W}$$

This means that it needs a 4761 watts, and we have $74m^2$ of glass facades south-facing.

$$E\_PV = \frac{4761}{74} = 64.33 \text{ W}$$

- Therefore, we need a glass interface in which the output power is minimum 64.33 watts per square meter.

Comparing the value of total power generated per day (59200 w) with the total consumption value (19044 w), 100% of the total energy consumption was covered from a clean and renewable source of energy. There is no need for any additional costs as the building was turned into a zero-energy building. And the energy cost was reduced by 100% due to covering the total load. Carbon emissions were reduced by 59 kg per day.

Doi: https://doi.org/10.54216/IJBES.060202
Received: October 18, 2022 Revised: December 25, 2022 Accepted: March 12, 2023

6. Conclusion

Syria's geographical location afforded great opportunities in investing renewable energy projects, especially solar energy, where solar radiation value 4.8 is regarded as an important indicator to produce electricity with high efficiency. Results showed that applying (BIPVs) systems using polycrystalline windows instead of traditional glass windows, 59 kilowatts were produced, thus the entire electrical load was covered, and carbon emissions were reduced by 59 kg per day. That means producing electricity from photovoltaic windows contributes to protecting the environment from emissions that are emitted when using fossil fuels. This paper emphasizes the importance of carrying out solar energy projects in Syria, it also indicates that developing construction methods is a good way to facilitate the integration of energy systems into both new and existing buildings, All calculations were done manually, but if BIM had been applied, it would have been easier, faster and more accurate to do all the calculations, for that I recommend using BIM to facilitate studies when converting to BIPV systems.

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Received: October 18, 2022 Revised: December 25, 2022 Accepted: March 12, 2023