A CASE STUDY OF CAIRO INTERNATIONAL AIRPORT “CIA”: PROPOSED INSTALLATION OF PHOTOVOLTAIC “PV” FOR HIGH ENERGY-PRODUCTION

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ABSTRACT

Airports play a pivotal role in the global air transport industry. The increase in passenger and air cargo traffic has led to increase of energy requirements. Airports have introduced a wide range of energy saving procedures. Solar technology is growing rapidly at airports. Solar energy reduces the airport operating costs, and has environmental benefits such as cleaner air and fewer greenhouse gases. Building Information Modeling “BIM” is a software tool that uses a relational database with a behavioral model to represent the building information dynamically. Using BIM helps with the urgent aspects of sustainability design, e.g., solar analysis. Also, BIM can perform yearly sun studies to define when the building is provided with natural shading. Furthermore, BIM can then reduce the capacity of cooling systems, and explaining the building is exceeding the baseline building energy requirements. This paper aims to reduce the energy consumption by proposing the installation of renewable energy Photovoltaic “PV” solar system. The performance is simulated by the Autodesk Revit, PVsyst software, and supported by theoretical calculations. The studied results can produce a high annual energy production of about 22,000 MWh/yr and reduce a considerable annual amount of carbon dioxide (CO₂), which represents 15,000 tons/yr.

KEYWORDS: Cairo International Airport, Solar Energy, BIM, PV, Autodesk Revit, PVsyst

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1. INTRODUCTION

The awareness of the impact of the built environment on the natural environment is still increasing. In the last years, the use of sustainable and green building concepts has developed very rapidly (Lawrence, Darwich, & Means, 2018, pp. 3-17). Energy is essential to advancing economic development and growing living standards. Majority of energy consumption for electricity, heating and cooling, and transportation is supplied by fossil fuels combustion. Energy used by the aircraft is needed over all phases of operations (International Civil Aviation Organization ICAO, 2017, pp. 3-39). As airport’s electricity is typically provided by the electric grid, the development of on-site electricity principally minimizes the request for off-site power (Whiteman, et al., 2015, pp. 7-39). Accordingly, airports systems have a high electrical-energy request due to the requirements of airport buildings and facilities such as terminal air conditioning, pre-conditioned air and power at gates, powering of many equipment, and other special airport systems (International Civil Aviation Organization ICAO, 2015, pp. 6-14).

1.1. History

1.1.1. Airport Renewable Energy Case Studies

In this section, some famous case studies are mentioned as examples of utilization of renewable energy in airports.

Seymour Airport: Managed by the Argentinian company Ecogal S.A. located on Baltra Island, the airport consumes 35% of its energy demand from solar PV panels (International Civil Aviation Organization ICAO, 2017, pp. 42-52). **George Airport:** In September 2015, George Airport became the first airport in Africa to draw power from renewable energy. It has 3,000 PV modules, with a nameplate capacity of 750 kW, which meets 41% of the airport's electricity needs (International Civil Aviation Organization ICAO, 2017, pp. 42-52). **Kansai International Airport:** Kansai Airport in Osaka, Japan has developed varied renewable energy projects. In 2014, it launched an 11.6 MW CIS (Copper, Indium, Selenium) installation. The system produces annually about 12 million kWh of electricity (International Civil Aviation Organization ICAO, 2017, pp. 42-52).

1.1.2. Building Information Modeling (BIM) background

The Associated General Contractors of America defines BIM as a smart and parametric digital representation to create information can be used to give decisions and improve the process (Jung et al., 2013). BIM reflects and affirms the process sides (Sacks, Eastman, Lee, & Teicholz, 2018, pp. 12-24). Thus, BIM maturity in 1990s was CAD, using drawings, lines, text, etc., and the tools were papers. In 2000s, using 2D and 3D models, the tools were file-based collaboration. In 2010s, the tools of BIM were files and libraries. In 2020s, BIM is developing to be Building Lifecycle Management to use Integrated Interoperable Data, and tools are Integrated Web Services BIM Hub (Sacks, Eastman, Lee, & Teicholz, 2018, pp. 12-24).

1.2. Motivation

1.2.1. PV Technology Features

There are various distinct features associated with using solar PV modules as follows: (1) It is relatively easy to modify the size of a system; simply by increasing or decreasing the number of solar panels (International Civil Aviation Organization ICAO, 2017, pp. 3-39). (2) It can feasibly be deployed on any stable, earthly place and produce electricity as all land receives some sunlight that can be turned into electricity (International Civil Aviation Organization ICAO, 2017, pp. 3-39). (3) The amount of electricity that will be generated by a solar facility for any specific location can be easily predicted based on existing knowledge of climate conditions (International Civil Aviation Organization ICAO, 2017, pp. 3-39).

1.2.2. Importance of BIM

Generally, there are many benefits of using BIM as: **Concept, feasibility, and design benefits:** An approximate or aggregate building model incorporated into and connected to a cost database can be of enormous value. **Increased building performance and quality:** Developing a schematic model previously to create a detailed building model specifically for a more accurate evaluation to define if it meets the building's functional, sustainability, and other requirements. **Improvement of energy efficiency and sustainability:** Linking the building model to energy analysis tools gives evaluation of energy and provides many chances to develop building quality (Sacks, Eastman, Lee, & Teicholz, 2018, pp. 12-24). BIM has the ability to achieve a more energy-efficient building (Abanda, & Byers, 2019).

1.2.3. Autodesk Revit Software

Revit is a renowned BIM platform, created by Autodesk in 2002. Revit is a major fit for the analysis for sustainable design. Revit enables model check, energy simulation and other analyses, connectivity of Mechanical, Electrical and Plumbing systems, modeling or geometry discrepancies, and annotation graphics (Sacks, Eastman, Lee, & Teicholz, 2018, pp. 70-85).

1.2.4. PVsyst Software

PVsyst offers results in the form of a full report, defined graphs tables, and data can be exported to be used in other software (Sacks, Eastman, Lee, & Teicholz, 2018, pp. 70-85). PVsyst is one of the best simulation software to evaluate the performance of a solar PV power plant. On a case study of Cochin International Airport, PVsyst software was found to match closely with actual site data (Sukumaran, & Sudhakar, 2017). PVsyst is able to estimate the performance of grid connected, stand-alone and DC solar systems based on the defined module and selected location (Sukumaran, & Sudhakar, 2017).

2. RESEARTH METHODOLOGY

2.1. Present Case Study

The aim of the present research is the reduction of energy consumption of Cairo International Airport-Terminal Building No. 02 "CIA-TB2" from the utility grid by installing renewable energy solar PV panels. The simulation software used for the study of PV energy production are Autodesk Revit, and PVsyst, and the results are supported with theoretical calculations.

2.2. Data Collection

Based on the data of ("Cairo Airport, " n.d.), ("Cairo International Airport," 2020) and ("CAI Google Earth, " 2020). CIA is consisted of the following: (1) Terminal Building 01 "CIA-TB1". (2) Terminal Building 02 "CIA-TB2". (3) Terminal Building 03 "CIA-TB3". (4) Seasonal Flight Terminal. (5) CIA Control Tower. (6) Parking Area. (7) Cairo Airport Hotel. (8) Parking Building. (9) CIA-TB3 Power & Cooling Plant. (10) CIA-TB2 Power Plant. (11) CIA Fire Fighting Building.

Thus, Cairo International Airport-Terminal Building No. 02 "CIA-TB2" is consisted of the following ("CAI Google Earth, " 2020): (1) Building A "BL-A". (2) Building B "BL-B". (3) Building C "BL-C". (4) Passenger Boarding Bridge Buildings, Qty. 11 Buildings. (5) CIA-TB2 Power Plant. (6) Taxiway Area. (7) Airside Area. (8) Landscape Areas.

2.3. Assumed Values of Energy Consumption for CIA

As many of the required data for the present research are not openly available, it is a must to assume them. These data concern mainly the values of energy consumption and CO₂ emissions. First, the data of CIA Terminals are presented. Then, data of other selected International Airports are presented. Accordingly, the values of the energy consumption of CIA can be assumed.

2.3.1. CIA Terminals Data

CIA-TB1 has 12 gates ("Cairo International Airport," 2020). **CIA-TB2** total terminal area is 230 m² ("Cairo International Airport," 2016), which was designed for a capacity 7.5 million passengers per year ("Cairo International Airport," 2020). TB2 has 14 gates and an additional 5 remote stands ("Cairo International Airport," 2020). **CIA-TB3** total terminal area is 211,000 m², which was designed for a capacity of 11 million passengers per year ("Cairo International Airport," 2008). TB3 has 23 gates ("Cairo International Airport," 2020). **Seasonal Flight Terminal** serves about 3.2 million passengers per year with 27 check-in counters and 7 gates ("Cairo International Airport," 2020).

2.3.2. Data of Other Selected International Airports and values of Energy Consumption

Kansai Airport: Terminal-1 has a total floor area 303,944 m² and Terminal-2 has a total area 29,680 m² (Baxter, Srisaeng, & Wild, 2018). In 2016, 25.2 million passengers used the airport. The annual electricity consumption is 122,000 MWh in 2002. Achieved many sustainable works and reduced this amount to be 102,000 MWh in 2015 (Baxter, Srisaeng, & Wild, 2018). **Copenhagen Airport:** The airport received close to 30.3 million passengers in 2019 ("Copenhagen Airport, " 2020). The annual electricity consumption is about 115,000 MWh in 2010 with CO₂ emissions are 27,707 tons. Achieved many sustainable works and reduced these quantities in 2013 to be about 95,000 MWh and 24,557 tons (Baxter, Srisaeng, & Wild 2015). **Hartsfield-Jackson Atlanta International Airport:** The airport has terminals and concourses totaling 630,000 m² ("Hartsfield-Jackson Atlanta International, " 2020). The airport serves more than 100 million passengers in a single year ("About ATL, " n.d.). The airport required over 240,220 MWh of electricity in 2010 (Hartsfield-Jackson Atlanta International Airport, 2011).

2.3.3. Assumed values for CIA

After presenting all the previous useful data for the international airports, values of electricity consumption and CO₂ emissions for Cairo Airport can be assumed (estimated) as shown in Table 1.

Table 1: Assumed Energy Consumption Values for CIA Buildings & Areas.

Cairo International Airport	Assumed Values of Electricity Consumption (kWh/yr)	Assumed Values of CO ₂ Emissions (tons/yr)
CIA-TB1	40,000,000	26,000
CIA-TB2	48,000,000	30,000
CIA-TB3	70,000,000	51,000
CIA Seasonal Flight Terminal	20,000,000	15,000
CIA Control Tower	6,000,000	3,900
CIA Hotel	10,000,000	5,100
CIA-TB3 Power & Cooling Plant	7,000,000	9,600
CIA-TB2 Power Plant	290,000	2,800
CIA Fire Fighting Building	150,000	1,800
CIA Parking Building	170,000	4,200
CIA Parking Area	150,000	4,000
Total	201,760,000	183,400

2.4. Calculation Methods

In the present research, the objective results are found by using three different methods of calculation for integration and reliability. These methods are as follows: (1) Using theoretical calculation. (2) Autodesk Revit software. (3) PVsyst software.

2.4.1. Theoretical Calculations

For the calculation of the solar energy output of a PV system, using the following ("Solar radiation databases, " n.d.):

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

Where, E = Energy (kWh). A = Total solar panel area (m^2). r = Solar panel yield (%) = PV panel kW/panel area. H = Annual average irradiation on tilted panels. PR = Performance ratio, i.e., coefficient for losses (range between 0.9 and 0.5, default value = 0.75). The yearly-sum of global irradiance on Egypt is $2,000 \text{ kWh}/m^2$ ("Photovoltaic software, " n.d.).

2.4.2. Autodesk Revit software

By using this software, two main simulation reports of solar analysis can be given: (1) PV energy production and energy savings. (2) Irradiance Insolation and Global Horizontal Irradiance (GHI).

2.4.3. PVsyst Software

This software gives results in the form of a full report, specific graphs, and tables. Thus, data can be exported for use in other software codes ("PVsyst software, " n.d.).

2.5. Significant Parameters and Indicators

There are some important parameters and indicators that are used in the present calculations, which can be listed as: **(1) PV Energy Production:** The total value of energy generated by the PV System and the output "O/P" unit is kWh/yr. **(2) Irradiance Insolation:** The amount of power is the product of the power ($1000 \text{ W}/m^2$) times the time length (1 hour), so that the unit of energy is the kWh. **(3) Global Horizontal Irradiance (GHI) or (GlobHor):** It is the total amount of shortwave radiation received from above by a surface horizontal to the ground. **(4) Performance Ratio (PR):** PR indicates the effect of losses on the power output of a PV power plant during DC to AC conversion. **(5) Tilt Angle "Elevation Angle":** It describes the vertical angle of the solar panels. **(6) Azimuth Angle:** It is their horizontal facing in relation to the Equator. On PVsyst, the azimuth zero corresponds to the south. For instance, 215 deg that is between South and South West, therefore the azimuth angle is 35° ("PVsyst Help. PVsyst, " n.d.). **(7) Saved Amount of CO_2 :** The yearly savings of CO_2 emissions, given in tons. A direct formula can be used to calculate the saved amounts of PV System (i.e., $0.000684 \text{ tons}/kWh$) (Armbruster et al., 2008, pp. 47-48)

2.6. Creating CIA Model by Autodesk Revit Software

Autodesk Revit software is a significant tool for sustainable design and analysis (Jung et al., 2013). It enables energy simulation and daylight analysis using accurate model location, and weather data file (Jung et al., 2013). After collecting the data, the model is created by Revit with running "Solar Analysis". Figure 1 illustrates CIA on Google Earth ("CAI Google Earth, " 2020) and the created model is shown in Figure 2.

Figure 1: CIA-TB2, CIA-TB3, and CIA parking area view on Google Earth ("CAI Google Earth, " 2020).

Figure 2: Created model by Autodesk Revit software for CIA-TB2 and CIA Parking Area.

3. RESULTS

In this section, the calculations are presented for Irradiance Insolation and for PV Energy Production using PV panel 320 W and 408 W by using Autodesk Revit software, and using PV panel 320 W and 410 W by using PVsyst software. Also, results of the theoretical calculations are demonstrated.

3.1. Results by Autodesk Revit Software

After creating the model, “Solar Analysis” can be applied for a selected area. Revit software gives values for Irradiance Insolation and Global Horizontal Irradiation. Also, it can offer the values of PV Energy Production and Energy Savings.

3.1.1. Irradiance Insolation and Global Horizontal Irradiation

Table 2 shows the complete values by Autodesk Revit over the year for CIA TB2 –BL-C Roof, Area 14,154 m², BL-B Roof, Area 19,568 m², and Parking Area 122,582 m².

Table 2: Solar Analysis Over the year by Autodesk Revit Software for CIA TB2 –BL-C Roof, Area 14,154 m², BL-B Roof, Area 19,568 m², and Parking Area 122,582 m².

Case Method	Month	BL-C Roof		BL-B Roof		Parking Area	
		Irradiation Insolation (kWh)	Global Horizontal Irradiance (kWh/m ²)	Irradiation Insolation (kWh)	Global Horizontal Irradiance (kWh/m ²)	Irradiation Insolation (kWh)	Global Horizontal Irradiance (kWh/m ²)
Case 1.1	January	1,274,251.00	90	1,566,802.00	80.00	10,730,578.00	88.00
Case 1.2	February	1,316,555.00	93	1,631,075.00	83.00	11,095,812.00	91.00
Case 1.3	March	2,102,584.00	149	2,628,986.00	134.00	17,721,587.00	145.00
Case 1.4	April	2,411,293.00	170	3,033,372.00	155.00	20,297,583.00	166.00
Case 1.5	May	2,838,793.00	201	3,582,283.00	183.00	23,861,558.00	195.00
Case 1.6	June	2,938,634.00	208	3,711,323.00	190.00	24,687,174.00	201.00
Case 1.7	July	2,969,401.00	210	3,749,581.00	192.00	24,947,026.00	204.00
Case 1.8	August	2,740,875.00	194	3,452,962.00	176.00	23,064,303.00	188.00
Case 1.9	September	2,302,377.00	163	2,887,515.00	148.00	19,395,562.00	158.00
Case 1.10	October	1,796,267.00	127	2,233,952.00	114.00	15,139,818.00	124.00
Case 1.11	November	1,268,336.00	90	1,562,355.00	80.00	10,689,457.00	87.00
Case 1.12	December	1,136,712.00	80	1,394,604.00	71.00	9,571,037.00	78.00
Year		25,096,078.00	1,775.00	31,434,810.00	1,606.00	211,201,495.00	1,725.00

3.1.2. PV Energy Production and Energy Savings

This section gives the results of energy production and savings using different proposed PV panels. **First: using PV panel 320 W** Figure 3 shows the simulation results for the roof of Building C. **Second: using PV panel 408 W.** Table 3 shows the Simulation Energy Production and Energy Savings by Autodesk Revit software using PV panel 320 W and 408 W.

Figure 3: The Solar Analysis Simulation by Autodesk Revit for CIA TB2 - BL-C Roof, PV Panel 320 W.

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Grid-Connected System: Main results		
Project : CAI TB2 - BL-C Roof		
Simulation variant : New simulation variant		
Main system parameters System type: No 3D scene defined, no shadings PV Field Orientation: tilt 27° azimuth 0° PV modules: Model JKM 320PP-72 (Plus) Pnom 320 Wp PV Array: Nb. of modules 6052 Pnom total 1937 kWp Inverter: Model PVS800-57-0630kW-B Pnom 630 kW ac Inverter pack: Nb. of units 3.0 Pnom total 1890 kW ac User's needs: Unlimited load (grid)		
Main simulation results System Production: Produced Energy 3306 MWh/year Specific prod. 1707 kWh/kWp/year Performance Ratio PR 82.25 %		

Figure 4: Sample Report of Simulation Result by PVsyst for CIA TB2 - BL-C Roof, PV Panel 320 W.

Table 3: Revit Simulation of Energy Production and Energy Savings Using PV Panel 320 W and 408 W.

Building / Area	PV Panel Area (m ²)	PV panel 320 W			PV panel 408 W		
		Case Method	Production Energy (kWh/yr)	Saving Power (EGP)	Case Method	Production Energy (kWh/yr)	Saving Power (EGP)
BL-C	11,478	Case 1.37	3,354,495	7,547,610	Case 1.51	4,276,981	9,623,205
BL-B	15,067	Case 1.38	4,237,019	9,533,295	Case 1.52	5,402,199	12,154,950
Parking	34,323	Case 1.39	9,815,759	22,083,540	Case 1.53	12,515,093	28,158,960
PBB-01	74	Case 1.40	19,600	44,100	Case 1.54	24,990	56,235
PBB-02	84	Case 1.41	22,450	50,520	Case 1.55	28,624	64,410
PBB-03	71	Case 1.42	20,280	45,630	Case 1.56	25,857	58,185
PBB-04	94	Case 1.43	25,255	56,820	Case 1.57	32,200	72,450
PBB-05	94	Case 1.44	26,256	59,070	Case 1.58	33,476	75,315
PBB-06	84	Case 1.45	23,867	53,700	Case 1.59	30,431	68,475
PBB-07	84	Case 1.46	23,708	53,340	Case 1.60	30,228	68,010
PBB-08	82	Case 1.47	23,028	51,810	Case 1.61	29,361	66,060
PBB-09	124	Case 1.48	35,176	79,140	Case 1.62	44,850	100,905
PBB-10	99	Case 1.49	27,561	62,010	Case 1.63	35,140	79,065
PBB-11	108	Case 1.50	30,759	69,210	Case 1.64	39,218	88,245

3.2. Results by PVsyst software

- Setting up the required inputs:** By using the collected data and data of the created CIA model by Revit into PVsyst as follows: **Choosing geographical site:** to get location and weather data. **Setting up orientation data** (Tilt angle and Azimuth angle) for the PV modules. **Selecting the system data:** Define PV panel area. Select PV module (Type and PV power). Select inverter (Type, operating voltage and output voltage). Design the array: Review for the number for modules and strings.
- Run Simulation: Get the report for the output values:** Produced Energy. Performance Ratio (PR). Graphs for the produced energy and performance ratio. Simulation tables of results over the year (e.g., GHI, ambient temperature, effective energy and PR): **First using PV panel 320 W** Run simulation for defined PV panel areas for CAI-TB2 Buildings. Figure 4 shows sample report of simulation result. **Second using PV panel 410 W.** Table 4 shows the simulation results.

Table 4: PVsyst Simulation Results of Energy Production and Performance Ratio Using PV Panel 320 W and 410 W.

Case Method	Building / Area	PV panel Area (m ²)	PV panel 320 W			PV panel 410 W		
			Production Energy (kWh/yr)	PR	Saving CO ₂ (tons/yr)	Production Energy (kWh/yr)	PR	Saving CO ₂ (tons/yr)
Case 2.1	BL-C	11,478	3,306,000	0.833	2,261	4,154,000	0.837	2,841
Case 2.2	BL-B	15,067	4,501,000	0.832	3,079	5,354,000	0.840	3,662
Case 2.3	Parking	34,323	9,262,000	0.847	6,335	11,693,000	0.847	7,998
Case 2.4	PBB-01	74	20,500	0.812	14	25,600	0.836	18
Case 2.5	PBB-02	84	20,800	0.824	14	24,200	0.836	17
Case 2.6	PBB-03	71	19,698	0.824	13	21,200	0.832	15
Case 2.7	PBB-04	94	25,500	0.800	17	28,200	0.830	19
Case 2.8	PBB-05	94	25,700	0.807	18	28,200	0.830	19
Case 2.9	PBB-06	84	20,800	0.824	14	24,200	0.836	17
Case 2.10	PBB-07	84	20,600	0.815	14	28,300	0.832	19
Case 2.11	PBB-08	82	22,400	0.803	15	28,200	0.830	19
Case 2.12	PBB-09	124	34,000	0.812	23	42,800	0.838	29
Case 2.13	PBB-10	99	27,700	0.819	19	34,200	0.836	23
Case 2.14	PBB-11	108	29,200	0.815	20	36,300	0.836	25

3.3. Results by Theoretical Calculations

Eq. (1) is used to calculate the solar PV energy output for the two selected PV panels: **First using PV panel 320 W** Calculate the PV energy output for CIA-TB2 Buildings. **Second using PV panel 410 W.** Table 5 shows the calculations results.

Table 5: Calculation the Oretical Results of PV Energy Output by Using PV Panel 320 W and 410 W.

Case Method	Building / Area	PV panel Area (m ²)	PV panel 320 W		PV panel 410 W	
			Production Energy (kWh/yr)	Saving Power (EGP)	Production Energy (kWh/yr)	Saving Power (EGP)
Case 3.1	BL-C	11,478	3,059,576	6,884,045	3,938,905	8,862,537
Case 3.2	BL-B	15,067	4,011,438	9,025,736	5,189,075	11,675,418
Case 3.3	Parking	34,323	9,302,906	20,931,538	11,919,348	26,818,533
Case 3.4	PBB-01	74	19,228	43,263	25,364	57,070
Case 3.5	PBB-02	84	22,149	49,836	28,792	64,782
Case 3.6	PBB-03	71	18,721	42,123	24,220	54,494
Case 3.7	PBB-04	94	24,064	54,144	31,988	71,973
Case 3.8	PBB-05	94	24,275	54,618	31,988	71,973
Case 3.9	PBB-06	84	22,149	49,836	28,792	64,782
Case 3.10	PBB-07	84	21,907	49,291	28,654	64,472
Case 3.11	PBB-08	82	21,071	47,409	27,905	62,785
Case 3.12	PBB-09	124	32,220	72,495	42,604	95,859
Case 3.13	PBB-10	99	25,946	58,378	33,933	76,350
Case 3.14	PBB-11	108	28,166	63,374	37,018	83,291

4. DISCUSSIONS

After applying the three methods of calculations by Autodesk Revit, PVsyst, and theoretical calculations for two types of PV Panels (320 W and 410 W). Tables 6 summarizes the calculation results for PV panel 320 and 410 W, also can be seen the average values for the calculated results of PV panel 410 W. Figures 5-8 illustrate the summarized calculation results.

Table 6: Summarized Calculation Results for PV Panel 320 and 410 W.

Building / Area	PV Panel Area (m ²)	Production Energy using PV panel 320 W				Production Energy using PV panel 410 W			
		Autodesk Revit (kWh/yr)	PVsyst (kWh/yr)	Theoretical Calculation (kWh/yr)	Average Prod. Energy (kWh/yr)	Autodesk Revit (kWh/yr)	PVsyst (kWh/yr)	Theoretical Calculation (kWh/yr)	Average Prod. Energy (kWh/yr)
BL-C	11,478	3,354,495	3,306,000	3,059,576	3,240,024	4,276,981	4,154,000	3,938,905	4,123,295
BL-B	15,067	4,237,019	4,501,000	4,011,438	4,249,819	5,402,199	5,354,000	5,189,075	5,315,091
Parking	34,323	9,815,759	9,262,000	9,302,906	9,460,222	12,515,093	11,693,000	11,919,348	12,042,480
PBB-01	74	19,600	20,500	19,228	19,776	24,990	25,600	25,364	25,318
PBB-02	84	22,450	20,800	22,149	21,800	28,624	24,200	28,792	27,205
PBB-03	71	20,280	19,698	18,721	19,566	25,857	21,200	24,220	23,759
PBB-04	94	25,255	25,500	24,064	24,940	32,200	28,200	31,988	30,796
PBB-05	94	26,256	25,700	24,275	25,410	33,476	28,200	31,988	31,221
PBB-06	84	23,867	20,800	22,149	22,272	30,431	24,200	28,792	27,808
PBB-07	84	23,708	20,600	21,907	22,072	30,228	28,300	28,654	29,061
PBB-08	82	23,028	22,400	21,071	22,166	29,361	28,200	27,905	28,489
PBB-09	124	35,176	34,000	32,220	33,799	44,850	42,800	42,604	43,418
PBB-10	99	27,561	27,700	25,946	27,069	35,140	34,200	33,933	34,424
PBB-11	108	30,759	29,200	28,166	29,375	39,218	36,300	37,018	37,512
Total		17,685,213	17,335,898	16,633,816	17,218,310	22,548,648	21,522,400	21,388,586	21,819,877

Figure 5 shows the summarized Production Energy results using PV panel 320 W for Building C Roof, Building B Roof, and Parking Area. It is clear that the results by Autodesk Revit, PVsyst, and theoretical calculations are very close to the average values for Building C, Building B and Parking Area. Similarly for PBB Buildings using PV panel 320 W as been shown on Figure 6. Figure 7 explains the summarized Production Energy results using PV panel 410 W for Building C Roof, Building B Roof, and Parking Area. The results by Autodesk Revit, PVsyst, and theoretical calculations are very close to the average values. Figure 8 displays the summarized Production Energy results using PV panel 410 W for PBB Buildings. It can also be shown that the results of other PBB Buildings are close to the average values. Briefly, Figures 5-8 confirm that the results of these calculation methods are very accurate. Moreover, Autodesk Revit, and PVsyst can be used in the design phase of installing PV energy.

Figure 5: Summarized Production Energy results using PV panel 320 W for CIA-TB2 (BL-C, BL-B and Parking).

Figure 7: Summarized Production Energy results using PV panel 410 W for CIA-TB2 (BL-C, BL-B and Parking).

Figure 6: Summarized Production Energy results using PV panel 320 W for CIA-TB2 PBB Buildings.

Figure 8: Summarized Production Energy results using PV panel 410 W for CIA-TB2 PBB Buildings.

5. CONCLUSIONS

This paper studied the consumption energy of Cairo International Airport and the possibility of using PV Solar Energy to reduce the electricity consumption and CO₂ emissions for Terminal Building 2. Thus, the prominent conclusions drawn are:

- PV panel 410 W is highly recommended to be used.
- It is possible to get a high annual production energy (about 22,000 MWh/yr) and reducing a large annual amount of CO₂ (About 15,000 tons/yr).
- The planned results can save around 45% of the consumed energy per year (Producing about 22,000 MWh/yr from the consumption energy 48,000 MWh/yr).
- Large roof and parking areas can be used for installing PV solar system and getting a high energy production.
- The PV performance results using simulation software (Autodesk Revit and PVsyst) is found to be very close to each other and also is close to theoretical results.

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