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“Cost effective PV-system for Residential Application -CASE STUDY OF ALEXANDRIA_EGYPT”

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الملخص

يعد توليد الكهرباء من مصادر صديقة للبيئة أحد أهم التحديات في الحرب العالمية ضد تغير المناخ. مع الأسف، لا يزال أكثر من 67% من الأنتاج العالمي للكهرباء يعتمد على الوقود الأحفوري (علي، 2019). و لذلك الهدف الرئيسي من البحث هو عمل تحليل اقتصادي من خلال متغيرات تتعلق بتكلفة حياة المشروع و تكلفة انتاج الطاقة، لإيجاد النظام الشمسي الأكثر ملائمة للتركيب المنزلي . و قد اعتمدت الدراسة على بيانات عملية آخذة في عين الاعتبار مدينة الإسكندرية لدراسة الحالة. و أوضحت النتائج أن نظام الربط على الشبكة هو النظام الأنسب للتطبيق المنزلي.

Abstract

Cost effective generation of clean electricity is one of the most important challenges in the global fight against climate change. Unfortunately, over 67% of global electricity production is still dependent on fossil fuels (Ali, 2019). The main objective of this research is to provide an economic analysis though cost of energy (COE), net present Cost (NPC) and the payback period (PBP), determining the most suitable PV-system for residential usage. The study relied on practical data, taking into consideration a case study of the city of Alexandria. The results show that the on-grid PV-systems is the optimum solution for residential application.

Keywords

Cost of Energy, Payback period, Net preset cost, HOMER-PRO, PV-systems, Cost effective.

1. Introduction

Green economy has become the talk of the day and how to integrate this concept into the development of strategies, policies, plans, and programs. Thus, emerged the new global trend, as many global countries adopted the approach of preparing policies in order to activate this concept in various sectors, including sustainable societies, eco-friendly cities and green buildings in order to achieve sustainable development and achieve the economic, social, and environmental objectives within a proper governance framework (Ministry of Planning, 2015).

Nearly all nations around the world have now adopted renewable energy targets aiming for specified shares, production, or capacity of renewable energy technologies. As shown in Figure (1) renewable power has received the vast majority of attention in producing electricity, with targets found in 113 countries (UN, 2017).

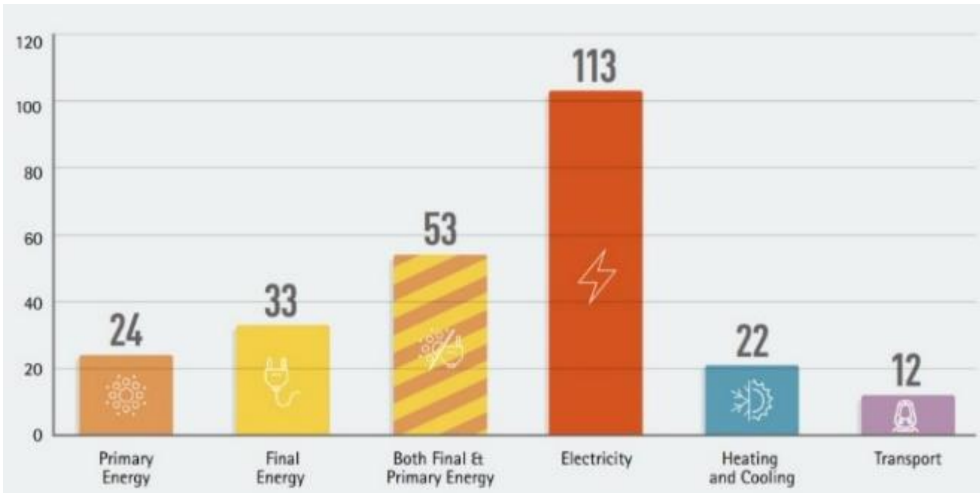

Figure (1) Country-specific average capacity factors by renewable technology (UN, 2017)

Like other countries the Egyptian electrification sector is facing some clear problems. The total load required in Egypt is increased by 4.8% between 2017 and 2018 according to the annual report from the Electrical Holding Company (EHC, 2019). So that clear strategies should be involved to recompense that increment from renewable sources to save the right of the future generations.

Moreover, with an average level of solar radiation between 2.000 to 3.200 kWh per square meter a year, Egypt has significant potential for solar energy which is latterly wasted (Atlas, 2019). Also, Hussien (2010) found that most of the locations in Egypt are suitable for implementing PV projects.

Furthermore, the price of electricity will rise continuously in the next years and the end users lack of knowledge about PV-systems and its environmental and economic benefits. Finally, Lack of serious strategies to encourage the investment in renewable energy systems. So that there is a need to increase the usage of renewables in Egypt.

This paper presents a discussion of an economic study for PV-systems life time to find the optimum PV-system for residential application in King-mariout region of Alexandria.

2. Literature Review

There are many reasons for the increasing importance of solar energy in Egypt, due to its availability and the need for a clean source of energy. Moreover, the economic benefit from investing in such field.

Potential of PV-systems in Egypt.

Hussien (2010) in his paper presented the potential of both wind and solar powers at different locations in Egypt. He found that most of the locations in Egypt are suitable for implementing PV projects.

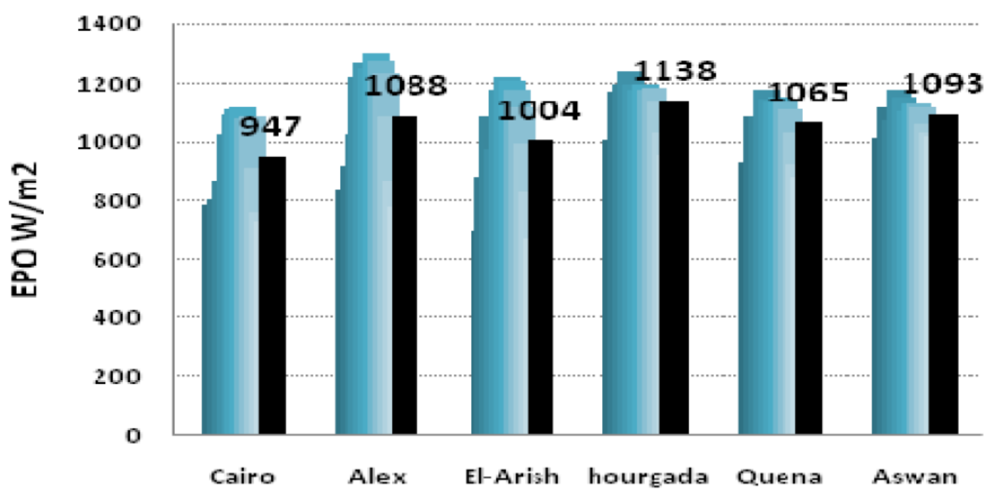

Figure (2) The monthly calculated PV output power of the selected Egyptian cities. Source (Hussien, 2010)

Said (2017) mentioned that Solar energy applications are becoming increasingly common in Egypt. The abundant sunshine in Egypt, as well as the increasing competitiveness of solar energy systems including-but not limited to photovoltaic (PV), - predicts that these technologies could be weighed to be raised in Egypt

Abu Roman (2017) mentioned in his thesis that alongside with the growth of renewable energy (RE) market, the need for an accurate and precise evaluation for an economic feasibility of these technologies is a pressing issue. The results show that the average module price is $0.56/Wp and the capital investment cost is $1.184/Wp. For a 20 years PV project life-time, the operation and maintenance cost forms 27% of the total LCC of the system.

3. Methods and Materials

The objective of this research is to evaluate the cost effective PV-system for the residential application.

3.1. Case study Description

The case study residential building is located in residential area community, King-Marriott in Alexandria, Egypt. Alexandria was taken into consideration as a start for such papers that can describe the cost-effective PV-systems all around Egypt. King-Mariout also was taken into consideration for the building's nature, where most of the buildings are villas. Moreover, the PV-systems are expensive and can be adopted by high standard of living people.

The Building is 31° North-east, and consists of 3 stories. Where the electrical load is allocated according to the building's owner payments for the last year.

3.1.1. Geographical and Weather data

The case is undertaken for a residential building in Alexandria city in Egypt which is the second largest city in Egypt. It lies along the Mediterranean Coast, stretching for about 70 km north-west to the Nile Delta as showing in Figure (3).

Figure (3) Existing Residential Building (Case Study) Location and Orientation (Google ™ Earth)

3.1.2. Electrical Load

The most important data to be considered in this case is the energy consumption data because it has a direct impact on the amount of energy consumed every month beside the electricity bills. Average consumption monthly rates were detected as shown in Figure (4) from the actual electricity bills of the case study building. Moreover, the electricity price defined as follow:

Table (1) Price of Electricity in Egypt

Consumption (kWh)	0 → 50	51 → 100	101 → 200	201 → 350	351 → 650	651 →1000	More than 10001
Price of kWh (EGP)	0.3	0.4	0.5	0.82	1	1.4	1.45

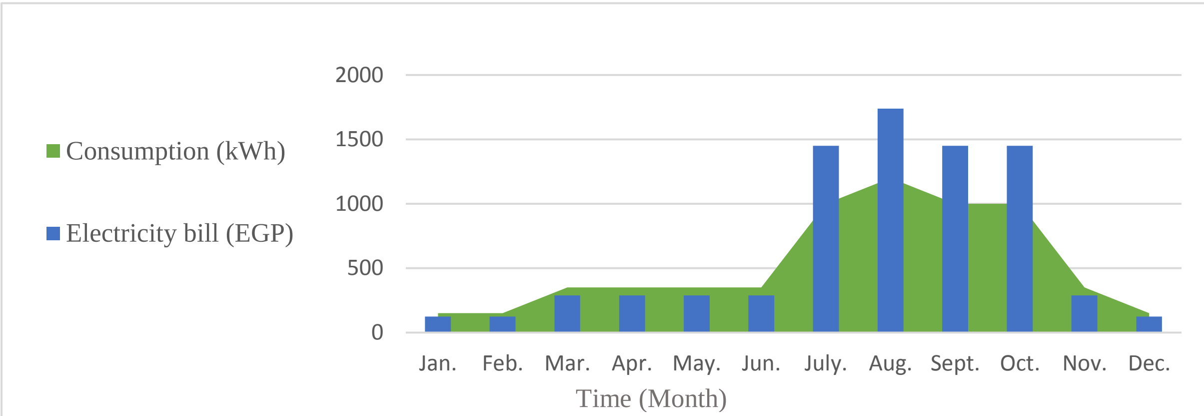

Figure (4) Villa Actual Monthly Consumption (kWh)

3.2. HOMER-PRO Software

HOMER was developed for nation renewable energy laboratory USA by Mistaya Engineering in Canada. For describing cost components and availability of the resource, Homer runs the model with the input, then display as a list of reasonable configuration sorted by NPV, LCOE and PBP. This software used to evaluate the economic calculation for some proposed scenarios. The case study’s electric load is shown in Figure (5). A daily, seasonal and yearly profiles created on the HOMER software. Moreover, an average and peak load are described.

Figure (5) Case study's Electric Load Profile on HOMER-PRO

Sinha (2014) mentioned in her study that HOMER is one of the best software with lots of software tools and options for designing the hybrid system. Furthermore, Roberts (2017) mentioned that HOMER is a great tool in modeling renewable energy sources and performing costs analysis. Furthermore, HOMER can help calculating a lot of economic values such as NPC, PBP, and COE, which will be used to assume the cost effective PV-system.

3.3. Net Present Cost

HOMER defines the net present cost (or lifecycle cost) of a component as the present value of all the costs of installing and operating that component over the project lifetime, minus the present value of all the revenues that it earns over the project lifetime.

3.4. Payback Period

The payback period is the time it takes to cover investment costs. It is calculated as the number of years elapsed between the initial investment, its subsequent operating costs and the time at which cumulative savings offset the investment (ISO 15686-5, 2017).

HOMER-PRO calculates the discounted payback by comparing two individual scenarios as the discounted cash flow difference line crosses zero.

3.5. Levelized Cost of Energy

The levelized cost of electricity (LCOE) is perhaps the most commonly referenced metric of PV system economics. In simple terms, the LCOE gives a levelized (average) cost of Electricity generation over the life of the asset. HOMER-Pro calculates the COE according to the following equation.

$$LCOE = \frac{C_{ann,tot}}{E_{Served}}$$

Where:

$C_{ann,tot}$ = Total life cycle cost for the system ,and E_{served} : is the total electricity load served (kWh/yr).

4. Selection of the Cost-Effective PV-system

A typical PV-system was simulated for each scenario. The cost effective PV-system selected according to COE, NPC, PBP and initial cost, whenever the required area required is available.

In this section will simulate different PV-Systems designs using HOMER-PRO software to allocate the most suitable PV-System for the selected case.

System parameters and components of the proposed Scenarios

Studied scenarios in this research are based on soma variables such as the capacity, connection type, PV-panels and battery types, where the proposed capacities are selected to be:

A. Half the minimum acceptable load (2.7 kWh.)
B. Equals the minimum acceptable load (5.5 kWh.)
C. One and a half times the minimum acceptable load (7.7 kWh), as shown in Figure (6),

Will design all the cases for On-grid, Off-grid, and Hybrid PV-systems, to find out the optimum system.

PV-Panels

- Mono-crystalline PV-Panels:

This type of PV-panels is not widely used in the Egyptian market due to the high price, in this research will use the mono-crystalline PV-panels with the following specifications.

The power of each panel is 345-Watt, efficiency 18.8%, and the derating factor is 88%. The price for each kW is 580$.

Poly-crystalline PV-Panels:

This type of panels is much more commonly used in Egypt due to the fine price for its efficiency and availability in the Egyptian market. In this research will use the poly-crystalline PV-panles with the following specifications.

The type the power of each panel is 275-Watt, efficiency 16.2%, and the derating factor is 88%. The price for each kW is 700$.

Inverters

- On-grid Inverter (3-5.5-8) kW

The researcher selected an on-grid inverter from the Egyptian market. The price for each capacity is (1070, 1960 and 2850) $ respectively.

This inverter's cost is average if compared to the available types in the Egyptian market.

Batteries

- Lead-Acid Batteries

This type of batteries still the most commonly used type, for its low price on the short term. In this research will use Lead acid battery from the Egyptian market with the following specifications. The voltage is 12 V, current is 1200 Ah, and its price is 300$.

- Lithium-ion Batteries

This type of batteries is not commonly used due to the high price. In this research will use the Lithium-ion batteries from the Egyptian market with the following specifications. The voltage is 12.8 V, 200 Ah and it' price is 800$.

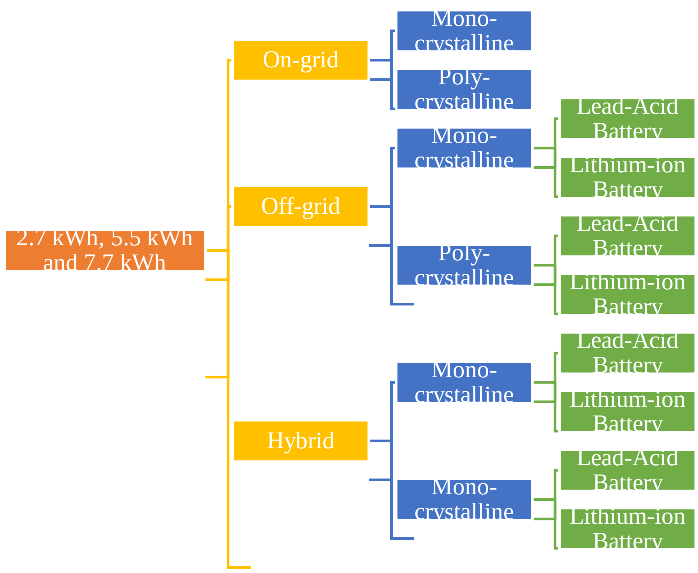

Figure (6) Proposed Scenarios to select the most suitable PV-system

Table (2) shows the results for simulating the previous mentioned scenarios.

Table (2) Simulation results for different types of PV-systems

Type	Capacity	PV-Panels	Battery Type	COE	NPV	Initial Cost	PBP
On-grid	2.76 kWhr.	Mono	/	$ 0.023	$ 3,410	$ 2,594	8.6
On-grid	2.76 kWhr.	Poly	/	$ 0.034	$ 5,068	$ 2,915	12
On-grid	5.5 kWhr.	Mono	/	$ 0.003	$ 721	$ 5,182	9.1
On-grid	5.5 kWhr.	Poly	/	$ 0.016	$ 4,011	$ 5,830	13
On-grid	7.6 kWhr.	Mono	/	$ (0.002)	$ (640)	$ 7,138	9.7
On-grid	7.6 kWhr.	Poly	/	$ 0.012	$ 3,866	$ 8,162	15
Hybrid	2.76 kWhr.	Mono	Lead-Acid	$ 0.027	$ 3,978	$ 4,094	14
Hybrid	2.76 kWhr.	Mono	Lithium-ion	$ 0.059	$ 8,837	$ 6,094	25
Hybrid	2.76 kWhr.	Poly	Lead-Acid	$ 0.038	$ 5,636	$ 4,415	19
Hybrid	2.76 kWhr.	Poly	Lithium-ion	$ 0.070	$ 10,495	$ 6,415	>25
Hybrid	5.5 kWhr.	Mono	Lead-Acid	$ 0.005	$ 1,289	$ 6,682	12
Hybrid	5.5 kWhr.	Mono	Lithium-ion	$ 0.025	$ 6,148	$ 8,682	22
Hybrid	5.5 kWhr.	Poly	Lead-Acid	$ 0.018	$ 4,579	$ 7,330	17
Hybrid	5.5 kWhr.	Poly	Lithium-ion	$ 0.038	$ 9,439	$ 9,330	>25
Hybrid	7.6 kWhr.	Mono	Lead-Acid	$ (0.000)	$ (611)	$ 8,638	12
Hybrid	7.6 kWhr.	Mono	Lithium-ion	$ 0.015	$ 4,799	$ 10,638	19
Hybrid	7.6 kWhr.	Poly	Lead-Acid	$ 0.013	$ 4,435	$ 9,662	17
Hybrid	7.6 kWhr.	Poly	Lithium-ion	$ 0.028	$ 9,294	$ 11,662	>25
Off-grid	2.76 kWhr.	Mono	Lead-Acid				

Off-grid	2.76 kWhr.	Mono	Lithium-ion	rgy produced less than the required load			
Off-grid	2.76 kWhr.	Poly	Lead-Acid				
Off-grid	2.76 kWhr.	Poly	Lithium-ion				
Off-grid	5.5 kWhr.	Mono	Lead-Acid	$ 0.225	$ 18,493	$ 11,182	22
Off-grid	5.5 kWhr.	Mono	Lithium-ion	$ 0.561	$ 46,035	$ 26,818	>25
Off-grid	5.5 kWhr.	Poly	Lead-Acid	$ 0.274	$ 22,451	$ 14,830	>25
Off-grid	5.5 kWhr.	Poly	Lithium-ion	$ 0.612	$ 50,232	$ 28,009	>25
Off-grid	7.6 kWhr.	Mono	Lead-Acid	$ 0.265	$ 21,777	$ 16,138	>25
Off-grid	7.6 kWhr.	Mono	Lithium-ion	$ 0.507	$ 41,615	$ 24,980	>25
Off-grid	7.6 kWhr.	Poly	Lead-Acid	$ 0.321	$ 26,363	$ 17,162	>25
Off-grid	7.6 kWhr.	Poly	Lithium-ion	$ 0.563	$ 46,214	$ 26,005	>25

The results show’s that the on-grid PV-systems is the most suitable systems for residential usage, and giving the best value of money on the long term and the payback period is less than any other system, Moreover, it gives the minimal cost of electricity.

5. Conclusion

The results show that the on-grid PV-systems is the most suitable system to be used for the residential usage in King-Marriott, because of the availability of electricity in this region and there is no need for storage systems “batteries”.

Moreover, the 5 kWh on-grid PV-system using mono-crystalline PV-panels is the cost-effective scenario for the moderate initial cost (5182 $) and the tiny COE (0.003$), NPC (721$) and the payback period is (9.1) years. So that, this research supports the usage of the 5 kWh on-grid PV-system in residential villas, for the low cost of energy and moderate payback period,

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