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Experimental Study on Feasibility and Affordability of Street Lights in Benghazi City by Using Photovoltaic System

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ABSTRACT

The world-wide demand for solar electric power or photovoltaic solar energy has grown steadily over the last two decades. Therefore, the need for a reliable and low cost electric power is the primary force driving the worldwide photovoltaic (PV) industry today. Recently, Libyan energy mix consists of local resources, such as natural gas at 38%, heavy fuel oil at 20% and light fuel oil at 42% but there is no contribution from renewable energy sources in the national energy.

In this work, an experimental investigation on the possibility of using solar energy as an alternative source for the traditional source of electricity for lighting columns in Benghazi city through solar panels will be introduced. The study has objectives including: firstly, the use of solar panels to meet the requirements of the solar lighting a column as a primary source. Secondly, to calculate the cost of electricity generated by solar energy compared to the cost of electricity produced from general gird. Eventually, to make a financial comparison to show the comparative expenses between the solar lighting column and the maintenance costs of the currently exist columns at the College of Mechanical Engineering Technology in Benghazi-Libya.

The results show that the choice of using the solar energy in the street column lighting is not just an environmentally friendly but it is also, a cost-effective and has a long lifespan.

KEYWORDS: *Energy, Photovoltaic, and Solar lighting*

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I. INTRODUCTION

Alternative Energy

The world-wide demand for solar electric power or photovoltaic solar energy has grown steadily over the last two decades. Therefore, the need for a reliable and low cost electric power is the primary force driving the worldwide photovoltaic (PV) industry today. The utilization of PV systems in electrical energy generation is considered as one of the most important alternative energy resources. The technological viability of solar photovoltaic systems has been proven especially for rural area applications in developing countries where solar energy is available [1].

Today, Libyan energy mix consists of local resources, such as natural gas at 38%, heavy fuel oil at 20% and light fuel oil at 42% but there is no contribution from renewable energy sources in the national energy. Libya's energy consumption is increasing at a relatively fast rate due to population growth and economic development. Libya's high dependency on the conventional energy resources and its accelerated growth of energy demand make the development of the current energy resources and the exploitation of a broader renewable supply mix one of the country's priorities. The annual consumption of electricity has increased very rapidly over the last decades, as it increased from 1,273 MWh in 1970 with high factor and reached to about 15,000 GWh in 2000 and about 32,000 GWh in 2010 with a constant annual growth rates between 6 and 8 per cent [2, 3]. Libya has installed twelve power plants which are capable of supplying 8.347 GW while the available capacity is 6.357 GW [2, 4].

In view of the future increasing demands for electricity in sustainable manner in the country, long-term energy sector roadmap was approved by the government to increase the use of the natural gas and improve the energy efficiency program. On the other hand, it should go to an alternative source for power generation, which requires no fuel and presents an opportunity for fuel consumption cost reduction to the government.

Solar energy Potential in Libya

Libya situates in the most favourable sunny belt (between 15^0 N and 35^0 N). The average daily radiation ranges from 7 kWh/m^2, in the northern region, to 8 kWh/m^2 in the far southern regions with more than 3500 hours of sunshine annually. The Global Horizontal Irradiance (GHI) in Libya is shown in Figure 1. This huge amount of solar energy is distributed over an area of 1,759,540 sq km and over 88% of the land is desert. Each square kilometre yearly in Libya receives solar energy equivalent to 1.5 million barrels of oil [1]. The country is struggling to satisfy its electricity demands while the sun is showering Libya with huge amount of sunshine every day. The installed PV capacity at the end of 2015 is 5 MW. Compared with Germany, the world leader in installed PV systems, with an area of 357,168 km², Libya has approximately the double radiation. In Germany, according to estimates, PV-generated power amounted to about 40 TWh and covered approximately 7.2 per cent of Germany's net electricity consumption including grid losses in 2017 with an installed PV capacity of 42,339 MW [5, 6]. This amount of energy is slightly higher the energy consumed in Libya in 2012. Bearing these facts in mind, Libya needs around half the installed PV capacity in Germany to satisfy its electricity needs. United Kingdom has an area with an average radiation of 2.95 kWh/m²/day, which is less than half of the average radiation in Libya. The installed PV capacity in the United Kingdom is 12.760 GW, in order to produce about 11.479 TWh, which is larger than the installed conventional capacity in Libya [7].

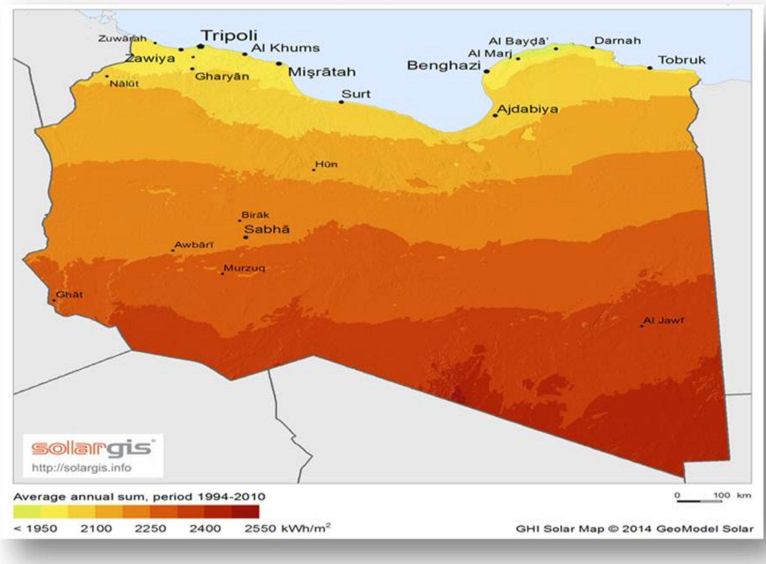

Figure 1 Solar Energy Potential in Libya [3]

The network of solar radiation measurements usually records global solar radiation on the horizontal surface. This important quantity is mostly variable on a daily and an hourly basis.

Values on horizontal surface can be used to compute the insolation received on inclined surfaces. In developing countries, the situation regarding solar radiation recording is very poor with only a few exceptions. In Libya, only fifteen stations recorded global solar radiation on the horizontal surface.

However, these data are not easily obtained. Therefore, for other locations in Libya one has to depend on the satellite based data, which are provided by NASA for example, or by various empirical relationships between global solar radiation and other climatological parameters that have been suggested so far by many authors.

In Libya, the functioning of instruments in the network of solar radiation measurements should be improved as soon as possible. However, such future improvement will not satisfy the current demand for insolation data because the existing network is too sparse. If new stations are established, it will take several years before a reliable radiation climate can be achieved. This is due to the great natural variability of solar radiation from year to year. As a temporary measure, the existing database should be improved by utilizing climate variables that are closely correlated with solar radiation such as sunshine duration and other meteorological parameters. In Pre-recorded readings of solar radiation and other climate parameters have been used in advance for the State of Libya from the NASA database. Table 1 and Figure 2 show the monthly averages of climate data and the average of solar radiation for the city of Benghazi respectively.

Month	Air temperature	Relative	Daily solar	Atmospheric	Wind	Earth temperature

		humidity	radiation - horizontal	pressure	speed	
	°C	%	$kWh/m^2/d$	kPa	m/s	°C
January	14.3	59.9%	2.55	100.3	5.1	15.1
February	14.2	58.4%	3.44	100.2	5.5	15.4
March	15.5	58.3%	4.70	100.1	5.3	17.0
April	18.1	54.4%	6.05	99.8	5.0	19.9
May	21.2	55.0%	6.89	99.9	4.8	23.4
June	24.0	57.3%	7.57	99.9	4.6	26.6
July	25.4	61.2%	7.50	99.7	4.8	28.3
August	26.4	59.8%	6.69	99.8	4.7	29.0
September	25.3	58.1%	5.52	100.0	4.6	27.6
October	22.7	58.0%	4.08	100.2	4.2	24.3
November	19.3	56.5%	2.90	100.2	4.7	20.3
December	15.8	58.4%	2.34	100.3	5.1	16.6
Annual	20.2	57.9%	5.02	100.0	4.9	22.0
Measured at (m)					10.0	0.0

Table 1 Monthly Averages of Climate Data [8]

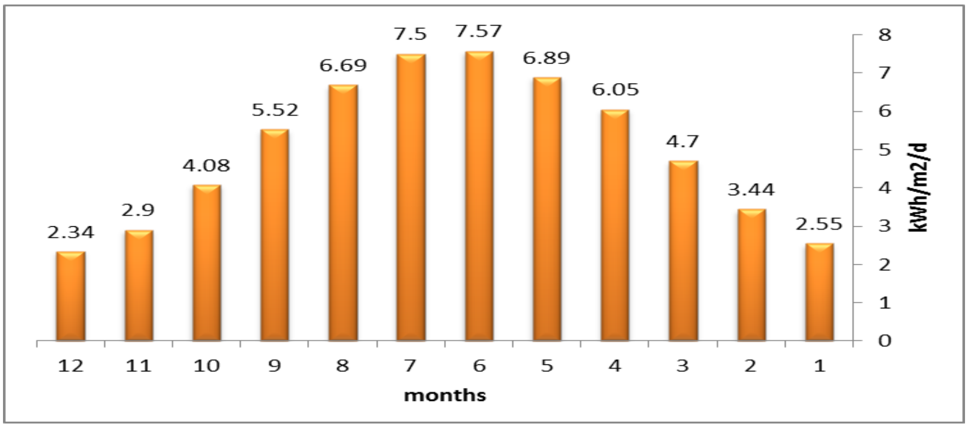

Figure 2 Average of Solar Radiation for the City of Benghazi [8]

II. METHODOLOGY

The building of the Faculty of Mechanical Engineering, shown in Figure 3, suffers from problems in the poles of lighting, in terms of cables and electrical connections, due to the entry of rainwater into the assembly rooms of wires and cables, which caused damage to cables and connections and led to power outages for some connections between columns. In this paper, a comprehensive comparative study of the maintenance of these columns, the change of cables, the repair of the wiring assembly rooms or the installation of new solar lighting poles instead of the previous columns connected to the general network of electricity will be conducted.

Figure 3 Main Building of College of Mechanical Engineering

Installation of Solar Street Light System

As shown in Figure 4, the solar street light system basically consists of solar cell, LED lamps, light pole and Control box (charger, controller, battery). The configuration of solar street light systems must be designed to be strong and must be good enough to withstand the harsh environmental conditions as the systems will be installed in road where they are continuously exposed to sun, rain, fog, pollution etc. The solar street lighting installations shall not damage aesthetic of the existing city or street plan; rather they shall add some beauty to the existing roadway. As showing in Figure 4, the solar street lights can be installed in following two ways: first configuration illustrates the situation where the battery is kept in the battery box on the pole whereas in second configuration the battery is installed in underground. Either of the configurations can be considered for installation of the system, and it has to be decided case wise case depending upon the requirement of the project site. Nevertheless the battery box mounted on the light pole is common practice in case of stand-alone solar street lighting systems [9].

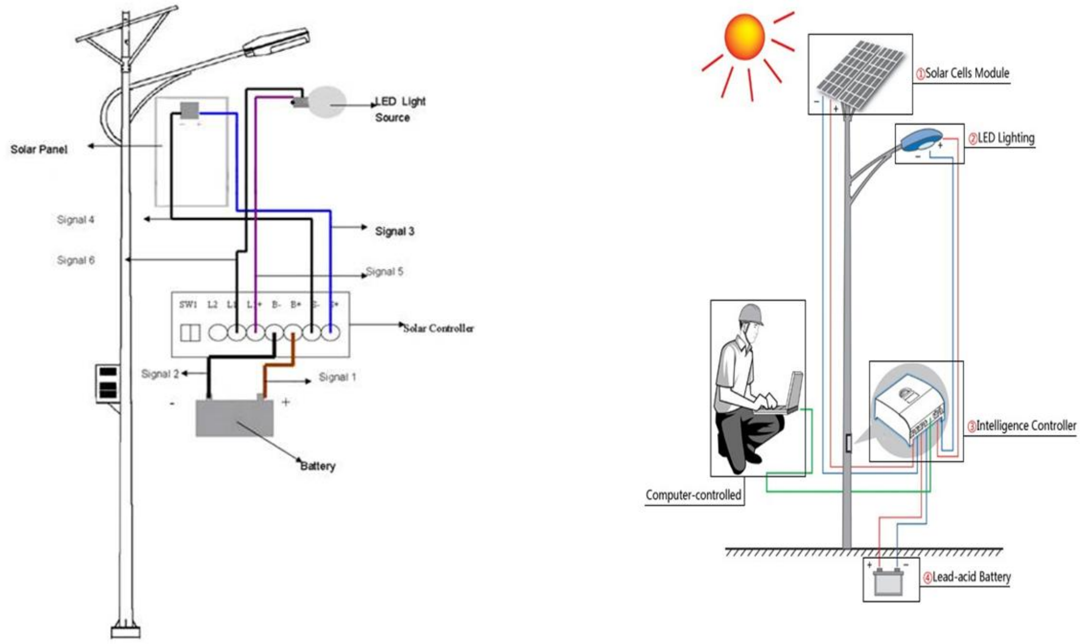

Figure 4 Designs for Installation of Solar Street Light [9]

Designing of an Optimal Model

In this section, information will be given on the calculation of the technical design of the system using the lighting column for street light with electrical energy generated by means of solar PV cells. In addition, calculating and selecting optimum model, and then apply the study experimentally on a column in the Faculty of Mechanical Engineering, and finally showing the results.

Some important factors that help to select the different components of the PV panel will be introduced as follows:

The maximum detection capacity that is suitable for the city of Benghazi which is located on latitude 32 N is calculated from the equation:

$$\text{Maximum detection Capacity} = 175 - (\text{Latitude} \times 3) \qquad (1)$$

To select the LED lamp, it is significant to determine the light intensity, in the unit of lux, which depends on the type of the road. For this study, the roads are internal road with a maximum speed 50 km/hr, therefore, the light intensity equals 6 lux.

In addition, the luminous power capacity is calculated according to the following equation:

$$\text{Lumens} = W \times L \times D / mf \times Cu \qquad (2)$$

where, W is the width of the road located under the spotlight field which is taken as 12m, L is the light intensity (in this study equals 6lux), D is the distance between columns which is measured from the site and found equals 20m. Finally the mf and Cu are the maintenance factor and coefficient of utilization factor which are taken as 0.82 and 0.9 respectively. By applying all these values in equation (2), it can be found that the luminous power capacity is 1580.48 lumens.

The LED lamps are scattered in the local market with different values of luminous efficacy ranging from 80 to 140 lumens/Watt, therefore, the average value of luminous efficacy of 100 lumens/Watt is selected to calculate the power consumption in watts by dividing the luminous power capacity (1580.48 lumens) on the luminous efficacy (100 lumens/Watt).

Before calculate the capacity of the solar panel, it is important to take into consideration the location of Benghazi (32 N) and the lamp operational hours which may reach up to 12 hours. Therefore, the total power required per day in Watts can be found from the equation:

Daily power consumption = operational hours × power consumption in Watts/ per cent of loss (3)

The calculation of the daily power consumption should take into account the loss of energy in solar lighting poles which is not less than 12%. This percentage is high due to the increase in the loss of dust, in addition, to the loss of wires, charging regulator and batteries. Therefore, the per cent of loss is 0.88.

Finally, to find the solar panel capacity the following equation is applied:

Capacity of the solar panel required = total power / hours of solar brightness (4)

Where the peak hours of the sun in the summer is 5 hours while in winter time is 4 hours.

So for the summer time, the capacity of the solar panel = 215.52 / (5×1.2) ≈ 36 watts

Where, the value 1.2 is the correction coefficient.

While for the winter time, the capacity of the solar panel = 215.52 / (4×1.2) ≈ 45 watts

Therefore, according to the solar panels available in the local market, a solar PV panel with a capacity of 50-watt has been selected.

III. RESULTS AND DISCUSSIONS

Installation of the Lighting Column

In the workshop at the Faculty of Mechanical Engineering Building, the parts and components of the solar lighting column system is assembled and installed as shown in Figure 5.

Cost Calculation the of a solar Lighting Column Project

The campus of the Faculty of Mechanical Engineering needs 89 columns. Table 2 shows the cost of a full installed solar column. These prices are suggested by Libyan entrepreneur in the PV solar application in the Libyan Dinar, L.D.

No.	Statement	The price	Installation cost	Quantity	Total project cost
1	Lighting column	715 L.D	45 L.D	89 pieces	70,000 L.D

Table 2 cost of lighting column

Figure 5 Final shape of the column of solar energy

Table 3 shows the cost of the maintenance of the existing street columns. The prices in Table 3 is calculated by the Libyan General Electric Company which is responsible for the accomplishment of the projects of operating and servicing the electric networks, stations of energy production and their distribution and transformation stations.

No	Statement	Result
1	Cost of changeable cable	10,731 L.D
2	Cable assembly in column	712 L.D
3	Cost of changing the searchlights	14,240 L.D
4	Main lighting control box	220 L.D
5	Consumer Meter reading	90 L.D
6	Cost of the sub-exit keys	300 L.D
7	Cost per worker (wire change)	17,675 L.D
8	Cost per worker (cable change)	1,335 L.D
9	total cost	45,000 × 1.25 = 60,000 L.D

Table 3 Maintenance costs of the existing street columns

Comparison in Cost Price

A comparison in the costs between installing solar lighting column and the maintenance costs of the current existing columns at the Faculty of Mechanical Engineering is introduced in Table 4. This table reveals that the maintenance of the 89 columns for the next 20 years is included in the economic study. Moreover, the price of electricity is taking into account which is estimated by the Libyan General Electric Company as well. It can be concluded from the table that the project will be pay backed in less than 2 years.

Comparison		
Statement	Solar street lighting	Maintenance of the existing street lighting
The cost of the project	70,000 L.D	--------
Initial maintenance cost	--------	60,000 L.D
Cost of maintenance within 20 years	10,000 L.D	30,000 L.D
The price of electric power during 20 years	--------	(134,568 x 1.25) =170,000 L.D
total cost	80,000 L.D	260,000 L.D

Table 4 Economic comparison between solar lighting and maintenance of the existing street lighting

IV. CONCLUSION

The issue of solar energy and alternative energy systems is a matter of concern to all, especially with high oil prices, increased environmental pollution caused by the excessive use of oil derivatives and continued energy cuts, prompting everyone to consider developing alternative sources of energy.

In this work, lighting poles were installed using solar energy in the building of Mechanical Engineering College in Benghazi. The study area is 32 degrees in latitude, which includes the municipality of Benghazi in terms of: average solar radiation, temperature and other climatic conditions for the possibility of using photovoltaic solar systems. The solar lighting system has been installed and operated experimentally for one column and the comparison to ease taking the decision whether to install a completely new solar street lighting or to repair and fix the old system street lighting and connect it with the general electric grid has been accomplished.

This study shows that the use of solar energy is cost-effective with a payback period less than 2 years and has a long and environmentally friendly lifespan.

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