Economic Feasibility Of Solar Powered Street Lighting System In Libya

Zakariya Rajab, Ashraf Khalil, Moneer Amhamed and Ali Asheibi
Electrical and Electronic Engineering Department
Faculty of Engineering, University of Benghazi
Benghazi, Libya
Zakreia.hassan@uob.edu.ly

Abstract— **Libya is one of the countries blessed with high potential of renewable energy. Currently, the electricity in Libya is produced from fossil fuel to meet the demand on the local electricity market. In the near future, the demand on the energy will increase significantly. The growth in energy demand will lead to more oil and gas consumption in Libya. Additionally, the CO_2 emissions will increase substantially. Therefore, Libya should make an urgent plan to use its alternative energy supplies to cover some of its load requirements. For example street lighting forms around 20% of the electricity consumption. The street lighting system in Libya is based on the high pressure sodium lamps which are powered from the electricity grid. The lamp rating ranges from 250 to 400 watts. As the country struggles to satisfy its electricity demands we propose replacing the conventional street lighting system with solar powered LED (Light emitting Diode) lighting system. The paper presents a case study for 4 km solar street lighting system in Almarj city. Two proposals are investigated, the conventional lighting system and the solar powered LED lighting system. A feasibility study of the street lighting system is carried out. The cost, energy savings and the CO_2 emission of the two proposed systems are compared. The cost of the solar powered LED street lighting system is 1,250,200 LD, while the cost of the high pressure Sodium lamp street lighting system is 2,117,255 LD. Additionally, the solar powered LED street lighting system has no CO_2 emissions.**

Keywords— LED; Libya; Photovoltaic; Social cost; Solar energy; Street lighting.

I. Introduction

Libya is situated in the middle of North Africa and is one of the largest oil producer in Africa with an area of 1,750,000 km^2. Following the political conflict and the civil war, the General Electrical Company of Libya (GECOL) is failing to satisfy the escalating electricity demands. The country's infrastructure has been damaged and the blockade of the oil refineries in 2013 weakened the economy. In the meantime installing fossil fuel centralized power plants is not possible. Furthermore, the oil and the gas are the only source of the income in Libya and burning more oil and gas reduces the country revenue and increases the CO_2 emissions. Therefore, Libya should utilize its alternative energy resources to cover some of its load requirements. With an average solar radiation of 7.5 kWh/m^2/day over 1,75,00 km^2 area, Libya has very high potential of solar energy. Moreover, the Desert covers much of the country where there is a high potential of producing electricity through thermal or photovoltaic and solar energy conversion. The renewable energy has been used in Libya back to the seventies where the main applications are for powering small remote loads [1]. Since 1976 photovoltaic (PV) systems have started to supply electricity for a cathodic protection station for the oil pipeline connecting Dahra oil field with Sedra Port. In 1979 four experimental stations in the communication field were installed. Later, in 1983 the solar water pumping projects started, where water was pumped for irrigation at EL-Agailat.

The solar energy is very promising technology in Libya. The average solar radiation in Libya is around 7.5 kWh/m^2/day with about 3000 to 3500 sunshine hours per year [1-3]. This huge amount of energy which falls on the earth every day is sufficient to secure the electricity needs of Libya and even can be exported to Europe. However, Libya is blessed with such high solar radiation over a very large area, the contribution of the solar energy in the Libya energy mix is still negligible. The electricity consumed by residential loads and the street lighting forms around 50% of the total electricity consumption [1,2]. The irrational use of the electricity has increased dramatically in the last few years. This will lead to more consumption of the precious resources; the gas and the oil. Renewable energy is one of the alternatives that could play a great role, especially in the street lighting system and home energy systems.

Solar powered LED street lighting systems have gathered a lot of attention in the past few years because of their many advantages. There are many studies which proved that the solar powered LED lighting systems are economically feasible and saves fuel in addition to the prevention of the CO_2 emission. For examples the papers [4-9] investigate the feasibility of the solar powered LED lighting system in different countries. In [4] a feasibility study of solar powered LED street lighting system is carried out for a road in Jordan. The solar powered LED street lighting system is economically feasible and can save 50% of energy with comparison to high pressurized sodium lamps (HPS) [4]. The LED lighting system is proposed to replace the HPS lamp lighting system in Egypt [5]. It is found that the cost of the solar powered LED street lighting system over 20 years equals 30% of the cost of the conventional street lighting [5].

978-1-5090-6751-0/17/$31.00 ©2017 IEEE

The paper reports the feasibility of the solar powered LED lighting system as new technology to mitigate the current energy crisis in Libya. The paper starts with the description of the current energy situation in Libya. Then the potential of the solar energy in Libya is briefly investigated. Depending on the current energy situation the solar energy is proposed to replace the conventional lighting system which is widely used in Libya. A 4 km street is chosen as a case study. Two alternatives are analyzed; the grid-powered high pressure sodium lamp street lighting system and the solar powered LED street lighting system. These alternatives are compared in terms of the capital cost, maintenance cost, total cost, fuel cost and the CO_2 emission. Finally the conclusions drawn from this study and the recommendations for the GECOL are presented.

II. THE STATE OF CURRENT ENERGY IN LIBYA

The GECOL is a state owned company and is responsible for the generation, transmission, and distribution. The GECOL has been established in 1984 and is the only body responsible for installing the power plants in Libya [10]. Figure. 1 shows the location of the installed power plants in Libya. Electrical energy is generated by twelve power plants, where most of them are located along the coastal side of Libya. Five of them are gas-fired power plants, and two of them are combined cycle power plants. The other five are steam power plants. These power plants are capable of supplying 8.347 GW while the available capacity is 6.357 GW. The national electric grid consists of an ultra high voltage capacity of 400 kV with a total circuit length of 442 km, and a high voltage transmission level of 220 kV with a total circuit length 13,677 km. The sub transmission voltage level is 66 kV, with a total circuit length of 13,973 km. The distribution network's voltage level is 30 kV with a total circuit length of 6,583 km [10]

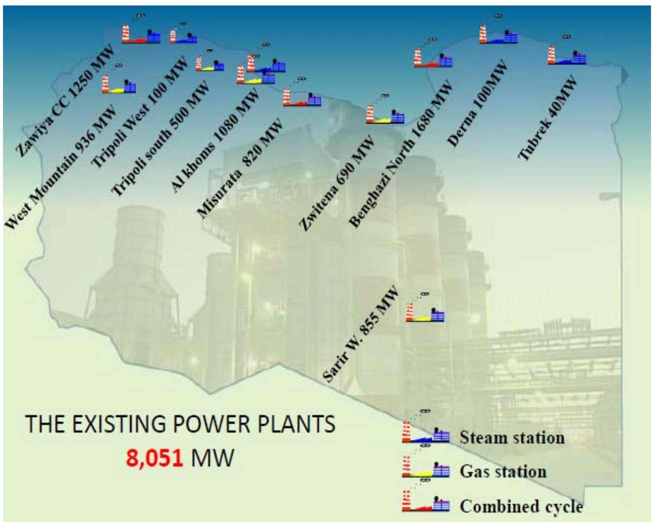

Fig. 1. Installed power plants in Libya [10].

The energy sector relies on the natural gas, heavy fuel oil and light fuel oil with the percentages shown in Figure 2. The GECOL increased the dependence on the natural gas in order to reduce the CO_2 emission and save more oil. The energy consumption is distributed among several load types as shown in Figure 3. The residential load is the most dominated load with 31% of the total consumed energy. The street lighting is around 19% of the energy consumption. While the other 50% is distributed in commercial, agricultural, and industrial. The load growth study is one of the essential subjects with regard to load demand prediction [11]. Figure 4 shows the energy consumption in Libya over the last ten years. The maximum electricity demand has increased gradually from 3.341 MW in 2003 to 5.98 MW in 2012 and it is expected to rise in the next years [11].

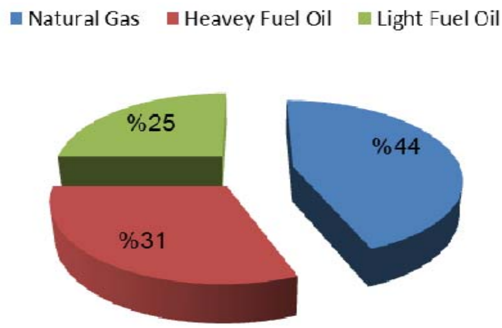

Fig. 2. Types and percentage of the fuel used in electricity generation [2]

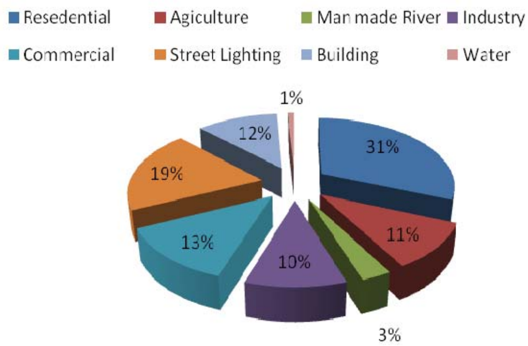

Fig. 3. Types and shares of customers of Libyan electricity generation [2]

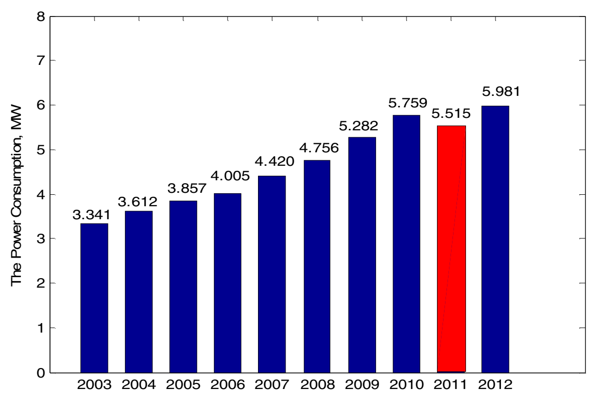

Fig. 4. The energy consumption over the last 10 years. [2]

III. PRODUCTION OF PV ENERGY AND CLIMATE

The Geographical location of Libya makes it one of the countries blessed with high solar energy resources. Solar energy is believed to be the most important and feasible renewable energy source in Libya. Libya lies within the most favorable sunny zone. The rain falls is below 150 mm in most of the country. The solar radiation in different cities in Libya is shown in Figure 5.

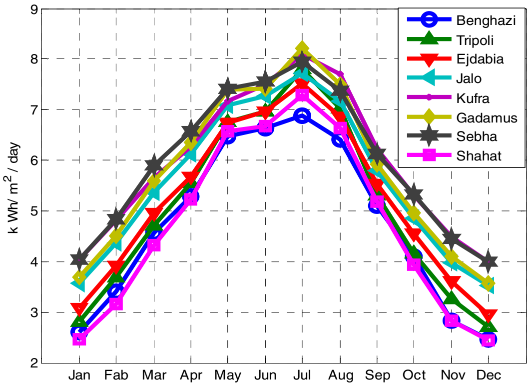

Fig. 5. The monthly solar radiation in different cities in Libya [11]

IV. CASE STUDY: PV STREET LIGHTING IN ALMARJ CITY

This section presents the Shaluoni road in Almarj city as a case study. Almarj is one of the biggest cities in Libya located in the eastern part of Libya. The road is located in the east of Almarj city and its length is 4 *km* and its width is ten meters. The road is located about 8 *km* far from the Almarj city and connects between Almarj city and Tobruk city. This is one of the roads that connects between the eastern part of Libya and Egypt. The main benefits of the road lighting systems is the safety and security of the drivers. The road locates in a very dangerous area between the mountains and the trees, and as a result the number of the accidents on this road is very high. Moreover, the road is around 1 *km* from the grid in a difficult terrain which makes the connection to the grid a cumbersome and expensive task. The average solar radiation in Amarj Libya is shown in table I.

TABLE I. THE AVERAGE SOLAR IRRADIATION IN ALMARJ LIBYA

Month	Average solar irradiation (kWh/m^2)
January	4.89
February	6.28
March	7.51
April	8.27
May	8.58
June	8.61
July	8.46
August	8.11
September	7.26
October	6.15
November	4.86
December	4.29

Two options are to be investigated for the road lighting. The first alternative, is the grid connected street lighting using the HPS lamp, which the one used in Libya. The second alternative is the solar powered LED lighting system.

A. *The grid connected HPS lamp street lighting system*

The two alternatives are compared in terms of the capital cost, maintenance cost, fuel cost and CO_2 emission in terms of the social cost. The two systems are compared over 20 years. The cost of the system is divided into:

- The cost of gaining of the products,
- The cost of installation,
- The energy consumption cost,
- Maintenance and operating costs.
- The cost of the CO2 emission.

1) Capital cost: The road length is 4 *km*. The distance used by the GECOL between two poles is 40 *meters*. This project will require 100 units of lighting. The road lighting components used in the conventional lighting system in Libya are given in Table II

TABLE II. THE AVERAGE SOLAR IRRADIATION IN ALMARJ LIBYA

Component	Quantity	Price in (LD)	Total amount (LD)
400 Watt HPS lamp including installation	100	350	3,5000
Lamp arm	100	60	6,000
Galvanized 9 m Pole, Including installation cost	100	276	27,600
Foundation of the poles (60 cm × 60 cm × 100 cm) including installation	100	152	15,200
Cable include installation	4000 m	35	140,000
Timer	100	35	3,500
Miscellaneous cost	4000 m	70	280,000
Distribution panel	2	2800	5,600
Initial investment cost LD			512,900

The miscellaneous cost includes the labor, wires, distribution boxes, digging, backfilling and restoring the location. The total cost of installing the grid connected HPS lamp lighting system is 512,900 LD (According to the Central Bank of Libya, 1$ US = 1.4 LD, the Black market price of 1 $ US is between 4 and 5 LD at the End of 2016).

2) Electricity consumption cost: The electricity generation cost in Libya is ranging from 0.15 $ to 0.20 $ per kWh [12]. The duration of the lights operation is 12 hours from 18:00 PM to 06:00 AM. The cost of the electricity in Libyan dinars is 0.2499 LD / kWh. A 400 W HPS lamp will consume 4.8 kWh daily. The road lighting will consume 175,680 kWh per year. The operation time of the system is selected to be 20 years. For the whole life time of the system, it will consume 3,513,600 kWh, which makes the fuel cost 878,048.64 LD if the losses in the Libyan network are neglected. The average losses in the Libya electricity network are around 30% [13].

Taking the losses into consideration the fossil fuel power plants in Libya need to generate 5,019,429 kWh which cost 1,254,355 LD. The cost of the grid connected HPS lamp lighting system with the fuel cost is 1,767,255 LD.

3) Maintenance fee: The main cost of the HPS lamp lighting system is the lamp replacement. The average lifespan of street lamps is between one to two years if no voltage fluctuation affects the lamps. The GECOL replaces the lamps frequently due to voltage fluctuation and the high number of blackouts. Considering the maintenance cost to be 350,000 LD, then the overall cost is 2,117,255 (1,767,255 + 350,000) over 20 years.

4) CO_2 Emission: Fossil fuel is the primary source of CO_2 emission. The CO_2 emission factor depends on the type of the fuel as given in Table III [13]. In Libya one light fuel oil generates 418 kWh, while one heavy fuel oil barrel generates 500 kWh, and one cubic meter of the natural gas generates 3.1722 kWh [10].

TABLE III. CO_2 EMISSION FACTOR FOR DIFFERENT TYPES OF FUEL

Fuel type	Gas	Light fuel oil	Heavy fuel oil
Conversion Factor	0.185 Kg CO_2/KWh	2.518 Kg CO_2/liter	2. 764 Kg CO_2/liter

Generating 5,019,429 kWh requires burning either 12,008 barrels of light oil, 10,039 barrel of heavy oil, or 1,582,304 m^3 of natural gas. The CO_2 emissions of the road lighting system with different types of fuel and generating technology are given in Table IV. The CO_2 emission should be a factor in designing electrical systems [14]. In most of the feasibility studies of the street lighting systems, the CO_2 emission cost is not considered. The CO_2 can damage the economy in many ways by affecting the health of the humans and the animals and reducing the agricultural yield. The cost of the CO_2 is known as the "social cost" and it is estimated at 220$ per ton of CO_2, according to a recent study by Stanford scientists [15]. The social cost with different types of fuel is given in Table IV.

TABLE IV. CO_2 EMISSION FOR THE STREET LIGHTING SYSTEM

Fuel type	Gas	Light fuel oil	Heavy fuel oil
Conversion Factor	0.185 Kg CO_2/kWh	2.518 Kg CO_2/liter	2.764 Kg CO_2/liter
Fuel Amount	1,582,304 m^3	12,008 barrels	10,039 barrels
CO2 emission	0,928,594 Kg CO_2	4,807,547 Kg CO_2	4,268,248 Kg CO_2
CO2 social cost	286,007 LD	1,480,725 LD	1,314,619 LD

B. Solar powered LED street lighting system

The proposed solar powered LED lighting system is shown in Fig 6. The main components are: the PV module, the charge controller, an LED luminaries, a battery, a pole, and cables. In order to insure the availability of the lighting system, the system should be designed carefully. The design procedure involves determining the size of the batter and the PV panel.

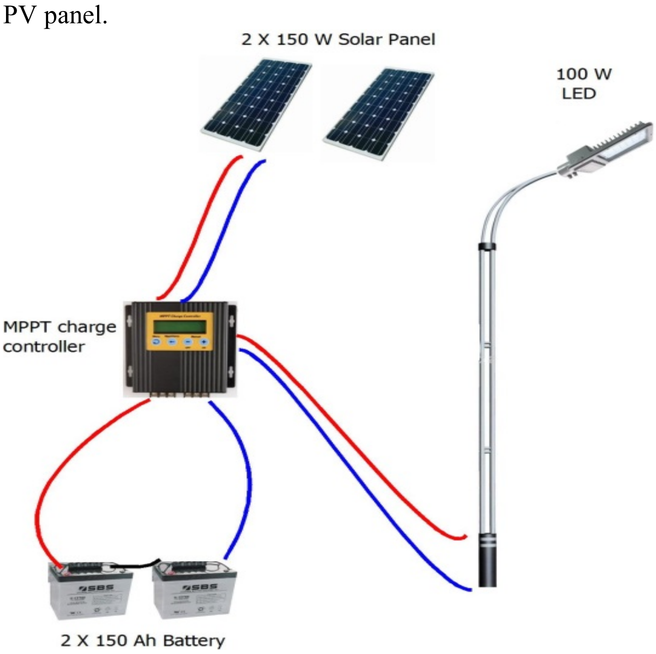

Fig. 6. The solar powered LED street lighting system

PV panel and Battery Sizing: To determine the battery and the PV panel sizes, we follow the following steps:

(1) Determine the number of the operation hours: The number of operating hours to determine the daily load. To calculate the daylight hours the following formula is used [16].

$$N = \frac{2}{15}\cos^{-1}(-\tan\phi\tan\delta) \qquad (1)$$

where N is the daylight length (hours), φ is the latitude, δ is the solar declination angle which can be determined using Cooper formula [16].

$$\delta = 23.45\sin(360\frac{284+n}{365}) \qquad (2)$$

where n =1,..,365. The monthly average daylight hours in Almarj city are given in table V.

TABLE V. THE AVERAGE DAYLIGHT HOURS IN ALMARJ CITY

Month	Declination angle	Average Daylight hours
January	-20.92	10.12
February	-12.95	10.88
March	-2.42	11.79
April	9.41	12.81
May	18.79	13.67
June	23.09	14.10
July	21.18	13.90
August	13.45	13.17
September	2.22	12.19
October	-9.60	11.18
November	-18.91	10.32
December	-23.05	9.91

From table V the average daylight hours is 12.01 which makes the operating hours of the street lighting 12 hours, from 18:00 PM to 06:00 AM.
(2) The Battery Size: The battery is a crucial part in deigning stand-alone PV systems. The battery serves daily and seasonal purposes. During the day the PV panel charges the battery and during the night the battery powers the load. In the winter where there is a lack of sunshine the battery should be capable of satisfying the load. The days of the autonomy are chosen to be 3 days. The battery voltage level is 24 V. The load has the following specifications:

- Hours of operations per day: 12 hours from 18:00 PM – 06:00 AM.
- Days of autonomy: 3 days
- Battery voltage level: 24 V
- 100 W LED street lighting.

The daily load current is 50 Ah, for three days of autonomy the battery size is 150 Ah. To insure that the battery will not discharge below 50%, the required capacity is then 300 Ah (150 Ah/ (1-0.5)).
(3) The PV panel size: From Table I, December is the month with the lowest radiation of 4.29 kWh/m^2. To satisfy the load requirements in the winter the array size should be 279.7 W ([50/4.29]*24). Taking the dust accumulation and the charging efficiency into consideration the panel size is 294.42 W (279.7/0.95). The nearest standard is 300 W or two 150 W panels. The energy output of the PV panel and the LED lighting load is shown in table VI. The optimum panel inclination in Almarj city is 32 degrees. The energy output of the PV system and monthly load energy are calculated according to [17]:

$$E = I_{Peak} \cdot d_m \cdot R_{average} \cdot \eta \cdot \alpha \cdot V \qquad (3)$$

$$E = P_{LED} \cdot d_m \cdot h \qquad (4)$$

where; I_{peak} the panel current at the standard operating conditions, d_m is the number of the days in the corresponding month, $R_{average}$ is the average monthly sunshine hours, η is the charge efficiency, α is the dirt accumulation factor, h is the hours of the load operation, and P_{LED} is the load power which is 100 W.

TABLE VI. THE PV SYSTEM ENERGY OUTPUT AND THE LED LAMP ENERGY CONSUMPTION

Month	Energy output of PV kWh	Load Energy consumption kWh
January	38.9	37.20
February	45.1	33.60
March	59.7	37.20
April	63.6	36.03
May	68.2	37.20
June	66.3	36.03
July	67.3	37.20
August	64.5	37.20
September	55.9	36.03
October	48.9	37.20
November	37.4	36.03
December	34.1	37.20

The specifications of the solar powered street lighting system for the road are given in Table VII. The cost of the road solar powered LED lighting system is given in Table VIII.

TABLE VII. SOLAR LED STREET LIGHTING SYSTEM SPECIFICATION

Item	Rating	Quantity
Solar Panel	150 W	200
Battery	150 Ah	200
LED lighting	100 W	100

TABLE VIII. SOLAR POWERED LED LIGHTING SYSTEM COST

Component	Quantity	Price in (LD)	Total amount (LD)
150 Wp PV panel	200	400	80,000
150Ah Battery	200	990	198,000
Foundation of the poles, including installation	100	1400	140,000
LED Lights	100	450	45,000
9 m Pole	100	810	81,000
Solar converter	100	68	6,800
Buried Box	100	54	5,400
Initial investment cost LD			556,200

The battery is still the crucial part in the stand-alone PV system. The battery needs to be replaced every five years. This means they will be replaced three times during the lifetime of the system. The maintenance cost of the solar powered lighting system is then 594,400 LD (200*3*990). The solar panel lifespan is between 20 to 25 years. From the experience with PV panels in Libya, they have been running for over 30 years [18]. The LED lamps have a lifespan over 50,000 hours, which means they can be used for more than 10 years without requesting any replacement; the lifetime of the controller and the LED lights is chosen to be 10 years. Then their cost is summed up to 100,000 LD (45,000 + 20,000+35,000). Then the overall expenses which include the maintenance is 1,250,200 LD for the twenty years.

V. DISCUSSION

In order to select the best choice the two alternatives are compared in the following aspects: (i) The initial investment, (ii) The maintenance cost, (iii) The fuel cost, (iv) The total cost, and (iv) the social cost. The results of the comparison between the two alternatives are summarized in table IX. The main barriers for solar energy installation is the high initial investment comparing with the conventional one. For the street lighting system in Libya the initial cost is comparable with the conventional one. Over twenty years the cost of the solar powered LED street lighting system is 1,250,000 LD while the cost of the HPS lamp street lighting system widely used in Libya is 2,117,255 LD. This shows around 60%

reduction in the cost over 20 years. Additionally, the solar powered street lighting system saves fuel and prevents the emission of CO_2. The maintenance cost of the solar powered street lighting system is higher because of the price of the batteries. It should be noted that the social cost of the CO_2 should be considered in energy systems design. As can be seen from Table IX, the social cost is very high when the fuel oil is used.

TABLE IX. SOLAR POWERED LED AND FOSSIL FUEL SUMMARY

	Solar Powered LED	Fossil Fuel HPS
Capital cost	556,200	512,900
Maintenance Cost	694,000	350,000
Total Cost without fuel	1,250,200	862,900
Electricity cost	0	1,254,355
Cost with fuel	1,250,200	2,117,255
The gas social Cost	0	286,007
The LO social Cost	0	1,480,750
The HO social Cost	0	1,314,600
Total Cost, (Gas fuel)	1,250,200	2,403,262
Total Cost, (LO fuel)	1,250,200	3,598,005
Total Cost, (HO fuel)	1,250,200	3,431,855

VI. CONCLUSION

In this paper, we propose replacing the grid connected HPS lamp street lighting system with a solar powered LED lighting system. The two alternatives are compared in terms of the capital cost, maintenance cost, fuel cost and the CO_2 emission. The cost of the solar powered LED street lighting system is 1,250,000 LD, while the cost of the high pressure Sodium lamp street lighting system is 2,117,255 LD. The solar powered LED street lighting proved to be economically feasible and saves fuel and money over its lifespan. On the other hand the current street lighting system in Libya is nonrenewable and unsustainable. The solar powered street lighting system is the optimum solution because Libya struggles to satisfy the energy demands and it is difficult in meantime to build new centralized power plants. As Libya relies on the oil and gas for electricity generation, these will reduce the country revenue when the load demands increase in near future. Furthermore the adoption of the PV system in Libya reducing the CO_2 emission. This study can be used by the energy sector policy makers in Libya as a guide.

REFERENCES

[1] Ali Asheibe, Ashraf Khalil, "The Renewable Energy in Libya: Present Difficulties and Remedies". In the Proceedings of the World Renewable Energy Congress, Australia, 2013, pp. 1-5.

[2] Ashraf Khalil, Ali Asheibe, "The Chances and Challenges for Renewable Energy in Libya". In the Proceedings of the Renewable Energy Conference, Palermo, 2015, pp. 1-6.

[3] Zakariya Rajab, Ashraf Khalil, Ali Asheib, "Modeling, Simulation, Analysis and Control of Stand-alone PV System", In proceedings of the 7th International Renewable Energy Congress "IREC 2016", Hammamet, 2016, pp. 1-6.

[4] Lina Al-Kurdia, Reem Al-Masria, A. Al-Salaymeh, "Economical Investigation of the Feasibility of Utilizing the PV Solar Lighting for Jordanian Streets," Int. J. of Thermal & Environmental Engineering, vol. 10, no. 1, pp. 79-85, 2015.

[5] Mokhtar Ali, Mohamed Orabi, Emad Abdelkarim, Jaber A. Abu Qahouq, Abdelali El Aroudi, "Design and development of energy-free solar street LED light system," in 2011 IEEE PES Conference on Innovative Smart Grid Technologies - Middle East, , Jeddah, 2011, pp. 1-7.

[6] M.S. Wu, H. H. Huang, B. J. Huang, C. W. Tang, C. W. Cheng, "Economic feasibility of solar-powered led roadway lighting," Renewable Energy, vol. 34, no. 2009, pp. 1934–1938, 2009.

[7] Mahmoud I. Masoud, "Street Lighting using Solar Powered LED Light Technology: Sultan Qaboos University Case Study," *2015 IEEE 8th GCC Conference & Exhibition*, Muscat, Oman, 2015, pp. 1-6.

[8] Ika Shinta Mardikaningsih, Wahyudi Sutopo, Muhammad Hisjam, Roni Zakaria, "Techno-economic Feasibility Analysis of a Public Street Light with Solar Cell Power," in Proceedings of the International MultiConference of Engineers and Computer Scientists 2016, Vol. 2, Hong Kong, 2016, pp. 1-5.

[9] Nallapaneni Manoj Kumar, Anup Kumar Singh, K. Vinay Kumar Reddy, "Fossil Fuel to Solar Power: A Sustainable Technical Design for Street Lighting in Fugar City, Nigeria," in 6th International Conference on Advances in Computing & Communications, ICACC 2016, Cochin, India, 2016, pp. 956–966.

[10] "General Electric Company Of Libya GECOL Annual Report," 2012.

[11] Ashraf Khalil, Zakariya Rajab, Ali Asheibi, "The Economic Feasibility of Photovoltaic Systems for Electricity Production in Libya," *The 7th International Renewable Energy Congress (IREC'2016)*, Hammamet, Tunisia, 2016, pp. 1-6.

[12] Joshua Charap, "Libya: Selected Issues," International Monetary Fund, Washington, D.C, 13/151, 2013.

[13] Mohamed Moktar, Belkasem El-Obadi, Salah Sanoga, Saleh Osman Khalil El-Arroudi, "Demand Side Management in Libya: A Case Study of the General Electric Company of Libya," General Electricity Company of Libya, Tripoli, Libya, 2009.

[14] P. Casals, X. Granados, R. Bosch, J.A. Martinez, "CO2. A new factor to be considered on the design of electrical distribution grids," in International Conference on Power Engineering, Energy and Electrical Drives, 2009. POWERENG '09, Lisbon, 2009, pp. 233-238.

[15] Frances C. Moore, Delavane B. Diaz, "Temperature impacts on economic growth warrant stringent mitigation policy," Nature Climate Change, vol. 5, no. 2015, pp. 127-131, January 2015.

[16] John A. Duffie, William A. Beckman, *"Solar Engineering of Thermal Processes*", 4th ed, Wisconsin–Madison: Wiley, 2013.

[17] Martin Green, *"Solar Cells: Operating Principles, Technology, and System Applications*", Prentice-Hall, 1982.

[18] I. M. Saleh Ibrahim Al-Jadi, M. A. EKhlat, N. M. Krema, "Photovoltaic in Libya Application, and Evaluation" in *Proceedings of the International Conference on Renewable Energy for Developing Countries*, pp. 1-11, 2005.

.