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Economical Investigation of the Feasibility of Utilizing the PV Solar Lighting for Jordanian Streets

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Abstract

Jordan blessed with a various type of renewable energy resources, being located on the Sun Belt is the most perspicacious and substantial matter. In spite of these facts the energy problem is one of the most frustrating challenges facing Jordan these days, causing tremendous pressure on the country's economy, obviously the solution lies in reducing the proportion of the imported fuel for the benefit of exploitation of renewable energy sources. Street lighting is a vital sector in any country growth. This vital sector represents 2% of annual electricity consumption in Jordan. This paper will introduce feasibility study for the installation photovoltaic cells in street lighting for existing and futuristic project as a step toward solving the problem facing this sector. The study shows that photovoltaic is feasible for futuristic due to minimizing the work frame time and the cost required for the infrastructure.

Keywords: *Renewable Energy, Photovoltaic, PV, Street Lighting, Solar Energy.*

1. Introduction

Due to the increase in electricity demand worldwide it is becoming more common for cities to cut their power consumption through self-generation from renewable energy sources such as solar and wind to produce electricity. Jordan imports 97% of its energy from neighbor countries despite the fact that it is blessed with great amounts of renewable energy resources especially that it lies in the sun built. Solar irradiance in Jordan is one of the heights worldwide; Figure 1) represents global irradiation at optimum angle in Jordan. The total direct annual solar radiation ranges from 2400 kWh/m2 to more than 2700 kWh/m2, with average hour of light 2007.5hr per year [2]. These high solar energy amounts encourage capital investments in solar energy systems in Jordan. According to the comprehensive strategy for energy sector, renewable is targeted to reach 10% of total energy mix by 2020, compromising 15-20% of consumed electricity [1]. The PV energy price, government utilization and legislation are factors that increase public motivation toward utilizing and developing PV systems.

The key to reach this target share of renewable energy is to encourage public participation in the implementation of renewable energy as it is evident from the examples of leading countries in renewable energy; the government has to take a leading role in utilizing renewable energy into sectors that touch the bases of daily life. Street lighting sector is a vital sector in any country's growth. This vital sector represents 2% of annual electricity consumption in Jordan.

The government showed an interest in reducing the energy consumption of the street lighting sector through many management decisions that recently has been, such as, reducing the number of lightened fixtures in selected streets around the country which had a direct impact on public satisfaction, well-being and on the number of accidents. Figure (2) shows the number of accidents in selected roads for the past three years. It is evident that the road safety decreased since implementation in 2012 by 50% for the first half of 2013 [4].

Photovoltaic systems may support the government management strategy without affecting streets safety; these systems have been commercially available for quite some time. The cost of photovoltaic has dropped significantly over the past few years due to technology improvement and increase in demand.

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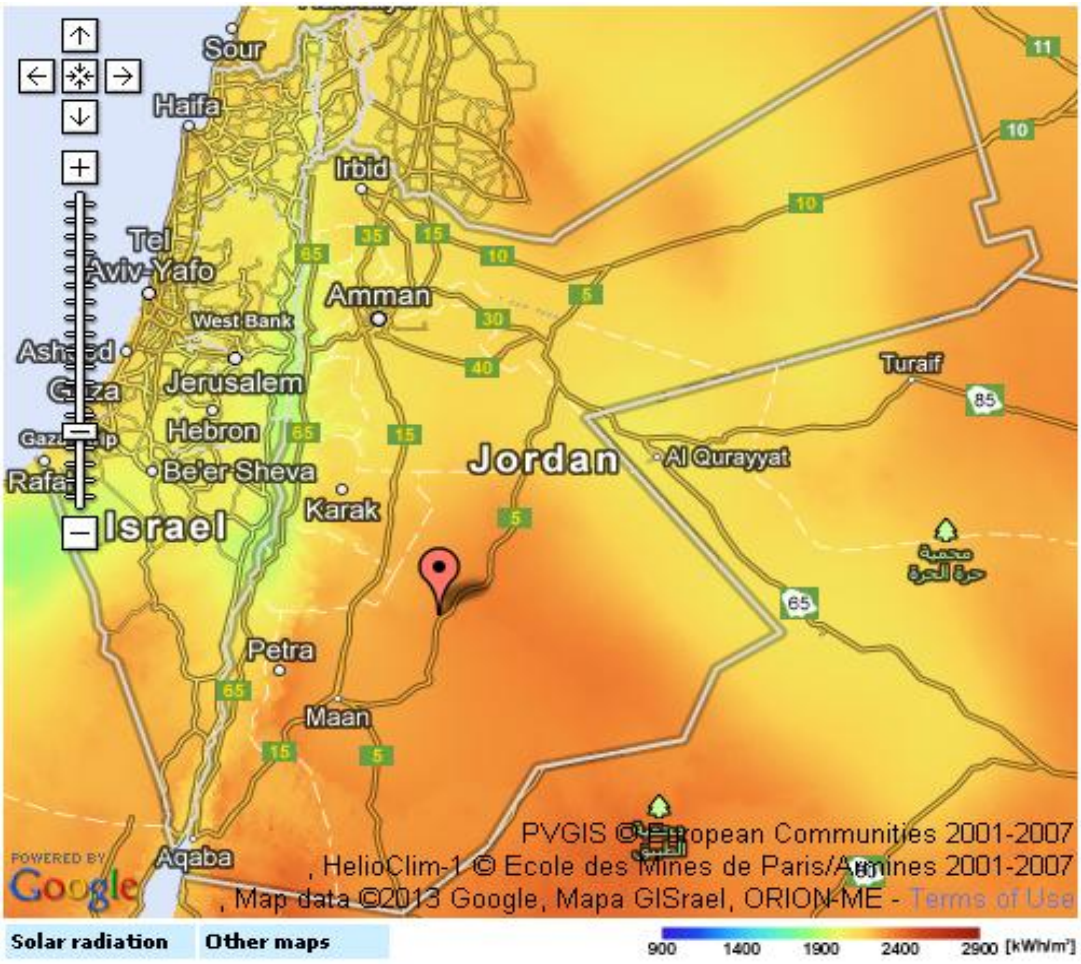

Figure 1: Global irradiation at optimum angle in Jordan [3]

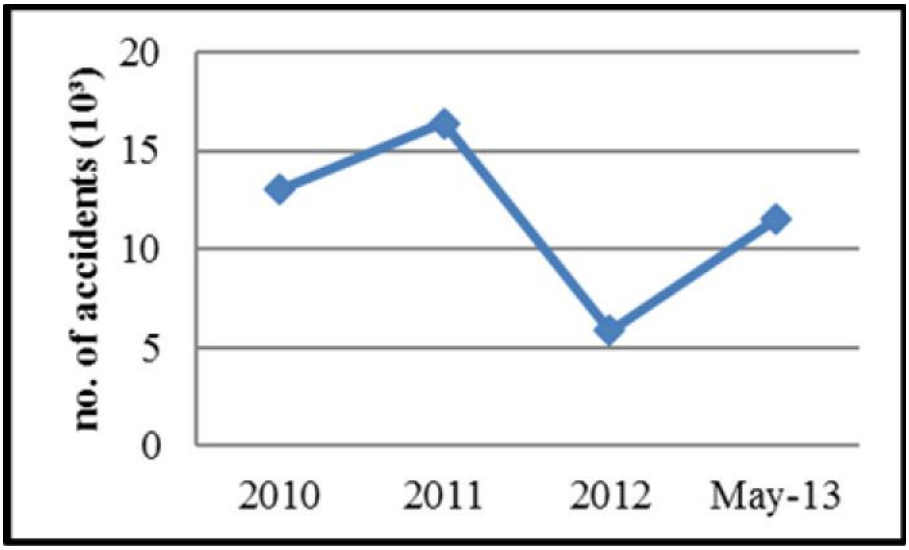

Figure 2: The number of traffic accidents in the last three years in Jordan [4].

This study aims to give an alternative option in street lighting in Jordan by introducing a comparison between solar powered LED street lighting for new road project and existing ones, in addition to determining the feasibility of these projects. The economic feasibility of the solar powered roadway lighting using LED luminaries 110 W for 2 km Naur highway is studied; the highest solar irradiation is 8.31kWh/m²/day and average maximum ambient temperature is 32°C while the average minimum temperature is 14°C. Figure (3) shows the monthly solar irradiation for Naur highway.

2. Literature Review

A comparative analysis on economics of street lighting powered by public electricity utility and solar energy in Nigeria was carried out by (Tsado and Ganiyu, 2012) [5]; the result showed that, the initial cost of installing solar energy for stand-alone street lighting is N 6,402/hr which is more expensive than using public electricity utility with a cost of N 2,508.9/h. However, over a period of 20 years such projects become feasible. The feasibility emphasizes the need to supplement and eventually replace the existing conventional street lighting powered by electricity from public utility.

Recently many studies had been made on the feasibility of introducing photovoltaic to the lighting sector. Wu, etal. (2009) [6] investigated the design of the solar-powered LED roadway lighting using high-power LED luminaries (100 W) and estimated the installation cost for a 10 km highway with 2 lanes. This solar-powered LED roadway lighting system can save 75% lighting energy as compared to the mercury lamp. The payback time for the excess investment of the whole lighting system is 3.3 years for high-power LED using solar-powered.

Rizaho, China is a solar powered city. In addition to 99% of households in the central district, most of traffic signals and street lights are powered by photovoltaic. The achievement was the result of an unusual convergence of three key factors: a supportive government policy, local solar industries that seized the opportunity, and strong political will among the city's leadership. In addition, government buildings and homes of city leaders were the first to have the panels installed [7].

In 2003, ten solar powered grid tied street lamps in south Wales, UK mainland where designed and installed by SolarGen Solutions. Excess power generated by the system is sold back for use by other customers. The annual energy supplied to the grid and the consumed energy were monitored. The objective of the project was to compare the consumption saving with the predicted 35% increase in electricity cost. It was found that street lighting projects are cost effective investment in securing tomorrow's energy at today's prices as well as going a long way to offsetting the effect of global warming [8].

3. Description of solar powered LED lighting fixture

A stand-alone design was advised by ministry of housing and public works which applies to the required specifications of the standard high pressure sodium street lighting design main specification are presented in table (1). The solar panel unit is a monocrystalline solar panel which has the advantage of better efficiency in low light conditions.

4. Economic analysis of LED and solar powered LED

The present paper studied the economic feasibility of the solar powered street lighting using LED luminaires for 2 km highway 40 m apart. Tables (2) presents an economic comparison for three kinds of street lighting projects, namely, solar power LED for existing projects, solar powered LED for new projects and conventional high pressure sodium street lighting projects is carried out. Each unit of solar powered LED street lighting system includes a two 300 Wp PV modules, four 100 Ah–12 V batteries, and two 110W LED lighting fixture.
Table (2) shows that the installation cost is 134.250 thousand JOD for LED lighting powered by grid and 126.200 thousand JOD for solar-powered. The total installation cost of high pressure sodium grid-powered street lighting is 110.250 thousand JOD. The excess cost of LED mainly comes from the cost of LED lamp and solar PV. But, the cost of electrical power generation and electrical transmission components can be greatly reduced since more than 50% of energy was saved using LED. Table (3) shows that the payback period for the excess investment of LED is 7.2 years for LED using grid power and 3.15 years for LED using solar power. This result shows the solar-powered roadway LED lighting is economically feasible for new road projects.

Table (1): Solar street lighting specifications

Description	value
Minimum luminous at mid line of the street	18 lux
Lamp efficacy [lm/W]	72
Lighting power per lamp [W]	110
Operating temperature of the lamp [°C]	-20 - 50
Power of one solar panel [W]	250
Pole hight [m]	12
No. of heads on each pole	2

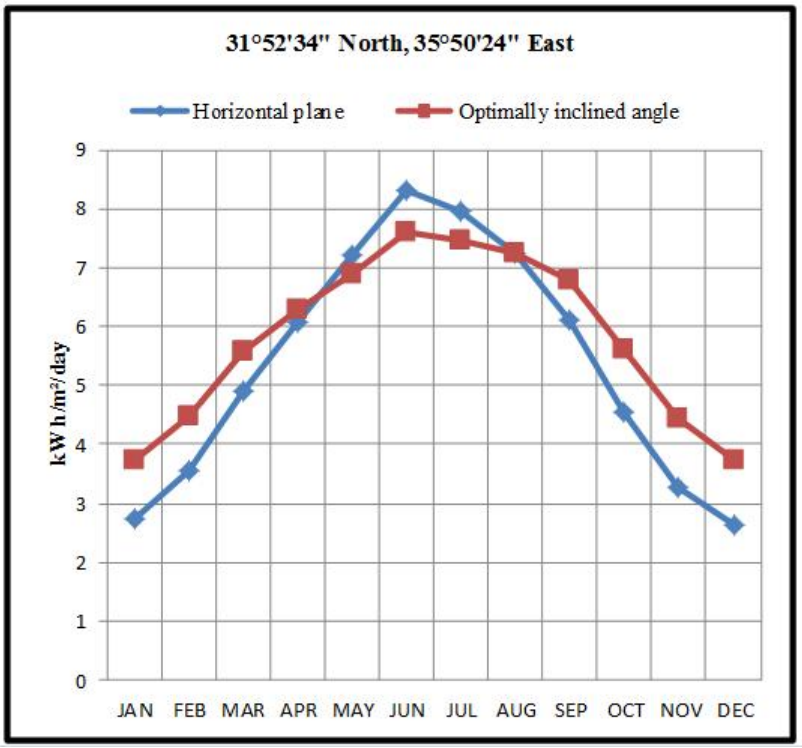

Figure 3: Monthly solar irradiation in Naur Highway Street [3]

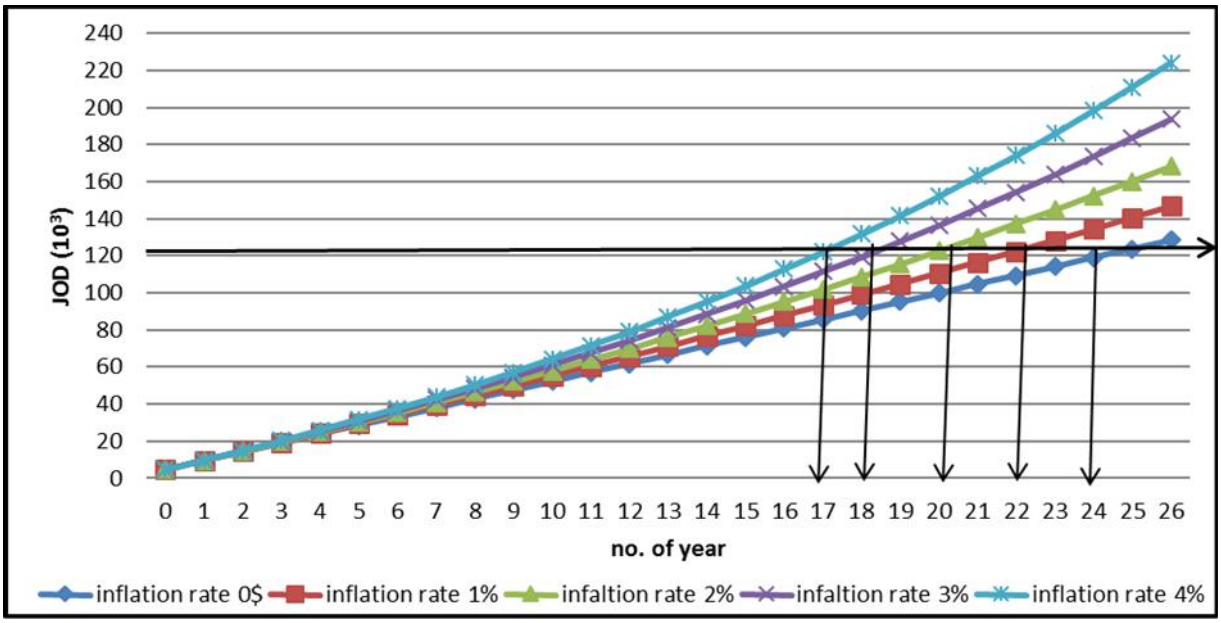

Figure 4: Accumulated saved costs as a result of installing stand-alone PV systems as a function of years for different values of inflation rate in electricity prices.

Table (2): Naur street lighting installation cost

Road way distance	2km					
No. of lamps installed	40m apart, 50 lamps					
Type of lighting design	Grid-powered High Pressure Sodium (18 LUX)		Grid-powered LED (18 LUX)		Solar-powered LED (18 LUX)	
	Unit Price, JOD	Subtotal	Unit Price, JOD	Subtotal	Unit Price, JOD	Subtotal
Lamp cost, JOD	70	3,500	620	31,000	620	31,000
Photocell cost, JOD		50		50	-	
Power line cost, JOD		30,000		30,000		25
PVC pipe cost, JOD		40,000		40,000		25
Pole cost, JOD	450	22,500	450	22,500	600	30,000
3 phase distribution board cost, JOD		1,200		1,200	-	
Grounding rod cost, JOD		500		500	-	
Flexible cable cost, JOD		1,000		1,000	-	
Total solar PV module cost, JOD	-		-		378	18,900
Total battery cost, JOD	-		-		660	33,000
Controller Cost, JOD	-		-		105	5250
Civil construction cost, JOD	-	8,000	-	8,000		8,000
Fright, JOD						
Total Installation Cost, JOD ($US)		110,250 (155,874.53)		134,250 (189,806.40)		126,200 (178,425.09)

(1$US is 0.7073JOD, 2013)

Table (3): Naur street economic analysis for new road projects

Road way distance, km	2km		
No. of installed lamps	40m apart, 50		
Type of lighting design	Grid-powered H.P.S (18 LUX)	Grid-powered LED (18 LUX)	Solar-powered LED (18 LUX)
Lighting power per lamp, W	250	110	110
Total power consumption, kW	12.5	5.5	5.5
Total installation cost, JOD	110,250	134,250	126,200
Maintenance and lamp replacement			
Maintenance cost, JOD/yr	(3%) 3,307.5	(1.5%) 2,014	(1.5%) 1893
Lamp replacement time per year	6	14	14
Battery replacement cost, JOD/yr	0	0	66 (included)
Maintenance, JOD/yr	3,307.5	2,014	1893
Economic analysis			
Power saving, kW	Base	7	12.5
Lighting hours, hr/day	10		
Electricity fixed price in Jordan, JOD/kWh	0.08		
Yearly energy savings, kWh/yr	Base	25550	45,625
Yearly energy savings, JOD ($US)/yr	Base	2,044 (2,889.86)	3,650 (5.160.47)
Maintenance savings, JOD ($US)/yr	Base	1,293 (1,828.08)	1,414.5 (1,999.86)
Additional investment, JOD ($US)	Base	24,000 (33,931.87)	15,950 (22,550.56)
Payback period, yr	Base	7.2	3.15

(1$US is 0.7073JOD, 2013)

Table (4) shows that the payback period for the excess investment on existing road projects of LED is 6.76 years for LED using grid power and 24.92 years for LED using solar power. This result shows the solar-powered roadway LED lighting is not economically feasible for existing road projects.

Figure (4) shows a Solar Powered LED system for existing Roads. The payback period of this system which is about 26 years in case of zero inflation rate in the cost of the grid electricity over the life time of photovoltaic system. Applying the same inflation rates to the increase in the price of grid electricity and maintenance cost, leads to a reduction in the payback period to 24 years, 22 years, 20 years, 18 years and 17 years for the inflation rates of 1 to 4% consequently.

Taking into account the continuous increase in fossil fuels prices and the decrease in photovoltaic technology prices, Photovoltaic will be a viable futuristic alternative.

Table (4): Naur street economic analysis for existing road projects

Road way distance, km	2km		
No. of installed lamps	40m apart, 50		
Type of lighting design	Grid-powered H.P.S (18 LUX)	Grid-powered LED (18 LUX)	Solar-powered LED (18 LUX)
Lighting power per lamp, W	250	110	110
Total power consumption, kW	12.5	5.5	5.5
Total installation cost, JOD	110,250	31,000	126,200
Maintenance and lamp replacement			
Maintenance cost, JOD/yr	(3%) 3,307.5	(2.5%) 762	(1.5%) 1,893
Time replacement time per year	6	14	14
Battery replacement cost, JOD/yr	0	0	66 (included)
Maintenance, JOD/yr	3,307.5	762	1,893
Economic analysis			
Power saving, kW	Base	7	12.5
Lighting hours, hr/day	10		
Electricity fixed price in Jordan, JOD/kWh	0.08		
Yearly energy savings, kWh/yr	Base	25,550	45,625
Yearly energy savings, JOD ($US)/yr	Base	2,044 (2,889.86)	3,650 (5,160.47)
Maintenance savings, JOD ($US)/yr	Base	2,545.5 (3,598.90)	1,414.5 (1,999.86)
Additional investment, JOD ($US)	Base	31,000 (43,828.67)	126,200 (178,425.09)
Payback period, yr	Base	6.76	24.92

(1$US is 0.7073 JOD, 2013)

5. Conclusion

Photovoltaic systems have been commercially available for quite some time. The present study investigated the feasibility of the solar-powered LED street lighting using LED luminaire 100 W.

This solar-powered LED street lighting system can save 50% of lighting energy as compared to the high pressurized sodium lamp.

The payback period for the additional investment of new road projects lighting system is 7.2 years for grid powered LED and 3.15 years for solar powered LED and ranges from 6.76 to 24.92 years for existing road projects. Therefore, the solar powered LED lighting system is economically feasible in considering the payback time and the lifetime for new road projects.

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