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An Economic Analysis of Centralized and Decentralized Solar Power System using HOMER Pro Software

Md. Kamal Hossain[1], Md. Feroz Ali[2]

[1](Department of EEE, Pabna University of Science and Technology (PUST), Pabna- 6600, Bangladesh).
[2](Assistant Professor, Department of EEE, Pabna University of Science and Technology (PUST), Pabna- 6600, Bangladesh).
Corresponding author: Md. Kamal Hossain

ABSTRACT: *The objective of this paper is to use the solar energy in powering density based traffic control system with remote override facilities. Solar power is the cleanest and most plentiful source of renewable energy. As the other alternative sources reduce gradually, Solar power is now becoming a very popular source of energy in remote areas as well as urban areas. Solar power system can be provided in two ways, centrally and de-centrally. Centralized solar power system is mainly a large scale installation of solar plant producing substantial electricity which is supplied to the loads. In contrast decentralized solar power system refers to solar energy solution that produce energy on-site or near-site. The growing demand for solar power renders it as one of the most valuable renewable source for electrical energy production. We have used HOMER Pro software for economic analysis for centralized solar traffic lighting system and de-centralized solar traffic lighting system. This paper briefly describes the different aspects of this to solar power system and provides a proper suggestion for a better and sustainable power system.*

KEYWORDS *– Photovoltaics, Solar radiation, centralized solar power system, Decentralized solar power system, Traffic light and Renewable energy.*

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I. INTRODUCTION

In today's world one of the main challenges is the limit the dependency on fossil fuel and the insured clean energy supply for future generation. Therefore, renewable energy is considered to be the key to ensure environmental friendly energy generation with long-term availability. More than One billion people globally lack access to clean electricity, which is addressed under the sustainable and modern energy for all [1]. Most common source of energy currently utilized worldwide for generating electricity include Coal (39.3%), Petroleum (0.7%), natural gas (27.6%), nuclear power (19.5%), Hydropower (6.7%), Wind (4.2%) and other renewable power (2.14%) that cover mainly geothermal, biomass and PV energy [2]. The International Energy Agency(IEA) reported that solar photovoltaic has the highest average annual growth rate of all the world renewable source at 45.5% [3]. The IEA predicts that solar energy could be the world largest source of electricity by 2050 [4]. Photovoltaic (PV) module and among the main devices used to convert solar energy to electrical energy [5].

Centralized solar power system refers to a large-scale solar plant installation to produce large amount of electricity like the conventional national grid system, Centralized Solar forms need the same infrastructure which includes electrical substation and transmission lines to be run over long distance to get that clean solar power to the consumer. Centralized plants are usually located at the point where the best resource is available at need a large amount of land to in a cell and highest depended on the geographical location of the country. The main disadvantage of this system is sometimes efficiency and voltage are lost, when electricity has to travel long distance the decentralized solar plant refers to solar energy solution that produce energy on site or near-site.

Decentralized solar power system is the opposite of centralized system. Now a day the power generation has become more localized with the deployment of decentralized energy generation systems [6]. For some cases, in the system there are less or no voltage losses as no transmission line is required to are reach electricity to the consumers. Decentralized electricity system emerges as an alternative option for remote areas

[7]. Decentralization solar power system can be more freely operated in any geographic location. To access the cost-effectiveness of both the decentralized and centralized is solution, least cost electricity plans are required. Such plants often combine geospatial analysis with electric electricity system for a certain country or region [8]. The geographical condition of Bangladesh is not very flexible to draw the transmission lines to a very long distance from national grid due to plenty of rivers of island for uneven ground condition as a result the rural areas are remaining without the access of electricity. Centralized and decentralized solar plant installation can be an effective solution in this regard because of its abundant potential. In our paper the cases we are considering for centralized solar traffic lighting system and desterilized solar traffic lighting system.

II. PROPOSED MODEL STRUCTURE

Traffic lights are signaling devices positioned at road inter sections, pedestrian crossings and other locations to controls the flows of traffic. They allocate the right of way to road users by using lights in standard colors (red, yellow and green), using a universal color code. Vehicular travel is increasing throughout the world, especially in urban areas as a result the traffic signal installation is also increasing. We can provide power using solar energy to these lights in two ways- Centrally and De-centrally.

The following Fig.1 shows the proposed schematic diagram of a centralized solar traffic lighting system. Here, 15 traffics lighting system required 5.4 KWh/d, PV capacity 1.5 KWp, 12 pcs batteries (each battery rating is 12 V, 83.4 Ah) and 0.3 kw inverter.

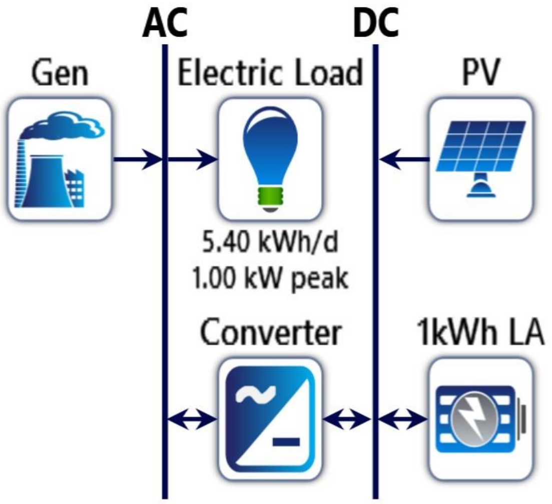

Fig.1 Schematic diagram of centralized solar traffic lighting system

The following Fig.2 shows the proposed schematics diagram of decentralized solar traffic lighting system. Here, 1 traffic lighting system required 0.36 KWh/d, PV capacity 0.3 KWp and 1pes battery (each battery reading is 12 V, 83.4 Ah).

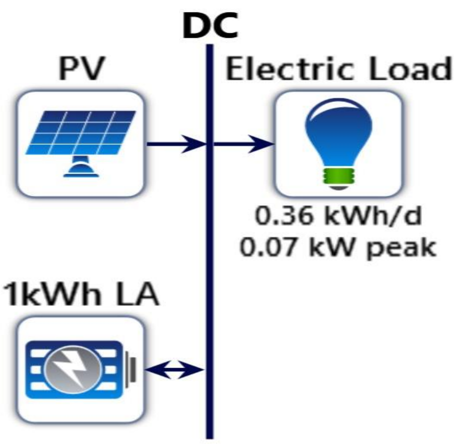

Fig. 2 Schematic diagram of decentralized solar traffic lighting system

III. SIMULATED RESULT AND DISCUSSION

A. System Simulation Tool

HOMER (Hybrid Optimization Model for Electric Renewables) is a computer based micro power system optimization model which allows the user to simulate, optimize and also has the ability to do sensitivity analysis on a system consisting of multiple energy sources like wind, PV, diesel generator, battery bank etc. and various loads like AC, DC and thermal loads along with converters and the grid. It is generally used for the design and analysis of hybrid power system [9]. Homers simulation model system ls the best system design and the optimization finds the best possible system configuration which gives the least total NPC that satisfies user defines constraints. It can also provide economic analysis and feasibility of the system. Here in our study we are not considering any sensitivity analysis but HOMER has the ability to do sensitivity analysis. Sensitivity analysis gives the effect of change in the input variables on the optimization results [10]. The HOMER pro software was used to model systems long term implementation. It is a micro power optimization model developed by the National Renewable Energy Laboratory [11] and widely used by many countries for the simulation and optimization of renewable energy systems and hybrid systems. This program is able to simulate the economic performance, environmental performance and hourly implementation of the system, and to supply the optimized system configuration and components sizing.

B. Centralized Soar Traffic Lighting System

b. Location, Load measurement and solar irradiation data

For centralized solar traffic lighting system we have considered our location Z6031, Pabna, Bangladesh(24°0.8'N,89°15.5'E) We considered a small area where a no of 15 LED traffic lighting systems is connected with our proposed system. Power rating of a 1 traffic lighting system (5w Red, 5w Yellow, 5w Green) =15Watt.

Table 1: Centralized Solar traffic lighting system load

Appliances	Watt	No of equipment	Total load (watt)	Hours (used/day)	Total unit (Wh/day)
LED Traffic Light	15	15	225	24	5400

From table 1, for 15 traffic lighting system 5.4 KWh is required.

Solar insolation has great effect on performance of the PV system. Monthly average solar insolation data(measured in KWh/m^2 $/day$) is considered for system design and analysis in this paper.Solar irradiance data for the study area Pabna is obtained from the HOMER pro data base

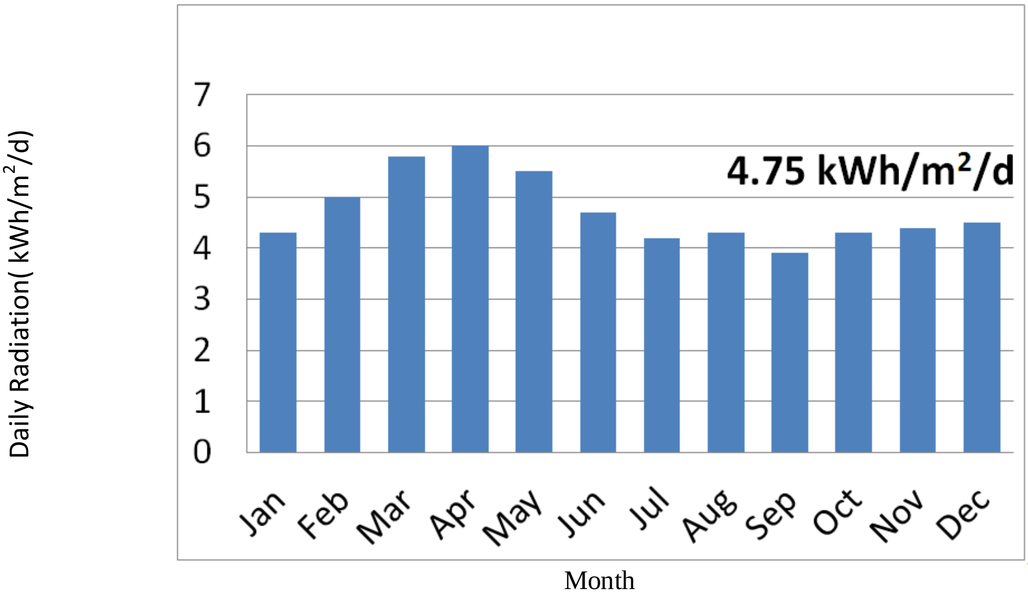

Figure 3. Solar irradiance data for the study area Pabna

Therefore, Daily Average Radiation=4.75 ($kWh/m^2/d$)
b. Centralized PV Module Modeling A mono-crystalline high efficiency solar panel module has been used for this PV model. The output power and efficiency of this solar panel is dependent on the solar cell temperature, solar flux and solar irradiation. Total PV panel needed in this system=5400×1.3=7020 Wh/day.Total Wp of panel capacity needed=7020/4.75≈1.5KWp.

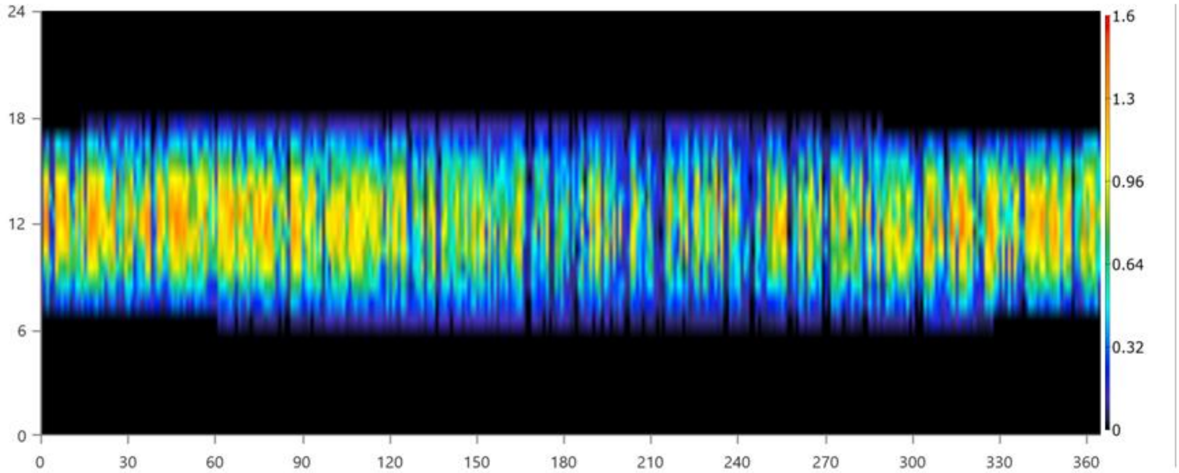

Fig. 4 System simulation PV output

c. Centralized Battery Storage, Inverter and Generator Modeling
In this model lead-acid batteries were used for the purpose of storing unused solar power. The charging and discharging characteristic of the battery were modeled to accurately validate the system. Here an important thing we should keep in mind that the battery should be large enough to store sufficient energy to operate the appliances at night cloudy days.
Battery capacity $(Ah) = \frac{5400X1}{0.85X0.5X12} \approx 1058$, Here Battery Days of autonomy =1,Battery loss=0.85,
Depth of discharge=0.5 and Nominal Battery voltage=12
Therefore number of Batteries required for our system $= \frac{1058\ Ah}{83.4\ \mathrm{Ah}} = 12$
Here, each battery rating is 12V, 83.4 Ah

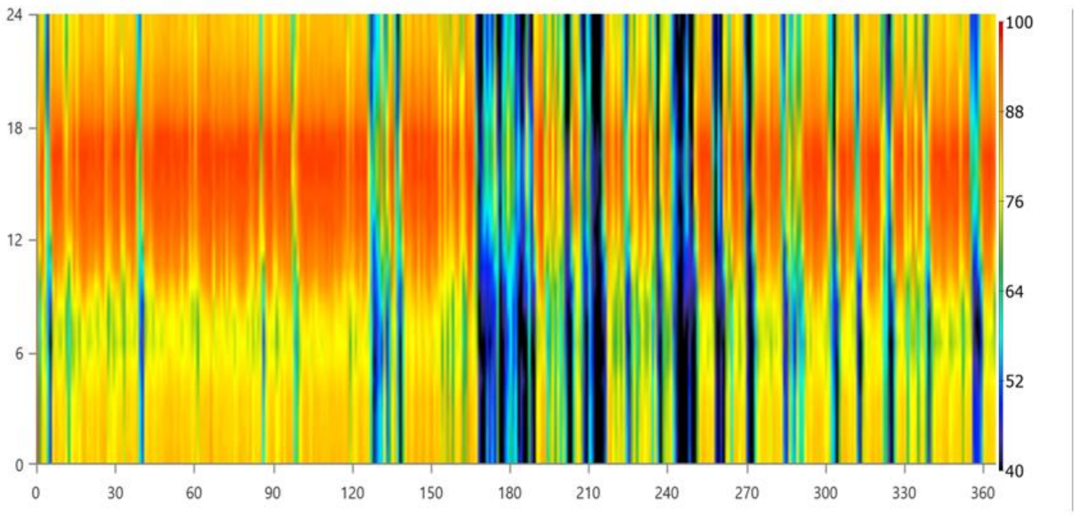

Fig. 5 Generic 1 kwh lead acid state of charge (%)

Inverter is required for any system that contains converts DC to AC. It's a matter of concern that the inverter size should be 25-30% bigger than total Watts of appliances.
Total watt of equipment's=15×15=225 watt.
Inverter capacity=225+(225×30%)≈0.3 kw. So our system need total 0.3 kw inverter.

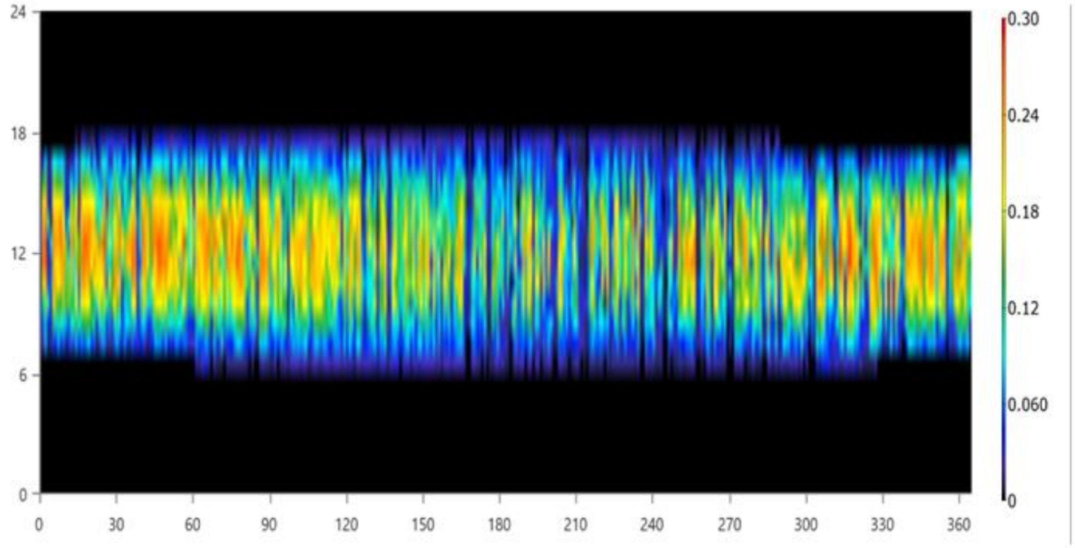

Fig. 6 system inverter output

A generator is a device that produces electric energy and consumes fuel. A backup generator is a backup electrical system that operates when there is not sufficient energy to supply. In our system we consider auto size generator. we consider fixed capital cost (include land cost) =1,50,000 BDT=$1754. We also consider O&M cost $35 which is 2% of our fixed capital cost.

b. Cost summary centralized solar traffic lighting system

Name	Capital	Operating	Replacement	Salvage	Resource	Total
Auto size Genset	$168.00	$386.15	$429.86	$0.00	$3,145	$4,129
Generic 1kWh Lead Acid	$960.00	$245.44	$1,953	$0.00	$0.00	$3,159
Generic flat plate PV	$600.00	$76.70	$0.00	$0.00	$0.00	$676.70
Other	$1,754	$447.42	$0.00	$0.00	$0.00	$2,201
System Converter	$36.00	$0.00	$73.25	$0.00	$0.00	$109.25
System	$3,518	$1,156	$2,456	$0.00	$3,145	$10,276

Fig. 7 Net Present Cost

From figure 7 it is seen that the capital cost $3518. The total net present cost (NPC), replacement cost, operating cost, resources cost over the 25 years' life time period is given as $10276, $2456, $1156 and $3145 respectively. In this system 15 traffic lighting system, total cost=$10276, Therefore 1 traffic lighting system=$685.

Per unit cost $=\frac{(\$10276\times85.5\times1000)}{(5400\times25\times365)}=17.83$ BDT .For 15 traffic lighting system annual AC primary load=1971KWh/y. Therefore 1 traffic lighting system annual AC primary load=131.4 KWh/y.

Per year energy cost=131.4×17.83=2342.8 BDT, So per month energy cost=195.23 BDT.

Payback period=$\frac{\$3518\times85.5}{17.83\times1971}$=8.5 years. Here, $3518 is capital cost.

d. Decentralized Soar Traffic Lighting System

We have considered our location and solar radiation is taken same that has been used in centralized. We considered 1 LED traffic lighting systems are connected with our proposed system. Power rating of a 1 traffic lighting system (5w Red, 5w Yellow, 5w Green) =15Watt.

Table: 2 Decentralized Solar traffic lighting system load

Appliances	Watt	No of equipment	Total load (watt)	Hours (used/day)	Total unit (Wh/day)
LED Traffic Light	15	1	15	24	360

From table 2, for 1 traffic lighting system 0.36 KWh is required. This system contains pv module and battery storage only. The model of the pv panel and battery storage is taken same that has been used in centralized system. The pv panel and battery storage lifetime, capital cost, O&M cost is considered same. From the simulation HOMER finds a total of 0.3KWp pv panel and 1 no of battery which is the best fit for the system.

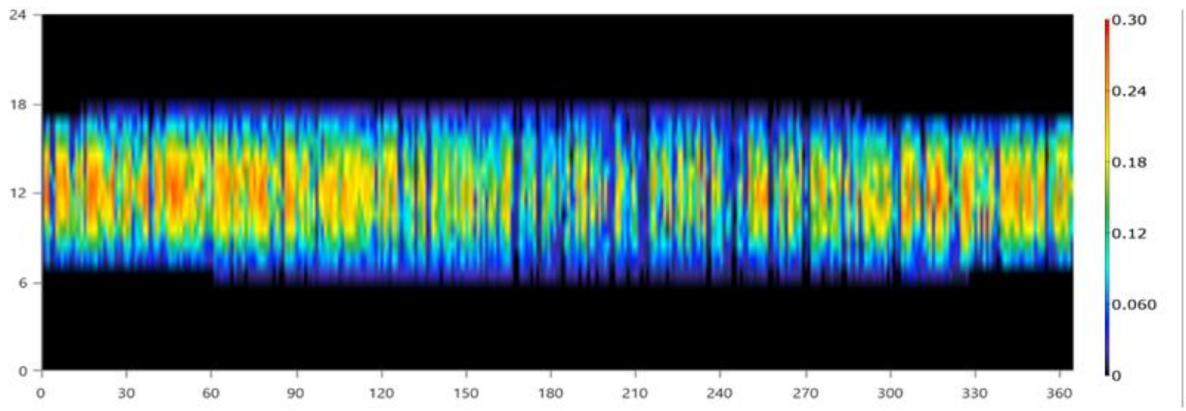

Fig. 8 System simulation PV output Cost summary decentralized solar traffic lighting system:

Name	Capital	Operating	Replacement	Salvage	Resource	Total
Generic 1kWh Lead Acid	$80.00	$20.45	$162.78	$0.00	$0.00	$263.23
Generic flat plate PV	$120.00	$15.34	$0.00	$0.00	$0.00	$135.35
System	$200.00	$35.79	$162.78	$0.00	$3,145	$398.57

Fig.9 Net present costs

From figure 9 it is seen that the total capital cost for the system is $200. The total net present cost (NPC), replacement cost ,operating cost over the 25 years life time period is given as $398.57 , $162.78,$35.79 respectively .For 1 traffic lighting system, Total cost=$398.57

Per unit cost=$\frac{(\$398.57\times85.5\times1000)}{(360\times25\times365)}$=10.37 BDT

For 1 traffic lighting system annual DC primary load =131KWh/y,

Therefore per month energy cost=10.76× 10.37 =111.35 BDT.

Payback period =$\frac{(\$200\times85.5)}{(10.37\times131)} = 12.7$ years,

Here $200 is capital cost.

e. Economic comparison between base case & current centralized solar power system.

Table: 3 Economic comparison between base case & current centralized solar power system

	Base Case	Current System
Net Present Cost	$15,985	$10,275.63
LCOE ($/kWh)	$0.634	$0.408

CAPEX	$3922	$3518
OPEX	$1,200	$1156
CO2 Emitted (kg/yr.)	2,922	847
Fuel Consumption (L/yr.)	1,116	324
Per unit cost (BDT)	34.67	17.83
Payback period (years)	10.89	8.5
Per month energy cost (BDT)	390.58	195.23

In table 3, it is seen that the current centralized solar power system net present cost, levelized cost of energy, capital expense, operating expense, fuel consumption, per unit cost, payback period is more cost effective than homer pro base case. So our research work is more economically benefits.

f. Economic comparison between base case & current centralized solar power system

Table: 4 Economic comparisons between base case & current decentralized solar power system

	Base Case	**Current System**
Net Present Cost	$598.64	$398.57
Levelized Cost of Energy ($/kWh)	$0.356	$0.237
CAPEX	$224.00	$200
OPEX	$49.09	$35.79
CO2 Emitted (kg/yr.)	0	0
Fuel Consumption (L/yr.)	0	0
Per unit cost (BDT)	34.67	10.37
Payback period (years)	9.5	12.7
Per month energy cost (BDT)	167.64	111.65

In table 4, it is seen that the current centralized solar power system net present cost, levelized cost of energy, capital expense, operating expense ,per unit cost, payback period is more cost effective than homer pro base case. So our research work is more economically

IV. Conclusion

The model of solar photovoltaic power centralized and decentralized traffic lighting systems has been successfully developed for the sustainability assessment. The model is capable of performing a long- term simulation of the system's economic, technical and environmental feasibility. From our simulation, the total system cost of one traffic light in centralized system is $685.04 in 25 years where in decentralized system it is $398.57. Here, decentralized system is more cost-effective. It is important to have a back-up power. Like in centralized system batteries are the main back-up power source to lighten up the traffic signal lights at night but it also has a back-up generator for powering the lights when there is not sufficient sunlight for many days. Hence, in decentralize system there is no such thing. So it is better to choose centralized system in order to get continuous power supply. Considering all these aspects, we can say that centralized solar traffic lighting system can be better if the place is non- developing area. Therefore, for city areas as well as for any places decentralized solar traffic lighting system is better option. Just proper monitoring and maintenance is required to make this system is the best.

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