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Feasibility Study of an Off-Grid Biogas Solar Hybrid System for a Dairy Hub at Pabna Zone in Bangladesh

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Abstract— *The major attempt of this paper is to solve the electricity demand of a dairy farm community in a rural area. Biogas and solar are two such renewable energy resources, which can meet a great amount of power lacks of this community. A feasibility study of a solar-biogas hybrid system is performed for a community of dairy farms of Pabna district in Bangladesh using simulation software HOMER. The predicted monthly average daily radiation in the area is 4.76896kWh/m2. Also, there is a huge opportunity to produce electricity from wastes of dairy farms. Three nearby dairy farms can supply approximately 1700kg of cow dung, from which 98159 kWh electricity may be produced every year, which can meet the power requirements of the farm owners. The farm owners can sell the excess electricity to the other nearby houses and shops around the plant. The system is economical, environmental friendly and makes an easy access to the rural people, who are still deprived from electricity.*

Keywords— *Biomass; PV; Off grid system; Renewable Energy; Hybrid system.*

I. Introduction

Worldwide demand of electricity increasing rapidly with the growth of industries and home appliances to improve daily life. In the road to development Bangladesh also trying to move forward parallelly along with other countries with limited natural energy resources. It is the per capita use of power, which determines the living standard of people of a country. But, the economical condition of the people and insufficient generation of electrical power has made an obstacle to access to electricity. Still in many remote and rural areas, electricity is not reached from conventional national grid system. Only 59.6% of its 161 million people have access to electricity. In rural areas, where more than 70% of the population lives, only 42% have access to electricity [1]. The per capita consumption of electricity is increasing in a significant rate every year in Bangladesh. The government has issued its vision and policy statement in February 2000, to bring the whole country under electricity service by the year 2020 [2]. It is worthy to note here that Bangladesh has not enough resources to meet the vast demand of electricity. Government of Bangladesh importing electricity from neighbouring country to meet the demand but there is still a large difference in between supply and demand which cause to load shedding. In order to resist the problem, it is high time we focused on renewable energy like biogas, solar, wind and so on. These energy resources solely may not be able to meet the situatoin. Arranging a number of renewable energy resource systems in a hybrid system is more efficient, reliable and environmental friendly [3-5].

Hybrid system is a technology to combine a number of systems. In power system, it consists of several generating systems with storage systems. A hybrid power system formed by solar, wind, diesel, hydro and biomass (may use more or less), can be connected to conventional grid, or a micro grid system or off grid [6-7]. Depending on size, a hybrid system can generate power ranging from kilowatts to several megawatts. In general, power generated by individual resource is integrated and collectively supplied to the load, besides the storage system stores energy for supply when shortage. The batteries may minimize the necessity of non-renewable resources. A hybrid system may be helpful to meet the national demand, decrease load shedding problems, supply power in remote and rural areas where electricity is not reaches yet.

Every renewable resource has limitations of use. For example, wind is not available for 24 hours; sunlight is not available at nights and cloudy weathers. A biogas plant may not have enough biomass for the continuous production of power supply during all the seasons. So, power is not available all the time from a single renewable source system. When a hybrid system is installed in a particular area, with all the feasible source a complementary system is formed which minimized the limitations and increase load factors, provide higher reliability, debilitate individual fluctuation, operational flexibility [3].

In this paper PV-biogas hybrid system is considered after surveying the dairy zone at Atghoria upazila of Pabna district in Bangladesh and analysis sources data. If we design a hybrid electric system with these renewable sources then reliability of the system will be improved as well as a convenient solution of shortage of power supply from national grid system to that area.

II. Early Work

Several works are made and going on considering solar system and biogas. Some of them are given below:

Ajai Gupta *et al. (2008)* [8] presented a paper about Hybrid Energy System for Remote Area. An Action Plan for Cost Effective Power Generation proposes, evaluation criteria present a general methodological outlook for the formulation for the small scale hybrid energy system for small village. The

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specific values chosen and the assumptions made are subject to large variations depending on a variety of local conditions. Modeling a stand-alone hybrid energy system capable of utilizing various resources, for supplying the basic energy needs of small village or areas has been presented and discussed. The section summarizes step by step for planning hybrid energy systems for small village, and gives the details previous work with respect to the design of small-scale hybrid energy systems. Supplying the energy needs of a hypothetical typical cluster of villages situated in a remote rural area is considered.

Gianni Celli *et al. (2008)* [9] presented a paper about analyze and research of Optimal Location of Biogas and Biomass power production that requires the use of optimization algorithm to take into account biomass availability, transportation and power facilities as well as all the territory related constraints. The integration of optimization tools within Geographic Information Systems allows better performances. Several causes are contributing to this situation: limited market, production costs, high disposal cost of the residues, more severe limits imposed by the laws, building and operation cost, optimal location of the sites, transportation costs of the biomass to the power plants sites, capital and operation expenses, revenues disposal cost and it has been roughly depicted the area under study and the distribution of the biomass resources. Combined heat and power production with biomass can help improve the energy efficiency of agricultural industries, and increase environmental sustainability of food. In order to be effective the use of biomass requires a very complicated optimization process to take into account not only the global production of biomasses but also local characteristics. Biomass productions can easily vanish both economic and environmental benefits.

Steven Durand *et al. (1996)* [10] presented a paper at photovoltaic hybrid power system comparisons prediction versus field results and discussed General System Performance. This paper analyzes the various design constraints of such systems and suggests design changes that can improve overall system performance in some cases (Evaluating Hybrid Systems by Operational Mode, Potential Advantages.). According to paper photovoltaic hybrid system is located in the specified location. When these systems are included in a hybrid system, the advantages of diesel generators are used to charge the batteries and are operated at higher loads in a more fuel efficient manner. The goal of installing a hybrid system is to realize the potential advantages of reduced fuel use lower operation and maintenance cost. And greater availability than diesel only systems and another configuration could use a single small inverter with sufficient over-load capability to allow time for the generator to start during peak-load periods.

Zhanping Youl *et al. (2009)* [11] presented a paper about Biogas Power Plants Waste Heat Utilization Researches. This paper discussed the significance of developing biogas power plants for large breeding farms. Biogas internal combustion engines would produce a lot of waste heat in the process of power generation. The continuously increasing of livestock breeding in various parts of county, how to dispose feces and sewage produced by live stocks became very urgent. The utilization technology of waste heat of biogas power plants, this would promote local economic development and partly resolve the employment problems of local farmers. This must use cold storages for poultry product storage. Economic and social benefits evaluation of biogas energy was almost 80% after comprehensive utilization of waste heat. Biogas power plants with straw and garbage as raw material could also adopt those schemes in utilization of waste heat.

Jiang Yao-hua *et al. (2009)* [12] presented a paper about Research of Biogas as Fuel for Internal Combustion Engine introducing briefly about component, physical & chemical characteristics of biogas and the problems of running engines. Biogas-diesel dual fuel engine is on the basis of diesel engine and refitted the intake hybrid system and dual-fuel accommodation system. Its working principle is to mix biogas and air in mixer to form combustible mixed gas. And some research work and develop of all-biogas engine, the exploration of purification, super pressure and vehicle using of biogas. A successful biogas-diesel dual fuel engine because of using a small quantity of leading diesel to be pressed and burning to ignite biogas; its energy of fire is higher than the energy of spark-ignition, and through the high compression ratio, purify and compress biogas, and then use it as vehicle fuel, it has feasibility on technology.

Mayank Aggarwal *et al. (2009)* [13] titled their paper as “Biogas as Future Prospect for Energy Dependency and Rural Prosperity in India: Statistical Analysis and Economic Impact and brief discussion” discussing the prospect of biogas in eradicating various problem in a developing country like India, its impact on environment, society etc. The need of the hour is to develop a technology that is cheap and do very little damage to the environment or rather provide a suitable solution to above problems. About 2.5 billion people, mostly in Asia, growth prospects of biogas plant, Reason for Slow Growth Rate of Biogas Plants in India. Financial Study of a Biogas Plant that biogas is a promising tool for employment generation, energy self-sufficiency and reduction of greenhouse gases Also it helps in reducing deforestation thus saving lots of species from extinction. If applied on large scale it can prove to be a boon for a developing country like India.

From the various earlier works that Hybrid system is designed of power generation with renewable energy resource, this is alone and unique system produces a sufficient amount of generation which may meet demand of small villages and rural areas. Hybrid system is a system which is fully used of over energy resource and gives healthy environment. The advantages of biogas are manifold. Biogas by itself can positively affect the economy of rural areas and give us clean environment.

Bangladesh is not solvent with electrical power. Government has to make a good subsidy on electricity every year to make the price of per unit to the consumers. Recent price of per unit electricity bill is: household 5.42 tk, commercial 9.58 tk. The price of unit is increasing every year. Although per unit cost of a non-conventional hybrid system is higher than the conventional power supply, it may possible within next three or four decades that both will cost the same.

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Also, the conventional system has uncertainty of continuous power supply. Hybrid system for a community can solve the electricity problems with competitive rate if it is designed properly.

III. Survey and Data Collection

A Survey is carried out in the selected Atghoria upozilla of Pabna district in Bangladesh; there are several small and big dairy farms, from which biogas can be easily produced for heating and electricity generation purpose. In Nowdapara village, there are three big and several small farms. Although some people are using biogas plant for heating purpose only, there is no practice of generating electricity from biogas in spite of lack of electricity supply. We will represent the data related about dairy farms and calculate loads that these dairy farms could serve electrical power, when connected in a hybrid biogas solar hybrid system.

A. Resource Info

Feasibility for selection of village Nowdapara in Atghoria upazila in Pabna district with the below mentioned criteria:

- Village Animal Population
- Geographical condition of village
- Optimum space for the project
- Co-operative culture of village
- Acceptance of new technology
- Easy availability of Water,
- Distribution of households: should be clubbed together, not scattered.

The livelihood of the people of Nowdapara in Atghoria upazila in Pabna district is mainly farming and fishing. Almost every villager has domestic cattle. Also, there are some small and big dairy farms, which are a great resource of cow dung, i.e., biogas raw materials. There are three dairy farms which have 80, 50 and 40 cows, situated within 1km. Table I shows the Survey data for the visited firms with calculated approximate power that can be produced from the biogas raw materials of dairy farms:

TABLE I. Biogas raw materials of the visited dairy farms.

Owners Name	No. cows	Average dung/cattle (kg)	Total dung/day (kg)	Approx. Power Production (calc.) kWh/month
Shofi Char.	80	10	800	7200
Shawkat ali	50	10	500	4500
Selim	40	10	400	3600

The wastes of these farms are mainly used as fish foods in different ponds. Small biogas plants have been set up in some houses individually, but large farms did not take any steps to set up biogas plant yet. With the help of the wastes of the dairy farms, nearly 125 kW electrical energy can be obtained which can meet the power requirement of the farm as well as the houses around the farm.

Though electricity has become a basic need of modern civilization but it is yet to reach about 78 villages in Iswardi and Atghoria upazilas and vast Chalan beel areas in Pabna district. A large number of people in Atgharia upazila, of the district have set up solar power panels on the roof tops of their buildings and over business centers to get respite from the everyday load shedding. A few non-government organizations including 'Grameen Shakti' and 'BRAC' have set up solar power panels in different rural areas of the district.

At Pabna, where the population density is high, wind speed is around 3.5 m/s. so wind energy is not feasible at this locality.

B. AC Load Estimation

Load is determined by the power consumption. Here we considered 60 houses around the dairy farm that could be benefited by the electricity produced by solar panel and biogas plant. In this region, mainly two seasons are observed. The months October, November, December, January and February may be considered as summer and March, April, May, June, July, August and September as winter. We assumed a typical day for summer season and a day for winter season.

We considered 60 houses, 3 dairy farms, 10 shops, one school and one mosque. We calculated loads as one light of 25W for 5 hours (00:00-05:00), 4 lights of 25W for 6 hours (06:00-00:00), one TV of 80W for 6 hours, one refrigerator of 110 W for 24 hours, one water pump of 746 W for 2 hours and 2 fans of 36W for 24 hours (in summer) at each house.

We considered 3 lights of 25W for 7 hours (22:00-05:00), 10 lights of 25W for 6 hours (06:00-22:00), one water pump of 4776 W for 4 hours and 10 fans of 36W for 24 hours (in summer) in dairy farm.

The loads of the school is most on day time, from 09:00 to 05:00. School loads are light, fan, and computer. The mosque may use electricity at night time prays, and fans in prayer periods. The water pumps need high power. These loads should run in such times that make the system efficiency high and more feasible. So, pumps should run within 05:00-08:00 and 17:00-20:00 for the household loads and dairy farm water pumps should run within 07:00-08:00, 12:00-14:00 and 20:00-21:00 hours. This understanding should be made among the community in order to decrease the peak load and reduce the size of the generator and reduce the initial cost of the system. Also, the users would have a continuous supply of electricity.

IV. Simulation Work

The purposed model consists of solar photovoltaic modules, biogas generators, electrical loads and converters. The purposed system is shown in fig. 1 is designed and simulated using HOMER software. Before run the simulation of the purposed system we have to configure paraments of various considered components with its latest associated installation, operational and maintenance cost.

A. Load Input

In this purposed area consist of 60 houses, 3 dairy farms, 10 shops, a school and a mosque. Daily electrical load profile is estimated based on basic demands of utilities such as lighting, cooling, communication and others appliances. The total electrical load consumption is 495 kWh/day of the village with a peak load of 56 kW. The daily load profile is shown in fig. 2.

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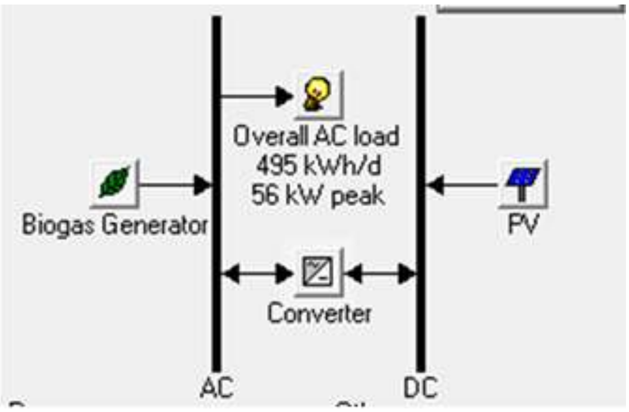

Fig. 1. Schematic in homer.

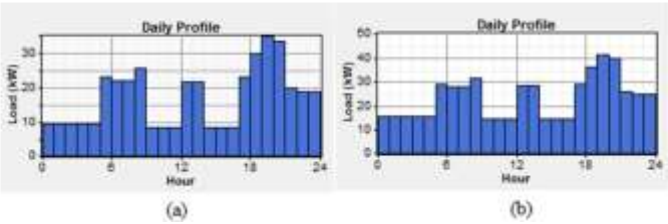

Fig. 2. Load profile: (a) March, April, May, June, July, August and September; and (b) October, November, December, January and February

During summer season (March, April, May, June, July, August and September), loads are assumed same. The peak load is 41.051 kW and total daily load is 556.509 kW.

Similarly, during winter season (October, November, December, January and February), the peak load is 34.895 kW and total daily load is 411.357 kW. Seasonal load profile for the selected dairy farms based community throughout the year is shown in fig. 3.

Fig. 3. Seasonal profile.

B. Solar

Solar resource indicates the amount of global solar radiation that strikes earth's surface. Solar radiation for this study area was obtained from internet entering the co-ordinate of the village. HOMER gives DC output in direct proportion to incident solar radiation. A derating factor of 90% is applied to each panel to account for the degrading factors caused by temperature, soiling, tilt, shading etc. The Global horizontal radiation for the selected location are shown in fig. 4.

The installation cost of PV array is taken 180000 tk/kW and replacement cost is 120000 tk/kW. Operation and maintenance (O&M) cost is 30000 tk/yr and its lifetime is 25 years. We considered different sizes as 1kW to 12kW.

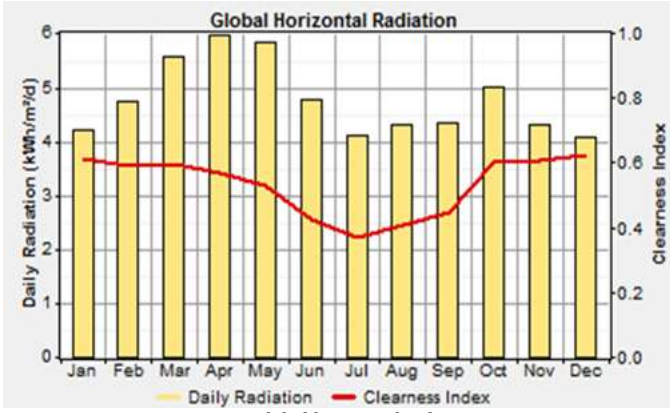

Fig. 4. Global horizontal radiation.

C. Biomass

As mentioned earlier, biomass comprises of wood chips and wastes from wood industry, agricultural and forest residues, animal wastes, kitchen wastes and energy crops if available. Biomass undergoes anaerobic fermentation to produce biogas in community scale or household scale biogas digesters. Biogas is used as fuel to generate power from engine-generator set. The average biomass available in study area is 1.7 tons per day. The monthly available average biomass resources for the selected community are shown in fig. 5.

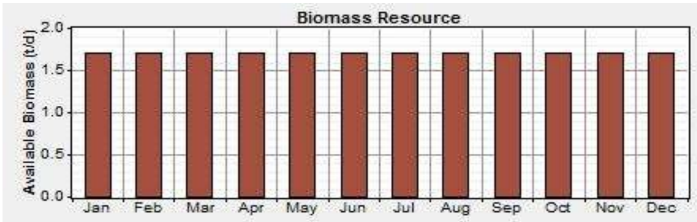

Fig. 5. Biomass resource.

The capital cost of biogas powered generator is 3,00,000 tk with replacement cost of 2,40,000 tk and O&M cost of 56.250 tk/hour for 30 kW.

D. Optimized Outcome

Main operational characteristics such as annual electrical energy production, annual electrical loads served, excess electricity, renewable energy fraction, capacity storage, unmet loads and others are obtained from simulation system. The environmental impact parameters of the system such as carbon emissions, SO_2 and NO_2 emission etc. are also obtained. HOMER eliminates all infeasible systems present in ascending order of net present cost (NPC). Different hybrid options are analyzed to get an optimized hybrid system.

In the Results view, HOMER displays two tables. The optimization result shows different systems accordingly from best feasible system. In this study, we defined maximum annual capacity shortage 0% and 1% and we have two tables of optimization results.

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Sensitivity Results | Optimization Results

Sensitivity variables

Max. Annual Capacity Shortage (%) 0

Double click on a system below for simulation results.

PV (kW)	BG (kW)	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Capacity Shortage	Biomass (t)	BG (hrs)
9	51	6	$ 2,172,000	2,841,802	$ 38,499,768	16.673	1.00	0.00	603	8,758
9	51	7	$ 2,179,000	2,841,293	$ 38,500,260	16.673	1.00	0.00	603	8,758
9	51	8	$ 2,186,000	2,841,299	$ 38,507,332	16.676	1.00	0.00	603	8,758
9	51	9	$ 2,193,000	2,841,456	$ 38,516,344	16.680	1.00	0.00	603	8,758
10	51	7	$ 2,359,000	2,868,092	$ 39,022,840	16.899	1.00	0.00	601	8,758
10	51	8	$ 2,366,000	2,867,794	$ 39,026,032	16.901	1.00	0.00	601	8,758
10	51	6	$ 2,352,000	2,869,139	$ 39,029,220	16.902	1.00	0.00	602	8,758
10	51	9	$ 2,373,000	2,867,844	$ 39,033,676	16.904	1.00	0.00	601	8,758
10	51	5	$ 2,345,000	2,871,104	$ 39,047,344	16.910	1.00	0.00	603	8,758
11	51	8	$ 2,546,000	2,894,593	$ 39,548,612	17.127	1.00	0.00	600	8,758
11	51	7	$ 2,539,000	2,895,323	$ 39,550,940	17.128	1.00	0.00	600	8,758
11	51	9	$ 2,553,000	2,894,425	$ 39,553,468	17.129	1.00	0.00	600	8,758
11	51	6	$ 2,532,000	2,896,795	$ 39,562,764	17.133	1.00	0.00	601	8,758
11	51	5	$ 2,525,000	2,899,207	$ 39,586,596	17.143	1.00	0.00	602	8,758
12	51	8	$ 2,726,000	2,921,757	$ 40,075,864	17.355	1.00	0.00	599	8,758
12	51	9	$ 2,733,000	2,921,262	$ 40,076,532	17.356	1.00	0.00	599	8,758
12	51	7	$ 2,719,000	2,922,857	$ 40,082,920	17.358	1.00	0.00	599	8,758
12	51	6	$ 2,712,000	2,924,710	$ 40,099,612	17.366	1.00	0.00	600	8,758
12	51	5	$ 2,705,000	2,927,488	$ 40,128,128	17.378	1.00	0.00	601	8,758
12	51	4	$ 2,698,000	2,931,381	$ 40,170,892	17.397	1.00	0.00	603	8,758
12	52	8	$ 2,736,000	2,953,787	$ 40,495,308	17.536	1.00	0.00	603	8,758
12	52	9	$ 2,743,000	2,953,306	$ 40,496,164	17.536	1.00	0.00	603	8,758
12	52	7	$ 2,729,000	2,954,552	$ 40,498,088	17.539	1.00	0.00	604	8,757

Fig. 6. Optimization results (maximum annual capacity shortage 0%).

The optimization results are shown in fig. 6, when maximum annual capacity shortage is 0%. The optimized system architecture of the proposed system is shown in table II.

TABLE II. Optimized system architecture.

System Component	Proposed Optimized system
PV Array	6 kW
Biogas Generator	42 kW
Converter	4 kW

E. Electrical Output

The Electrical tab in the Simulation Results window shows details about the annual production and consumption of electrical energy by the system. Here the production of electricity by PV array is 9,386 kWh/yr and biogas generator is 181,731 kWh/yr which are 5% and 95% respectively shown in table III and fig. 7.

TABLE III. Power production per energy source.

System Component	Annual Production (kWh)
PV Array	9,386
Biogas Generator	181,731
Total	191,11

For the optimized system AC Primary Load Served is 180,060 kWh/yr. So the excess electricity 5.49% and there is 0.34% unmet load. The capacity shortage is 1,888 kWh/yr which is 1.05%. The renewable fraction is the fraction of the total electrical production that is produced by renewable sources here 1 which indicate that all the demand power is produced from renewable sources.

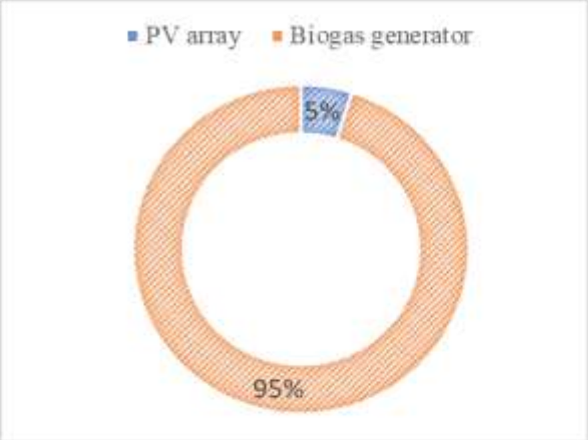

Fig. 7. Resource wise power production form designed system.

V. Conclusion

The hybrid system will bring enormous benefit to the community where there is crisis of electricity supply from the conventional grid system. The study shows a convenient solution of discontinuous power supply. The selected area has sufficient amount of renewable energy resources. But small and big farm owners did not take any steps to reuse them. Many small farms with 10-15 cattle are also not using their biomass resource in order to generate electricity. They can set up small plants. Also it is possible to make a collective system of gathering the biomass feedstock in a particular big plant. In this study, we considered nearly situated three big cattle farms. With an average available biomass of 1.7 tons/day and a combined solar panel, the hybrid system can meet the demand of the local 60 houses, 10 shops, school, mosque and the farms. The levelized cost of electricity (CEO) is found 14.47

tk/kWh. Comparing with the tariff, the system can be a source of annual profit. The project lifetime is approximately 20 years. For the present tariff rate, it may be a lengthy period to get back the initial and operation costs, but if the electricity bill rate increases, the project may return back the costs within 8 to 10 years, and hence will provide a very cost effective system. A less pollution in environment will provide cleanliness. The project will promote the socio-economic development including studies of students at nights, increase the options of business to the local people by getting continuous electricity supply. These types of projects can decrease the load on conventional grid system. Also, there are many regions, where there is such a huge amount of resource that is sufficiently enough after meeting the local demands. These types of regions can be connected to the grid system and can increase the total generation of electrical power of our country. However, proper maintenance and unity of the people of the locality can make such a project successful.

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