Sustainable Energy Plan for a Village in Punjab for Self Energy Generation.

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Abstract- Increasing electricity demand, hike in fuel prices, environmental concerns are the main factors which motivates the use of renewable energy sources in India. In past few year India has shown a significantly growth in utilization of renewable energy sources. Today the share of renewable energy sources is almost 12% in total electricity generation. According to Ministry of Power in India so far 1.15 thousands of villages still unelectrified. In this paper the potential of renewable energy sources (solar + biomass) is estimated in a village in Punjab, India. Based on a survey conducted in an Indian village named "Kaidupur" situated in district Patiala in Punjab, the available resources like biomass and solar are identified. This paper provides a complete solution to meet energy demand of a village by renewable energy sources. The optimization (biomass + solar) is done by Hybrid optimization Model for Electric Renewable (HOMER). Hybrid energy system is becoming popular in area where grid extension is considered uneconomical or not feasible. This paper provides a better understanding of utilization of renewable resources in an isolated /off grid locations.

Keywords- HOMER, Hybrid Systems, Biomass, Solar Energy, Solar water pumping systems.

1. Introduction

In India, Punjab has highest production of wheat and rice. In Punjab burning of crop residues is a common approach to eliminate waste after harvesting (Fig.1). This practice emits trace gases like carbon dioxide, methane, carbon monoxide, nitrogen oxide, sulphur oxide and large amount of particulate matters, which adversely affect human health as well as the environment making the soil less fertile. Government of Punjab has banned the burning of agriculture wastes so plenty of biomass is available for utilization. Exploiting these resources will eliminate the requirement of electricity transfer to rural areas and improve the quality of life of the rural people by providing electricity for productive use in agriculture, ensuring the clean energy environment and also a less burden on conventional grid [2]. In order to provide feasible solution analysis has to be done on how the existing resources in a village could be utilized and they can be made useful for supplying the clean form of energy to the village itself and makes it sustained in its requirements [3]. This paper deals with a survey conducted in a village, "Kaidupur" of district Patiala in India. This village comprises of 80 household and the energy needs of the village based on the survey are noted down. The following methodology for renewable sources of energy is proposed.

- Biomass and Photovoltaic based hybrid renewable energy system (HRES) is proposed for meeting the electricity demand from households and other community loads which comprises the load demand of school, dispensary, shops, community offices etc.
- Animal waste/crop residue is used for the production of biogas which serves as cooking gas.
- A solar water pumping system is proposed principally for village water supply and irrigation purpose.
- Solar street lights are used for village street lighting

Fig. 1. A farmer burning crop residue in open

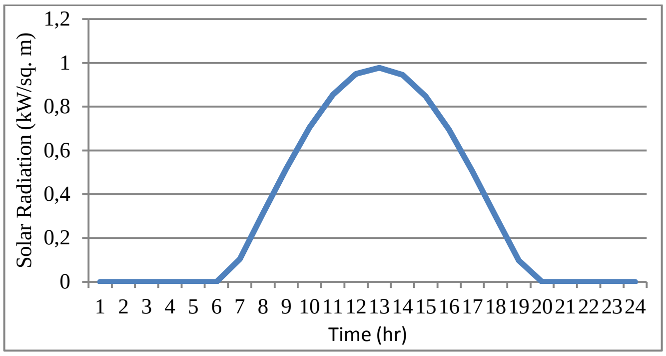

Fig. 2. Average hourly solar radiations

2. Problem Formulation

2.1. Estimation of available resources

The site under examination is surveyed and various particulars of the village are demonstrated in a "Table 1."

Table 1. Village particulars

Name of village	Kaidupur
Location	$30^0 26' 6''$ N latitude and $76^0 12' 26''$ E longitude
Number of house hold	80
Main occupation	Farming.
Main crops	Paddy/Wheat /pulses
Farmed area (hectare)	243
Average Connected load (kWh/d) Domestic Community	 444 30

The renewable sources of energy which are proposed to be used in meeting the energy demand of a village include biomass and solar.

Biomass can be produced from agro waste, mainly paddy and wheat in the case of this village and can be utilized to generate electricity in a biomass plant. The average biomass available in area is 4 tons per day [4].

Average solar radiation at a location is found to be 5.14kWh/m^2/day which could be used as source for a PV panel and for solar water pumping system. "Fig. 2" shows average hourly solar radiation of a day at proposed site.

2.2. Current use of resource

There is no suitable method available for managing the crop residues in the village. Crop residues / biomass are simply burned in open field after harvesting and no utilization of available resources is done. The daily energy requirements like cooking are also met by LPG cylinders and fire wood.

Discontinuous power supply because of difficulty in connecting them with grid and increase load on conventional system is another problem for villagers so most of them are using diesel pump for irrigation purposes which are again inefficient and polluting.

So, for the place like in Punjab where biomass and solar resources are abundantly available for electricity generation to meet the demand without any environmental hazard and making the village self sustained in its energy requirement is the most suitable one.

3. Planning

"Fig.3" demonstrates the requirement of energy in a typical Indian village and proposed method to meet the energy demand.

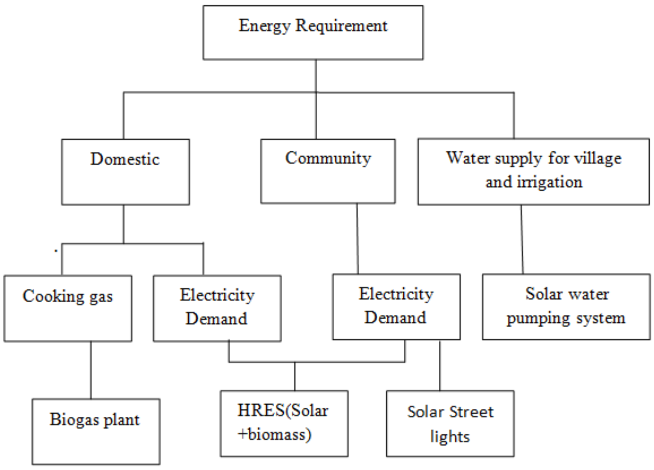

Fig. 3. Energy requirement and proposed plan for a village.

3.1. The proposed solution for meeting the electricity demand

Hybrid (biomass + solar) renewable energy system (HRES) is proposed for meeting the electricity demand.

HRES is designed based upon the certain important sensitivity variables to optimize the cost & size effectively [5]. Hence, before designing the model, certain parameters like solar irradiation, available biomass and load profile must be evaluated. HOMER software is used to determine the optimal sizing and operational strategy for a HRES. HOMER is a user friendly software tool developed by National Renewable Energy Laboratory (USA). It can be free downloaded from NREL website [6] [7].For carrying out the analysis the load profile taken from Kaidupur village is used to simulate the whole operation for this system. A proposed hybrid system is shown in "Fig.4" which consists of biomass generator, PV modules, a battery bank (for backup) and converters. The different components used in HOMER are explained hereby in detail.

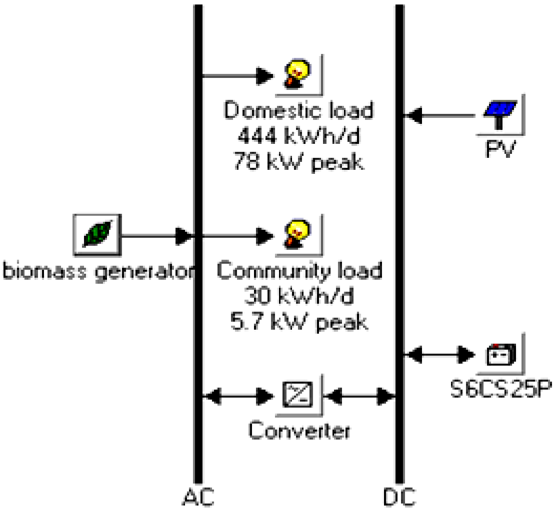

Fig. 4. Proposed hybrid system at village

3.2. Village load assessment

In a village the demand for electricity is not as high as in urban areas. The basic energy requirements in such areas can be classified as domestic, agricultural and community.

- In the domestic sector electricity is required to use appliances like television, compact fluorescent lamps, ceiling fans, refrigerator, cooler, heater etc.
- In irrigation for water pumping,
- The community load serves the community centre, village community offices, shops, schools and medical centre.

"Fig.5" and "Fig.6" shows hourly average domestic and community load profile respectively in proposed village.

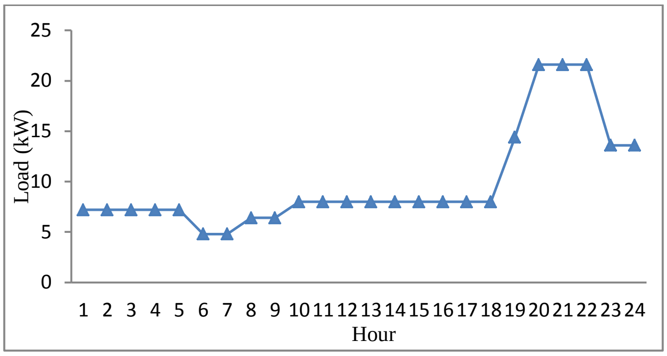

Fig. 5. Hourly average domestic demand of proposed village

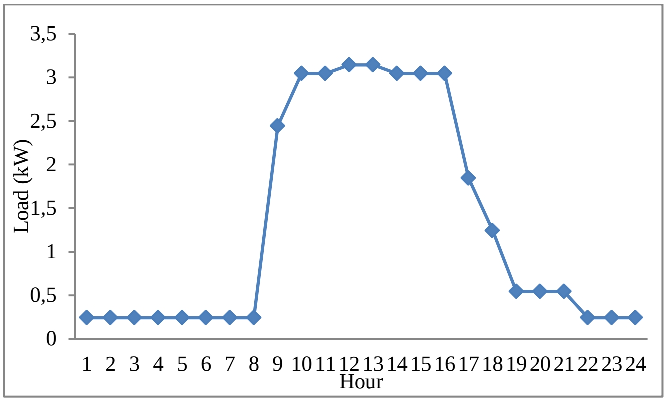

Fig. 6. Hourly average community load profile of the village.

3.3. Photovoltaic (PV) economic information and solar resource

The panel of PV array system that is 1kW. The cost of a PV system is expressed in $ per peak watt and are detailed in "Table. 2". Peak watt is defined as power at Standard Test Conditions (STC, 1000W/m^2, 25^{0}C). [8]

The typical data for solar energy resources are present in the official NASA surface meteorology and solar energy website [9]. "Fig. 7" shows the solar resource profile for this area over a one-year period with an annual average solar radiation equal 5.14 kWh/m^2/d.

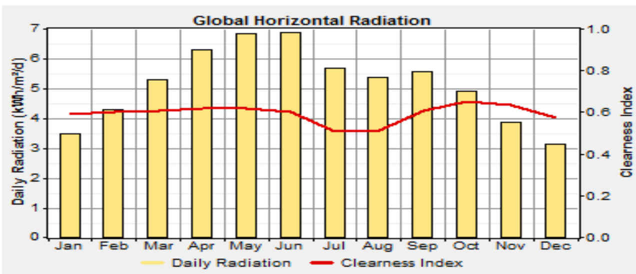

Fig. 7. Monthly average solar radiation

3.4. Biomass generator and biomass resource

The biomass gasification system is a technology which converts any kind of biomass energy with low heat value (such as waste from agriculture and forest and organic waste) into combustible gas and then feeds this gas to a generator for electricity generation. It is found that in village there is sufficient feedstock available for operating and installing a 40kW power plant [10]. The average biomass available in study area is 4 tons per day [11].

3.5. Battery

Batteries are used in HRES to store excess electricity and to operate the system when power from system is insufficient or absent. A deep cycle lead acid battery that is used more frequently in renewable energy application is considered. The type of battery that is used in this system is Surrette 6CS25P of Rolls Battery Company with rating of 6V, 1156Ah.

3.6. Power converter

A power converter is used to maintain the flow of energy between ac and dc components. The size of power converter used in this system is 1kW.

The capital, replacement and operation and maintenance costs of different components used in system are given in "Table 2."

TABLE 2. System components costs and ratings

Component	Rating	Capital cost.	Replacement cost.	O&M cost.	Details used
PV panel	1kW	$2500	$2250	$75/year	Avg. radiation: 5.14 kWh/m^2/d
Biomass generator	9 kW 40 kW	$14429 $50321	$7215 $25161	$0.08/hr $0.3/hr	Available biomass: 4 tons/d
Surrette 6CS25P	1 battery	$1250	$1100	$5/year	Rolls battery company
Power Converter	1kW	$800	$750	$0/year	No maintenance

3.7. Simulation result

HOMER simulates every combination system configuration in the defined search space. Only the feasible one will be displayed at optimization result sorted based on the Net Present Cost (NPC). The combination of system components is arranged from most effective cost to the least effective cost.

The proposed hybrid renewable energy system for the village consists of domestic load which is 444kWh/d and annual peak load of 78kW, community load which is 30kWh/d and annual peak load of 5.7kW. According to the optimization result as shown in "Fig. 8" the optimal solution is using only a biomass generator with a total net present cost of 3, 74,186$ but the feasible solution used is hybrid energy system using 0.5kW PV array and 40kW biomass generator which is having a levelized cost of energy (COE) of $0.170/kWh and total net present cost (NPC) for such a system is $3, 76,133. "Fig.9" shows output waveforms of different components used in the system.

PV (kW)	Gen (kW)	S6CS25P	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Biomass (t)	Gen (hrs)
	40	40	35	$ 128,321	19,233	$ 374,186	0.169	1.00	272	6,224
0.5	40	40	35	$ 129,571	19,288	$ 376,133	0.170	1.00	271	6,275
1.0	40	40	35	$ 130,821	19,254	$ 376,950	0.170	1.00	270	6,251
1.5	40	40	35	$ 132,071	19,256	$ 378,229	0.171	1.00	269	6,234
	40	45	35	$ 134,571	19,067	$ 378,308	0.171	1.00	271	6,132
2.0	40	40	35	$ 133,321	19,230	$ 379,142	0.171	1.00	268	6,209
	40	40	40	$ 132,321	19,334	$ 379,477	0.171	1.00	272	6,224
0.5	40	45	35	$ 135,821	19,109	$ 380,095	0.172	1.00	271	6,168
2.5	40	40	35	$ 134,571	19,216	$ 380,216	0.172	1.00	267	6,194
0.5	40	40	40	$ 133,571	19,389	$ 381,423	0.172	1.00	271	6,275
3.0	40	40	35	$ 135,821	19,219	$ 381,502	0.172	1.00	266	6,176
1.0	40	45	35	$ 137,071	19,131	$ 381,628	0.172	1.00	270	6,159
1.0	40	40	40	$ 134,821	19,354	$ 382,233	0.173	1.00	270	6,252
	40	35	45	$ 130,071	19,746	$ 382,486	0.173	1.00	273	6,393
1.5	40	45	35	$ 138,321	19,106	$ 382,560	0.173	1.00	269	6,135

Fig.8. Optimization results for the PV and Biomass generator configuration.

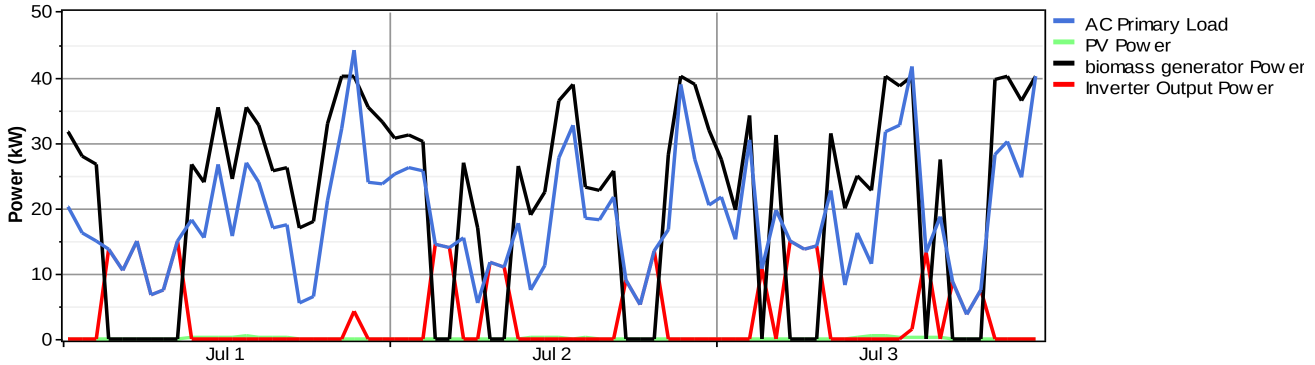

Fig.9. Hourly electricity production from various sources and primary load

4. Proposal for other demand

4.1. Plan to meet cooking gas demand

The cooking gas demand can be met by producing biogas locally. Biogas is a clean and efficient fuel. Biogas is produced from Cattle Dung, Human Excreta and other organic matter in Biogas plant, through a process called 'Digestion'. Biogas contains 55% to 60% methane which is inflammable. The produced gas can be directly used for the cooking purpose which reduces the usage of firewood and its inefficient burning. For promoting the setting up of biogas plant the central sector scheme on National Biogas and Manure Management Programme (NBMMP) provides for central subsidy in fixed amounts, free maintenance warranty, financial support for repair of old-non functional plants, training of users, financial support for institutions for cattle dung based power generation plants, etc. There is numerous model design of family type bio gas plant approved by Punjab Energy Development Agency (PEDA).

The installation design of the bio-gas plant depends on the average population of cattle and the amount of dung available. The size of a plant, cattle dung available and estimated cost is shown in “Table 3.” [12].

Table 3. Details of plant capacity and there cost.

Size of a plant	Quantity of cattle dung required daily	Number of cattle heads required	Estimated cost ($)
1 cubic meters	25 kg	2-3	121
2 cubic meters	50 kg	4-6	155
3 cubic meters	75 kg	7-9	181
4 cubic meters	100 kg	10-12	216
6 cubic meters	150 kg	14-16	259

As per the survey it is found that each household owns about 3-4 cattle heads on an average resulting in a total of about 14 heads for four houses, so the family type biogas plant of 6 cubic meter size for four houses is proposed to meet the cooking gas demand which would be costing about $259. So the total biogas plant proposed for villages are twenty.

4.2. Plan to meet irrigation load and water supply of a village

A solar water pumping system is proposed principally for village water supply and irrigation purpose. It consist of SPV modules of capacity 1800 Wp (75 Wp modules), 2 h.p. solar pump cables, switches and also available in 4 h.p. “Fig.10” shows a typical solar water pumping system installed in Punjab. This kind of solar water pumping system is useful for small farmers and replacement of diesel operated water pump sets. SPV Pump set will have the capacity to give discharge of 1, 20,000 to 1, 40,000 liters on clear sunny day (approx.) subject to variation due to solar radiation and water table condition. This discharge will be suitable for irrigating 1.6-2 hectare of land. The main advantage of solar water pumping set are saving of electricity, diesel, long operating life, highly reliable and trouble-free performance, easy to operate and maintain and environmental friendly.

The specifications of solar water pumping set provided by Punjab Government are [13]

- Solar PV Panels: 1800 Wp comprising of (75Wp panels)
- Motor pump sets type: 2 h.p.
  Centrifugal DC monoblock
- Operating Voltage: 60V DC (nominal)
- Max. Suction Head: 7.0 m
- Max. Dynamic head: 10.0 m
- Bore well size (diameter): 150 mm
- Required shadow free area: 100 m^2

Fig. 10. A solar water pump installed in a village in Punjab

Government of Punjab announced 40% subsidy on solar irrigation pumps towards the promotion of state's flagship programme of agriculture diversification. A solar pump costs nearly $4, 237, out of that 40% ($1,695) and 30% ($1,271) as subsidy are borne by the state government and the union government respectively, and the balance 30% ($1,271) has to be paid by the beneficiary farmer (Table 4) [13].

Table 4. Cost of solar water pumping system in Punjab

Specification	Total cost	Subsidy by Central government	Subsidy by State government	Paid by farmer
2 h.p. solar water pumping system	$4,237	$1,695	$1,271	$1,271

4.3. Solar Street lighting:

Solar street lighting is an ideal application for village street lights. The specification of one of the available solar lights is given in "Table 5."

Table 5. Street lights specification**.**

Parameters	Specifications.
Output light intensity	16 lux at 12 feet
Nominal power	20W
Efficiency	86%
Lamp	9W*2

The system is provided with battery storage backup sufficient to operate the light for 10-11 hours daily during nights and cost to about $294 each. 20 street lights will be sufficient in village with a total cost about $5, 880[12].

5. Cost analysis

To meet electricity demand of village, a hybrid energy system is proposed whose optimized result is found with the help of HOMER software. The optimal configuration is 0.5kW PV array and 40kW biomass generator, with a levelized cost of energy (COE) of $0.170/kWh and total net present cost (NPC) of $3, 76,133.

The cooking gas demand are met by effective use of manure available and a family type biogas plant of 6 cubic meter size for four houses is proposed which is costing to about $259. So a single household will pay about $64.75 to meet the cooking need instead of depending on LPG cylinders. It is found that at least 1 cylinder per month which costs $7.24 is needed by a family for cooking. So 960 cylinders would be needed for fulfilling the cooking demand of 80 families costing to about $6952 in a year and for a single household it would be $87 per year. Thus a payback period of about 9 months or a year is estimated.

For village water supply and irrigation a subsidized solar water pump of 2 h.p. is proposed which costs about $1,294 to farmers and is proved to be a very good solution for replacing the pre existing diesel pumps which are comparatively expensive and polluting. 20 solar streetlights which cost about $5,880 are found to be sufficient for whole village. "Table 6" shows the total cost used in project to make a village self sustainable.

Table 6. Cost details of proposed plan

Requirements.	Existing. System	Proposed. System	Cost of the proposed system
Electrical demand for domestic and community loads	State electricity supply which is unreliable and discontinuous	100% renewable and continuous supply	$376,133
Cooking	LPG cylinders and fire wood which is costly, inefficient and unhealthy	Biogas plant which is cheap and eco-friendly. A by-product left is also a good fertilizer	$5,180
Irrigation and water supply	Diesel pumps which are uneconomical and polluting	Solar water pumps which are economical and have long operating life	$1,271

Street lights	Few street lights which are damaged most of the time due to low maintenance	Solar street light which are of low power and less maintenance	$5,880

6. Conclusion

Hybrid system has the advantage of stability and providing power on environmental friendly basis. The objective to meet electricity demand of village can be achieved by making proper utilization of resources like biomass and solar. The two major problem of managing the residue left after harvesting and inconvenient electricity supply of villages could be well overcome by utilizing the existing resource of village and making itself sustainable in its energy requirements.

In this paper a hybrid system is proposed to integrate the abundantly available renewable resources which are a clean source of energy and are currently wasted due to lack of awareness. In this paper efforts are made to exploit biomass and solar resources in the region and suggest some of the cost effective and environment friendly ways to meet the demand. The cost analysis predict in spite of having huge capital and installation cost renewable energy sources prove to be more reliable and environmental friendly source to provide electricity in remote or off grid areas.

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