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Optimization and Economic Analysis of Standalone Hybrid PV-Biomass-Hydel Energy System Using HOMER

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Abstract: This study proposes optimization and economic analysis of standalone PV-Biomass and Hydel as a hybrid energy system that also includes diesel generator and battery array as back up source of power. This off-grid system serves the electrical energy demand of a rural location which further reduces the dependency on conventional fossil fuel generation that induces high cost of energy and results in increased carbon contents emission. State of the art tools like Hybrid optimization model of electric renewables (HOMER) have brought new opportunities for utilization of renewable energy sources. A hybrid optimization model for renewable energy is used to determine the optimum configuration of the proposed off-grid PV-Biomass-Hydel energy system with minimum net present cost (NPC) and levelized cost of energy (LCOE) while minimizing total annualized cost of the system. Analysis of the result shows that off grid PV- Biomass and Hydel hybrid energy system with Diesel generator and Battery system is economical and secure for rural electrification.

Keywords: HOMER, Hybrid energy system, Levelized cost of energy, Net present cost, Annualized cost.

Section 1

Introduction

As a developing nation India's energy demands are increasing exponentially. To meet energy demands conventional sources of energies are limited, costly and will exhaust with time. To tackle this state of condition renewable energy sources may prove a feasible solution. Nearly, 346 GW power generation capacity has been installed in India until October 31, 2018. Coal, gas and oil fuel combustions are main contributors, approximately 64%, of the total generation while share of generation from renewable sources is around 21% which include PV, Biomass, small hydel and wind energy. During peak load hours there is still 2% unmet loads and in summer the conditions becomes worse as the electrified villages also have to face unscheduled electricity cuts [1, 2]. As a crop rich state Punjab (India), has a vast amount of agriculture residue or waste, which is having high potential to generate energy but due to lack of adequate planning and improper handling of agriculture wastes this potential remains untapped. It is estimated that 40.142 Metric tons of biomass are left behind every year in Punjab. About 71% of this waste is used in different forms and rest may be used for biomass generation. Such huge amount of waste can generate around 1.4 GW capacity of power [3, 4]. The inefficient handling of crop residue has become a matter of huge concern for India. After each crop ending season, stubble burning causes increase in fine dust particles to spread over the whole northern India and causes atmosphere pollution [5].

Renewable energy sources based hybrid systems are recognized as one of the important options as clean source of energy in supply side planning for microgrids. While designing an optimal system in terms of reliability and profit of microgrid Lei *et al.* [6] presents optimal design of capacity configuration, which could fulfil the power demand. In terms of economic and environmental aspects Baharozu and Soykan [7] designed a small scale smart microgrid. Potential of Biomass and PV energy resources for rural electrification cannot be disregarded as numerous researchers have been exploring the feasibility of Biomass and PV based energy systems for rural electrification in recent years. Optimal solution consists with minimum cost of energy, less emissions and high reliability is presented in [8].

HOMER's high level capability in simulating a micro-power system with long term operations, optimization and sensitive analysis attracts the researchers, HOMER software is used by [9-14]

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various researchers for designing, optimizing and to evaluate wide variety of configurations for various Hybrid energy system. To meet the energy demands of rural locations possible potential of micro hydro power plants are used in [15-18] while designing various feasibilities technically and economically are considered. This paper analyzed various factors as discussed above and their impact on the proposed energy hybrid system. The main intent of this work can be summarized as follows:

- Planning, Optimization and economic analysis of off-grid Renewable hybrid energy based microgrid while taking various system configurations with pragmatic inputs on their economic, operating and physical characteristics.
- Finding feasibility of components and their optimal size with least Net Present Value (NPV) and minimum levelized cost of energy (COE) while minimizing total Annualized cost of the system.
- Appropriately decide Hybrid System configuration by performing various sensitive analysis for different parameters.
- Compare overall benefits in terms of economy and size with existing microgrids.

This paper is organised in V sections: Section I represents the overview of Hybrid Energy system design, optimization and economic aspects. Section II describes the problem formulation. Section III briefly discusses off-grid system having PV-Biomass-Hydel and input data required, Section IV presents different case studies considering off-grid having PV-Biomass-Hydel hybrid systems, results are presented and discussed. Section V contains the conclusion and future scope followed by references.

Section II

Problem Formulation

All the system configurations have been classified in the optimization results on total net present cost using HOMER [19]. It computes the total annualized cost and the levelized cost of energy (LCOE) and total NPC by adding the total deducted cash flows in every year of the project lifespan. Main economic output of HOMER is Net Present Cost (NPC) of system, which is the present value of all the costs like initial investments, replacement costs, operation and maintenance costs, fuel costs, emission penalties and other miscellaneous costs in a standalone system, the system incurs over its lifetime and subtracts the present value of all the profits it earns. The total annualized cost is calculated using the annualized value of the total net present cost, which can be evaluated as follow:

$$C_{ann,tot} = CRF(i, R_{proj})C_{NPC,tot} \tag{1}$$

where:

$C_{NPC,tot}$ the total net present cost of system[Rs.]

i the annual real discount rate [%]

R_{proj} the project lifetime [yr]

CRF a function returning the capital recovery factor.

HOMER calculates the annual real discount rate from the “Nominal discount rate” and “Expected inflation rate” inputs as shown by (2). It uses this real discount rate to calculate discount factors and annualized costs.

$$i = \frac{i' - f}{1 + f} \tag{2}$$

where:

i' nominal discount rate (the rate at which you could borrow money)

f expected inflation rate.

The capital recovery factor function as given by expression (3) used to calculate the present value of annuity.

$$CRF(i, N) = \frac{i(1+i)^N}{(1+i)^N - 1} \tag{3}$$

where:

N number of years.

The expression for Levelized cost of energy (COE), is given in (4).

$$COE = \frac{C_{ann,tot}}{E_{served}} \tag{4}$$

where:

$C_{ann,tot}$ total annualized cost of the system[Rs./yr]

E_{served} total electric load served[kwh/yr]

Salvage value (S.V) for the system components calculated by HOMER is given by (5).

$$S.V = C_{rpc} \cdot \frac{R_{eml}}{R_{cl}} \tag{5}$$

where:

R_{eml} component remaining life at end of project lifetime.

$$R_{eml} = R_{cl} - (R_{pl} - R_{rcd}) \tag{6}$$

where:

R_{rcd} replacement cost duration

$$R_{rcd} = R_{cl} . Int. \left(\frac{R_{pl}}{R_{cl}}\right) \tag{7}$$

where:

C_{rpc} cost of replacement [Rs.]

R_{cl} lifetime of component [yrs]

R_{pl} lifetime of project [yrs]

Int function which returns integer amount of real number.

Section III

System under Consideration and Input data

The plan proposed is for a small village Mandhaur near Sirhind, Punjab having coordinates of 30^0 $37.12^{'}$N latitude and 76^0 $20.20^{'}$ E longitudes is presented in this paper. Village Mandhaur is situated on the bank of Bhakra canal. Daily load profile for this village is shown in figure 1.

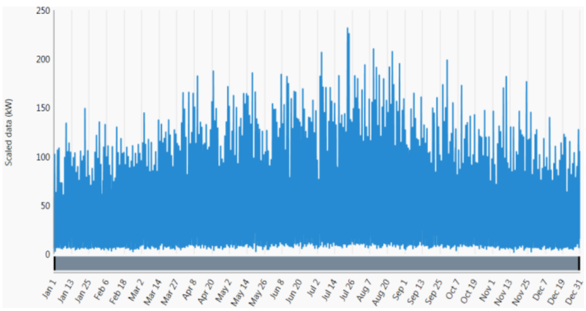

Fig. 1: Daily Load Profile

Monthly load profile for the village is shown in figure 2. Village has higher load demand during summer season that is from month of April and maximum load demand occur during month of July.

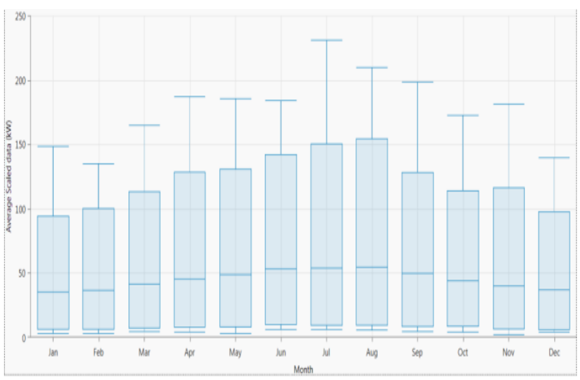

Fig. 2: Monthly load Profile

Table-1: Calculated Average Load Demand

No. Of Houses	**Energy consumed in each house (in kWh/day)**	**Total energy consumed (in kWh/day)**
43	11	473
60	7.5	450
35	4	140
Total Houses=138		1063 kWh/day
No. Of Shops	**Energy Consumed in Each Shop (in kWh/day)**	**Total Energy consumed (in kWh/day)**
4	6.7	26.8
Total energy consumed is		**1063+26.8=1089.8 kWh/day**

The village has approximately 138 houses and 4 shops. Energy consumption of all the houses is not uniform. The average daily electrical demand is calculated as in Table 1.Total energy consumed by 138 houses is 1063 kwh/day and by 4 shops is 26.8 kwh/day. Hence the total load demand of the village is taken as roughly 1090 kWh/day. Considering that the main occupation in this village is farming, biomass and hydel sources of energy are proposed for the hybrid energy system. Biomass availability in the area is approximately 4 tons which includes animal wastes and crop residues. In addition, the village being located near a canal, potential of the microhydel will be significant. Hence, the proposed solution is a PV-Biomass-Hydel hybrid system as a part of site plan.

A. Resource data and model inputs

The Renewable energy supply alternatives in the proposed hybrid off-grid system are Solar PV array, Biomass, Hydro turbines, battery bank, diesel generator and AC/DC converter are shown in figure 3.

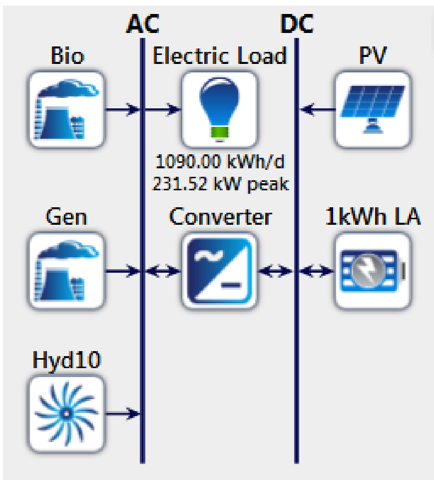

Fig. 3: Available Portfolio of Hybrid System

B. Solar resource

For the proposed site plan, solar resource data is taken from NASA surface metrology website [20]. For this region, the annual average radiation is 5.44 kWh/m^2/day. Average Solar radiation for whole year and clearness index of this location is shown in figure 4.

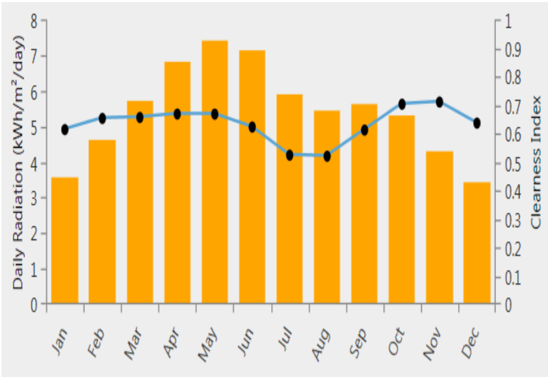

Fig. 4: Solar Radiation Profile of Proposed Site

Average solar radiation and clearness index for each month is given in Table-2 for the proposed site plan. With change in season there is variation in average solar radiation, minimum daily radiation 3.450 kwh/m^2/day occurs in the month of December and maximum daily radiation 7.420 kwh/m^2/day occurs in the month of May

Table 2: Average solar radiation and clearness index profile

Month	Daily Radition (kwh/m^2/day)	Clearness index
January	3.570	.614
February	4.610	.653
March	5.710	.656
April	6.810	.668
May	7.420	.668
June	7.120	.623
July	5.890	.524
August	5.460	.520
September	5.620	.612
October	5.290	.703
November	4.320	.710
December	3.450	.636

C. Biomass resource

Inefficient handling for the agriculture residues and cow dung in the rural parts of Punjab leads to stubble burning and environment pollution. Further no utilization of available resources is done. To operate a 40kW power plant [21] sufficient biomass is easily available in a village. In the proposed region availability of biomass is 4 tons per day [22]. It is estimated that to produce 1kWh of electricity roughly 1.2–1.5 kg biomass is needed. Biomass price, includes transportation and labour charges in the region is approximately Rs.3 per kg ($1=Rs.70 approx.).

D. Hydel resource

As an energy potential, hydel energy sources cannot be neglected. The proposed site plan is also located on the bank of Bhakra Main line (BML) Canal which is used as a source of drinking and irrigation purpose. Capacity of this canal is 12455 Cusec (1 Cusec=28.37 L/sec) [15] and from [16] it is very much clear that a minimum discharge of 0.072 m^3/sec can produce 31.81 kW of power, so economically and technically it may also be a part of the system to achieve the load demand of the region.

E. Component Costs

Cost of PV module, biomass gasifier, hydro turbine, diesel generator, converter and battery in terms of capital cost per kw, replacement cost per kw and maintenance cost per kw, are presented in Table-3. Lifetime of each component in years/hours is also presented in the same.

Table 3:Component Costs

Component	Capital cost per kw ,Rs	Replace-ment cost per kw, Rs	Maintena-nce. cost per kw	Lifetime
PV module [23]	70000	63000	Rs100/yr	25 yr
Biomass gasifier [23,24]	70000	63000	Rs.35/hr	20000hr
Hydro turbine [16]	400000	400000	Rs 8000/yr	25 yr
Diesel Gen. [10]	35000	35000	Rs.5/hr	15000hr
Converter [10]	47000	47000	Rs.0	15 yr
Battery [10]	10000	10000	Rs.135/yr	10 yr

Section IV

Results and Discussions:

Data for Hybrid PV-Biomass and hydel energy system is feed to HOMER tool and results of simulation and economic analysis are presented in this section. Different scenarios have been considered for figuring out the optimal value of each supply options.

A. Comparison of various cases

All available sources are used in Case-1 to meet the load demand while Case-2 completely relies on renewable sources by excluding the Diesel generator (DG), again in Case-3 DG mixed with renewable options is considered while there is exclusion of micro-hydel from the system and in Case-4 configuration is considered by excluding both DG and micro-hydel from the system. All the scenarios in terms of size of various components are presented in Table-4.

Table 4: Sizing of Components

Component	CASE-1	CASE-2	CASE-3	CASE-4
Diesel Gen, kW	30	0	30	0
Solar PV, kW	338	370	414	442
Biomass Gen., kW	170	170	170	170
Micro Hydel, kW	11	11	0	0
Converter, kW	143	180	152	173
Battery Numbers	1906	1908	2581	2308

In Table-5 comparison of various costs like net present cost, annualized cost, levelized cost of energy, operating cost and capital cost in different.

Table-5: Comparison of various cost components

Item	CASE-1	CASE-2	CASE-3	CASE-4
Net Present Cost (M Rs.)	Rs.108M	Rs.110 M	Rs.124 M	Rs.127 M
Annualized Cost (M Rs.)	Rs.6.2M	Rs.6.3M	Rs.7.1M	Rs.7.2M
Levelized Cost of Energy, (Rs./Kwh)	Rs. 15.56	Rs. 15.92	Rs. 17.89	Rs. 18.28
Operating Cost (MRs/year)	Rs. 2.37 M	Rs. 2.35 M	Rs. 2.82M	Rs. 3.02M
Intial Capital Cost M Rs.)	Rs.66.4 M	Rs.69.3 M	Rs.74.9 M	Rs.74.1 M

Scenarios is presented. Most economical among all scenarios is case-1 where diesel generator and all renewable energy sources are operated together. This system has least values for NPC, Annualized Cost, Levelized cost of energy, Operating cost and Initial investment as compared with all other cases. Levelized cost of energy in case 1 is also lower than other studies [10,13].In case-2 operating cost is less due to use of all renewable sources but all other costs are high. In case 3 due to exclusion of Hydel source and in case 4 due to exclusion of Hydel source and diesel generator levelized cost of energy and operating costs are very high in both cases. All other costs in case3 and 4 are also too high due to increase in number of PV and battery array.

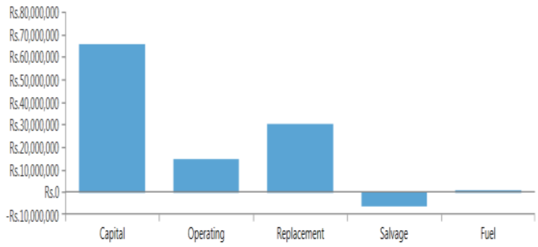

Fig. 5: Cost Type Case 1

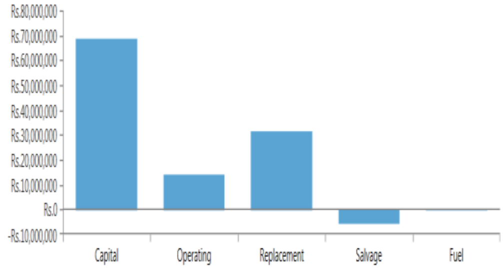

Fig. 6: Cost Type Case 2

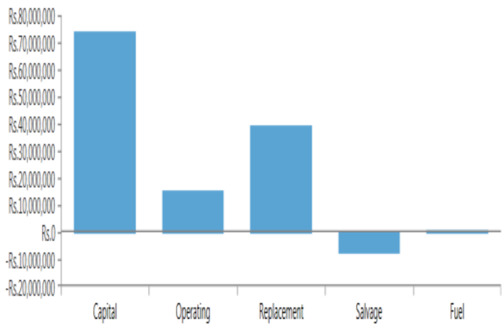

Fig. 7: Cost Type Case 3

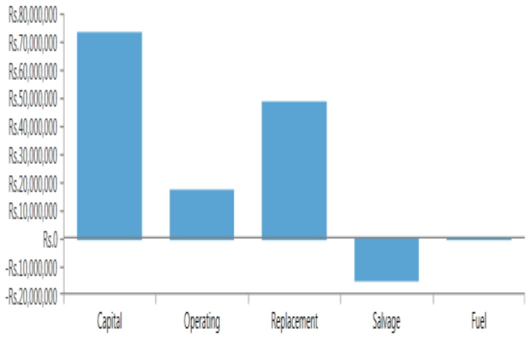

Fig. 8: Cost Type Case 4

Figures 5-8 show cost type of the system. Cost type includes capital cost, operating cost, replacement cost, salvage value and fuel cost of the system. In figure 5, cost type of case 1 are presented where capital costs and replacement costs are less as compare to other cases. In figure 6, operating cost and fuel costs of case 2 are less as compare to others. Figure 7 and figure 8 of case 3 and 4 shows high capital costs and replacement costs due to increase in number of battery array. Salvage value in case 4 is higher as compare to all other scenarios.

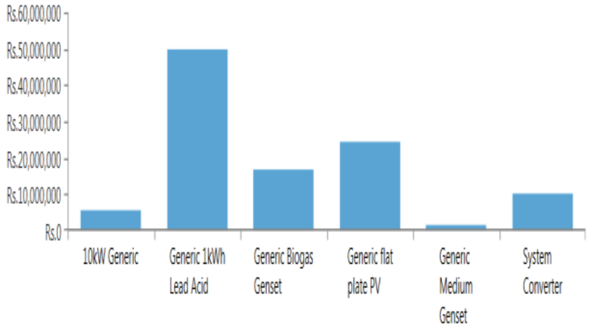

Fig.9: Cost component Case 1

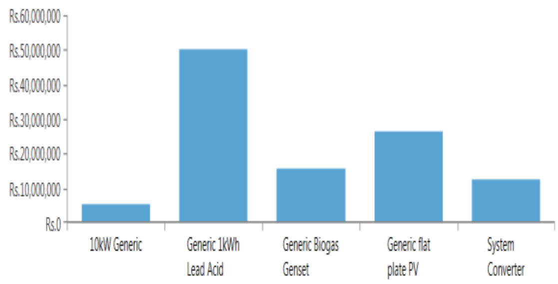

Fig.10: Cost component Case 2

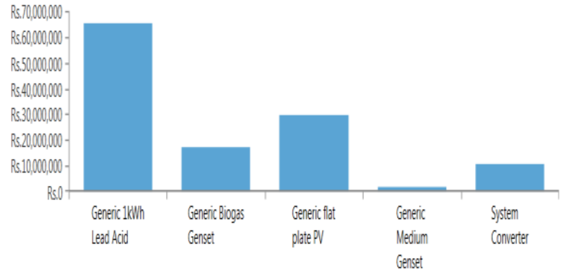

Fig.11: Cost component Case 3

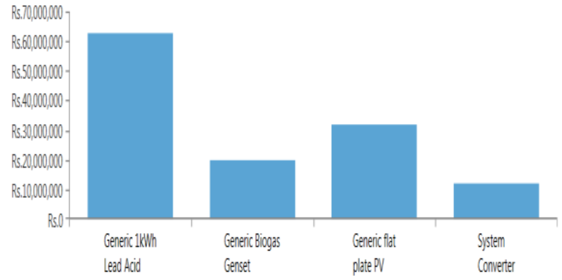

Fig.12: Cost component Case 4

Figures 9-12 show cost of components used by system in all scenarios. Components include 10 kw Genric turbine system, Genric 1 KWh Lead Acid (Battery), Genric Biogas Generator, Genric Flat Plate PV, Genric Medium Genset (Diesel Generator) and System converter. Costs of almost all the components are less in case 1 as compare to all other cases , as the size of components is less in case 1.

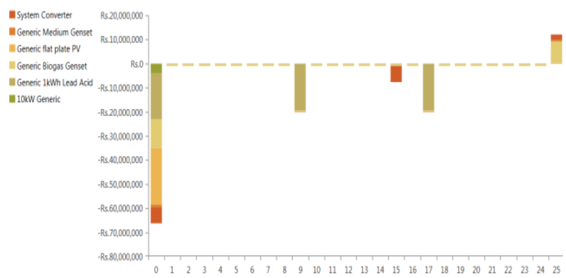

Fig. 13: Cash Flow Case 1

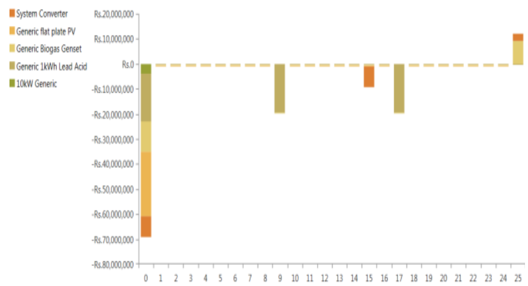

Fig. 14: Cash Flow Case 2

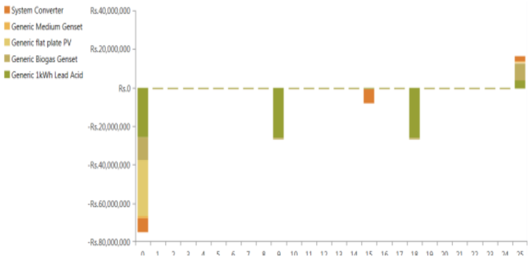

Fig. 15: Cash Flow Case 3

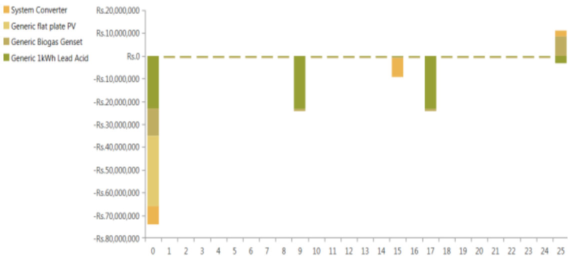

Fig. 16: Cash Flow Case 4

Figures 13-16 present the annual cash flows for all the cases respectively. Cash flow pattern for Case-1 and Case-2 are similar. Replacement cost of batteries and system converter is sporadically distributed over its lifetime in both cases. Due to increase in number of batteries in system configuration, replacement cost of batteries in Case-3 and Case-4 increases.

Table 6-9 presents cost summary of all the cases by using cost type and cost component. Table 6 shows that capital cost, replacement cost, system cost and total component cost of case 1 is lower as compare to all other cases. Operation and maintenance cost and fuel cost in case 2 presented in Table 7 has lower value due to use of only renewable sources. Capital cost shown in Table 8 of case 3 and capital cost presented in Table 9 of case 4 are almost equal. Salvage value has higher value in case 4 presented in Table 9 as compared to other cases.

Table-6: Cost Summary Case-1

Component	Capital Cost	Replacement Cost	Operation & Maintenance Cost	Fuel	Salvage	Total
10 KW Genric turbine	Rs.4 M	0.00	Rs.1.4 M	0.00	0.00	Rs.5.4 M
Genric 1 KWh Lead Acid Battery	Rs.19.06M	Rs.26.48M	Rs.4.4M	0.00	Rs -0.17M	Rs.49.77M
Genric Biogas Generator	Rs.11.9M	0.00	Rs.8.6M	Rs.0.68M	Rs. -4.5 M	Rs.16.68M
Genric Flat Plate PV	Rs.23.68M	0.00	Rs.0.5M	0.00	0.00	Rs.24.18 M
Genric Medium Genset (Diesel Gen.)	Rs.1.05M	0.00	Rs.0.4M	Rs. 0.56M	Rs.-0.36 M	Rs.1.65 M
System converter	Rs.6.72M	Rs.4.31M	0.00	0.00	Rs.-1.06 M	Rs.9.97 M
System	Rs.66.41M	Rs.30.79M	Rs15.3M	Rs.1.24M	Rs. -6.09 M	Rs.107.6M

Table-7: Cost summary Case-2

Component	Capital Cost	Replacement Cost	Operation & Maintenance Cost	Fuel	Salvage	Total
10 KW Genric turbine	Rs.4 M	0.00	Rs.1.39 M	0.00	0.00	Rs.5.39M
Genric 1 KWh Lead Acid Battery	Rs.19.08M	Rs.26.5M	Rs.4.48M	0.00	Rs -0.02M	Rs.50.04M
Genric Biogas Generator	Rs.11.9M	0.00	Rs.7.8M	Rs.0.61M	Rs. -4.6 M	Rs.15.71M
Genric Flat Plate PV	Rs.25.86M	0.00	Rs.0.6M	0.00	0.00	Rs.26.46M
Genric Medium Genset (Diesel Gen.)	Not Used	0.00	0.00	0.00	0.00	0.00
System converter	Rs.8.44M	Rs.5.4M	0.00	0.00	Rs.-1.34 M	Rs.12.5M
System	Rs.69.28M	Rs.31.9M	Rs14.27M	Rs.0.61M	Rs. -5.96 M	Rs.110.1M

Table-8: Cost summary Case-3

Component	Capital Cost	Replacement Cost	Operation & Maintenance Cost	Fuel	Salvage	Total
10 KW Genric turbine	Not Used	0.00	0.00	0.00	0.00	0.00
Genric 1 KWh Lead Acid Battery	Rs.25.8M	Rs.35.1M	Rs.6.06M	0.00	Rs -2.09M	Rs.64.87M
Genric Biogas Generator	Rs.11.9M	0.00	Rs.9.01M	Rs.0.73M	Rs. -4.55 M	Rs.17.09M
Genric Flat Plate PV	Rs.28.96M	0.00	Rs.0.72M	0.00	0.00	Rs.29.68 M
Genric Medium Genset (Diesel Gen.)	Rs.1.05M	0.00	Rs.0.41M	Rs. 0.53M	Rs.-0.37M	Rs.1.62M
System converter	Rs.7.15M	Rs.4.5M	0.00	0.00	Rs.-1.13M	Rs.10.52M
System	Rs.74.86M	Rs.39.6M	Rs16.20M	Rs.1.26M	Rs. -8.14 M.	Rs.123.7M

Table-9: Cost summary Case-4

Component	Capital Cost	Replacement Cost	Operation & Maintenance Cost	Fuel	Salvage	Total
10 KW Genric turbine	Not Used	0.00	0.00	0.00	0.00	0.00
Genric 1 KWh Lead Acid Battery	Rs.23.08M	Rs.43.9M	Rs.5.4M	0.00	Rs. -9.6M	Rs.62.78M
Genric Biogas Generator	Rs.11.9M	0.00	Rs.11.6M	Rs.0.95M	Rs. -4.4M	Rs.20.05M
Genric Flat Plate PV	Rs.30.96M	0.00	Rs.0.77M	0.00	0.00	Rs.31.73 M
Genric Medium Genset (Diesel Gen.)	Not Used	0.00	Rs.0.00	0.00	0.00	0.00
System converter	Rs.8.15M	Rs.5.23M	0.00	0.00	Rs.-1.29 M	Rs.12.09 M
System	Rs.74.09M	Rs.49.13M	Rs17.77M	Rs.0.95M	Rs. -15.29M	Rs.126.7 M

B. Energy Profiles in various scenarios:

Comparison of electrical energy profile for various scenarios are conducted and presented in Table-10.

Table-10: Comparison of Energy Profiles kWh/Yr

Component	CASE-1 KWH/YR	CASE-2 KWH/YR	CASE-3 KWH/YR	CASE-4 KWH/YR
Diesel	1,595	0	1,517	0
Solar PV	553,349	604,427	676,792	723,427
Biomass	9,921	8,869	10,625	13,781
Micro Hydel	84,148	84,148	0	0
Total Production	649,013	697,443	688,934	737,207
Consumption	397,850	397,850	397,850	397,850
Unmet Electric Load	0	0	0	0
Excess Electricity	194,790	242,791	219,009	267,986

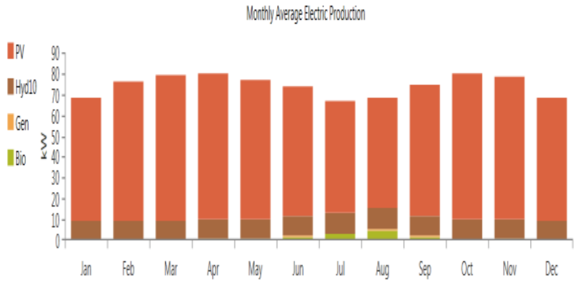

Fig. 17: Power Production Case 1

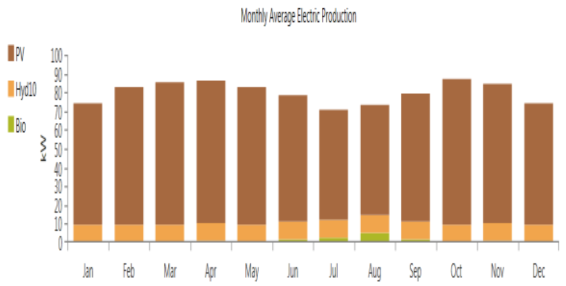

Fig. 18: Power Production Case 2

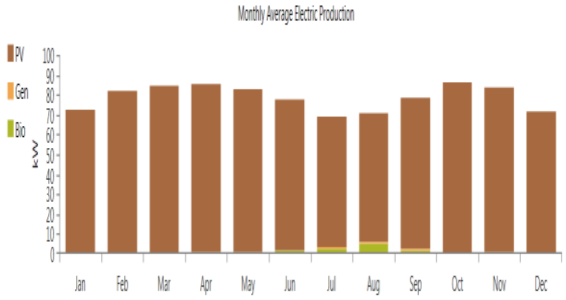

Fig. 19: Power Production Case 3

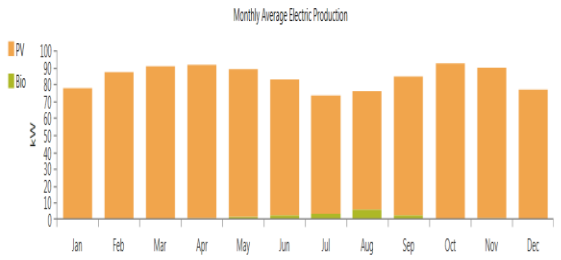

Fig. 20: Power Production Case 4

Table-10 shows that the total energy generated is sufficient to meet load demand of the proposed site. Unmet energy in all scenarios is nil and there is excess energy in each case, Figure 17 shows that power is generated by all renewable sources including a minor share of diesel generator, in figure 18 power is generated only by renewable sources. Figure 19 shows major power generated by PV among all the sources while excluding hydel energy. Figure 20 presents the power is generated by system excluding diesel generator and hydel system.

C. Sensitivity Analysis

Table 11 sensitivity analysis are presented while considering various factors like Nominal discount rate, diesel price and biogas fuel price which are having impact on NPC, COE and Operating cost. Due to variation in inflation in recent times there is direct impact on Nominal discount Rate which further hits various prices of fuels and other factors which may directly or indirectly effects the economic feasibility of the Hybrid system. Fig. 21 and 22 shows the variation of nominal discount rate with Gen Fuel price and Bio Fuel Price.

Table-11: Sensitivity Cases

Nominal discount Rate	Diesel Price (Rs.)	Biogas Fuel Price (Rs.)	Net Present Cost (Rs.)	Cost Of Energy (Rs.)	Operating cost (Rs.)
3	60	1300	108 M	15.56	2.37 M
6	60	1300	97.1M	19.09	2.62 M
3	65	1300	108M	15.56	2.36 M
6	65	1300	97.1M	19.10	2.62M
3	70	1300	108M	15.57	2.42M
6	70	1300	97.2M	19.11	2.62 M
3	60	1400	108M	15.56	2.36M
6	60	1400	97.1M	19.10	2.62M
3	65	1400	108M	15.58	2.42M
6	65	1400	97.2M	19.11	2.62M
3	70	1400	108M	15.58	2.42M
6	70	1400	97.2M	19.12	2.63M

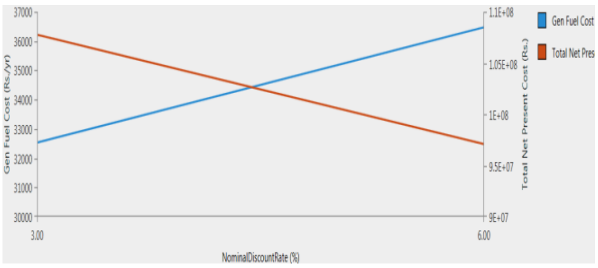

Fig. 21: Variation of Nominal Discount Rate with Gen. Fuel Cost and NPC

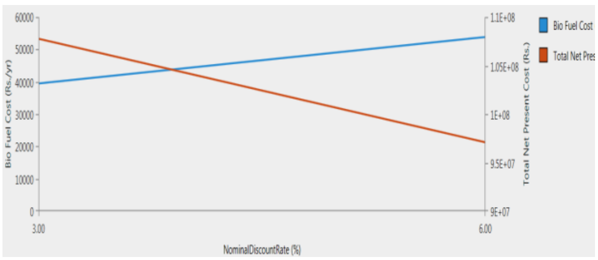

Fig. 22: Variation of Nominal Discount Rate with Bio Fuel Cost and NPC

SECTION V

CONCLUSION

This paper presents the optimization, economical viability and technical feasibility for standalone PV/Biomass/Hydel energy system. A comparative study for diesel- renewable mixed, only renewable based, diesel mixed with renewable options excluding microhydel from the system and only renewables by excluding both microhydel and DG from the system, is carried out. For optimization and least cost combination renewable energy alternatives are micro hydel, PV and biomass in the microgrid plan. For case study, HOMER software is used for Simulation, Optimization and Sensitivity Analysis.

Results show that diesel renewable microgrid plan has least net present cost, minimum levelized cost of energy and minimum annualised cost of system. This system can achieve the demand at a cost of Rs.15.56/kWh. Significant contribution of energy in the proposed plan is from the microhydel plant and biomass generation that proves a cheap and neat source of energy which further reduces the stubble burning in the area and promote others to follow the course. Presence of diesel generator helps the system in dealing with the problem arising due to variability of renewable sources. There is excess energy in the system which can be further used to meet the load demands of nearby villages and an electric welding workshop may be run in the village for the repair of agriculture tools. As there is variation in inflation rate, nominal discount rate, diesel price and biogas fuel price which are having impact on NPC, COE and operating cost. Cost effective option for hybrid applications must be appropriately supported by the Governments.

In future, off-grid PV-Biomass and Hydel hybrid energy system can be connected to grid system which not only improves reliability but also excess energy of the system can be sold out to the grid. Excess energy can also be utilized to run a small scale industry in the village or can supply to nearby village.

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