JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

FEASIBILITY ANALYSIS OF HYBRID POWER GENERATION FOR HOSTEL LOADS USING HOMER PRO

[1]P. Ganesan, Asso.Prof.
[2] S. Arockia Edwin Xavier, Asst.Prof.
[3] S. Suresh Kumar, Asst.Prof.

[1, 3] Department of EEE, Government College of Engg., Srirangam, Trichy, Tamilnadu, India.
[2] Department of Electrical Engg. Thiyagarajar College of Engg. Madurai, Tamilnadu, India.
[1]kponnarganesh@rediffmail.com [2]saexeee@tce.edu [3] sureshneyan@gmail.com

Abstract: Development of Energy infrastructure is vital for development of any nation. With abundant human waste resource and tropical climate, India has plenty of opportunities to tap energy from non fossil renewable energy sources. In this work, an academic institutions' hostel load is considered. In order to get self sustainable energy supply, the three hybrid distributed energy generation system components chosen for this work are Solar – Biomass – Battery, Solar – Biomass and Wind – Biomass which are site specific and viable. The objective of the present work is to find optimal hybrid energy system among these three by choosing corresponding input fuel quantities as sensitivity variables. The parameters taken for considerations from the optimal simulation results are Net Present Cost (NPC) and Cost of Energy (COE). Also, the present work focuses to find feasible economic solution by using Homer Pro Software by considering inflation rate and discount rate in India. Both of the cases are simulated and solar – biomass – battery system is found to be most economical for the given load.

Key words: Distributed Generation, Hybrid power generation, Solar – Biomass – Battery Hybrid system, Wind – biomass Hybrid system, Feasible Economic solution, Homer Pro software

1. Introduction

India as developing country needs to grow in the energy sector to be self sustaining. But still India has relied much more on fossil fuel to attain self satisfied in energy sector. It has enormous potential of Solar, wind and other renewable energy sources. Since world population of 7 billion produce 14 million tonnes of human waste every day and India has 14 percent of world population, it has some 6000 MW potential extracted from human waste alone to add [1]. Most of the educational institutions use grid power for their all needs in india. In order to harass the potential of human waste in institutions, we have taken three different configurations based on the availability of resources.

A technique to obtain the amount of electric energy that can be extracted from the human waste and various methods followed by the researchers for years to estimate this potential has been reviewed. [1]

The optimisation of Solar PV, wind and diesel generator hybrid energy system has been done using Homer Software and the cost of energy has been reduced much without grid supply by effective utilisation of storage systems in that work. In a work [3], hybrid energy system PV/biomass which supplied irrigation and residential needs in a village at Punjab province of Pakistan has been reported. Cost of energy has been reduced much from that of grid supply and it has been reported as much suitable in both investor's and customers' point of view.

In the work cited in [4], PV – Biomass and grid connection for different village loads near the grid and distant to the grid has been reported. In that work optimisation simulation has been done for different capital cost and also separate simulation has been done for breakeven distances from grid as sensitivity inputs. Also grid purchase and grid sale prices have been considered. Finally, it has been concluded that villages near grid can be supplied from grid and villages far away from the grid can be supplied from the hybrid energy systems economically.

The work cited in [5], a hybrid Solar – biomass energy system which supplies to the load of a textile mill has been considered. In that particular work, it has been dealt with three cases such as Grid – alone, Standalone Biomass – Solar Hybrid system and Both grid and Solar – Biomass system. Optimisation simulation has been done and it has been concluded that among all, the standalone Biomass – Solar hybrid system as most economical. Also calculation of carbon credit when using Biomass – Solar Hybrid system has been done and also it has been proved that the system considered as more eco friendly. In work cited in [6], it has been dealt with merits and limitations of Homer Energy software. In most of the literature cited [7 – 14], it has been dealt with economic, environment studies of various hybrid renewable energy systems with the help of homer and homer pro software.

Bhatt et. all [15] has been proposed 4 systems (Micro hydro/PV/Biomass/Diesel/Battery, PV/Diesel/Battery, Diesel/Battery & PV/Battery) among which they concluded that except PV/Battery system, all the other 3 systems have nearly same COE and PV/Diesel/Battery system has lowest NPC.

Anurag et all [16] have been performed techno – economic analysis for a rural load for which they designed and analysed nine different varieties of hybrid energy generation and found the most economic case.

Rahman et all [17] have been performed optimisation simulation for PV – Biomass hybrid energy system which supplies both electrical and thermal (cooking) loads in rural india. The authors have developed linear regression model for costs of solar, battery and biomass systems. The biomass (cattle dunk) parameters have been given by them on practical basis. They have been come to conclusion that the household which have both PV and cattle dunk can be catered with both thermal and electrical loads. Also, they concluded that household which doesn't have cattle dunk cannot cater thermal load. Also, they concluded that overloading of biomass generator increased COE.

In this present work, it is proposed to compare Solar – Biomass – Battery Hybrid system, Solar – Biomass Hybrid energy system and Biomass – Wind Hybrid system for the given Hostel Loads and discount and inflation rates are taken as sensitivity variables for the given configurations and results are discussed.

Homer is multi objective Optimisation tool [21]. Homer software calculates the Net Present Cost (NPC) and Cost of Energy (COE).[17]

$$NPC = \sum_{i=0}^{N}(C_{c,i} + C_{r,i} + C_{o,i} + C_{f,i} - S_{p,i}) \quad \text{...... (1)}$$

$$COE = \frac{Annual\ Electricity\ Production\ Cost}{Served\ Electricity\ Production} \quad \text{......... (2)}$$

where, $C_{c,i}$ – Total capital cost for ith year
$C_{r,i}$ – Total replacement cost for ith year
$C_{o,i}$ – Total O&M cost for ith year
$C_{f,i}$ – Total fuel cost for ith year
$S_{p,i}$ – Present Salvage for ith year

2. Solar – Biomass – Battery Hybrid system

2.1. Biomass resource

In present considered system, both boys and girls hostels are considered in current working institution. In both boys' and girls' hostels around 500 and 350 inmates are lived. Both the hostels are equipped with each two septic tanks of dimensions (9.5×3.5×3 m^3). The four septic tanks are cleaned every two months. So, It is calculated that the both the hostels provide 4293.33 Kg of human waste every day. The calculations are done as per the model calculation cited in [1]. Biomass Resource Availability in tonnes/day for every month is shown in the Fig. [1]. Homer scaled the baseline data to the scaled annual average value of 3.91tonnes/day. As the biogas produced from anaerobic digestion, have 65% to 70% of methane, LHV (Latent Heat of Vaporisation) of Biogas is taken as 38.77 MJ/kg. Also Gasification ratio and Carbon content are taken as 0.99 kg/kg and 5% respectively.

Fig [1] Biomass Resource

2.1.1. Setting up Biogas Generator

For the above biomass resource, the generic bio gas generator of own size is used. The search space variables are set as 50kW, 100 kW and 150 kW. The capital, replacement and O&M cost/hr are taken as Rs.5, 00,000, Rs.5, 00,000 and Rs.300 respectively. As fuel curve parameters, Intercept coefficient is given as 0.1 kg/hr/kW rated and slope as 2 kg/hr/kW output.

2.2. Solar Resource

Our institution situated at Melapachakkudi, Tiruchirappalli, Tamilnadu, India at latitude and longitude of 10°40.7'N and 78°36.0'E. The solar irradiation data for the given coordinates is taken from NREL database [22] in Homer Pro as shown in Fig.[2]. The Capital and replacement cost for the chosen Panels (SMA – 60 US) are $3000 each. Maintenance cost is zero. Solar panels are installed in order to supply DC bus and by means of converters to supply the load. In order to reduce cost, the panel are chosen as fixed type i.e. no tracking system is chosen.

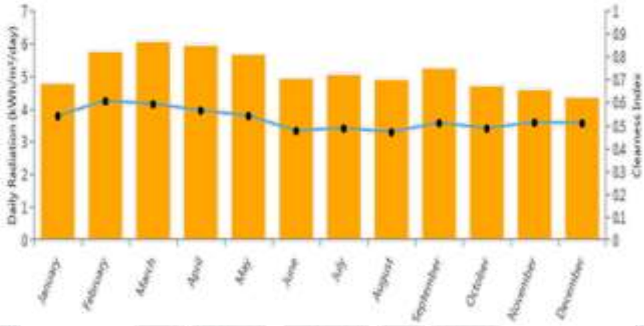

Fig.[2]. Solar Horizontal Irradiance (KWh/m^2/day) per month

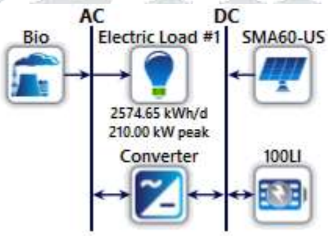

Fig. [3] System Architecture of Solar – Biomass – Battery Hybrid System

Solar Scaled Average (kWh/m²/day)	Biomass Scaled Average (tonne/day)
5.14	4.33
3.4	3.4

Fig. [4] Sensitivity Variables applied for solar – biomass – battery hybrid system

2.3. Battery

100 kWh Li – Ion battery was used in this simulation with 600V and 10 strings. Capital, replacement and Maintenance cost are given as $600, $600 and $10 respectively. Initial SOC and minimum SOC are given as 80% and 20% respectively.

2.4. Converter

A 236 kW converter was used to supply from DC bus to AC bus. The capital and replacement cost were given as Rs.60, 000 each and Operation & maintenance cost was given as Rs.6000. This converter configuration is used for all three cases.

3. Wind – Biomass Hybrid system

As the second alternative in this work, wind – biomass – battery hybrid system is taken. The architecture of the system taken is given in Fig.[6].

3.1. Wind Resource and G10 Wind Turbine

The average wind speed data was downloaded for the site from NREL website [22] for the given coordinates which is shown in Fig.[5]. Generic 10 kW Wind Turbine was taken and connected to AC bus of the system. Wake up losses, Turbine Performance losses and Electrical losses are taken as 2%. The search space variables are taken as various quantities varied from 1 to 5. The Homer Pro software searches for the optimum wind turbine quantity for the site given.

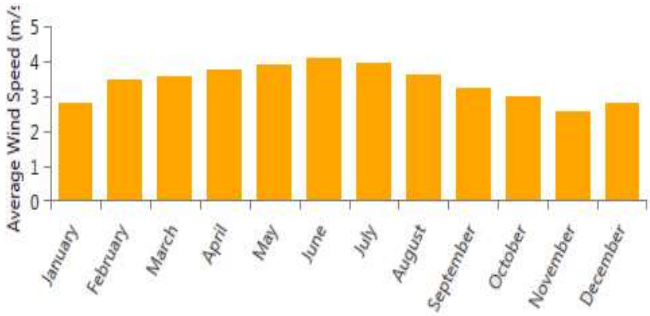

Fig. [5] Wind resource data

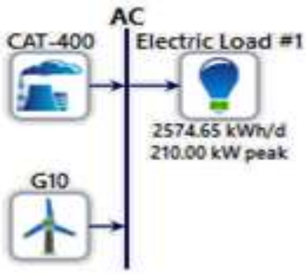

Fig. [6] System Architecture of Wind – Biomass – Battery Hybrid System

NominalDiscou (%)	ExpectedInflatic (%)
8.5	4.96
6	5.8
5	9.5

Fig.[7] Sensitivity variables applied for both systems

3.2 Biogas Generator:

Biomass resource taken in this case is same as that of the first case. Biogas generator taken here is Caterpiller 400kVA Generator which runs under both diesel and biogas. The diesel price assumed here is $1/litre.

4. Solar – Biomass Hybrid Energy System

The configuration taken in this case is same as that of Solar – Biomass – Battery Hybrid Energy system as described in Sections 2.1 & 2.2.

5. Load Profile

Average Load of both Boys' Hostel and Girls' Hostel of our institution in presented in the Table 1. But since the load profile in hostels has drastic variation throughout the year, it was proposed to study the entire load profile of the hostel by reading KW and KWh both weekdays and weekends. The data obtained from real situation is given as input to the Homer Pro Software. The data presentation given in Fig.[8].

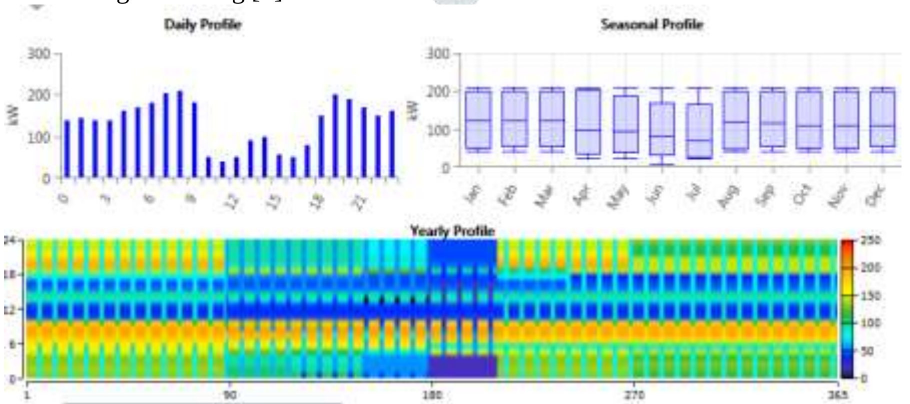

Fig. [8] Yearly Load Profile of Both Hostels

6. Results and Discussions

In order to get feasible economical NPC and COE of both the system, [20] gives that the most economic point can be the point of intersection of NPC and COE curve against the annual interest rate for the given inflation rate. The inflation rate and discount rate variations are taken as sensitivity variables as shown in Fig.[7] are taken from Reserve Bank of India [15] & [16].

6.1. Solar Biomass Battery Hybrid system

Two separate sensitivity analysis were done for the solar – Biomass – Battery hybrid energy system. The analysis is done using Solar Scaled Average (kWh/m^2/day) and Biomass scaled Average (Tonnes/day). The sensitivity input are shown in Fig.[4] and their corresponding outputs are shown in Fig.[9]. From the output, it is clear that the solar scaled average of 5.14 kWh/m^2/day and Biomass scaled average 3.14 tonnes/day yields lowest NPC of all. But the contribution of biomass in this case is some 1% and most of the loads are driven by Solar – Battery system.

Table [1] Average Load in Both Hostels in KWh/Day

Sl.No.	Name of the Load	Quantity	Power	Time	Wh
1	Light	360	40	10	144000
2	Fan	380	150	12	684000
3	Lights on Mess	27	40	7	7560
4	Fans on Mess	18	150	7	18900
5	Lights on Common Usage	150	40	8	48000
6	Fans on Common Usage	20	150	8	24000
7	CFLs on Common Usage	16	11	4	704
8	Exhaust fans	15	250	4	15000
9	RO pumps	1	370	14	5180
10	RO process Pumps	1	1100	14	15400
11	Grinder 10 Litres	1	1500	4	6000
12	Grinder 5 Litres	1	746	2	1492
13	Grinder 20 Litres	1	1500	4	6000
14	Wheat Flour Mixer	1	746	2	1492
15	Grinder 10 Kg	1	1500	3	4500
16	Mixie	1	746	2	1492
17	Freezer	1	164	24	3936
18	Veg Cutter	1	746	2	1492
19	Pulwariser Grinder	1	1500	3	4500
20	Grinder 30l	1	3730	4	14920
21	Water Pump	2	3730	6	44760
22	Street Lights	5	250	10	12500
				Total Wh	1065828
				in KWh/D	1065.828
	Including Ladies Hostel (KWh/D)				2131.656

NPC in this case Rs. 9,87, 635 and Where as if we take the case of 3.14 kWh/m^2/day and 3.4 tonnes/day, the contribution of biomass is somewhat increased to 5% and 45% and other 50% is supplied by battery and solar respectively. But the number of batteries used is 548, the autonomy hours of 25Hrs/year and Annual throughput of 5,78,608 kWh. The initial cost goes to Rs.1.1 crores, in which some Rs. 5 lakhs contributed to biomass and Rs.50 lakhs contributed to solar.

The result of above simulation result (shown in Fig.[10])is fed in to the system and that system is again simulated to the sensitivity inputs of Nominal Interest rate and Expected Inflation rate for Solar – Biomass – battery system. NPC of Rs.9, 50,000 at Nominal Interest rate of 7.5% and levelised cost of energy levelised at Rs. 0.06 are found as feasible economic solution.

6.2. Wind – Biomass Hybrid energy system

The sensitivity analysis done for Wind – Biomass system and the result is presented in Fig.[11], NPC of Rs.5 crore at nominal interest rate of 7.5% and levelised cost of energy at Rs.25.36 at expected inflation rate of is found as feasible economic solution.

6.3. Solar – Biomass Hybrid energy system

The sensitivity analysis done for Solar – Biomass system and the result is presented in Fig.[9]. The optimum sensitivity variables are Solar average of 3.4 kWh/m2/day and biomass average of 3.4 tonnes/day which can be verified from Fig.[9].

The another sensitivity analysis using inflation and discount rates done for Solar – Biomass system and the result is presented in Fig.[14]. NPC of Rs. 11,61,81,50,000 at Nominal Interest rate of 7.5% and levelised cost of energy levelised at Rs. 694.7 are found as feasible economic solution.

Table [2] Comparison of Performance parameters

Parameters	Grid and DG	Solar-Biogas		Wind-Biogas		Solar-Bio-Battery		
		Solar	Bio	Wind	Bio	Solar	Bio	Battery
kWhr/yr	99,99,999	77,48,868	5,72,501	3752	10,16,132	54,91,854	175	5,47,560
kW	250	7725	200	20	210	5475	50	3400 kWh
NPC (Rs.)	13,50,00,00,000	11,61,81,50,000		66,27,35,900		11,63,662		
LCOE (Rs.)	0.099	739.79		28.35		0.07411		

Fig.[9] Solar – Biomass Sensitivity Output

Fig.[10] Solar – Biomass – Battery Sensitivity Output

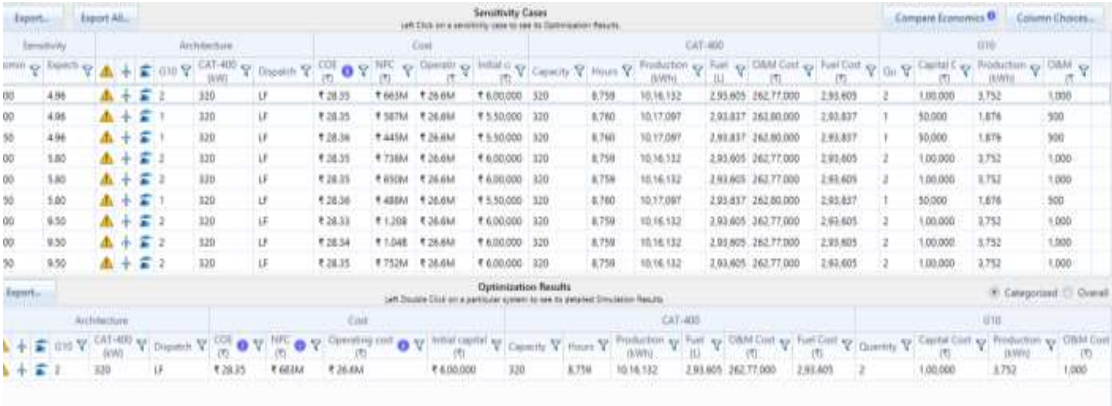

Fig.[11] Wind – Biomass Sensitivity Output

It is concluded that the Cost of Energy is less in case of Solar – Biomass system compared to Wind – Biomass system. For both of systems, Net Present Cost and Cost of Energy are presented in the Table [2]. NPC and COE are less in case of Solar – Biomass – Battery system. In case, if the battery is removed, the kWh supply is increased by solar and biomass by 2.2% and 6.5% respectively. Also the rated capacity is increased by 2250kW and 150kW for both solar and biomass respectively with no change in capacity factor (as shown in Fig.[15]) which shows battery system does major impact on NPC and COE. Also when comparing to the grid and DG system, NPC and COE are less for Solar – bio – battery system as seen in Table [2]. Further reduction in COE can be accomplished by using part of biogas produced for cooking purposes (i.e. inclusion of thermal load).

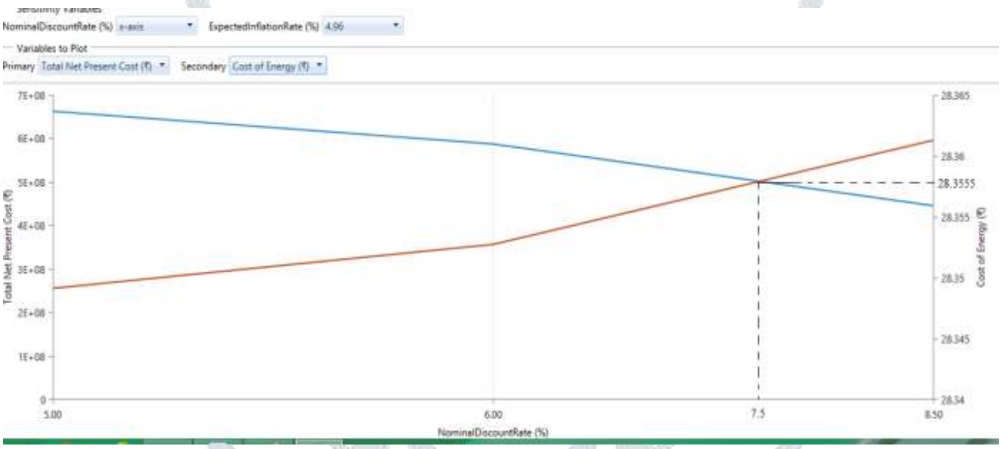

Fig [12] Plot of NPC & COE Vs Nominal Discount Rate for Wind – Biomass Hybrid system

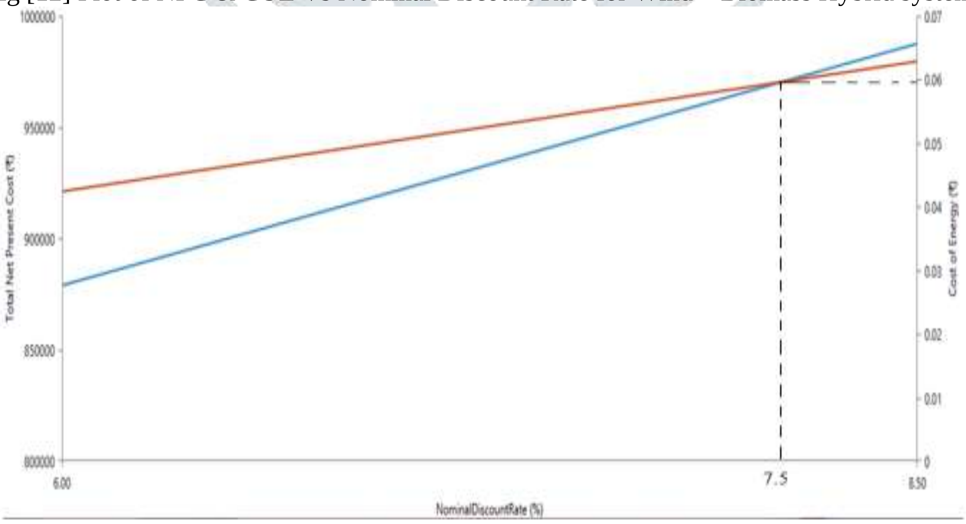

Fig [13] Plot of NPC & COE vs. Nominal Discount Rate for Solar – Biomass – Battery Hybrid System

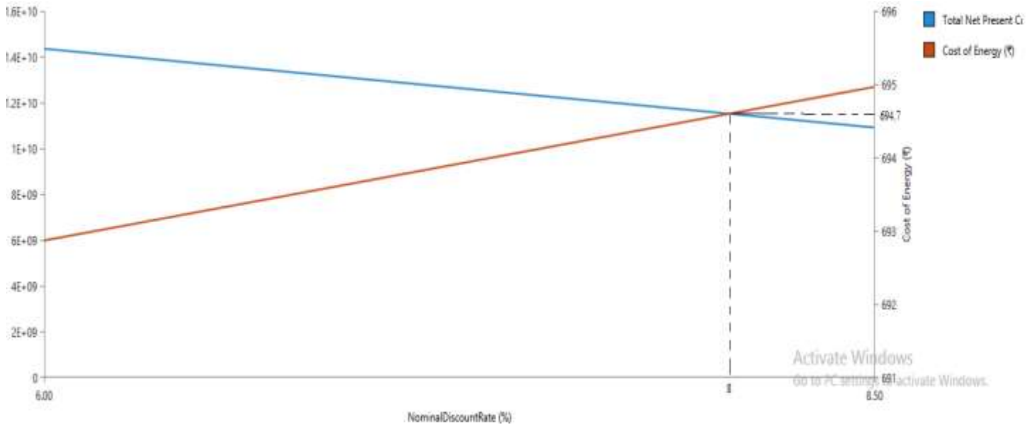

Fig [14] Plot of NPC & COE vs. Nominal Discount Rate for Solar – Biomass Hybrid System

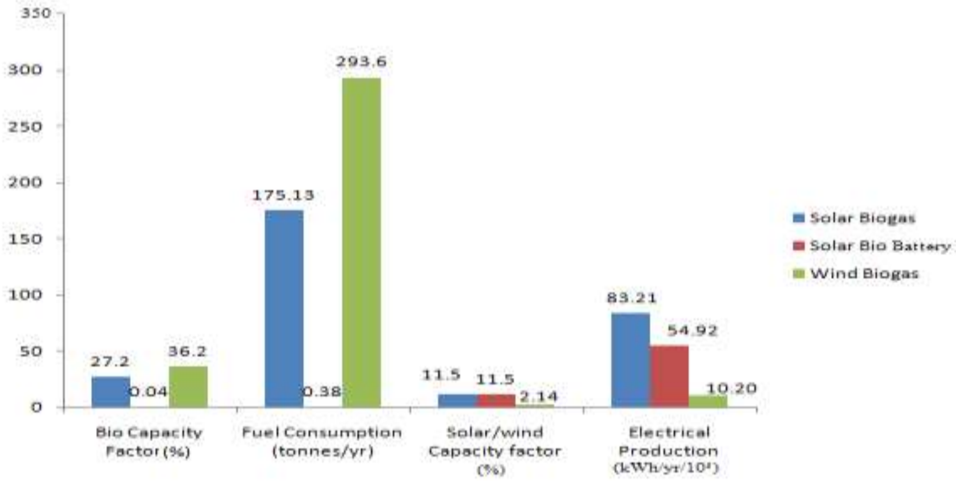

Fig.[15] Bar chart comparison of physical parameters of three cases

7. Conclusions

This paper studies the possibility of three different hybrid energy systems using renewable energy for successfully replacing the grid and diesel generators used in academic institutions' hostels. All the three configurations met the load completely, among them Solar - Biomass - Battery system is found to be more economical. This system consists of Biomass Generator of 50 kW, Solar PV as 5475 kW and Battery of 34 numbers of 100 kWh with 25.4 hours of autonomy.

REFERENCES

[1] Onojo.O.J., Chukwudebe.G.A., Okafor.E.N.C., Ononiwu.G.C., Chukwuchekwa.N, Opara.R.O., Dike.D.O.: 'Estimation of The Electric Power Potential Of Human Waste Using Students Hostel Soak – Away Pits.', American Journal of Engg. Research, Vol.02, Issue – 09, pp – 198 – 203, 2013.

[2] Swarnkar, N. M., Gidwani, L., & Sharma, R.: 'An application of HOMER Pro in optimization of hybrid energy system for electrification of technical institute', Proceedings of International Conference on Energy Efficient Technologies for Sustainability (ICEETS), 2016, Pg. No: 56 – 61. doi:10.1109/iceets.2016.7582899.

[3] M. Kashif Shahzad, Adeem Zahid, Tanzeel ur Rashid, Mirza Abdullah Rehan, Muzaffar Ali, Mueen Ahmad.: 'Techno-economic feasibility analysis of a solar-biomass off grid system for the electrification of remote rural areas in Pakistan using HOMER software', Renewable Energy, 106, 2017, pg.no. 264 – 273. DOI: 10.1016/j.renene.2017.01.033.

[4] Rumi Rajbongshi, Devashree Borgohain, Sadhan Mahapatra.: 'Optimization of PV-biomass-diesel and grid base hybrid energy systems for rural electrification by using HOMER', Energy Rev. 126, 2017. Pg. 461 – 474, http://dx.doi.org/10.1016/j.energy.2017.03.056.

[5] Mahadevan Mahalakshmi, Salai Latha.: 'An economic and environmental analysis of biomass-solar hybrid system for the textile industry in India", Turkish Journal of Electrical Engg. & Comp Sciences, 23, Pg. No. 1735 – 1747, 2015. doi: 10.3906/elk-1404-228.

[6] Kenneth E. Okedu, Roland Uhunmwangho.: 'Optimization of Renewable Energy Efficiency using HOMER', International Journal of Renewable Energy Research, Vol. 4, No. 2, 2014.

[7] W. O. Amor, H. B. Amar, M. Ghariani.: 'Energetic and Cost Analysis of Two Conversion Systems Connected To The Grid By Using Homer Pro', International Journal of Renewable Energy Research, Vol.5, No.3, 2015.

[8] P. Nema, S. Dutta.: 'Feasibility Study of 1 MW Standalone Hybrid Energy System: For Technical Institutes', Journal of Scientific Research, Low Carbon Economy, 2012, Pg. 63 – 68. doi:10.4236/lce.2012.33009.

[9] Prateek Malhotra & Tarun Naruka.: 'Checking the Feasibility of Hybrid Solar PV-Biomass Power Plant in Rajasthan', International Journal of Electrical and Electronics Engineering Research, Vol. 7, Issue 4, Aug 2017, Pg. 37-48.

[10] O.J.Onojo, G.A. Chukwudebe, E.N.C. Okafor, S.O.E. Ogbogu.: 'Feasibility investigation of a Hybrid Renewable Energy System as a backup Power Supply for an ICT building in Nigeria', Journal of Natural and applied Sciences, Vol. 4 No. 3, May 2013, Pg.149 – 169.

[11] Farid Barrozo Budes,Yulineth Cardenas Escorcia, Guillermo Valencia Ochoa.: 'Optimization of a Biomass, solar and fuel cell Hybrid energy systems for a specific energy load using Homer Pro software', International Journal of Chem. Tech Research, 2018, Vol.11 No.01, pp 335-340.

[12] Harish Kumar R. N.: 'Feasibility Study of Photovoltaic (PV) Modules, and Biomass Generator to Supply Electricity to Auckland City, North Island Context-New Zealand', Journal of Clean Energy Technologies, Vol. 2, No. 4, October 2014.

[13] Mishra.S, Panigrahi.C.K., Kothari.D.P.: 'Design and simulation of a solar–wind–biogas hybrid system architecture using HOMER in India', International Journal of Ambient Energy Volume 37, 2016, Issue 2.

[14] S. R. Pradhan, S. P. Sahoo, R. Das, P. Sen.: 'Design of Off-Grid Home with SOLAR-WIND-BIOMASS Energy', International Journal of Engineering Research and Applications, Vol. 4, Issue 1(Version 2), January 2014, pp.76-81.

[15] Bhatt.A, Sharma.M.P., Saini.R.P.: 'Feasibility and sensitivity analysis of an off – grid micro hydro – photovoltaic – biomass and biogas – diesel – battery hybrid energy system for a remote area in Uttarakhant state, India', Renew. Sustain. Energy Rev., 2016, 61, pp. 53 – 69. Doi: 10.1016/j.rser2016.03.030.

[16] Anurag Chauhan, Saini.R.P.: 'Techno-economic feasibility study on Integrated Renewable Energy System for an isolated community of India', Renew. Sustain. Energy Rev., 2016, 59, pp. 388 – 404. Doi: http://dx.doi.org/10.1016/j.rser.2015.12.290.

[17] M. M. Rahman, M. M. Hasan, J.V. Paatero, R. Lahdelma: 'Hybrid application of biogas and solar resources to fulfill household energy needs: A potentially viable option in rural areas of developing countries' Ren. Energy Rev., 2014, 68, pp. 35 – 45.

[18] Reserve Bank of India Interest rate Data https://m.rbi.org.in/Scripts/PublicationsView.aspx?id=18577

[19] Reserve Bank of India Expected Inflation rate data of CPI https://rbi.org.in/Scripts/PublicationsView.aspx?id=18711

[20] Ali Saleh Aziz, Mohammad Faridun Naim bin Tajuddin, Mohd. Rafi bin Adzman.: 'Feasibility Analysis of PV/Wind/Battery Hybrid Power Generation: A Case Study', International Journal of Renewable Energy Research, Vol.8, No.2, June, 2018, Pg. No. 661 – 671.

[21] Homer Energy official reference: https://www.homerenergy.com/products/pro/docs/3.11/index.html

[22] NREL Solar & Wind Database for India:
https://maps.nrel.gov/gst-india/?aL=Jz0zCj%255Bv%255D%3Dt%26nbUQqn%255Bv%255D%3Dt%26nbUQqn%255Bd%255D%3D1&bL=clight&cE=0&lR=0&mC=11.049038346537106%2C78.68408203124999&tour=splash&zL=8