Design and Optimization of a Biogas-Solar-Wind Hybrid System for Decentralized Energy Generation for Rural India

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ABSTRACT - *Energy access is not only essential at the household level, but is also very critical to the provision of basic infrastructure such as hospitals, schools, industry and others. For a country like India, developmental goals and energy access are very closely linked but still many parts of rural India use traditional sources of energy and don't have proper access to modern energy sources such as electricity. As per 2011 census report, more than 68 % people in India live in rural area. As per 68th round of National Sample Survey (NSSO, 2011-12), more than 96.68 % villages were found to have access to electricity, but the total number of households having access to proper electricity was much less. The survey suggested that a large number of people depended on biomass for their cooking and lighting requirements (27% for lighting purpose while more than 77% use biomass for cooking purpose) in rural India.*

India is rich in availability of solar and wind energy and also it holds world's largest cattle inventory, which make good potential for renewable energy generation. Hence the solar-wind-biogas hybrid energy system can be a very effective solution for the problem of rural energy access. Animal shelters can be used for generation of biogas and can be combined with other renewable resources such as solar and wind to form a hybrid renewable energy system. Such decentralized systems in remote locations can fulfil energy needs of the local community while the excess energy generated can be supplied to the grid wherever possible. In this project a medium sized animal shelter of 500 cattle heads located at Uran, Maharashtra has been selected to design a Biogas-Solar-Wind hybrid renewable energy system. This system will be able to supply electricity to small community of 300 houses. HOMER software has been used to optimize the Biogas-Solar-Wind hybrid system for least net present cost. A vermicomposting unit running on slurry of biogas digester is also included in the system to enhance financial viability of the project. Financial analysis is done for the complete project which considers capital cost and operational cost as well as the revenue generated from selling electricity, vermicompost and carbon credits. Based on the financial analysis the discounted payback period and internal rate of return for the project have been calculated.

1 INTRODUCTION

Many parts of rural India use traditional sources of energy and don't have proper access to modern energy sources such as electricity. As per 2011 census report more than 68 % people in India live in rural areas [1]. A decentralized renewable energy system can be helpful to provide the deficit of electricity between energy demand and energy generation but single renewable systems are not always completely reliable. Hence the hybrid renewable energy systems can be a very effective solution for the problem of rural energy excess. Animal shelters can be used for generation of biogas electricity and can be combined with other renewable resources such as solar and wind to form a Biogas-solar-wind hybrid renewable energy system. Such decentralized systems in remote locations can provide electricity to the surrounding areas while excess energy can be supplied to the grid wherever possible. This paper deals with how renewable energy resources in rural India can be utilized by integrated or hybrid renewable energy systems (HRES), especially Biogas-solar-wind hybrid systems. To fulfil the energy demand of the nation and to meet the commitments done by country as per Paris climate change agreement 2016 at UN to produce at least 40% of country's electricity by non-fossil resources by 2030[2], Hybrid Biogas-Solar-Wind energy systems can play an important role in coming decades for India's energy portfolio

2 RURAL ELECTRIFICATION IN INDIA

While large-scale reforms have repeatedly been attempted in the past, India's achievement in the field of rural access to electricity leaves much to be desired. According to IEA India was home to 35% of the global population without access to electricity in 2002 [2] After many successful government programs such as Pradhan Mantri Gramodaya Yojna (PMGY), Kutir Jyoti Program (KJP), Rural Electricity Supply Technology Mission (REST) and Rajiv Gandhi Grameen Vidyutikaran Yojna(RGGVY) in India many villages were electrified. Over 95% villages have reportedly become electrified today but number of households electrified is comparatively much less.

3. HYBRID RENEWABLE ENERGY SYSTEM

A hybrid energy system consists of two or more energy sources used together to provide increased system efficiency as well as greater balance in energy supply. When a hybrid system consist all renewable sources of energy generation the system is known as hybrid renewable energy generation system. A single renewable energy source such as wind or PV is not 100 % reliable due to uncertainty in its power output. In comparison combination of two or more energy sources are more reliable and have uninterrupted power supply.

3.1 Suitability of Solar-Biogas HRES for India

Suitability of a HRES for a particular region depends on the geographical pattern and location of that region. The suitability of different systems on basis of the geographical features is mentioned in Table-1 below. India being a geographically diverse nation has regions suitable for almost all type of hybrid combinations.

Table-1: Suitability of Different Hybrid Systems on Basis of Geographical Terrain
(Source - Hybrid Renewable Energy Systems & their Suitability in Rural Regions [3])

Geographical Feature	Type of HRES Applicable	Recommendation
High Altitude	Biomass-wind-fuel cell, PV-wind, PV-biomass	PV-biomass
Mountain	Biomass-wind-fuel cell, PV-wind, PV-biomass	PV-biomass
Plain	PV-biomass, hydro-wind, biomass-wind, PV-wind,	biomass-wind
Semi Desert	Wind-fuel cell, wind-PV, , PV-biomass, PV-wind-biomass	PV-wind-biomass
Desert	Wind-fuel cell, wind-PV, PV-biomass, PV-wind-biomass	PV-wind-biomass

4 MODELLING FOR HYBRID RENEWABLE ENERGY SYSTEM

Hybrid renewable energy systems comprises different renewable energy systems within it. Since the design and operation of such systems is very complicated for many reasons, it is important to provide tools that help to select the best energy sources mix system and configuration. The design of multi-energy systems includes resolving the problems such as the efficiency of the different systems, the correct sizing, cost and availability of different energy at different time [4]. This is known as Modelling for hybrid renewable energy system.

4.1 Mathematical Modelling of Wind-Solar-Biogas Hybrid System

A hybrid energy system can consist of different renewable energy conversion component in this case which are Wind turbine, PV array, and Biogas plant along with storage device like battery. The system also includes PCU along with MPPT Charge controllers. In order to properly select the subsystems and components for optimal sizing of the complete system the modelling of individual components is essential.

$$P_{Total} = P_{Biogas} + P_{Wind} + P_{Solar} \quad (1)$$

Where, $P_{Total}, P_{Biogas}, P_{Wind}$ & P_{Solar} are Total power generated, Power generated by Biogas energy, Power generated by Wind energy and Power generated by Solar energy respectively.

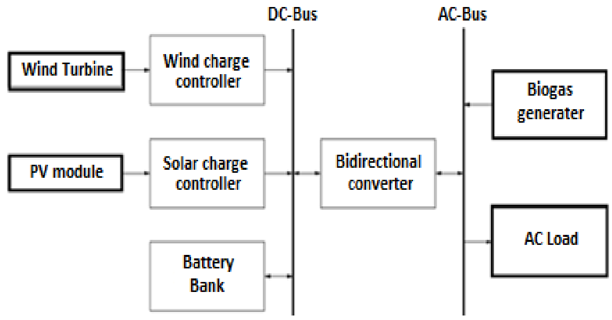

Figure-1: Circuit Diagram of Solar-Wind-Biogas Hybrid System

A) Biogas Energy Modelling

1) Power obtained from Biogas

$$P_{Biogas} = \eta_{gen} * B_o \quad (2)$$
$$B_o = D * Y \quad (3)$$

Where - η_{gen}, D, Y and B_o are Efficiency of generator, Total fresh Dung collected per day(kg), Biogas yield per Kg of fresh dung & Biogas produced per day respectively. Y can be taken as taken as 40 lit/kg or 0.04 m^3 Biogas generation from 1 kilogram of fresh dung [5]

$$D = N * F * d \quad (4)$$

Where, N, d and F are Number of Cattles, Fresh dung produced per cattle in a day (kg) and Fraction of dung collected respectively. Dung produced in a day per cattle (d) is usually around 10 kg for Indian cattle, while the fraction of dung collected is taken 0.7 if the cattle are allowed for grazing outside (30% is lost due to grazing). If cattle are not allowed outside and complete dung is collected 'F' is taken as 1.

2) Volume of Digester

$$V_D = (V_S/0.90) \quad (5)$$
$$V_S = V_1 * T_R \quad (6)$$

Where V_D, V_S, V_1 and T_R are Volume of digester, Total volume of slurry in digester, volume of slurry feed daily and Retention time for slurry respectively. Slurry occupies only 90% volume of digester.

Table-2: Retention Time for Different Raw Material
(Source: B H Khan [6])

SN	Raw material	Retention time
1	Cow dung	50
2	Poultry dropping	20
3	Rice straw	33
4	Sugar cane tops	43

$$T_R = m_s * \varrho \quad (7)$$
$$m_s = m_D * 2 \quad (8)$$

Where m_s, ϱ and m_D are Mass of slurry feed/day, Density of slurry and mass of cow dung input /day respectively.

B) Wind Energy

$$P_o = 1/2(\varrho * A * V^3) \quad (9)$$
$$P_T = Cp * P_o \quad (10)$$

Where P_o, ϱ, A, V, P_T and Cp are power available in wind, Density of air, Area swept by blades, Average velocity of wind, power extracted by turbine and betz coefficient respectively.

$$P_G = \eta_{gen} * P_T \quad (11)$$

Where P_G and η_{gen} are power generated by generator and efficiency of generator respectively. Power generated by wind turbine can also be calculated by using power curve of wind turbine and Average wind speed at the particular site.

C) Solar Energy

$$P_{Solar} = A * N_p * \eta_{panel} * \text{Daily peak hours} \quad (12)$$

Where P_{Solar}, A, η_{panel} and N_p are Power generated by solar energy, Area of solar panel, Efficiency of Solar panel and Number of PV panels. Commercial panels have an efficiency of around 15%.Power generated by Solar system can also be found by below equation.

$$P_{Solar} = R_p * N_p * \text{Daily peak hours} \quad (13)$$

Where R_p is Rated power output of panel selected. Daily peak hour is the power generated in a day by PV panels it depends on solar energy available at particular site. Throughout the India peak hours varies between 4-7 kWh [7].

4.2 MPPT Tracking

When it comes to power control, wind and solar show a special feature; unlike other power systems power generation here cannot be controlled by controlling amount of energy applied to the generator or the fuel inflow rate, thus solar and wind demand for a special control system. The voltage-current relation and voltage power relation are non-linear MPP (Maximum power point) should be tracked for efficient extraction of solar energy in the PV system and wind energy in wind turbines. Since the variable for MPPT (maximum power point tracking) of wind and PV system is different, individual tracking system should be implemented for each system. Maximum power point tracking (MPPT) not only maximizes the system's efficiency but it also helps to minimize the return period of the installation cost [8].

4.3 Technics for Optimization

Optimization techniques are to determine the appropriate sizing of technologies as well as other auxiliary components that balance local demands and meet physical constraints. Simulation-based optimization is a widely utilized approach for performing economic evaluations and designing small-scale energy systems. Some common optimization tools are HOMER, HOGA and Hybrid2 [6].HOMER is most widely used Software for hybrid system. In a review by Sunanda Sinha and S.S. Chandeln [9] they compared 20 software tools for hybrid renewable energy systems on basis of various parameters such as economic analysis technical analysis availability of different renewable resources and thermal system inclusion which HOMER was found with most features of all. José L. Bernal-Agustìn and Rodolfo Dufo-lópez [10] in simulation and optimization of hybrid energy systems compared 12 different software's out of which HOMER had most features. Hence HOMER is selected for optimization of HRES.

4.4 HOMER Energy

Hybrid Optimization Model for Electric Renewables often known as HOMER in short and is designed by National Renewable Energy Laboratory (NREL). The HOMER tool performs three principal tasks of simulation, optimization and sensitivity analysis. After simulating all of the possible system configurations, HOMER displays a list of configurations, sorted by net present cost (sometimes called lifecycle cost), that you can use to compare system design options. The optimization process determines the best possible system configuration based on the lowest total Net Present Cost.

5 ANIMAL SHELTERS – GOOD PROSPECT FOR SOLAR-BIOGAS-WIND HRES

As per Foreign Agricultural Service of USDA India has world's largest cattle inventory. There are a huge number of animal shelters in India which look after the retired and unusable cow progeny. The information on www.cowbank.in suggests that in India more than 1500 such animal shelters exist apart from the dairies. Animal shelters has good potential to generate biogas from cow dung and the rooftop of cattle shed can be utilized for PV panel installation. Free space available within the premises can be used to install wind turbines. All the three energy system can be combined to form Solar-Biogas-Wind hybrid system to increase its reliability. Thus such animal shelters are great prospects to install Biogas–Solar-Wind HRES

6 ESTIMATION OF ENERGY POTENTIAL FOR A MEDIUM SIZED ANIMAL SHELTER WITH 500 CATTLE HEAD

From the studies conducted and data collected at various animal shelters an estimation of energy generation potential of an animal shelter can be done. Considering a medium sized animal shelter with 500 cattle head at Uran located at latitude and longitude 18.88°N and 72.94°E respectively. Uran is part of Navi Mumbai city of Maharashtra state in Konkan division. Uran is selected since it is surrounded by sea on three sides and has good potential of wind energy.

6.1 Potential of Solar Energy

Based on the data collected from 6 animal shelters near Bhiwandi city average roof top area available per cattle head is calculated in table below.

Table-3: Average Area per Cattle Head at Different Sites

SN	Place	Cattle Heads	Area (ft^2)	Area / Cattle Head (ft^2)
1	Aangaon	1600	56255	35.1
2	Valshind	400	22221.4	55.55
3	Bhiwandi	60	2800(40*70)	46.66
4	Deodal	53	2250(50*45)	47.2
5	Bhiwandi	24	1200(40*30)	50
6	Bhiwandi	17	800(40*20)	47.06
Average area per cattle head				**46.93**

Total rooftop area can be calculated by product of Number of cattle and Average area per cattle head. Total shelter roof top area available at animal shelter is 2183 m^2. A 300Watt panel JJ-M672 by Jain Photovoltaics of Dimensions 1960mm * 996 mm i.e. 1.952 m^2 is considered for calculation of solar energy potential.

A) Array Spacing

All the panels are considered facing south direction for maximum solar radiation. For fixed tilt angle throughout the year, the angle of the latitude is preferred [11] which in this case is 18.87. The tilted panel will cast shadow which can affect the panel behind it and it is important to calculate the maximum shadow length within solar window .Maximum shadow caused by panel within the solar window is calculated 1.68 m with the help of equation below

$$\sin \alpha = \cos \emptyset = (\sin L * \sin \delta) + (\cos L * \cos \delta * \cosh)$$

Where α, Ø, L, δ and h are incidence angle, zenith angle, Latitude, angle of declination and hour angle respectively. Area occupied by one row of panel equal to the Maximum shadow length, while width of a Single panel is 1.96m

Number of panels rows on shed (N_R) = $\frac{Lenght of shed}{Area occupied by one row of panel}$ (15)

Number of panels in one row (N_P) = $\frac{width of shed}{Single panel width}$ (16)

Total number of panels = $N_R * N_P$ (17)

Total 638 panels (29 * 22) of 300W each can be placed on available roof area which will generate power of 191.4kW_p. In a solar PV system it is important to consider system. Controller, Converter and Battery are the major components of the Solar PV system. Taking converter & controller efficiency 98% and battery efficiency 85% we get Overall Efficiency as 81.63%.Power available after considering system losses the available power from panels will be 156.24 Kilowatt

6.2 Potential of Bio-Electricity

Considering dung produced rate for each cattle be 10 kilogram per day the total dung produced by 500 cattle will be 5000 kg/day. The average gas production from 1 kilogram of fresh dung is taken as 0.04 m^3 of Biogas generation [12]. Total 200 m^3 of biogas can be produced daily. Calorific value of 1 m^3 biogas may vary around 21 to 23 Mj based on composition of gas. For further calculation Calorific value of 1 m^3 of biogas is taken as 22 MJ. Energy of one mega joule is equal to 0.278 kWh so 200 m^3 of gas is equal to 1223.2 kWh. But conversion of biogas to electricity is not is not 100% efficient. As per a report 'Efficiency in electricity generation' by Eurelectric in 2003 the efficiency of electricity generation from biogas is between 30-40 % [13]. Considering the conversion efficiency of biogas to electricity as 35% [14].Energy available for use is found to be 428.12 kWh per day.

6.3 Wind Energy Potential

Total Wind Potential is calculated from the monthly average wind speed taken from HOMER (NASA Surface Meteorology) and power curve of 1Kw wind turbine by Bharat Diesel engineers (Mumbai) Daily. Monthly output by a single wind turbine is calculated in table below.

Table-4: Monthly Power Output by Single Wind Turbine

SN	Month	Average Wind Speed(m/s)	Power Output (KW)	Daily Output (KW)	Monthly Output (KW)
1	January	3.970	0.064	1.536	46.08
2	February	5.300	0.23	5.52	165.6
3	March	6.190	0.357	8.568	257.04
4	April	6.630	0.489	11.73	351.9
5	May	6.570	0.471	11.304	339.12
6	June	6.910	0.57	13.68	410
7	July	8.260	0.8624	20.64	619.2
8	August	7.520	0.704	16.896	506.88
9	September	5.040	0.2	4.8	144
10	October	3.990	0.063	1.51	45.3
11	November	4.000	0.064	1.53	45.9
12	December	3.690	0.044	1.056	31.6

Table above shows that maximum power generation takes place during monsoon in Uran. Total Potential of wind energy can be calculated by multiplying the power output by single turbine by number of wind turbine (N) installed

7 OPTIMIZATION OF HYBRID POWER GENERATION SYSTEM BY HOMER FOR A COMMUNITY SIZE OF 1500 PEOPLE

To designing and optimize a Solar-Wind-Biogas hybrid system for a community of 1500 people in area which does not has access to electricity daily load consumption is assumed that each home has 1 fans, 2 CFL bulbs and a LCD Television running for 16 Hr, 6 Hr and 4 Hr daily. An animal shelter of 500 cattle is considered for power generation by installing and Solar-Biogas-Wind hybrid system to meet the load of a medium sized community of 1500 people i.e. around 300 houses. Based on this calculation Daily 1.536 kWh is consumed by each house. Daily load Consumption by all 300 houses in community will be 460.8 kWh. As it can be seen in load consumption profile from Table below that during 7.00 pm, 8.00 pm and 10.00 pm all the appliances are running at the same time. This can be considered as peak load for the system.

Table-5: Power Consumption Profile of Community

Appliances	CFL	Fan	TV 21"
Power Rating	18 W	75 W	30 W
No. of Units	2	1	1
No. of Hrs. of Use per Day	6	16	4

Clock Hrs.	Daily Load Profile		
12 am - 1am			
1 am – 2 am			
2 am – 3 am			
3 am – 4 am			
4 am – 5 am			
5 am – 6am			
6 am – 7am			
7 am – 8 am			
8 am – 9 am			
9 am – 10 am			
10 am – 11 am			
11 am – 12 pm			
12 pm – 1pm			
1 pm – 2 pm			
2 pm – 3 pm			
3 pm – 4 pm			
4 pm – 5 pm			
5 pm – 6 pm			
6 pm – 7 pm			
7 pm – 8 pm			
8 pm – 9 pm			
9 pm – 10 pm			
10 pm – 11pm			
11 pm – 12 am			
Total Energy Consumption per Day	**216 Wh**	**1200 Wh**	**120 Wh**

7.1 Input Data for HOMER

Total load of community is 460.8 Kwh/day and the whole system will be designed to meet this load also the system peak load 42.3 kW considered. Input data for HOMER and life of Various Components is taken as mentioned below.

Table-6: Input Data for HOMER

SN	Description	Unit
1	Cost of 1 kw Battery (83 Ah,12 V)	8000 Rs
2	Cost of PCU with MPPT charge controller	20000 Rs /Kw
3	Cost of PV system(without battery, Inverter and Charge controller)	90000 Rs / Kw
4	Wind System cost	80000 /Kw
5	19 Kw Biogas generator Cost	224200 Rs
6	Biogas Digester cost	7500/M^3

Operation and Maintenance Cost of Various Technology is taken from National Renewable Energy Laboratory [15]. Project duration is for 20 years while the Life of PV panels, wind turbine, biogas generator, battery and PCU with MPPT charge controller are 25 years, 20 years, 15 years, 10 years and 10 years respectively Resources for wind and solar are taken from the HOMER software while daily biomass input is 5 tons per day.

7.2 Optimization by HOMER Energy

Result by HOMER shows the most economical system has 19 Kw biogas generator, 8 Kw wind turbine and 10.7 Kw PV component. Biogas generator is running for 22.85 hours daily and is utilizing all the available biogas. The unit cost of electricity is Rs 6.88 and NPC is Rs 13.4 million.

8 FINANCIAL ANALYSIS

8.1 Vermicompost

Slurry generated from biogas can be utilized to prepare Vermicompost. Vermicomposting is a simple biotechnological process of composting, in which certain species of earthworms are used to enhance the process of waste conversion and produce a better product [16]. Amount of Vermicompost generation at the animal shelter is computed in table below.

Table -7: Computations for Amount of Vermi-compost Generated per Year

Particulars	Value	Calculations/ Remark
Amount of Vermicompost Generated		
Material input to digester per day	10000 kg	5000 x 2 (Dung: water = 1:1)
Slurry produced	9500 kg	10000 x 0.95
Slurry weight after drying	2375 kg	9500 x 0.25 [18]
Slurry + Biomass input to the pit	9500 kg	2375 kg x 4 (Slurry : Biomass = 1:3)
Vermicompost produced per day	2850 kg	10260 kg x 0.3 [18]
Vermicompost produced per year	1040 tons	2.85 tons x 365 days

1040 tons of Vermicompost can be generated per year from the animal shelter with 500 cattle. Capital cost and operational cost for Vermicompost unit to produce 1040 TPA Vermicompost annually is calculated based on a case study by Indian Institute of Bank Management [18]. These calculations are based on an example project with 200 TPA Vermicompost production and it costs Rs 1183300 for capital cost and Rs 342080 as operational cost annually. Project of 1040 tons will cost Rs 5405700 for capital cost and Rs 1710400 annually as operational cost. Total revenue generated from this vermicompost plant is Rs 4160000 as calculated in table below.

Table-8: Revenue Generated from Vermicompost Unit

Particulars	Value
Revenue generated through sell of Vermicompost(3RS/kg)	Rs.31,20,000
Revenue generated through sale of worms @ 5 Kg/ton of compost and @ Rs.200/Kg.	Rs. 10,40,000
Total Revenue generated from Vermicompost Unit	**Rs. 41,60,000**

8.2 Computations for Emissions Mitigation per Year

The revenue earned through Carbon Credit may help in making renewable energy generation a viable energy option. One CER (Certified Emission Reduction) is equivalent to 1 ton of CO_2 avoided. It is defined under article 16 of the Kyoto protocol. The rate of CER fluctuates with the price of crude oil. As per Carbon Trade Exchange (CTX), the leading market platform for buying and selling Carbon Credits, on July 28, 2017 the price of one CER was $ 5.18 i.e. app. Rs. 332 [19]. The computation below depicts the amount of mitigation of equivalent carbon emission per day and per year by means of the considered hybrid power plant.

Table -9: Computations for Emissions Mitigation

Green House Gas	Global Warming Potential	Emission per kWh of Electricity from Coal Fired Power Plants	CO2 Equivalent of Emission
CO2	1	0.93 kg of CO2	0.93 kg of CO2
N2O	310	4.25 g of N2O	1.32 kg of CO2
Total emissions mitigation per kWh			2.25 kg of CO2
Emission mitigation per day = 461 *2.25 = 1037.25 kg of CO2			
Emission mitigation per year = 1037.25 *365 = 377.56 Tons of CO2			

8.3 Total Capital Cost for Individual Units

Total project cost including cost of all units such as biogas system, Solar system, Wind system, cost of Power Conditioning Unit, Cost of battery and Vermicompost unit is calculated in table below.

Table-10: Total Capital Cost for Individual Units

Particulars	Value (Rs)
Cost of Vermicompost unit	54,05,700
Cost of biogas plant	21,72,000
Cost of solar PV	963086
Cost of wind turbine	640000
Cost of battery	29,39,200
Converter	832000
Total capital cost	**1,29,51,986**

8.4 Annuity of the Bank Loan

Let the 90% of the capital cost i.e. Rs. 1,16,56,787 be sourced through a bank loan at an interest rate of 13% and let the repayment period be 10 years. Then annuity of this repayment can be calculated as follows:

$$A = PV*r / [1- (1+r)^{-n}]$$

Where, A, PV, r and n are Annuity i.e. annual payment, Present value, rate of interest and number of periods. Annuity for the project is Rs 1236256.

8.5 Total operational cost

Total operational cost of project includes operation and maintenance cost of all units within the project. It includes Operational cost for Biogas system, Solar system, Wind system and operational cost for the Vermicompost unit. Total operational and maintenance cost for project is found to be Rs 1872486 annually

8.6 Total Revenue Generated

All the revenue generated from project is calculated in this section. It includes revenue generated from selling the electricity produced by Solar-Biogas-Wind HRES, Revenue generated from selling the Vermicompost produced and the Revenue of carbon credit for mitigation of CO_2.

Table-11: Computations for Total Revenue Generated from Hybrid Power Plant per Year

Particulars	Value	Calculations/ Remark
Revenue generated through sell of electricity	Rs. 5,047,95	461 kWh x 3 Rs. /kWh x 365 days
Total Revenue generated from Vermicompost Unit	Rs. 41,60,000	
Revenue generated through Carbon Credits	Rs. 1,25,350	377.56 Tons of CO2 x Rs. 332
Total revenue from plant per year	Rs. 47,90,645	-

8.7 Discount Payback Period

Table-12: Costs and Benefits

Cost	Amount in Rupees
Annuity of the bank loan	12,36,256.
Total Operational cost	18,72,486
Total cost per year	**3108742**
Benefit	**Amount in Rupees**
Total revenue from plant per year	47,90,645
Net benefit	**1681403**

Discounted payback period can be calculated from the formula below

$$DPP = \left(\frac{1}{1 - \frac{O_1 * r}{CF}} \right) \div \ln(1 + r)$$

Where O1, r, CF and DPP are Initial Investment (Outflow),Rate, Periodic Cash Flow and Discounted payback period. DPP is found 6.156 years or 74 months

Discounted Payback Time is 6 years and 2 months

8.8 Internal Rate of Return

IRR or Internal Rate of Return can be found by below formula.

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - C_0$$

Where C_t, C_o, r and t are net cash inflow during the period t, total initial investment costs, IRR and number of time periods respectively.

Setting NPV equal to zero we get IRR = 22.12% per annum

Internal Rate of Return is found to be 22.12%

9 CONCLUSION

Study conducted at different animal shelters within and around the Bhiwandi city for data collection made clear that such animal shelters have good potential for biogas generation and enough roof area for installation of PV system. An animal shelter with good potential of wind energy can be a good prospect for Biogas-Solar-Wind hybrid energy system. After analyzing a medium sized animal shelter of 500 cattle heads at Uran village in the state of Maharashtra for Biogas-Solar-Wind Hybrid system, it was found that the site had good potential for energy generation for serving the local community. The solution provided by HOMER to meet the load of a community of 300 houses at Uran with the least net present cost includes 10.7 kW of PV panels, 2kW wind turbine and a19kW biogas generator running for around 22 hours daily. System also includes 41.6 kW of power conditioning unit with MPPT charge controllers and 332 kW capacity of batteries for storage of energy. Proposed hybrid system by HOMER will cost 6.88 Rs for every unit of electricity, NPC of Rs. 13.4 million with a project life of 20 Years. By Financial analysis net benefit from the whole project per year has been estimated to be Rs. 16,81,403 for first 10 years, while for rest of the project life the estimated net benefit is Rs 29,18,159. Based on the above calculations the payback period and internal rate of return for the project have been found to be 6.16 years and 22.12% respectively.

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