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Novel Design of Power Generation Using Windmill in Integration with Biomass Energy System

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ABSTRACT
More than two billion people living in underdeveloped countries, the bulk of whom reside in rural areas, do not have access to electricity. Kerosene and animal dung are used to provide many of the region's energy needs in addition to traditional and non-electric energy sources, such as human and animal muscle power. There has been a rise in recent years in environmental concerns due to fossil fuel consumption and the global warming phenomenon. For these reasons, renewable energy hybrids have been proposed as a possible option. Wind energy is supposed to contribute to the global state of the environment because of its purity. Also, every year, metric tons of residential garbage is collected, mostly being dumped in spread areas. In India, paper and plastic make up the majority of municipal solid waste (MSW), accounting for 80 percent of total MSW. Using anaerobic digestion or direct combustion, the waste of the municipality can be transformed into power for use. Employing a windmill to power a biomass generator is the topic of this paper. For a windmill that operates on an intermittent basis, a sufficient number of battery banks are installed. Biomass and windmills are used to generate electricity, and a battery bank can also be employed to store excessive and deficit power. All of the biomass generator's operations can be scheduled to save on costs. As part of this article, a compact wind farm with biomass energy and a battery backup is described. Proficient assessments of a wind-bio energy hybrid power plant with an output of 6 kW are provided. The paper's goal is to determine the feasibility of the system and optimize it.

Keywords
Windmill, Biomass, Fossil energy, Hybrid, Energy, Municipal Solid waste

1. INTRODUCTION
When economies grow, energy consumption grows as well, because economic expansion is directly tied to energy consumption. Although numerous solutions have been proposed to improve energy producing capacity in developing countries, many people still live in non-electrified areas. Non-renewable energy sources would not be sufficient for the demand for energy since they are finite and exhaustible [1]. Some long-term scenarios forecast a large increase in the employment of renewable tech. These problems suggest that it might provide up to fifty percent of the world's power needs by the middle of the 21st century if appropriate policies and technical breakthroughs are combined.
The variable generation of renewable energy and its time-dependent nature pose a challenge. However, even while flexible demand management [3, 4, 5] and smart energy management [6, 7] may be able to aid, they aren't enough for balancing the output of power and demand. When it comes to renewable energy production, storage technology could be a viable solution [8]. It is possible to store energy in order to collect it when production falls short.

1.1 Energy System Based On Wind
As far as renewables are concerned, wind power is by far the most important, and its importance has grown over the past few years. Many countries have stated plans to invest extensively in wind power in the foreseeable future, and the number of wind power plants erected each year increases. A turbine's overall energy output can be calculated by adding all possible wind speeds together during a specified length of time. As a result, our energy estimations reflect not only the turbine's power efficiencies but also the likelihood distribution at various wind speeds. In order to figure out what a turbine's cut-in, rated, and cut-out velocities are, you need to know the current wind speeds in the vicinity. The most efficient utilization of wind energy necessitates an in-depth knowledge of the local wind conditions.

1.2 Energy Systems Based On Biomass
Biomass, moisture, and ash make up the majority of animal manure's composition. Animal dung decomposition can happen in an anaerobic or aerobic setting. CO_2 and stabilized organic materials (SOM) are created under aerobic circumstances, whereas anaerobic conditions also yield extra CH_4. India has a high potential for CH_4 generation due to the abundance of animal dung, which allows for a large amount of energy. Through thermochemical and biochemical conversion routes, biomass crops can be used to make ethanol and biodiesel. In addition to these energy crops, bio-chemical technologies have the potential to generate a considerable amount of energy from a variety of industrial wastewaters [9]. Therefore to biomass to energy and fuel conversion in India may turn out to be a profitable endeavor [10].

1.3 Biomass Wind Hybrid Power System
As a result, numerous investigations into hybrid biomass systems have been carried out. In seven different Australian locales, Liu et al. tested a hybrid photovoltaic-wind-biomass system. According to their findings [11], the suggested process is more effective than a gasoline one. Eventually, the hybrid wind-biomass gasifier system developed by Bulamurugan came to fruition. In this study, the system was found to be a feasible alternative to the diesel-wind system [12]. Researchers

Soares and Oliveira used a numerical approach to examine concentrators. There is a 3 to 10% increase in efficiency [13] with hybridization. Homer program was used by Singh and Baredar to evaluate the techno-economic of a hybrid PV, and biomass system.

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Conclusion: The hybrid system is able to deliver the loads in nearly all seasons [14]. In another study, the possibility of supplying a small area's energy needs with Photovoltaic, wind, and energy storage devices was examined. In the end, they determined that the suggested system is able to meet the demand without any significant restrictions [15] Raheem et al. investigated several combinations of wind and biomass using a hybrid wind-biomass software named HOMER [16]. Traditional hybrid wind systems may not be suitable for all locations, including those at high terrains where the transfer system is not strong and solar energy is insufficient [17]. [18] As a result of these findings, it is possible to power a modest off-grid wind farm with battery backup using bioenergy A 6kW wind-biomass hybrid power system is analyzed from both a technical and economic perspective. The study's goal is to see if the system can be made to work and then optimize it.

2. AIM AND SCOPE OF THE WORK

- Power quality and reliability in many parts of India are low. In addition to topographical variables, grid failures are caused by a variety of causes. In the study, a site where grid electricity is unreliable and uncertain is taken into account.
- We have a moderate wind speed year-round because of the geographical location of the proposed scheme As a result; wind power is sporadic in nature and not continuous. Several storage devices must be retained in order to overcome this problem, with batteries being the most often employed.
- . There is also a large amount of biomass on the proposed location. You can find them in the nearby forest. They're made up of food waste, livestock waste, crop residue, and other bio-stocks available. This generator is capable of producing a fixed amount of electricity and is weather independent; therefore it will undoubtedly complement the wind energy to provide enough amount of power to suit the community's needs.
- As a result, the current work intends to introduce the combined wind-biomass system, analyze its viability, and optimize it to provide a cost-effective and continuous power supply.

3. LITERATURE REVIEW

Wind energy resources are abundant in India, according to P K Chaurasiya et al (2019). Importance is attached to evaluating how wind energy can change the energy scenario in the country in the foreseeable future. As of September 2018, there were 34605MW of installed wind power capacity. India ranks fourth in the world when it comes to converting and using wind energy An overview of India's wind energy industry is provided in this document. On the other hand, this research discusses alternative techniques to increasing and expanding exploitation of wind resources [18].\

Using the Auto - regressive Autoregressive Distributed Bounds Testing (ARDL) method, Bildirici (2013) examines the short - range and long correlation studies between the use of renewable energy and economic growth in the marked emerging nations. From 1980 to 2009, annual data was collected. These tests have shown that in nine out of 10 countries, biomass energy usage and economic growth are linked (Argentina, Cuba, Costa Rica, Paraguay, Peru) No correlation is there between biomass power usage and growth in economy in Paraguay, according to the results of the cointegration test [19]..

It is intended to build a MW wind farm, which would be evaluated using real data. In order to assess changes in wind park power generation, a probabilistic technique was used to quantify power compensation demands. An analysis of the hybrid wind-biomass system is conducted in order to determine the major characteristics of the hybrid system design. Using a hybrid system, wind errors in prediction can be minimised, resulting in a reliable supply of power. Simulations of hourly power compensation demands over the course of a full year have been conducted, taking into account capacity of storage and excess energy requirements of the biomass power plant and idly generating to ensure reliable energy relaxation during high functioning hours.

4. METHODOLOGY

4.1 Assessment of Wind Energy

Relativity among offshore wind (per unit time) and the thickness of the air A (kg/m3), which is dependent on air temperature and pressure among several other variables, in the event that the wind speeds up to v (m/sec).

$$Power = \frac{1}{2}\rho v^3$$

Using a wind tunnel, we were able to measure the deterministic output power as a function of the input wind velocity for a specific wind turbine, as shown in Figure 1. It's clear from this machinery input power that a particular range of wind speeds is necessary below a certain minimum wind speed. When the wind speed surpasses the nominal wind speed, there are technical alternatives to keep this level of service, as shown in Figure 2. Finally, when the speed is high the so-called disconnecting speed, the windfarm is unplugged to avoid damage from high wind gusts.

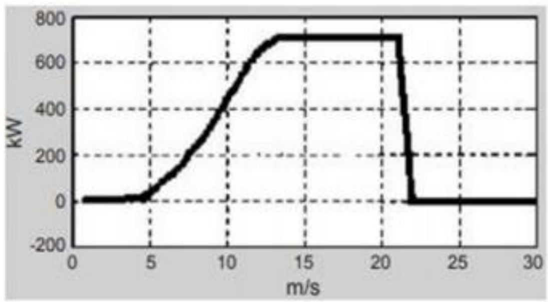

Figure 1: Wind tunnel power curve

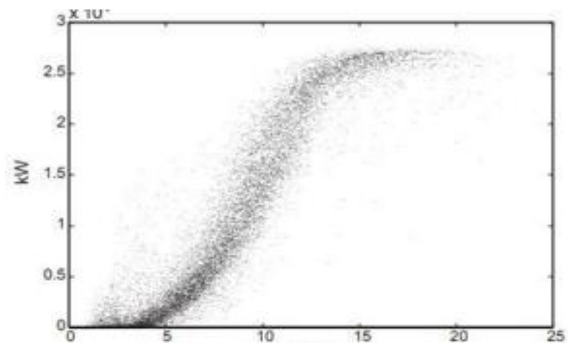

Figure 2: Empirical data on wind speed and power output in a genuine wind farm (average hourly numbers)

Equation for the balance of energy: Where E_{in} is the energy IN a system and E_{use} is the energy used in a system, the equations regulating energy balance can be stated as follows:

$$E_{in} = E_{FUN} + E_{FSN} + E_A + E_{BU}$$
$$E_{use} = E_{TUN} + E_L + E_{TSN}$$

Electrical energy amount: In addition to energy transported to or from a storage device or utility grid link, electrical energy amounts can be computed for the overall system and its components. When it comes to determining the contribution of a wind turbine to the overall operation of the system, the most important parameters are the net delivered energy to and from storing devices; net energy delivered to & from utility grids; overall energy intake and output of the process; Wind turbine energy contribution as a percentage of all sources of energy; and transmission efficiency of all power sources to consumers.

4.2 An Assessment of Biomass Energy

Biomass with a carbon basis is produced by living organisms (plants, algae, and animals). Wood, agricultural and forest waste, manure, energy crops, MSW organics, food processing wastes, sewage sludge, and leachate are all examples of biomass [22]. Biomass accounts for about 35% of primary energy consumption in developing countries and 35% in developed countries [23]. Because to its high amount of volatile materials (80 percent in biomass vs. 20 percent in fossil fuels), biomass is also a highly flexible fuel source with excellent ignition stability [24]. Therefore direct combustion is possible, as well as the conversion of biological, chemical and thermochemical processes [25] into other higher-value fuels (solid, gaseous or liquid). In comparison to most coal and oil, biomass has an energy density that is between 10 and 40 percent lower than that of biomass. Notwithstanding their cheap cost, biomass waste and leftovers are still regarded as valuable and cost-effective energy sources. More ecologically beneficial than destroying this trash is using them in the bio-energy industry.

5. SIMULATION MODEL

Since many previous hybrid energy system studies have been conducted in different nations, this micro power optimization program has been widely used to model a viable hybrid system for the location. For modeling and simulation purposes, this work makes use of the U.s' HOMER (Hybrid Power system Model for Electric Renewables) initiative (NREL)

5.1 Simulation of Wind Energy

Ratio of tip speed: Tornado-like conditions are created by the passage of a rotating blade through the air. A rotor blade that arrives here when the air is still turbulent will be unable to effectively harness the wind's energy, resulting in wasted energy. In contrast, by slowing down the rotation speed, the air contacting each turbine blade would no longer be turbulent. To prevent excessive air turbulence, the blades' tip speed ratio is also set [18].

$$Tip\ speed\ ratio = \frac{Tip\ speed\ of\ blade}{wind\ speed}$$

Betz limit: Wind turbines have a theoretical maximum efficiency of 59 percent, which is known as the Betz Limit Tip speed ratio (TSR) is just under 6 for this particular rotor, with a power density of 0.45 (= 45 percent).

Tower Height: The windmill is erected on top of the roof for ease of calculating and to save money (40 feet). This means that the entire height is approximately 30 meters.

5.2 Simulation of Biomass Energy

It is possible to evaluate the power generation potential of biomass collected from different resources by applying the equation below:

$$P_e = \frac{f_{CH4} \times H_{vCH4} \times B_{igas} \times \eta_e}{3.6 \times 10^6 \frac{MJ}{GW\ h}}$$

In this equation, P_e is the electricity generation potential in GWh/year, B_{igas} is produced in m^3/year, e is the electricity generating system efficiency in percent, and H_{vCH4} is the heating value of CH4 (390.0 MJ/m^3). The conversion from MJ to GWh is then 3.6 x 1006.

The following equation can be used to calculate the electricity generation potential of biomass matter through burning, gasification, and pyrolysis.

Where P e is the energy potential GW h/year, m i is the leftover mass kg/year, H v is the warming value of wood (MJ/kg), and η_c is the power conversion effectiveness (for gasification 0.7), and η_e is the efficiency of thermal energy to electrical converting (for gasification 0.3)

$$P_e = \frac{\eta_c \eta_e m_i H_{vi}}{3.6 \times 10^6 \frac{MJ}{GW\ h}}$$

5.3 Parameters of the Economy

Net present cost: All of a system's costs over its lifetime are subtracted from its revenue over its lifetime to arrive at its overall net-present cost. You'll also have to pay for capital expenditures, maintenance and repair (O&M) charges, gasoline, penalties for pollution, and grid-based power. Among the revenue sources are salvage value and grid sales.

Recovery of capital factor: The current value of an income is computed using capital extraction efficiency (a series of equal annual cash flows). The continuity formula for the investment recovery factor yields the following result:

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

There will be N years and I annual real interest rates, respectively. This research assumed a real interest rate of 6% and a project life of 25 years.

Salvage value: When a power system component reaches the end of its useful life, it has a salvage value. The salvage value of components is directly proportionate to their remaining useful life, because they decline linearly over time. As a result of these assumptions, it's anticipated that salvage value is estimated on the basis of real replacement costs than the original money cost, this may be written as

$$s = C_{rep}.\frac{R_{rem}}{R_{comp}}$$

, R_{rem}, the component's remaining life at the conclusion of the project's lifespan

Interest rate per year: This is the yearly rate of interest. One-time cost to annualized cost conversion using the discount rate. It can be found in the Economic Inputs section of the programme. The following equation illustrates the relationship between the nominal rate and the yearly real interest rate.

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

i = real interest rate, i'= nominal interest rate and f = annual inflation rate.

6. SYSTEM ANALYSIS

There is a power generator (wind mill, biomass generator and battery), an end-user (load), and a control station in the proposed system. A stand-alone system configuration is depicted in Figure 3.

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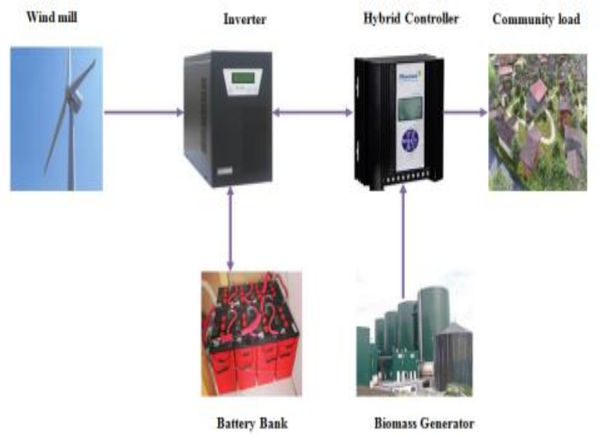

Figure 3: Wind-Biomass Hybrid System

As a result of this study's design, the load can be supplied with energy on a continual basis. As long as the wind pressure is more than 4m/s it will run and create power. This is due to the fact that the output of a windmill depends on the weather. The biomass generator is able to produce a fixed amount of energy regardless of the weather conditions. This variant is capable of delivering steady power; however the battery bank is included to make the system more cost-effective. a battery bank that can absorb changes in windmill output. As a result, the biomass generator is able to create power when the windmill cannot. Aside from that, the battery is sufficient to handle a light workload. A windmill can be operated with a battery bank to produce power and fulfil the load demand when there is enough wind pressure. The battery also balances excess and deficit energy. For light loads, battery bank will take care of any power loss in case of windmill failure. It's time to switch over to the biomass generator if your windmill isn't working during the evening hours! Based on the state of battery charges, the biomass generator runs until the windmill starts generating electricity (SoC). PV array and wind turbine DC power outputs are converted to AC electricity by an inverter unit. After satisfying the load and battery charge controller, a dump load is used to feed the extra power. If the charging and discharging rates, as well as the capacity, are sufficient, a dependable and sustainable energy supply can be ensured 24 hours a day.
System components include a windmill, a biomass generator, a battery as well as inverters, converters, and charge controllers as secondary components.

6.1 Profile of Load

With a peak load of 6.4 kW, the suggested system can handle a daily load of 49 kWh/day. Nevertheless, this is the average load demand for a given period of time. In addition, as the number of machines grows, so will the demand for electricity. Mainly, the system is designed to meet the domestic market's needs. It is also evident that the highest demand for electricity occurs in the evening. Homer software is then used to build a believable load profile for the proposed system using a 49-kilowatt-hour daily base load. There are no adjustments made to accommodate for seasonal fluctuations. It is assumed that the simulation year's load for the proposed technique will be constant, independent of the month Hourly load is shown in Figure 4.

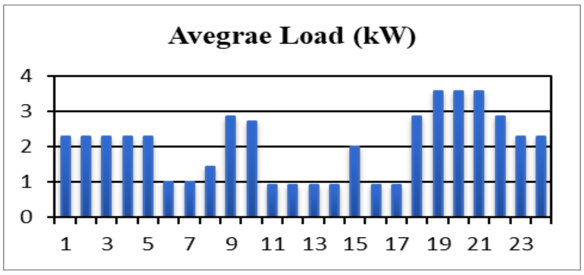

Figure 4: Hourly load

6.2 Wind and Biomass Resource

As part of the proposed scheme, windmills will be a major energy source. As indicated in Figure 5, a generic 3 kW DC windmill with a rated speed of 4m/s is used in this investigation. At the proposed site, the scaled annual average wind speed is 4.956m/s. It costs INR 2,97,000 to build the windmill, INR 2,46,000 to replace it and INR 4998 to maintain it.
The weather-independent resource in the proposed concept is the biomass generator. Because most people have cattle, which is a key source of income, the suggested site has enough biomass resources available. Biodegradable trash, such as food residue or leftover food, as well as agriculture waste are also found. Figure 6 depicts the biomass resources. On the location, there is ample forest cover for the biomass generator. a 3kW Biomass Generator costs INR 1,59,000 in construction and replacement costs (including gasifier and generator), INR 1,26,000 in replacement costs, and INR 12/hr in operation and maintenance.

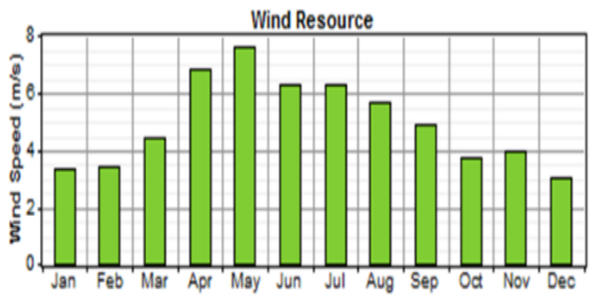

Figure 5: Wind Energy Resources

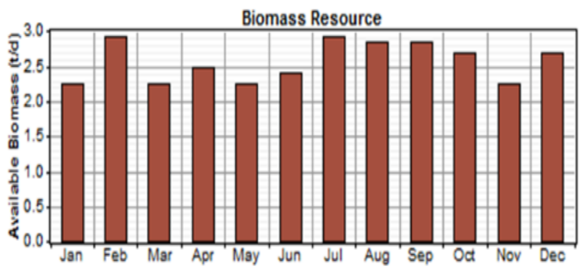

Figure 6: **Biomass Resources**

Battery: Ten Surrette 4KS25P batteries are used in this model. The proposed plan assumes a capital cost of INR 2,10,000 for the battery subsystem, a replacement cost of INR 1,50,000, and an O&M cost of INR 2,000 per year.

Inverter: Wind turbines generate a variable (DC) that is transformed to a utility frequency (AC) by a converter and then fed into the corporate electricity network or used locally in an off-grid network. As a result, standard AC-powered equipment can be utilized.

7. RESULTS AND OBSERVATIONS

7.1 Resource and Output Power of Biomass

As the biomass resource changes, so do the Biomass power output, as seen in Figure 7. The maximum output is 3kW, with an operating life of 15,000 hours and a 30 percent load ratio. The biomass generator is set to run in its most efficient setting. Forced shutdowns and restarts are not taken into account.

7.2 Wind Speed and Wind Power

The graph in Figure 8 shows the connection between wind speed and wind power generation. Throughout the year, the proposed site is subjected to moderate wind speeds. The mounted windmill has a speed range of 3.3 to 7.6 m/s, depending on the direction. The suggested site has a wind penetration of 80.3 percent. In this case, the installed windmill is of the Generic 3kW kind, which is designed to produce 3 kW DC.

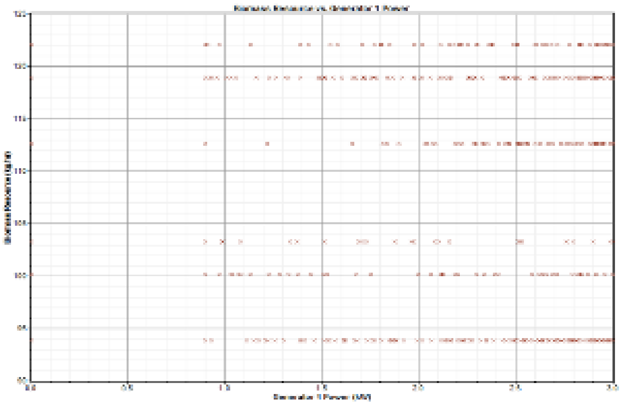

Figure 7: Biomass Resource and Output Power

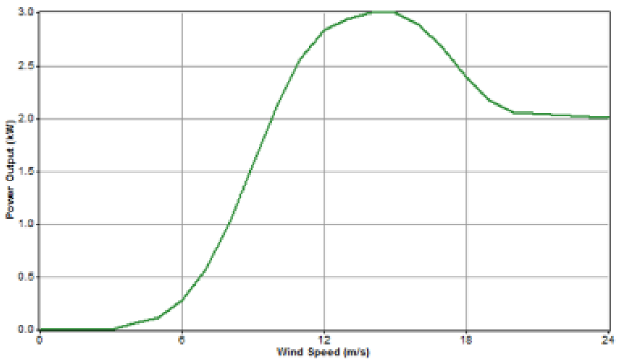

Figure 8: Wind speed and output power

7.3 Output of the Battery

This is because the battery will be used as a secondary power source in the system architecture. Windmills and biomass power plants would be allowed to use some of the surplus energy that is generated.. Storage energy will be released to satisfy load demand if the windmill and/or biomass generator are unable to meet it. Battery unit charge controller as shown in Figure 9 The battery has a nominal capacity of 76 kWh, however, HOMER calculates that it has a usable nominal capacity of 45.6 kWh. The battery's annual throughput is 5,931 kWh/yr, with an autonomy of 22.5 hours and a storage depletion of 2 kWh/yr.

7.4 Variation of SOC under Load

Figure 10 shows the battery state of charge variation from June 4th to June 6th for the simulated year. Load fluctuates every minute in the connected system. The battery's output changes accordingly. Charge and discharge of a battery bank can be done simultaneously in the manner outlined below. Studies have shown a rise in the SoC of batteries with a lower load demand since the majority of electricity supplied by a windmill is used to charge the battery. A reverse occurs when the wind's power output is less than its rated output. Even the SoC changes depending on whether or not you're using biomass.

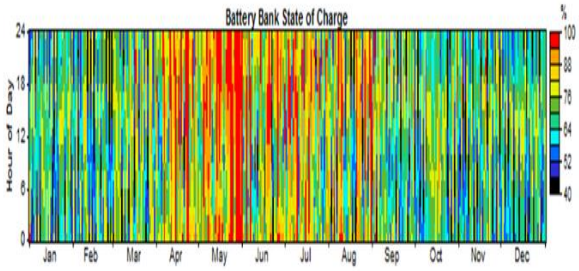

Figure 9: Charge state of a battery

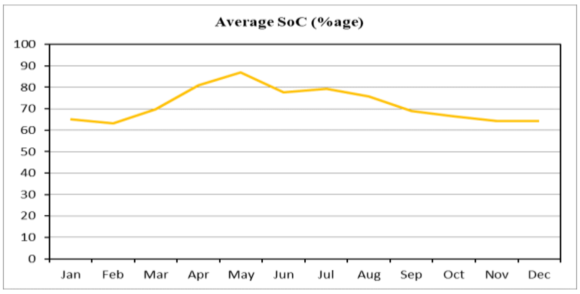

Figure.10.Charge state of battery monthly variation

7.5 Energy Production and Load Demand on a Daily Average

When it comes to the proposed scheme, Biomass and wind turbines are the key sources. As part of the system, you'll have access to a 3 kW biomass generator and a 3 kW wind turbine. As a result, the windmill serves 56 percent of the demand, and biomass serves 44 percent of the load. This means that the maximum amount of load can be served by the source and load profile. Windmill energy production is shown in Figure 11 as a blue bar for each month, with a line representing the average of both methods.

7.6 Hourly Energy Balance of the Proposed System

Figure 12 shows the hourly simulation result for the 9th of March. To meet the load requirement, windmill power will be employed, with additional energy being stored in batteries. Because of the intermittent nature of solar windmills, the battery bank is constantly charged and discharged. For the biomass generator to work, there must be a deficit of energy available to power it. In the same way that the wind energy changes, so does the biomass generator's functioning and energy output.

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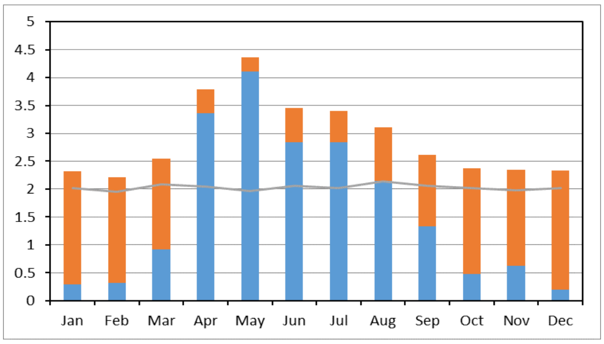

Figure 10: The average daily energy production and demand

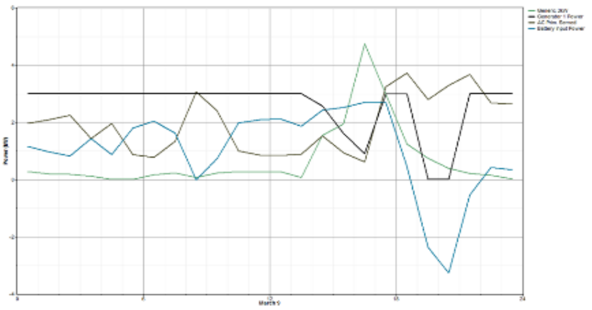

Figure 11: Hourly Power balance

7.7 Analysis of the Economic Effects

HOMER software generates an overall optimization result for the hybrid system, as shown in Figure 13. An example system configuration is shown in each row. The quantity or size of each component appears after the icon in the first four columns. Among the most important simulation outcomes are the upfront capital expenditures, operating costs, and net present costs shown in the final seven columns. In terms of NPC, the best setup consists of a 3 kW windmill, a 3 kW biomass generator, 10 S4KS2P battery banks, and a 4 kW converter with an NPC of 0. INR 6,91,200 is the original capital outlay, and INR 97,305 is the annual operating cost, for a total of INR 19,35,087 in NPC. The COE is found to be 8.521/kWh, with a 100 percent renewable fraction of the energy source.

G3	Label (kW)	S4KS25P	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Biomass (t)	Label (hrs)
3	3	10	4	$ 691,200	97,305	$ 1,935,087	8.521	1.00	241	4,008
2	4	10	4	$ 645,200	107,667	$ 2,021,544	8.897	1.00	286	3,595
3	4	10	4	$ 744,200	100,887	$ 2,033,881	8.951	1.00	249	3,205
2	4	8	4	$ 603,200	112,476	$ 2,041,017	8.982	1.00	287	3,827
3	4	8	4	$ 702,200	106,171	$ 2,059,420	9.063	1.00	253	3,458
4	4	10	4	$ 843,200	98,423	$ 2,101,383	9.248	1.00	226	2,978

Figure 12: Optimization Result of Wind Biomass Hybrid System

7.8 Performance Summary of Different System Components

Table 1: Performance summary of Windmill

Parameters	Value	Unit
Generic 3 kW (Wind mill)		
Total rated capacity	9.00	kW
Mean output	1.63	kW
Capacity Factor	18.1	%
Total Production	14,26	kWh/yr
Minimum output	0.00	kW
Maximum output	8.99	kW
Wind penetration	80.3	%
Hours of operation	7,092	hour/year
Levelized cost	2.44	$/kWh
Label Generator 1		
Hours of operation	4,008	hr/yr
Number of starts	339	starts/yr
Operational life	3.74	yr
Capacity factor	42.7	%
Fixed generation cost	20.4	$/hr
Marginal generation cost	0.00	$/kWh
Electrical production	11,224	kWh/ yr
Mean electrical output	2.80	kW
Min. electrical output	0.900	kW
Max. electrical output	3.00	kW
Bio. Feedstock consume	241	t/yr
Specific fuel consumption	15.000	kg/kWh
Fuel energy input	257,219	kWh/yr
Mean electrical efficiency	4.4	%

Table 2: Performance summary of converter and Battery

Parameters	Value	Unit
Converter		
Capacity	4.00	kW
Mean output	1.12	kW
Minimum output	0.00	kW
Maximum output	4.00	kW
Capacity factor	28.1	%
Hours of operation	5	hours/yr
Energy in	10	kWh/year
Energy out	9	kWh/year
Losses	1	kWh/year
Battery		
Nominal capacity	76.0	kWh
Usable Nominal Capacity	45.6	kWh
Autonomy	22.5	Hr
Lifetime throughput	105,686	kWh
Battery wear cost	1.587	$/kWh
Average energy cost	0.000	$/kWh
Energy in	6,603	kWh/yr
Energy out	5,305	kWh/yr
Storage depletion	25	kWh/yr
Losses	1,273	kWh/yr
Annual throughput	51,736	kWh/yr
Expected lifetime	12.0	Yr

8. CONCLUSION

For a community load, the viability of a Wind-Biogas hybrid system is explored. As a result of these efforts, there is a lot to look forward to in the Energies can be generated without relying on the grid; this means that their reliability is substantially increased. When these systems are integrated, power output improves, there is no shortage of capacity, and the optimized energy cost is 8.521 INR/k Watthour, which may decrease in the near future as the costs of these systems are on the decline. As both sources are renewable, the system has proven to be environmentally favourable

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