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# Business Viability of off Grid Hybrid Biomass model over on Grid Solar Generation for RE in Developing countries

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## Abstract

This paper outline the business viability of Distributed or Stand-alone hybrid power system consisting of Biomass and Diesel versus Traditional Top down grid connected solar power generation. The environment considered in this paper is for RE. It emphasizes and recommends the use of localized renewable hybrid power generation system in order to ascertain a reliable and self sufficient system. The localized renewable system also positively influences the macro economic conditions of area by way of optimization of the components size and the capital investment. The main power source of the energy system is considered as biomass generator and suitable supported by Diesel Generators. The NREL HOMER package is used for optimization realization. The Business viability of Stand-alone hybrid power system consisting of Biomass and Diesel versus Traditional Top down grid connected solar power is done on the basis of Net per unit revenue collected post factoring Transmission, distribution, billing and collection inefficiencies.

**Keywords**: HOMER, Renewable Energy, Grid Hybrid biomass model, Grid Solar generation

## Introduction

Energy plays a very vital role in technological, economic and social development of any society. A better world cannot be dreamed without electricity as it's an important blessing that science has given to mankind. Electricity has become an integral part of any modern society we one cannot think of a world without it. Electricity has multiple uses in every aspect of our day to day life. According to an empirical analysis, per capita electricity consumption, economic indices (such as GDP per capita, Current Employment Statistics), social development indices (such HDI, life expectancy, mortality rate etc) has a strong. High electricity consumption per capita directly fuels faster economic growth and indirectly accelerates enhanced social development especially for countries with low and medium human development indices. As Electricity plays a vital role in both economic and social development, it is desired that world leaders need to wisely allocate their human, financial and natural resources to achieve stable and viable power supply systems.

It is difficult and uneconomical to transmit power over long distances through transmission lines, to electrify remote and rural areas, especially in developing countries like India. The lack of efficient grid network in remote areas, very high grid extension cost and irregular topographical issues evokes to evaluate the other possibilities.

This paper is on optimization and modeling of a hybrid energy system with comparison to unit price of PPA based on grid solar power supplies to meet the electrical requirements of a remote area for lightening and small industrial load. It spotlights the optimized renewable hybrid power system to obtain a reliable and self sufficient standalone system for required load and capital deployment need. This hybrid energy model consists of biomass plant accompanied by diesel generator based on load and time of year, considering availability of weather dependent re-sources. Firstly, a test area has been decided for measuring the electrical load, load profile, availability renewable sources, condition and specifications. Then, the whole system is simulated in Hybrid Optimization modeling tool (HOMER) environment. Finally, simulation results are presented and compared with the published cost of the PPA based grid connected solar plants.

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For the purpose of study and comparison a surrounding areas of Kanpur, Uttar Pradesh, India is considered. This is due to the fact that Kanpur has undeserved rural areas that are remote from robust grid connections and have renewable resources available. Also, the Kanpur is highly industrialized with a high proportion of captive power with huge shortage and rapid demands of Uttar Pradesh.

Uttar Pradesh is a most populous state of India. With total area of 95,000 square miles (246,000 sq km), if Uttar Pradesh were to declare independence, it would be the world's fifth most populous country as it has about the same number of residents as Brazil. The economy of Uttar Pradesh would only be the size of Qatar and GDP per head is close to that of Kenya.

## Materials and methods

### Hybrid Modeling using HOMER Model

HOMER stands for the Hybrid Optimisation Model for Electric Renewables and was developed by the National Renewable Energy Laboratory in Golden, Colorado, USA. HOMER was developed as a hybrid system design tool "accurate enough to reliably predict system performance, but simple and efficient enough to conveniently evaluate a large number of design options" and then rank the results to find the optimum configuration (NREL, 2003). HOMER identifies the least cost system for supplying electricity to remote loads by performing hourly simulations of thousands of potential power systems and rank ordering them by life cycle costs. It also performs sensitivity analyses to evaluate the impact of a change in any of the input parameters and provides both annual and hourly outputs in tabular and graphic form. Hybrid system design is made difficult by the intermittency of renewable resources, the need to match electrical supply and demand, and the large number of potential component size combinations. HOMER provided an excellent platform on which to test hybrid viability and eliminated the need to spend time building an optimization model from scratch. The HOMER model is also well tested and validated (Lilienthal, Flowers et al. 1995).

The formulae details for the three most important output variables of the model are below.

### Net Present Cost

The net present cost is the discounted value of all the cash flows needed to operate and purchase the hybrid system over its lifetime of 20 years. The following formula was used:

$$\mathbf{C_{NPC}} = \frac{C\ ann,tot}{CRF\ (i,R\ proj)} \qquad (1)$$

Where

C ann,tot = total annualised cost (dollars per year)
$CRF\ (i, R\ proj)$ = capital recovery factor
i = interest rate (percent)

$R_{proj}$ = project lifetime (year)

The first variable is the total annualised cost of the system, which is equal to the sum of each component's annual operating cost plus its annualised capital cost over its useful lifetime plus the annual fuel cost, if applicable (NREL, 2003). By adding the results for all components, the total annualised cost can be calculated, $C_{ann,tot}$ . The capital recovery factor is a function of the real interest rate and the project lifetime and is used to discount the cash flows to time zero.

### Cost of Energy

The cost of energy (COE), in dollars per kWh, is the level of tariff needed to recoup the net present cost (NPC) of the hybrid project. However, differential tariff structures can be used to aid poor clients, so the COE figure is only indicative of the median level of charges that must be supported by the host community:

$$\mathbf{C_{NPC}} = \frac{C\ ann,tot}{E\ Prim+F\ def} \qquad (2)$$

Where as,

Cann,tot = total annualised Cost of the system (dollars per year)

$E_{prim}$ = primary load served to domestic load (kWh per year)

$F_{def}$ = deferrable load served to industrial load (kWh per year)

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## Results and discussion

**Electrical Demand and Recourses Analysis**

**Load Profile**

15 places visited in Kanpur city during data collection to understand the load profile apart from other applicable information. List of areas visited are as follows:

| Sr.No. | Place | Sr. No. | Pla |
|---|---|---|---|
| 1 | Prerna | 8 | Pan |
| 2 | Barra - I | 9 | Pareda |
| 3 | Barra - II | 1 | Gumti |
| 4 | Barra - | 1 | Sarvodya Nagar |
| 5 | Barra - I | 1 | Kalyan Pur |
| 6 | Gujani | 1 | Kakadev |
| 7 | Daboli | 1 | Chamanganj |
| | | 1 | Bakarganj |

Survey revealed the Domestic load profile for 50 Domestic users is as follows:

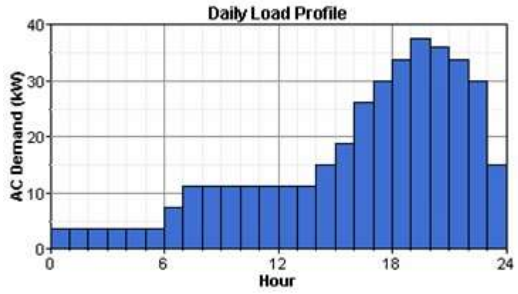


***Figure 1 Load Profile for domestic users***

The high use during the evening hours reflects the high demand for lighting and power for radio and television and the lower relative demand for industrial uses in rural areas.

As small scale factory (small concrete parts factory) operates seven days a week from 7:00 AM to 11:00 PM, with two shifts of workers. The equipment requires a reliable three-phase supply during all operating hours and the demand is near the full capacity of the genset. The engineer in charge commented that the addition of more than a light bulb would trip the system and he estimates that the load factor during operating hours was near 95 percent.
Load profile of the Industries comes out to be as follows:

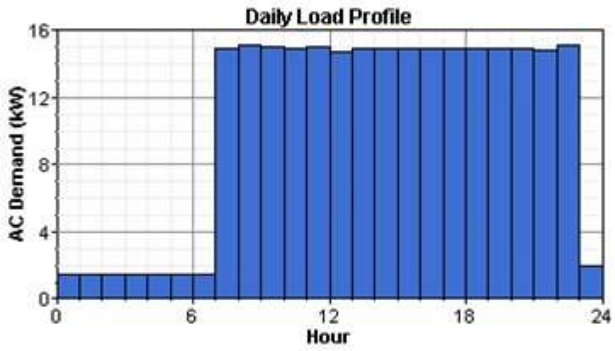


***Figure 2 Load Profile for Industries***

**Solar power status in Uttar Pradesh**

Power deficit Uttar Pradesh is expected to get an investment of about Rs 880 crore in solar power projects cumulating to 110 Megawatt (Mw). UP is targeting 500 Mw of solar energy by 2017 under its Solar Power Policy 2013.

In year 2013, the government had signed power purchase agreements (PPA) with developers on rates ranging from Rs 8.01/unit to Rs 9.33/unit.

A typical solar power plant needs capital deployment of Rs 8 crore per Mw of installed capacity. This leads to high initially power tariffs. However subject to other technical and business performance indicators, over a period of time the power tariff would become cheaper.

**Transmission and Distribution loss status in Uttar Pradesh:**

Uttar Pradesh power utility faces challenges and criticism over short supply of electricity from the customers.

Of the state's demand for 12,700 Mw, power utilities are able to cater about 10,700 Mw is met, leaving a shortfall of 2,000 Mw. The state's power utilities are suffering transmission and distribution losses to the tune of 32%, which translates into loss of Rs 7,000 crore per annum to state exchequer. Power utilities of Uttar Pradesh are able to supply electricity for less than 13 hours in urban areas and eight hours in villages.

**Power Theft**

About a third of India's electricity is lost each year. It just never gets billed. Some of it is stolen or disappears because of technical problems. It is enough power to light up all of Italy for a year, according to a University of Michigan study.The

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problem gets especially bad during elections when electricity is used to win votes, the study adds.

The research focused on state elections in Uttar Pradesh — the country's most populous state — and found that power losses increased by three percentage points just before polls. Our paper offers a political explanation on electricity loss and why it persists in plain sight," said Brian Min, assistant professor of political science. "In short, elected political leaders benefit at the polls when their constituents receive more electricity."

The study highlights two big challenges in the world's most populous democracy: corruption and wobbly infrastructure. Both are frequently blamed for the recent slowdown in India's economy — a major issue in the ongoing general elections. Min said because power companies such as the Uttar Pradesh Power Corporation Ltd were state-owned, they were beholden to the interests of elected officials.

The study said 29% of all power sent out from 1970 to 2010 in UP was unbilled. Moreover, rates of line loss in UP are higher now than in the 1970s, despite numerous policy interventions, regulatory reforms and increased efforts to prosecute power theft. Rural areas don't have meters and usually pay a flat rate for electricity.

**Collection Efficiency**

Power distribution in India needs sweeping reforms if it is to bring back the country to a high growth trajectory and meet its goal of expanding access to electricity to all by 2019, says a new World Bank report. Today, India's annual per capita power sector consumption at around 800 kWh is among the lowest levels in the world.

"The crux of the matter is that distribution utilities are not run on commercial lines. Despite corporatization, their boards remain state-dominated and are rarely evaluated on performance. Regulators have not pushed them sufficiently to improve performance, in part because of limited regulatory accountability and also the difficulty of regulating a state-owned entity. And a history of state rescues has meant that lenders do not pressure distributors to improve their operational and financial performance, expecting to be paid back by the state," said Sheoli Pargal, Economic Advisor, World Bank and author of the report.

Utilities face pressure to provide below-cost power to agricultural and rural residential consumers for which they are reimbursed through subsidy payments by state governments. However, currently, 37% of the subsidies booked by state utilities are not paid to them. Since 2003, in fact, subsidies booked have grown by 12% per year, and subsidies received by 7% per year; the cumulative gap between them was Rs 466 billion (US$10 billion) for 2003–11. This has had a crippling effect on the already struggling financials of the utilities, the report says.

The report also highlights the need for better targeting of domestic subsidies. Lack of effective targeting of such subsidies has led to anomalies such as economically weaker sections of the population ending up paying more for consuming less power. In fact, in 2010 some 87% of the domestic electricity supplied India-wide was subsidized. Over half of subsidy payments (52%) India-wide went to the richest 40% of households in the country in 2010, the report says.

**Distributed Hybrid Power Systems**

Hybrid Power Systems incorporate several electricity generating components with usually one major control system which enables the system to supply electricity in the required quality.

The term Hybrid Power System does not give any information about the size of the energy system. Generally, Hybrid Power Systems are considered to supply loads in the size of several watts up to several megawatts. They usually supply island networks that are not connected to an integrated grid covering countries or even continents – but represent small grids with a limited number of consumers. Due to the resulting fluctuating consumption pattern several specific features are required concerning the electricity supplying Hybrid Power System.

**Biomass-diesel hybrid system**

The economic feasibility of a hybrid system is determined by local conditions and re- source availability. Based on survey and feasibility result a Biomass-diesel hybrid system is recommended for the Kanpur. In line to this different hybrid distribution system can be executed across Uttar Pradesh based on the availability of local fuel resources.

For establishing a Biomass-diesel hybrid generation system, the economics depend on six key variables as follows:

1. Available waste biomass resources

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2. Delivered price of diesel fuel
3. Capital costs of the waste biomass, genset and auxiliary equipment
4. Life-cycle operating costs, including maintenance
5. Value of secondary load
6. Reliability of demand and revenue collection

**Biomass fuel availability and sensitivity:**

Bio mass fuel availaibility changes depend upon the fuel type and the climatic condition. Hence the Bio mass power availability during different part of year comes out to be a critical factor. To understand the same a sample biomass power plant is considered.

- The plant is installed for the generation of 10 kW of using up to 85 cubic meters per day gas generation capacity.
- K.V.I.C Floating drum type with water jacket, external guide frame for gas holder and a gas cleaning system.
- A power generation unit comprising of 30 kVA 100% Biogas generator set has been installed near the plant whereas the electricity line has been laid for almost 1 km distance to the potato cold storage for its use to power lights.


*Figure 3 85 cubic meters Biowaste based Power Generation Plant by MNRE, Govt. Of India*

The most important variable in determining the viability of a hybrid system is the Biomass usage. In mentioned figure the sensitivity results are shown for a Biomass based 30 – 40 cubic meters against changes in primary load levels. Focusing on the x-axis, the winter days, not surprisingly, show the only-diesel option as the most economical, but that dominance only lasts to biogas production.

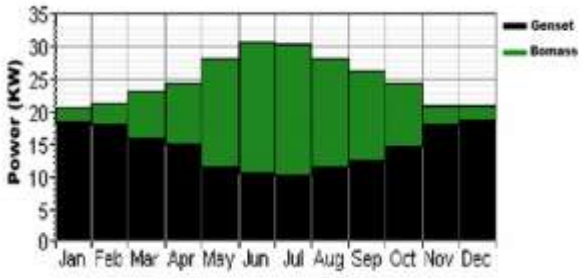


*Figure 4 Sensitivity results for Biomass based 30 – 40 cubic meter plant*

**Homer Simulation**

In the present work, the sizing and selection of components of a hybrid power system has been done by using NREL's HOMER software. HOMER is general purpose hybrid system design software that facilitates design of an electric power system for stand-alone applications. The input information that are provided to HOMER includes electrical loads, renewable resources, etc. HOMER designs an optimal power system to meet out the desired loads requirement. HOMER is a simplified optimization model, which performs hundreds or thousands of hourly simulations over and over in order to design the optimum system. The model has been tested for PV, Diesel and a biomass generator.

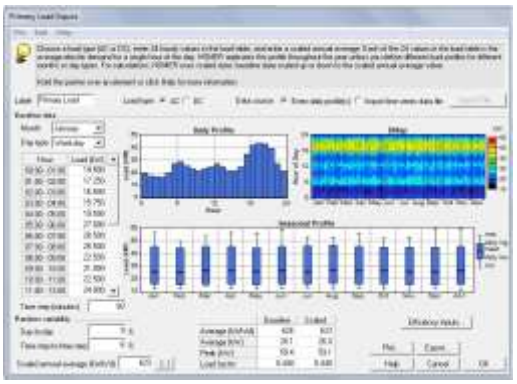

*Figure 5 HOMER tool with Primary Load input*

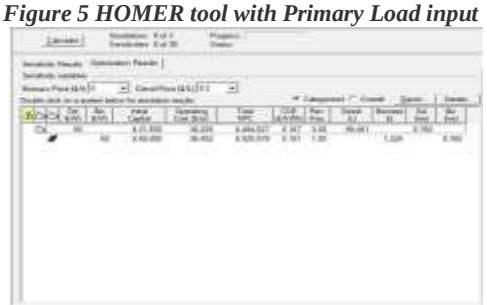

*Figure 6 COE for Biomass as per Homer Calculation*

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**Simulation results**

The simulation results for hybrid system are presented in table II. The first row shows the optimum hybrid system consisting of Diesel generator and Biomass generator to meet the load demand. The cost of energy for purposed hybrid Diesel/biomass generator has been found to be is 0.167 (US$/kWh) as shown in table III. The annual electric energy production and annual electric energy consumption is shown in table

**Hybrid System Components:**

| Diesel generator set | Biomass generator set |
|---|---|
| Size : 60kW | Size : 60kW |
| Capital cost : 21,500$ | Capital cost : 60000 $ |
| Operating Cost$/year : 36229 | Operating Cost$/year : 36452 |

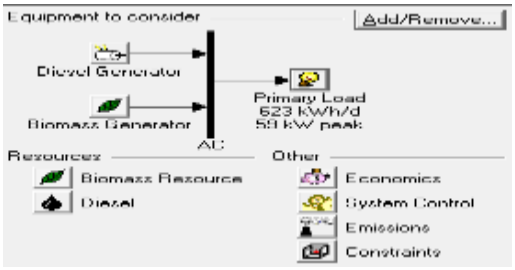


***Figure 5 HOMER toools***

***Figure 7. Results showing the electricity generation***

***Figure 7. Results showing the electricity generation***

Table 1. **Per unit Business viability comparison of Grid Solar Power and off Grid Hybrid model in INR**

| | Solar | Hybrid |
|---|---|---|
| Generation cost | 9 | 10.8 |
| Transmission loss | 32% | 0 |
| Cost after compensating Transmission loss | 11.88 | 10.8 |
| Distribution loss | 0% | 0 |
| Cost after compensating Distribution loss | 11.88 | 10.8 |
| Loss on account of theft | 29% | 0 |
| Cost after compensating Theft loss | 15.33 | 10.8 |
| Collection in-efficiency, unpaid subsidies | 37% | 0 |
| Cost after compensating colletion efficiency | 21.00 | 10.8 |
| **Over all per unit cost of billable power** | **21.00** | **10.8** |

This work investigates the economic feasibility of the use of a hybrid energy system consisting of biomass/Diesel for energy requirement of a remote area. Here, biomass generator is chosen as a major source of power in the rural areas due to its high efficiency and cost effectiveness.

## Conclusion

Model of De-centralized off Grid production can be implemented for addressing the power issue in Rural Energy sector with low efficient distribution system. De-centralized off Grid production is basically a means of establishing a power generation facility keeping in view to serve particular area or a cluster of areas (villages or communities). Such facilities can be operated by a local business associates who will also help to create employment and availability of power at rural level. These plants can be targeted to operate at desired optimum level based on the local consumption pattern. Issues like T&D loss, Theft, Billing and collection etc. can be easily addressed. The plant need to be operated on localized bio-mass resources. Different business models can be adopted according to area, load, consumption pattern, different economic classes etc at rural level. This way power

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retailing can be established as promising and very viable business model. Also, it generates a wide scope of Innovative business models.

Modeling and calculation shows that the billed and collectable cost of power per KWh is around 50% lower in case of distributed Hybrid Biomass w.r.t to PPA based grid connected solar power for Rural electrification.

## Acknowledgements

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