CHAPTER 1 INTRODUCTION

1.1 Motivation

In the rapidly growing economies of the developing countries the demand for electricity is constantly increasing. Electricity is one of the driving forces in a growing economy and increasing demand puts incredible pressure on the countries' energy infrastructure to match that demand. India as a developing country, where majority of the population lives in villages without electricity, the problem assumes greater importance. Extension of the central electricity grid to such areas is either financially not viable or practically not feasible as these locations are geographically isolated, sparsely populated and have a very low power demand. In India, out of 112,401 un-electrified villages there are 24,500 villages listed under the category of remote off grid villages. The Government of India has been continuously trying to improve the rural electricity scenario in India since 1947 by initiating various programs. Also, the Ministry of New & Renewable Energy (MNRE), GOI has taken essential steps towards the implementation and promotion of decentralized electricity generation through RET systems. Additionally, the GOI announced the National Electricity Policy (NEP) in 2005, which addresses the issues related to rural electrification and promotes the use of both renewable energy technologies (RETs) and conventional technologies depending on the best techno-economical option suitable for a particular off-grid location. At the same time renewable energy (RE) generation is its top priority and will be considered even in grid-connected areas, if the cost of energy (COE) is competitive to conventional source generation. In India, the rural electrification program is run by the State Governments in their respective areas and is supported by the Rural Electrification Corporation.

Recent programs include the Remote Village Electrification Program (RVEP) by MNRE, the Rajiv Gandhi Garmin Vidhuitikaran Yojana (RGGVY) initiated by the Ministry of Power in 2005. The RVEP aims at providing electricity to un-electrified villages through renewable energy sources (RES) whereas the RGGVY aims at providing electricity to all villages by using grid connection. The JNNSM 'develops and deploys solar energy technologies in the country at both centralized and decentralized levels thus also helping to meet the climate change challenge. However, rural electrification has several issues hampering the success of such programs. These issues need to be resolved using techno-economic-social analysis.

1.2 Techno Economic Analysis

Village electrification is a vital step for improving the socio-economic conditions of rural areas and crucial for the country's overall development. The villages' welfare is one of the main aims of the rural electrification program. Enormous benefits can be achieved in irrigation, food preservation, crop processing, agriculture and rural small-scale industries. It creates employment opportunities for the villages' youth and promotes a better standard of life. Therefore, availability of electricity removes poverty and helps economic development by fulfilling the health, education, water supply (for drinking and irrigation) needs of the rural population .Rural electrification is relatively costly compared to electrification of urban areas. At any off-grid location, the delivered COE from the grid depends on four factors: -

(a) COE generation from the central power plant.

(b) Cost of T&D of electricity through the new network lines.

(c) T&D loss. (Technical and non-technical)

(d) Load factor.

From the factors mentioned above, the load factor plays a crucial role as it indicates the amount of electricity a village requires. Villages in hilly terrain have an even lower load demand and smaller peak loads than villages in plain terrain. This is because in hilly terrain, the village house density is more scattered and moreover there is no commercial or industrial load. Also the cost of establishing a new electricity distribution system in hilly terrain is higher due to expensive labor and specialized logistics. Therefore, the COE distribution is higher in remote villages situated in hilly terrains. In one of the World Bank's reports (published in 2000), it is stated that for every kilometer the average cost of grid extension in remote rural areas varies from $8000 to $10,000 and rapidly increases up to $22,000 for extremely difficult terrains. Rural electrification is almost seven to ten times more expensive than that in urban areas. In some states T&D losses can be up to 70%. (6) This includes both technical and non-technical losses. On other side the ever changing government policies of free or subsidized electricity supply to rural areas add on to the above mentioned losses. The rural electrification programmed in India is severely affected by these factors and all State Electricity Boards have recorded huge financial losses as a consequence. Consequently, these state bodies are not in a position to invest in any new projects .Decentralized electricity generation with the help of RET systems has received considerable attention in recent years and is the best suited alternative solution. Moreover, from an environmental perspective RES are sustainable and environment friendly. In the generation of electricity from conventional sources, the combustion of fossil fuels emits greenhouse gases, which are a major cause for global warming leading to climate change. Also, the issue of energy supply security arising from the increasing costs of fossil fuels on one hand and the gradual decrease in the cost of RET based systems as the technology is maturing have made the utilization of RES such as SHP, SPV, solar thermal, wind, bio fuels, biogas, biomass, etc. attractive for rural electrification.

Certain barriers prevail with RETs. The concept of integrated or hybrid RET systems is an ideal solution to overcome these barriers. For off-grid locations single technology approaches like stand-alone SPV, wind turbines, SHP or biomass do not meet the load demand continuously. Often these approaches lead to an over-sizing of the system and are not sustainable for longer periods due to high expenses.(1) In India, out of the RES available for decentralized electricity generation, SHP is the best suited option to combine with other RES in a hybrid system, with biomass based electricity generation as second-best. Modern technologies such as SPV systems and biomass based generation systems have made the use of RES an efficient option for decentralized, off-grid village electrification. Yet, one factor is even more important than the environmental sustainability of these technologies and their suitability for off-grid locations, and that is costs. In the end, only the most economic option of electricity generation will prevail. This is especially significant for RE generation, where the costs and the RET employed usually depend on the specific location.

Both solar and wind energy are non-delectable and non-polluting power sources. On the other hand, these resources are both unpredictable and do not produce electricity for a considerable part of the year. To reach system reliability, one consequently has to concurrently rely on using both these technologies. Otherwise, individual usage of these technologies generally results in an over-sizing of the system and consequently in higher costs. There have been several previous studies related to the use of two or more RETs for electricity generation in off-grid locations. A combination of wind and hydro has been used both in a remote island for the optimization of system components and in the rural villages on the Western Ghats (Kerala), India. A wind-solar hybrid has been used to study electricity generation in other parts of the west coast of India. To resolve the electricity fluctuations of the grid network, wind energy was used with a biomass gasified system.

1.3 ***Aim of Research***

Now the research question is to find the best combination of RET from the available resources in a given village location that can meet the electricity demand in a sustainable manner and to see whether this is a cost effective solution or not. This dissertation is an attempt to structure a model of electricity generation based on multiple combinations of RETs with the application of HOMER energy software at an identified off-grid village location in India. This model analyses the techno-economic factors with respect to the COE generation and then compares these performance indicators to grid extension related costs.

The main objectives of this study are to analyze: -

a).The best suited configuration of a hybrid RE system out of various combinations to meet the village load requirement reliably, continuously and sustainably.

b).The minimized COE generation from the Hybrid RET system.

c).The system's cost-effectiveness, to calculate the COE from hybrid RETs, then compare it to the cost of grid extension to determine the EDL.

A hybrid RE system is the most cost-effective and reliable way to generate electricity at off-grid locations. But all systems have their own pros and cons, for example solar and wind energy have fluctuations in the power individually generated, a hybrid of the two resolves the problem and also reduces the number of batteries required. However, a hybrid system still requires a string of batteries so that the peak load situation can be dealt with and also to synchronize the timing for occurrence of peak load and maximum electricity produced. Also, battery storage is required to supply power when the RES are not available. In study of a hybrid system, this intermittent nature of RES can be overcome with the help of system engineering and designing with HOMER. HOMER is capable of selecting an optimized hybrid model to serve the given village load. In a decentralized electricity generation the COE depends on the selection of various RETs and their resources. In contrast to this, electricity from a grid source depends on the COE from the grid connection which in turn depends on the distance of the off-grid location from the existing grid connection point. The difference between the COE from the grid and COE from decentralized hybrid renewable system generation gives the EDL.This dissertation aims to combine two or more RETs in one hybrid system. Depending on the RES available in the village and by gathering the village load data, a stand-alone/mini-grid hybrid RE system is set up based on the combination of SHP, wind turbine, SPV panels, batteries, advanced electrical equipment and a BDG for back-up. The system’s sizing and the design optimization has been done by application of the National Renewable Energy Laboratory’s (NREL) software HOMER.

CHAPTER 2 Hybrid Concepts

We used genetic algorithms to assess the optimal size of a stand-alone hybrid system to minimize its costs. We found that using a wind-solar hybrid system is cheaper than to rely on one of these resources individually. When carrying out analysis, we took into account various technical details of the system such as the PV modules' tilt angle or the installation height of the wind turbines that were significant for either the COE or for the installation and maintenance costs.

2.1 Introduction to Solar-Wind Hybrid System

In electrical power generation system solar energy generation & wind energy generation is quite clean, available in unlimited amount, inexhaustible & consider as environmental friendly. All these characteristics forces scientist to look forward in renewable energy system on a bigger way. In electrical system the renewable energy has a lot of advantages but still they are come with some disadvantage when they worked alone, so it is found that if we used this system in hybrid way by removing their drawbacks & only using their advantages can be lead to great extent of power energy generation. This hybrid system will overcome the drawbacks of wind & solar energy system give a complement to each other in production of electrical energy. Wind & solar energy is depending upon the unpredictable factors such as weather & climatic condition. As in individual electrical system generation of power are different as in weather where is lot of wind is available in nature have less effect of sun energy while if there is no wind the sun will have more power compare to wind place. It means that abnormal condition for individual energy system is worked complementary factor for others. So this complementary factor invent a new idea to produce the energy by combine of these two condition where prediction weather lying between the two specific condition which full fill the both energy generation criteria broadly known as Hybrid solar wind energy power plant concept. More over Hybrid power plant will be very much affective in decreasing factor for rate of fossil fuels; more over it is also give a lot of convenience in supplying energy to remote area where it is costly to supply the electricity by trendy ways & also does not harm the environment.

Distributed Generation (DG) refers to small power plants (a few watts up to 1MW) at or near the loads, operating in a stand-alone mode or connected to a grid at the distribution or sub-transmission level, and geographically scattered throughout the service area. Distributed generation system involves small & custom power generation technologies for the electricity production. These generation units are suitable to locate near the load. Distributed generation system is very much used technologies both fashion of standalone mode as well as in grid parallel mode. It is also a fact that in our conventional electricity generation system it will be convenient that generation unit is placed near to the fuel source. This condition are so applied in practical is tend to operate the system away from the town or residential area so we can say that by the convention energy generation it may be possible that the either generation system can be located near the load side or near to the fuel side. If load is away from the generation system then there is also one more term affect the system is required large investment in power transmission. So for the better & cheap power transmission again for the remote areas this hybrid system can be effective for the power generation. More over if we talk about the distribution generation system there would be a lot of losses are involved in the system which further introduce the various equipment for the protection unit which further increase the electricity charges to the consumer so it is need for the electrical system that there should be as much as possible low cost will be introduce in the system in which HYBRID SOLAR- Wind Energy system is very much helpful.

2.1.1 WIND POWER

Wind energy system is a phenomenon worked on the movement of air masses at different solar heating at earth’s surface. It is assumed as the primary phenomenon of air movement which is depending upon the sun heating. Some other criteria are also important for the flow of air such as environment pressure, sea pressure & other terms which are related to cause of temperature difference.

In environment the weather also affect the strength of energy received from the sun as in different seasonal condition the energy which are received from the sun for the wind turbine are different & this will ultimately affect strength & direction of wind which is further also affect the energy production.

The wind turbine captures the winds kinetic energy in a rotor consisting of two or more blades mechanically coupled to an electrical generator. The turbine is mounted on a tall tower to enhance the energy capture.

2.1.2 SOLAR POWER

The solar modules (photovoltaic cell) generate DC electricity whenever sunlight falls in solar cells. The solar modules should be tilted at an optimum angle for that particular location, face due south, and should not be shaded at any time of the day.

2.1.3 HYBRID SOLAR-WIND SYSTEM

A stand-alone wind system with solar photovoltaic system is the best hybrid combination of all renewable energy systems and is suitable for most of the applications, taking care of seasonal changes. They also complement each other during lean periods, for example, additional energy production through wind during monsoon months compensate the less output generated by solar through wind during monsoon months compensate the less output generated by solar. Similarly, during winter when the wind is dull, solar photovoltaic takes over. The hybrid solar wind power system is as shown in figure 1.

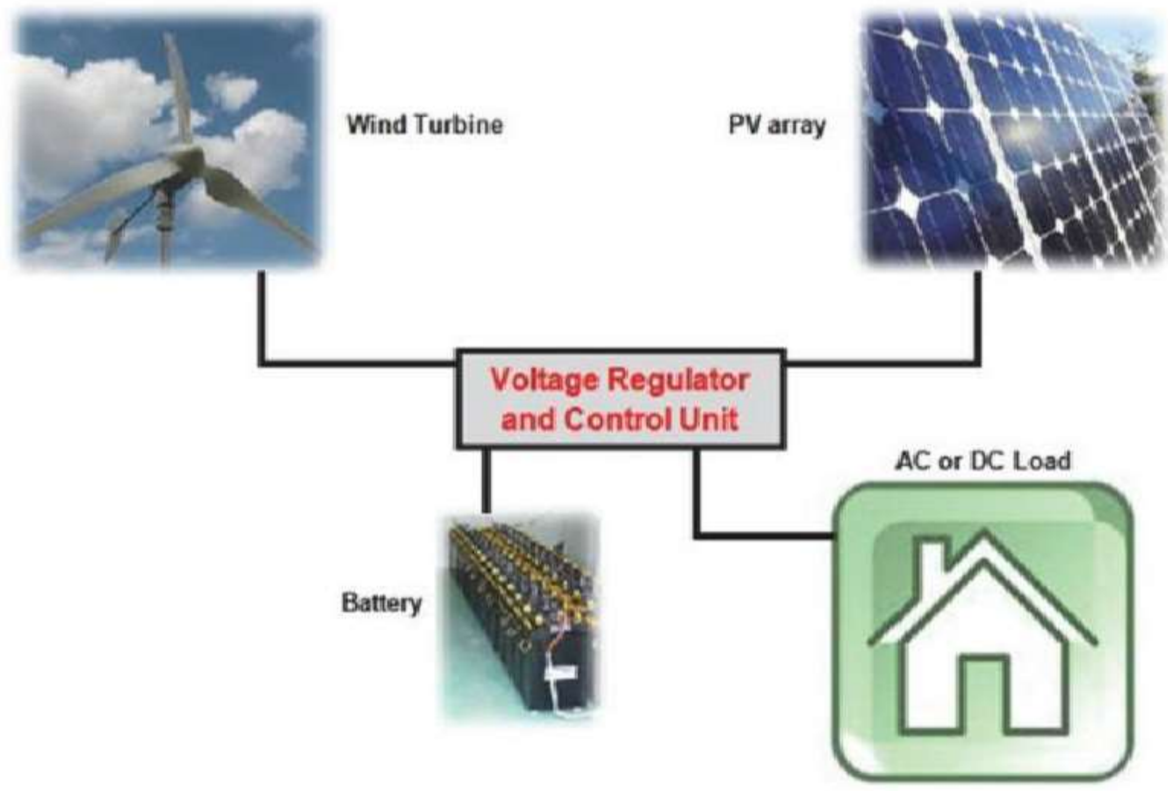

Figure: 1 Solar-wind hybrid power system

2.1.4 Benefits of hybrid system:

- Reliable,
- Continuous power,
- Maximizing renewable usage,
- Benefit in terms of fuels, flexibility, economics
- High Efficiency:- Incorporating heat, power & highly- efficient devices.
- Enhanced Reliability,
- Lower Emissions: lower Emissions of Pollution & less use of Fossil Fuels.

2.1.4 Application of solar wind energy

Applications of Solar-Wind Hybrid Power System are listed below as:

- Remote and rural village electrification
- Ideal for cell phone recipient stations,
- Residential colonies and apartments for general lighting
- Street lighting

With the use of renewable energy based system the emission of carbon and other harmful gases are reduced to approximately 80% to 90% in environments. This quality of electrical energy is quite important from the point of environmental view as far as for the saving the nature from the pollution & also preserving the natural resources in the nature too as wind & solar energy are available in the climate are free of the cost & available in great amount & never going to end. This is the best phenomenon which is associated with the hybrid power generation system forces us more to look forward this in near future for the huge generation purpose.

CHAPTER 3 MODELLING IN HOMER

The models for RET systems are highly dependent on specific site meteorological data and the load profile. A system relying only on one energy source can never provide a viable solution; to make a system feasible it is always necessary to rely on a combination of two or more different power sources. This study tries to take a general outlook and considers alternative options including biodiesel. The work uses HOMER but this study has tried to go beyond by including a detailed load analysis and suggesting ways of analyzing the results.

3.1 CONCEPT OF HOMER (*The Hybrid Optimization Model for Electric Renewable energy)*

Homer micro power optimization software is a computer model that was developed by NREL in the U.S.A. One of the major applications of HOMER is the design of micro power systems for the efficient evaluation of various RE power generation technologies. It compares a wide range of equipment with different constraints and sensitivities to optimize the system design. In the early phases of planning and decision making in rural electrification projects, HOMER can be of significant use for the designing of the system due to its flexibility. Its analysis is based on the technical properties and the LCC of the system. The LCC is comprised of the initial capital cost, cost of installation and operation costs over the system's life span.

The modeler can input varying data and compare different designs based on their technical and economic factors. HOMER also considers the effects of uncertainty in its modeling. It allows modeling of grid-connected or off-grid systems, generating electricity and heat from various combinations of SPV Modules, Wind turbines; Biomass based power generation, micro-turbines, fuel cells, batteries, hydrogen storage, and generators with various fuel options. Designing a micro power system with various design options and uncertainty issues in demand loads and fuel prices makes it a challenge. HOMER was designed to overcome these challenges and also the complexity of the RES being intermittent, seasonal, and non dispatch able and having uncertain availability.

Simulation, Optimization and Sensitivity analysis are the three major actions run by HOMER. In the simulation process, different micro power system configurations for every hour of the year are generated with their technical feasibility and LCC. In the optimization process, HOMER selects one system configuration out of all configurations generated in the simulation process that satisfies all technical constraints and has the lowest LCC. In the sensitivity analysis, multiple optimizations are performed on the selected configurations by Homer with a range of uncertain input parameters that is assumed to affect the model inputs with time. For the different variables known to the system designer- that is, the mix of system components and their respective quantity and size - the optimization process allows to calculate the optimal value. There are, however, also unknown factors such as uncertainties or changes in the variables outside the designer's control (for example, rises in the fuel price or the average wind speed). The effects of these can be analyzed with the help of the sensitivity analysis.

From figure 2 the correlation between simulation process, optimization by HOMER & different selectivity analysis are shown. From a very first view of figure it can be easily understandable that an optimization may consist of one simulation process or multiple simulation process. Again the selectivity analysis also can consist of multiple optimization process but for any given plant there will be only a selectivity analysis is possible. So here by to illustrate HOMER 3 process are need to be explained which are categorized as

1. *SIMULATION*
2. *OPTIMIZATION*
3. *SENSITIVITY ANALYSIS*

1: SIMULATION

This is the first process to start work in the HOMER. In simulation tool firstly we design our system in the HOMER and also assign the entire system component with their specific value which are relate to that component. HOMER leads energy balance calculation for each of the hour in year to simulate the operation of system. It will compare electrical & thermal demand in the hour and will calculate the flows of energy to & from each component of the system. In a system there is provision of adding batteries or fuel powered generators & other supporting element. HOMER also is capable to decide the on which time it is required to operate the generator & whether there is need of charging the batteries or not?

When the simulation is started in the HOMER it will perform all the energy balance calculation for each of configured system that has been integrated with the system. After the energy balance calculation HOMER will determine that whether this configuration is feasible or not. When it is feasible, an estimation of cost for the installing & operating the system over the required life of project. It will represent the cost calculation such as capital cost, replacement cost, operation & maintenance cost fuel cost & interest on the capital investment

2. OPTIMIZATION Technique

When the simulation of any given system is been performed with their respected possible configuration then HOMER has tool name of *OPTIMATION* tool which is able to give the list of all possible configuration sorted by net present cost which is also some time termed as lifecycle cost, which is used in comparing the system design option for the economic purpose.

3. SENSITITIVITY ANALYSIS

There is in system a many of instrument or input are available which are variable & this will caused the confliction in data obtained for the designed system & also by this there is a lot of chances that obtained result from the HOMER is differ than the actual value. So there is a need of sensitivity in the systems which are tending to be varying time to time. In HOMER these problems is overcome by SENSITIVE ANALYSIS which senses the entire sensitive variable as input side & repeat the analysis for the optimization process for each sensitive variable which have been specified in the designed system. Mostly the things which are varying in the system are wind speed, cost of fuel, intensity of the sun light & others in the HYBRID SOLAR WIND energy System is found frequently.

Let for an example if wind speed is a sensitive variable it will simulate system configuration for the wind speed range that has been specified in the data sheet.

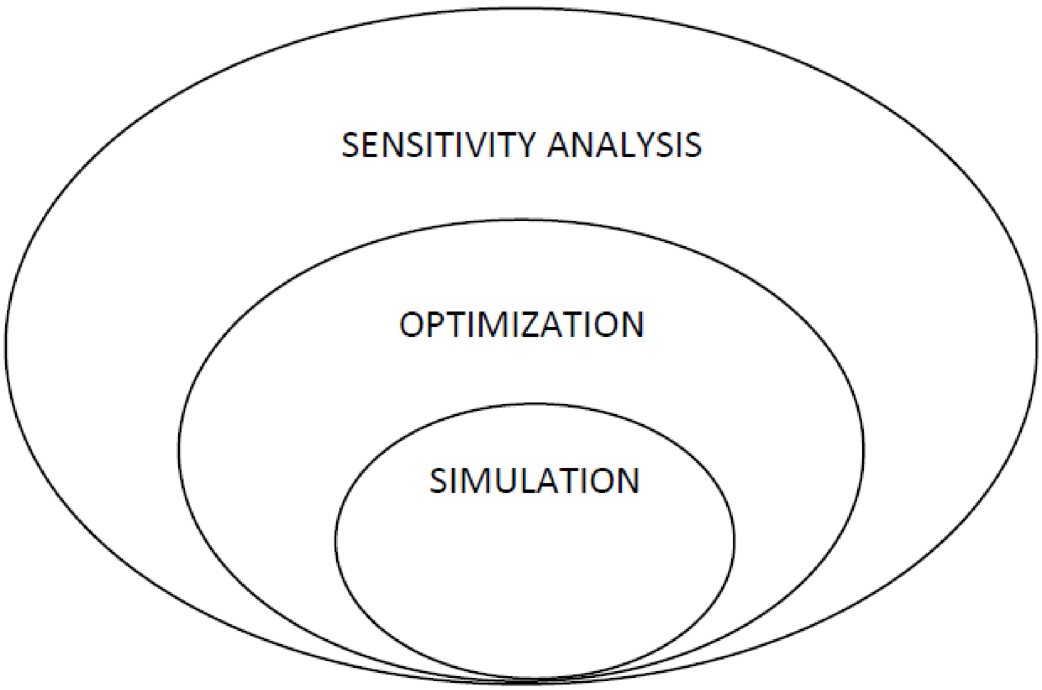

Figure 2: - Relationship between simulation, optimization, and sensitivity analysis.

One of the results of HOMER's simulation is the EDL (kilometers), where creating a renewable stand-alone/mini-grid system is cost-competitive with a grid extension. HOMER has advantages over the usual statistical models, since its high processing speed allows it to run and evaluate an hourly simulation of thousands of possible system configurations, whereas statistical models usually only compare the average monthly performance of the configurations. Simulations modeled by HOMER are thus more accurate.

3.2 PHYSICAL MODELING IN HOMER

In section 3.1, HOMER's role for the simulation of micro power systems was described. Also, the three principal tasks that HOMER performs were briefly discussed. This section provides details about the physical operation that HOMER models for its simulation process. The subsections describe the various input parameters HOMER requires to model the system: The energy load demand (village load) that the system has to serve, the selected energy components to generate electricity, the various energy resources associated to the selected components, and how this hybrid combination operates to serve the loads.

3.2.1 Resources Assessment

In the system designed by HOMER, resource is anything that can be used to generate electricity and comes from outside the system. RES available at a location can differ considerably from site to site and this is a vital aspect in developing the hybrid system. As RES like wind, solar are naturally available and intermittent, they are the best option to be combined into a hybrid system.

All of these resources depend on different factors – apart from seasonal or even hourly changes: Whereas the amount of solar energy available is dependent on climate and latitude, the hydro resource depends from the location's topography and its rainfall patterns; the wind resource is influenced by atmospheric circulation patterns and geographic aspects. The resources' dependence of various factors in turn influences when and how much power can be generated and thus the behavior and economics of the hybrid system. As a consequence, successful system modeling significantly depends on the accurate modeling of the RES. This section describes the modeling of the selected RES and Biodiesel (B100) fuel by HOMER.

3.2.2 Solar Energy Resource

The solar resource used for *MATHANIA* village at a location of at Latitude 26.2900° N and Longitude 73.0300° E was taken from Indian Surface Meteorology and Solar Energy.

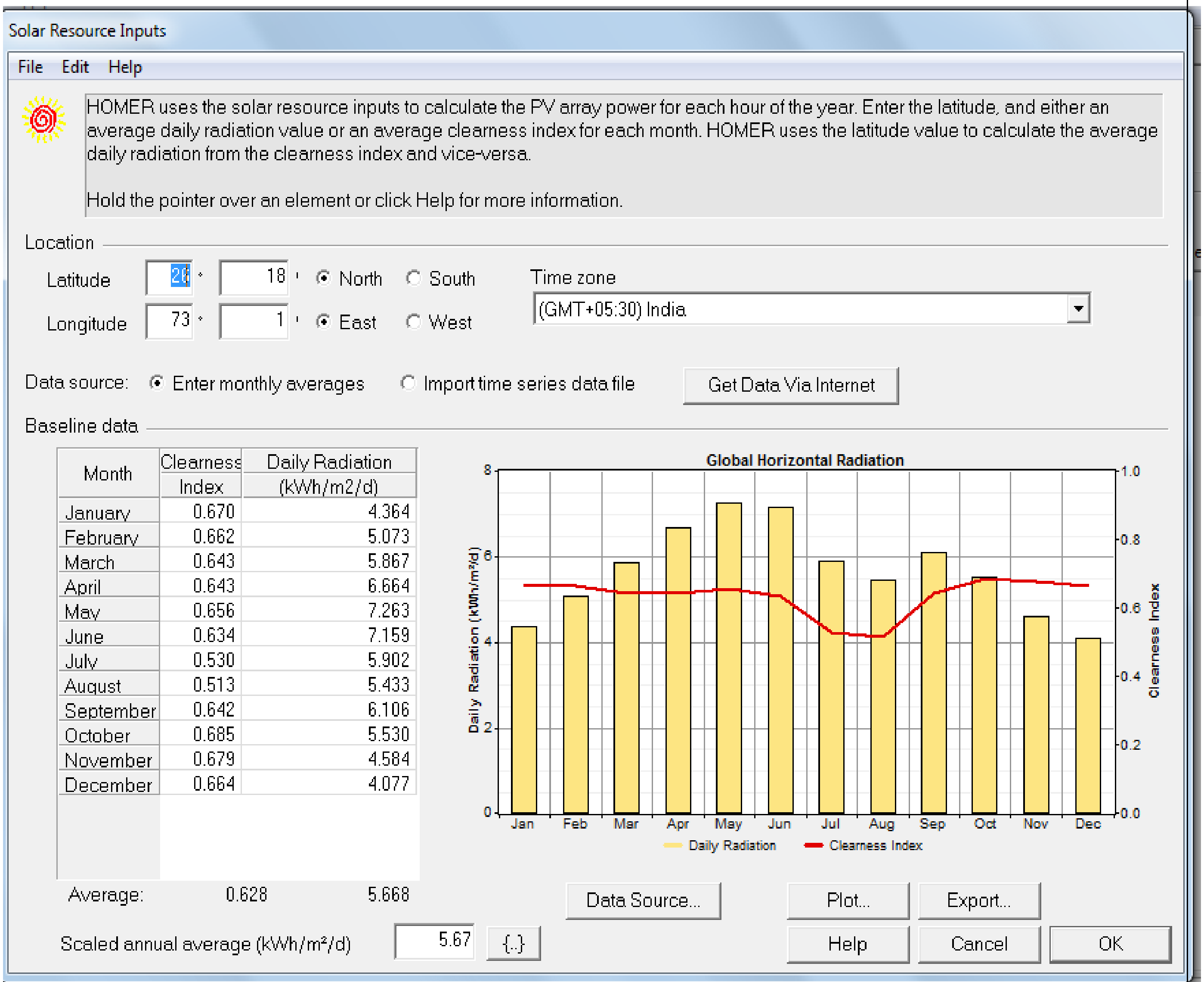

Figure 3: - Solar energy resource.

Figure 3 shows the solar resource profile considered over a span of one year. The annual average solar radiation was scaled to be 5.67 kWh/m2/Day and the average clearness index was found to be 0.548. The graph plot in the figure 3 shows that solar radiation is available throughout the year; therefore a considerable amount of PV power output can be obtained.

3.2.3 Wind Energy Resource

The monthly average wind resource data from an average of ten years was taken from the Nasa resource website based on the longitude and latitude of the village location. Figure 4 shows that the annual average wind speed for the location is 4.49 m/sec with the anemometer height at 50 meter 43 cm.

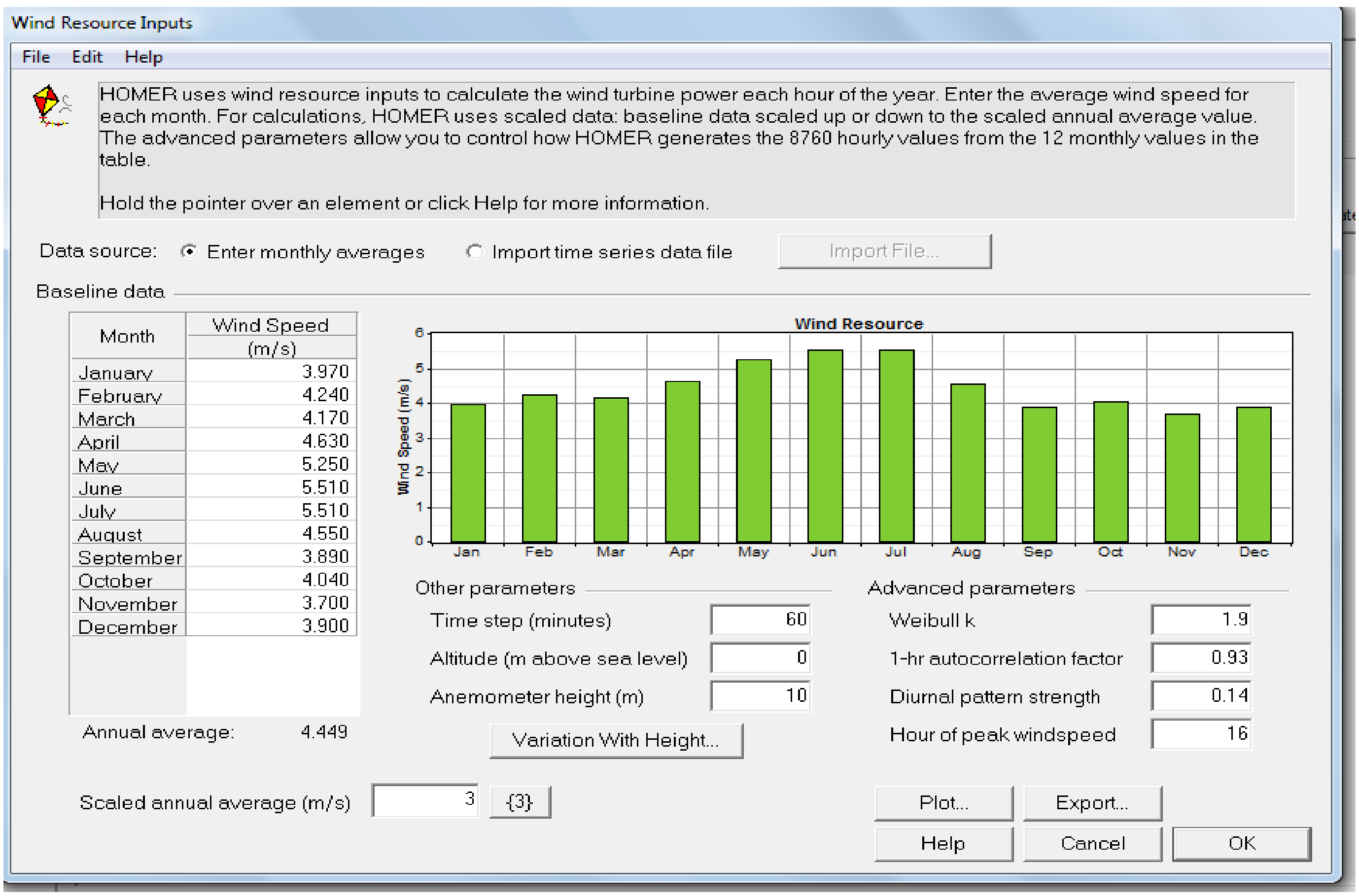

Figure 4: - Wind energy resource .

The wind speed probability and average monthly speed throughout the year can be observed from the table and graph in the above figure. It also shows that there are 15 hours of peak wind speed. The wind speed variation over a day (diurnal pattern strength) is 0.25 and the randomness in wind speed (autocorrelation factor) is 0.85.

3.2.4. Biodiesel (B100) Fuel Source

Biodiesel is a bio-fuel predominantly made from vegetable oil; or sometimes animal fat. Biodiesel can be used to run diesel engines with minor engine modifications (if required). In the world's share for biodiesel feedstock rapeseed oil has 82%, sunflower oil 10%, soybean 5% and palm oil 3%. The raw material used for the production is very much depending on the particular country's resources. In India, with the help of extensive agricultural research, Atrophic Cruces oilseed was chosen as main feedstock for the biodiesel production in India's Biodiesel program. Since biodiesel is mostly derived from plants, there is no addition of CO2 from its combustion. The plants used for the production took CO2 out of the air during their lifetime, which makes the combustion of biodiesel carbon neutral. Depending on the type of crop harvested for production, the CO2 content of the atmosphere can actually be reduced.

There are different blends of biodiesel available in the market to be used commercially.

3.2.5. Biodiesel in India

On 12th September 2008, the Planning Commission of the Government of India (GOI), announced its National Biodiesel Mission. For the development and commercialization of biodiesel, the National Biodiesel Mission launched the Biodiesel Programmed with the aim of biodiesel meeting 20% of the country's diesel requirements by 2012. The GOI decided to use the non-edible oil from Atrophic Cruces instead of edible vegetable oil as the demand for the latter in India is higher than the supply and this decision is a vital element towards India attaining its energy sustainability. India's total biodiesel consumption is projected to grow to 3.6 million metric tons by 2012-13; hence its biodiesel market will grow rapidly. With a view to this, the

Indian state Chhattisgarh aims at becoming a bio-fuel self reliant state by 2015 and decided to 36 plant more than 160 million Atrophic saplings throughout its 16 districts during 2007-2008. It anticipates earning more than $800 million. Lots of initiatives are being taken by the state government in this regard.

3.2.6 Advantages & Disadvantages of Biodiesel

Advantages: -

- Safe to handle and store, biodegradable, non-toxic and made from renewable resources.
- Diesel engines can use pure biodiesel or any blend of biodiesel with conventional petroleum-based diesel fuel with or without any minor engine modifications
- The high cetin numbers of biodiesel contribute to easy cold starting and low idle noise.
- Reduced emissions: - biodiesel comparison with conventional petroleum diesel. Results of the emission tests for pure biodiesel (B100) and 20% biodiesel blend (B20) compared to conventional diesel.

Disadvantages: -

- NO2 emissions are slightly higher than those of petroleum diesel, especially with older engines. This can be eliminated with the use of a catalytic converter.
- Biodiesel has a shelf-life of 6 months.
- B100 and other higher percentage blends of biodiesel might create engine problems in the form of filter plugging, injector choking, piston ring sticking and severe engine lubricant degradation.
- As biodiesel is thicker than petroleum diesel, it can cause problems in areas with low temperatures, which can be solved by adding winterizing agents as done with petroleum diesel.
- There is not much information available on the effects of B100 usage on an engine's lifespan with respect to different environmental conditions. More information and results are needed for further growth in the usage of biodiesel in diesel engines.

- As it is a good solvent, biodiesel can be corrosive and dissolve rubber and some plastics. It can remove paints and form oxides with some metals such as aluminum.

In India, the Ministry of New and Renewable Energy (MNRE) along with the Confederation of Indian Industry (CII) is making continuous efforts for the growth of the Biodiesel industry. The study conducted by MNRE and CII recommends to increase the price of Biodiesel from Atrophic from the current price of $0.58/liter to $0.8/liter for the industry's benefit and to make the growth sustainable. But there are still other issues confronting the biodiesel industry.

One of the main problems in getting the industry rolling is the lack of large-scale cultivation of Atrophic. Farmers do not see Atrophic cultivation as a lucrative option. They lack confidence as there is not much information on the technology and not enough awareness of the government policies for biodiesel. At the same time, any other body concerned with this program for the farmers and small-scale entrepreneurs. This leads to another 40 problem, that of a lack of proper infrastructure for seed collection and oil extraction, which in the absence of long-term purchase contracts from any public body creates disruption in the circulation with no guarantees or arrangements. Finally, there is a problem with the utilization of the excess glycerol (12% of biodiesel produced, 88% pure).

3.2.7. Biodiesel Fuel Inputs

As there is a biodiesel plant in the neighboring city of Raigarh, therefore there is no information about the availability of the fuel for the system

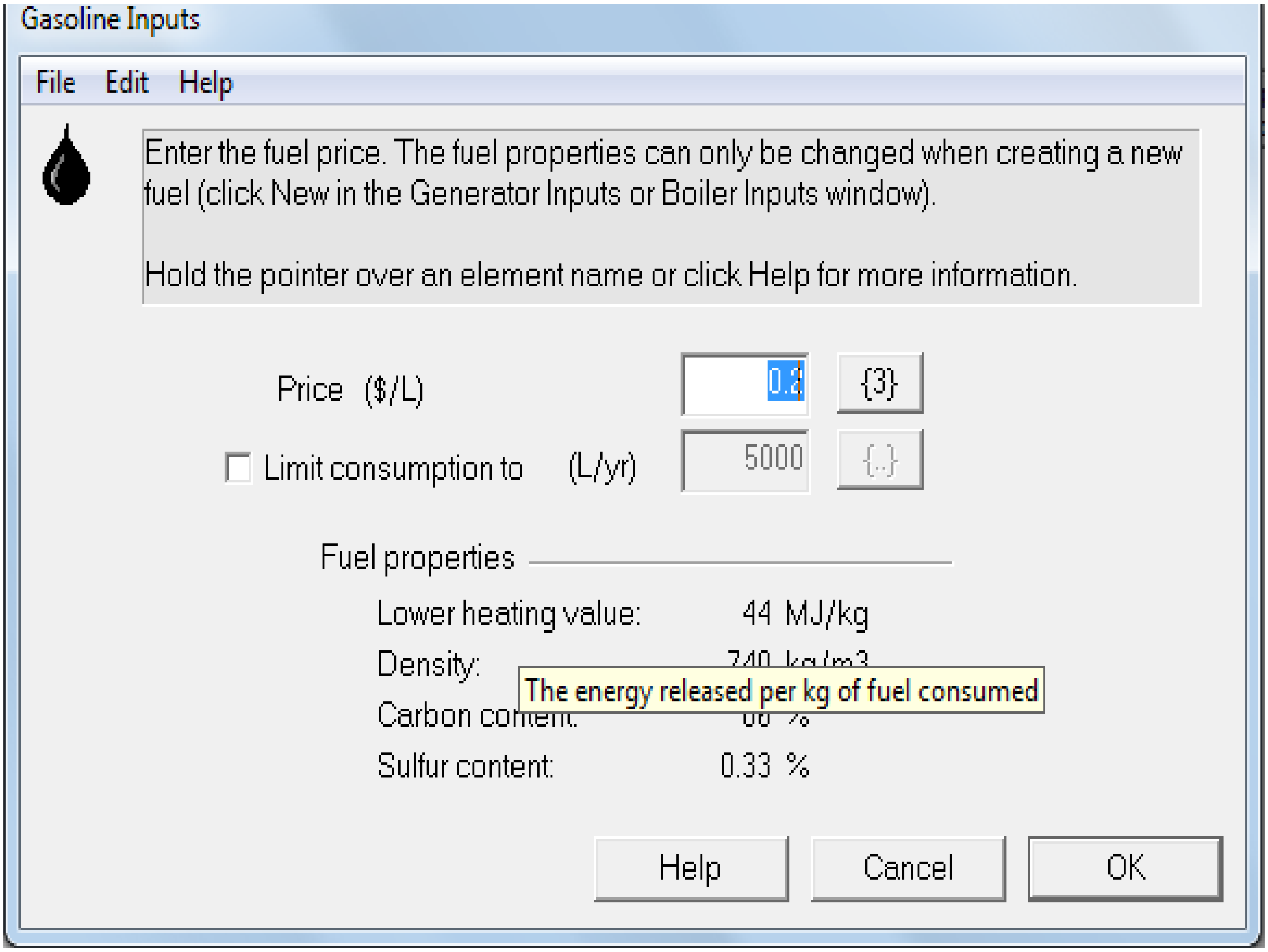

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Figure 5: - Biodiesel (B100) fuel window in HOMER

The fuel properties of B100 are show in figure 5 and the fuel price entered is 0.6 $/L. The current market price of biodiesel in India as per GOI is about 0.58 $/L, though it varies based on region, logistics and state level agencies.

3.3. Components Assessment

In a micro power system, a component generates, delivers, converts and stores energy. In this HOMER analysis, SPV, wind turbines, and run-off river hydropower are the intermittent RES selected with a BDG for backup. Batteries and Converter are for storing, respectively converting, electricity. The Grid connection in this study is only used as a comparison for the analysis and determination of the EDL. The performance and cost of each of the system's components is a major factor for the cost results and the design. Thus, the development of these data was carried out with much diligence. A different set of performance and cost parameters is used by HOMER to characterize each of these different components. The components' technical and cost parameters for this study are based on data collected from The Ministry of Non-Conventional Energy Sources (GOI), The Energy Research Institute (TERI) in India, previous published literatures, information from personal sources of Indian manufactures, and assumptions.

3.3.1 Solar Photovoltaic

The SPV panels are connected in series parallel system. When rays incident on a panel it produces electricity. Power generated by SPV is more than wind turbines at this location due to better solar insulations. The capital cost and replacement cost for a 1kW SPV is taken as $6000 and $5000 respectively. As there is very little maintenance required for PV, only $10/year is taken for O&M costs. The SPV is connected to a DC output with a lifetime of 20 year. The de-rating factor considered is 90% for each panel to approximate the varying affects of temperature and dust on the panels. The panels have no tracking system and are modeled as fixed titled south at 26.01 N latitude of the location with the slope of 76.18.

3.3.2 Wind Turbine

A Generic 1.4kW horizontal-axes wind turbine is considered for this hybrid RET system. The amount of electricity generated by the wind turbine greatly depends on the availability of and variations in the wind speed. The G10 wind turbine selected gives a 1.4kW of DC output. The cost of one unit is taken as $40, 00, while the replacement and the maintenance cost are considered to be $32, 00 and $200/year respectively. This wind turbine has a hub height of 25 meters and a lifetime of 25 years.

3.3.3 Biodiesel Generator

As there is a variety of DG's available from various manufacturers and distributors, it is difficult to compare all the different information. As shown in figure 6 the capital cost, replacement cost, O&M costs of a 100kW BDG are taken as $1200, $1000, and $1.03/hr respectively.1 A normal old DG can be used as well, but it might need certain modifications. The per kW costs are for a new modern DG that can be used for biodiesel as fuel as well and include the costs of installation, logistics and dealer mark-ups. In reality the costs can be higher or lower than those used in this study.

The prices considered are an interpolation of data (quotations) obtained from local Indian manufactures and distributors.

3.3.4 Battery

Batteries are used as a backup in the system and to maintain a constant voltage during peak loads or a shortfall in generation capacity. HOMER models a number of individual batteries for creating a battery bank connected in series-parallel connections.

The prices considered are an interpolation of data (quotations) obtained from local Indian manufactures, distributors and previous published literatures.

3.3.5 Converter

A converter is an electronic power device that is required in a hybrid system to maintain the energy flow between AC and DC electrical components. It has an inverter and a rectifier to do the conversions from DC to AC and vice versa. The capital cost, replacement cost and O&M costs for 1kW systems, which were considered as $750, $750, and $100/year respectively. inverter efficiency of 90% and rectifier efficiency of 85%. In this hybrid system HOMER simulates the system with the inverter and AC BDG to operate simultaneously whenever required. The prices considered are an interpolation of data (quotations) obtained from local Indian manufactures, distributors and previous published literatures.

3.3.6 Equipment Considered

The search space (Figure 6) shows the list of component sizes considered in the analysis to design the correctly sized hybrid system. This way, the best suited combination to serve the village load can be obtained.

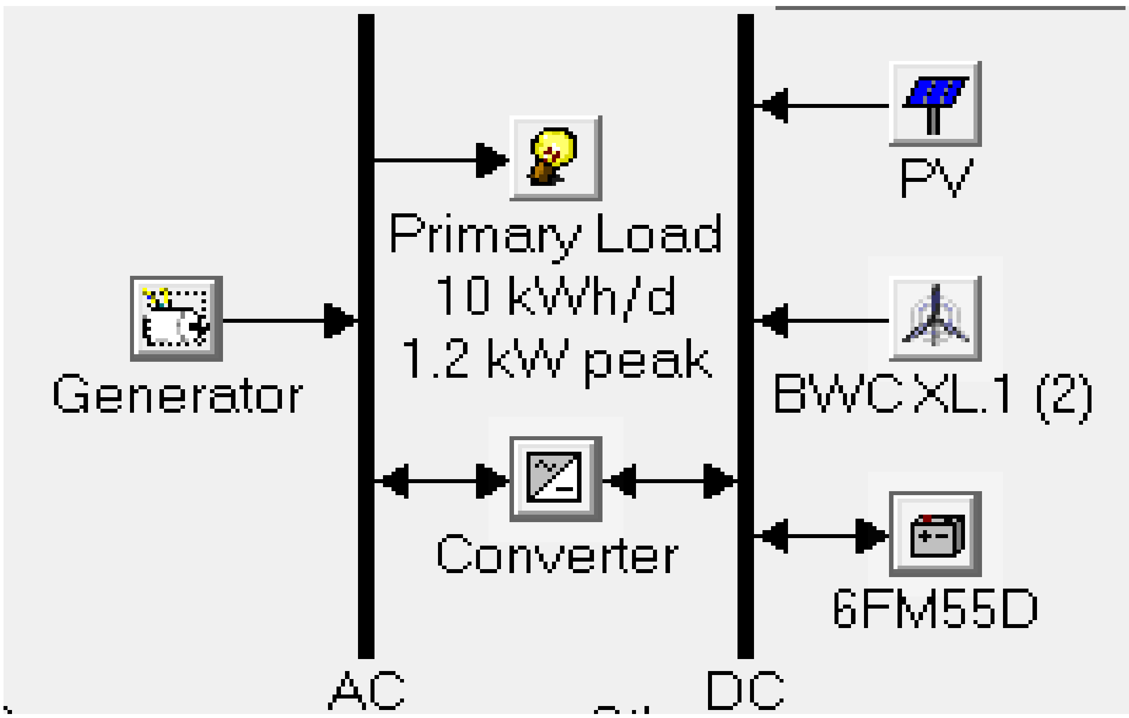


Figure 6: - Equipment search space for different sizes considered.

The figure shows the sizes selected as overall winner and category winner in different combinations for the SPV array, BDG, G10 wind turbine, converter and the S6CS25P battery. All equipment details, resource details and component parameters, efficiency curves, cost curves, etc.

3.4 Sensitivity Inputs

The key variables for the micro power system are, however, often uncertain. This is a major problem to be overcome in the designing of the system. Here, one of the most important characteristics of HOMER comes into play: This software is able to conduct a sensitivity analysis on hourly data sets with the help of scaling variables. This way, uncertainties in the primary electric load or the RES (wind, hydro, solar and biomass) can be taken into account. Consequently, the sensitivity analysis allows the system designer to create a good and practical design in spite of uncertainties in the key variables. The hourly data sets used for the sensitivity analysis consist of 2560 values each.

3.5 System Dispatch

Apart from choosing the different components, HOMER has to make various decisions regarding the working together of these components, such as whether power should be sold to or bought from the grid, whether batteries should be charged or discharged, which generators should operate and at what power level etc. Furthermore, all of these decisions have to be taken for every hour of the day. The concepts of operating reserve and load priority affect HOMER's dispatch decisions and are briefly discussed in the sections below.

3.6 Operating Reserve

Problems arising with micro power systems are the variability of the RES' power output and the possibility that the electric load demand might suddenly increase to surpass the operating capacity (which will lead to an outage). Therefore, every system needs an operating reserve, which is surplus generating capacity to provide a safety gap and be able to respond to these problems. The amount of a system's operating reserve always equals its operating capacity minus the electrical load.

3.7 Load Priority

Homer follows a load priority system, where it takes a separate set of decisions on the allocation of electricity produced by the system. HOMER serves the electricity produced from an AC source to an AC load first, the same goes for DC. In this study, as all loads are of AC connections, HOMER serves primary load 1 and primary load 2 followed by the deferred load

3.8 Economic Modeling

As it is HOMER's aim to minimize the total net present cost (NPC) both in finding the optimal system configuration and in operating the system, economics play a crucial role in the simulation. The indicator chosen to compare the different configurations' economics is the life-cycle costs (LCC), and the total NPC is taken as the economic figure of merit. The advantages of these indicators are described in this section.

The main difference between renewable and non-renewable resources regarding to costs is that non-renewable resources usually have low capital and high operating costs, whereas for RES the costs are generally distributed in the opposite way: After a considerable investment in the beginning, the system can be operated at a comparatively low cost. To be able to compare the economics of numerous different system configurations with a varying share of renewable and non-renewable energy sources, HOMER has to take into account both the operating and capital costs. Since the LCC comprises of all costs incurred during the system's life span, it considers these factors and therefore is the appropriate parameter to compare the different configurations' economics.

This LCC is determined with the help of the NPC, which expresses all costs and proceeds occurring during a system's life span in one total sum (in dollars). Future earnings are discounted back to the present using the discount rate, which is – just as the system's life span – set by the system designer. The different items making up the NPC are the costs for construction, maintenance including component replacements, buying power from the grid and miscellaneous other costs. Furthermore, the NPC also considers salvage costs that is the residual value of system components after the project's end.

HOMER factors inflation out of the analysis with the help of the assumption that prices

3.9 Analysis with HOMER

HOMER performs the simulation for a number of prospective designed configurations. After examining every design, it selects the one that meets the load with the system constraints at the least LCC. HOMER performs its optimization and sensitivity analysis across all mentioned components and their resources, technical and cost parameters, and system constraints and sensitivity data over a range of exogenous variables. The results for two different hybrid system options are compared regarding the least-cost scenario.(10) The competitiveness of the best suited hybrid RET system for rural electrification is compared with the conventional option of grid extension, based on the COE for both options and based on this the EDL is determined. The cost of low tension transmission distribution lines within villages has been excluded, since it is the same in all the cases.

CHAPTER 4 **SIMULATION ON HOMER**

"*A case study on jodhpur and its energy demand of 10 kWh/day was conducted. They built a hybrid SPV-wind-battery system, with 1 kW wind and 2.6 gasoline g, which led to a COE of 0.83 $/kWh. The authors envisaged several scenarios in their study and examined the difficulties arising in each such as unmet load situations, emission decrease, excess electricity and the energy cost."*

4.1 Representation of Model in HOMER

The simulated model of Hybrid Solar Wind energy system is shown in figure

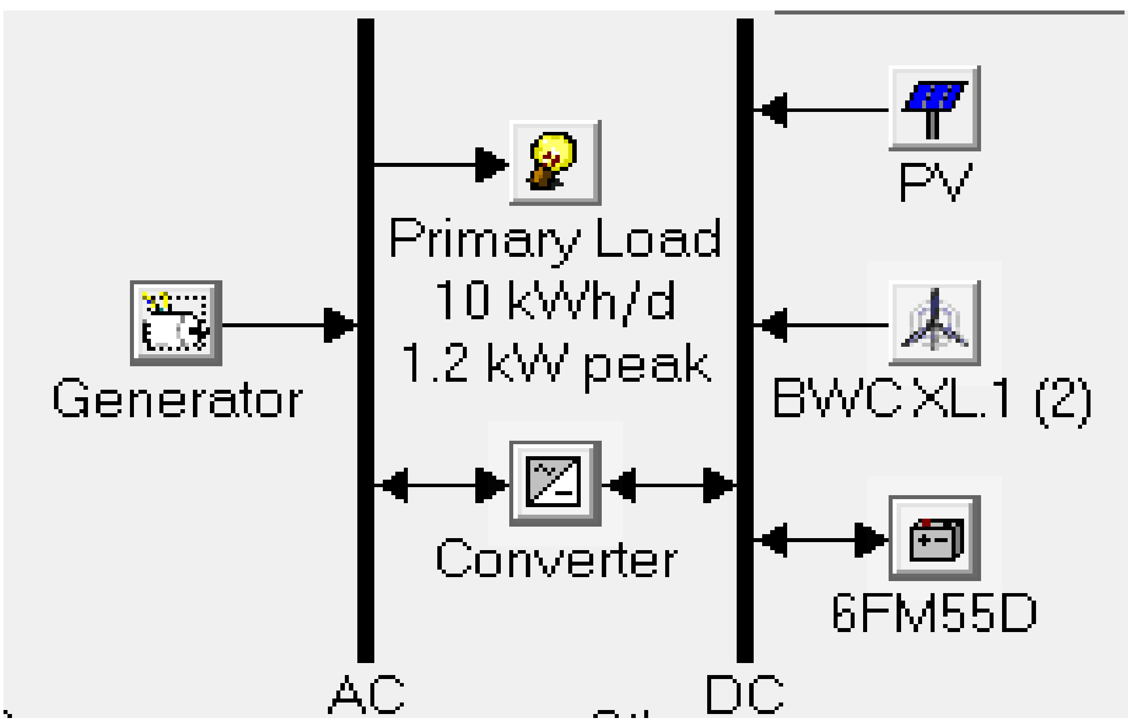


Fig 7: Hybrid model of solar-wind in HOMER

A combination of SPV and a small wind turbine with fuel cells was used. The combination with fuel cells for excess electricity was found to be well suited for remote communication applications. The use of fuel cells could stabilize the electricity supply for communication stations in unfavorable weather. The fuel cell system responded to fast load switching and its efficiency of converting hydrogen into electricity was over 42%.

The Hybrid Optimization Model for Electric Renewable (HOMER) software is used as a tool to carry out the research. The main objective of this report is to assess the feasibility and economic viability of utilizing hybrid Solar–Wind–battery based standalone power supply systems to meet the load requirements.

The PV, wind turbine, generator and battery as back-up is the basis of assessment. The results from the simulation of renewable hybrid system shows that in order to reduce the COE, it is important to look into the amount of excess energy the system produced. COE is defined as the ratio of total annualized cost and annual load served, reducing the annualized or/and increasing the annual load served should be one of the objective of optimization.

Discusses on the optimization of the renewable energy hybrid system based on the sizing and operational strategy of generating system. In this case study, PV array system, wind turbine, diesel generator with battery and converter are the components chosen for the analysis.

HOMER is the software which as enable to simulate the system based on calculation of installation cost of the generating unit, replacement cost of the generation unit, their maintenance cost, fuel expenses & interest on the capital cost as all these prior information are feed to the HOMER as the input & able to calculate the approx cost of generation.

By this cost calculation we are able to discuss the advantages & disadvantages of the Hybrid solar & wind energy power plant at Jodhpur site & can compare with the trendy power generation system. HOMER is also capable to calculate the cost per kilowatt of central grid or at utility supply. The other important factor about the Hybrid power generation from solar & wind energy is the payback period of this energy is quite longer than the previous and almost for more than 35 years. The supply grid option is till now found that it is a very cheap option but this option is not suitable for the rural areas where population is not so much that the transmission may become costly & too much losses are involved during the transmission & distribution of the energy.

In our research simulation is done on HOMER software and the research is going on it is found that Hybrid solar energy would be cost effective where central grid utility is expensive & require in reduction in equipment cost by installation of many hybrid system in a farm thereby lowering the investment cost per kilowatts

The various inputs which has been taken on the site for the simulation of my research are as follows

In this study, decision variables in HOMER include:

- Solar data: scaled annual average:5.67KWh/m2/d.
- Wind data: Auto correlation factor: 0.93, Hours of peak wind speed: 13, Anemometer height: 10 m, Scaled annual averages: 3 m/sec.
- 1KW size DC/AC converter used
- Diesel Data: Life time: 2.6 kW generators: 30,000 hours, life time, Minimum load ratio: 30% are used.

4.2 Detail of data Used in HOMER as Input

4.2.1 AC Load: Primary Load

Table 1: load on primary side

Data source:	Synthetic
Daily noise:	15%
Hourly noise:	10%
Scaled annual average:	10 kWh/d
Scaled peak load:	1.22 kW
Load factor:	0.342

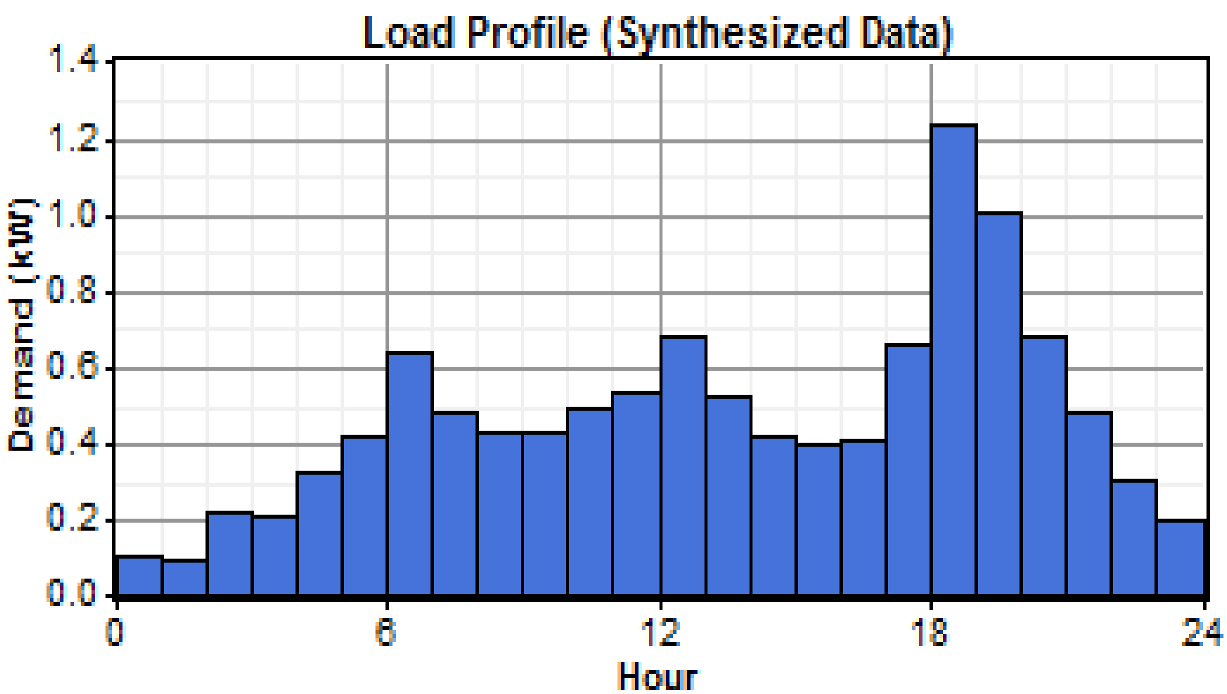


Figure 8: load profile for the primary load with respect to demand per hour in a day

4.2.2 Solar power plant Specification

Table 2: Solar power plant Specification (PV)

Size (kW)	**Capital ($)**	**Replacement ($)**	**O&M ($/yr)**
1.000	6,000	5,000	1

Sizes to consider:	0, 1, 2, 3, 4, 5 kW
Lifetime:	25 yr
De-rating factor:	90%
Tracking system:	No Tracking
Slope:	26.3 deg
Azimuth:	0 deg
Ground reflectance:	20%

4.2.3 Solar Resource

Table 3:Position of sun in MATHANIA

Latitude:	26 degrees 18 minutes North
Longitude:	73 degrees 1 minutes East
Time zone:	GMT +5:30

Table 4: solar radiation resourse

Months	**Clearness Index**	**Average Radiation**
		(kWh/m^2/day)
Jan	0.670	4.364
Feb	0.662	5.073
Mar	0.643	5.867
Apr	0.643	6.664
May	0.656	7.263
Jun	0.634	7.159
Jul	0.530	5.902
Aug	0.513	5.433
Sep	0.642	6.106
Oct	0.685	5.530
Nov	0.679	4.584
Dec	0.664	4.077

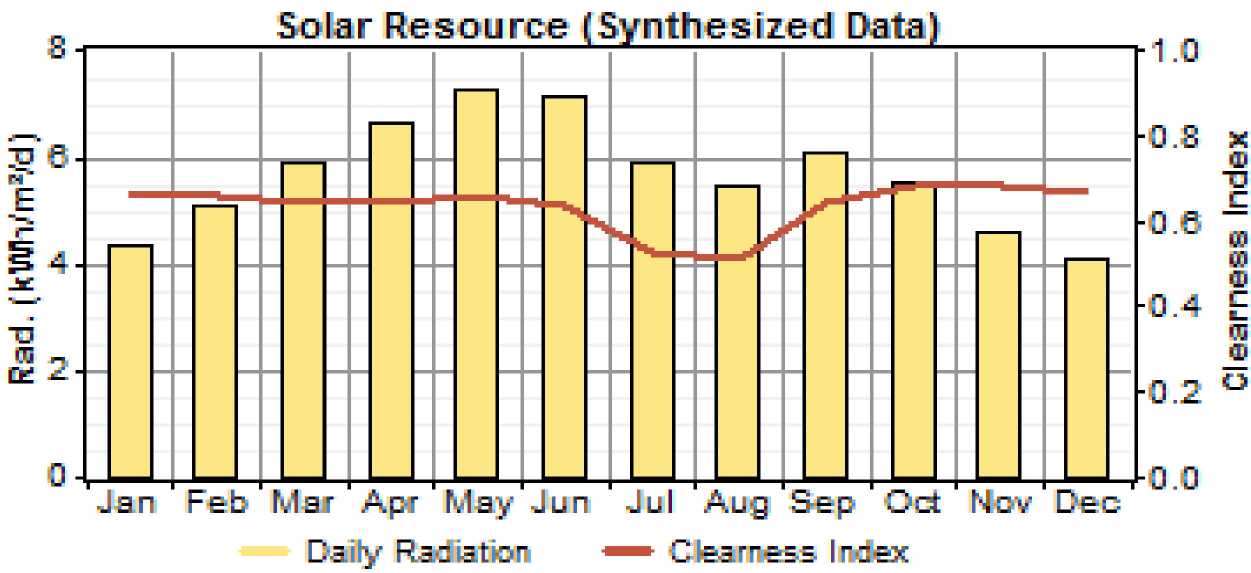


Fig 9: solar resource profile

4.2.4 DC Wind Turbine: BWC XL.1 (2)

Table 5: Wind turbine specification

Quantity	Capital ($)	Replacement ($)	O&M ($/yr)
1	3,900	3,900	100

Quantities to consider:	0, 1, 2
Lifetime:	20 yr
Hub height:	10 m

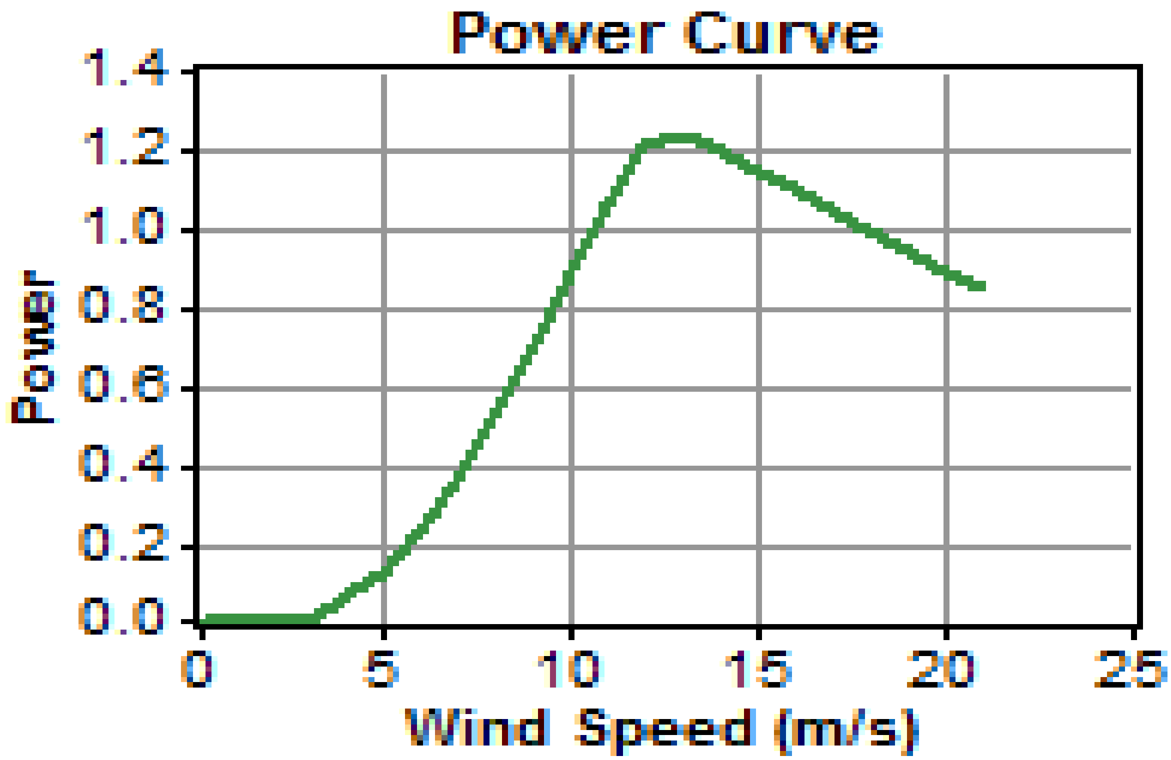


Figure 10: curve between Wind Speed & power Generated by Turbine

4.2.4 Wind Resource

Table 6: wind resource profile

Month	Wind Speed (m/s)
Jan	3.97
Feb	4.24
Mar	4.17

Apr	4.63
May	5.25
Jun	5.51
Jul	5.51
Aug	4.55
Sep	3.89
Oct	4.04
Nov	3.70
Dec	3.90

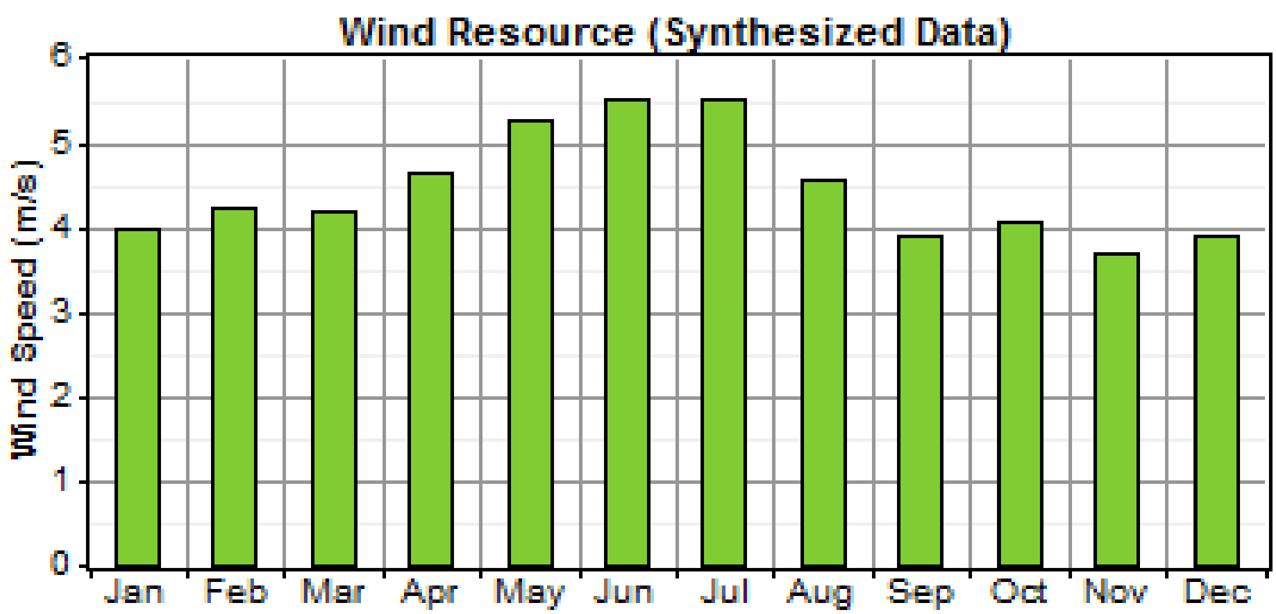


Figure 11: graph for wind speed in month wise

4.2.5 AC GENARATOR

The specification for the AC generator is given in following table

Table 7: specification of alternator

Sizes to consider:	0.0, 2.6 kW
Lifetime:	5,000 hrs
Min. load ratio:	20%
Heat recovery ratio:	0%
Fuel used:	Gasoline
Fuel curve intercept:	0.13 L/hr/kW
Fuel curve slope:	0.32 L/hr/Kw

Table 8: Advance parameter for wind resource

Weibull k:	1.90
Autocorrelation factor:	0.930
Diurnal pattern strength:	0.140
Hour of peak wind speed:	16
Scaled annual average:	3, 4, 5 m/s
Anemometer height:	10 m
Altitude:	0 m
Wind shear profile:	Logarithmic
Surface roughness length:	0.01 m

Size (kW)	Capital ($)	Replacement ($)	O&M ($/hr)
2.600	900	900	0.040

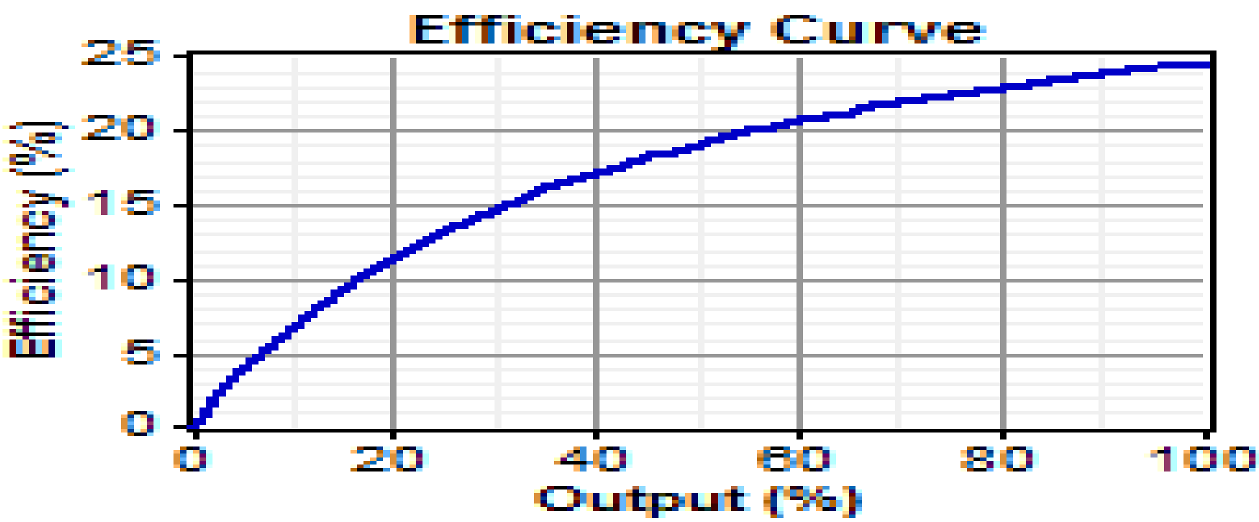


Figure 12: efficiency curve for Hybrid Solar wind energy system

4.2.6 Fuel: Gasoline

Table 9: specification of Gasoline

Price:	$ 0.2, 0.4, 0.6/L
Lower heating value:	44.0 MJ/kg
Density:	740 kg/m3
Carbon content:	86.0%
Sulfur content:	0.330%

4.2.7 Battery: Vision 6FM55D

Table 10: Battery specification

Quantities to consider:	0, 6, 12, 18, 24, 32, 40
Voltage:	12 V
Nominal capacity:	55 Ah
Lifetime throughput:	256 kWh

Quantity	Capital ($)	Replacement ($)	O&M ($/yr)
1	220	220	4.00

4.2.8 Converter

Table 11: Specification of converter

Sizes to consider:	0, 1, 2, 3, 4 kW
Lifetime:	15 yr
Inverter efficiency:	90%
Inverter can parallel with AC generator:	Yes
Rectifier relative capacity:	75%
Rectifier efficiency:	85%

Size (kW)	Capital ($)	Replacement ($)	O&M ($/yr)
1.000	750	750	0

Grid Extension

Table 12: cost of grid

Capital cost:	$ 10,000/km
O&M cost:	$ 0/yr/km
Power price:	$ 0.1/kWh

Economics

Table 13: economic specifications

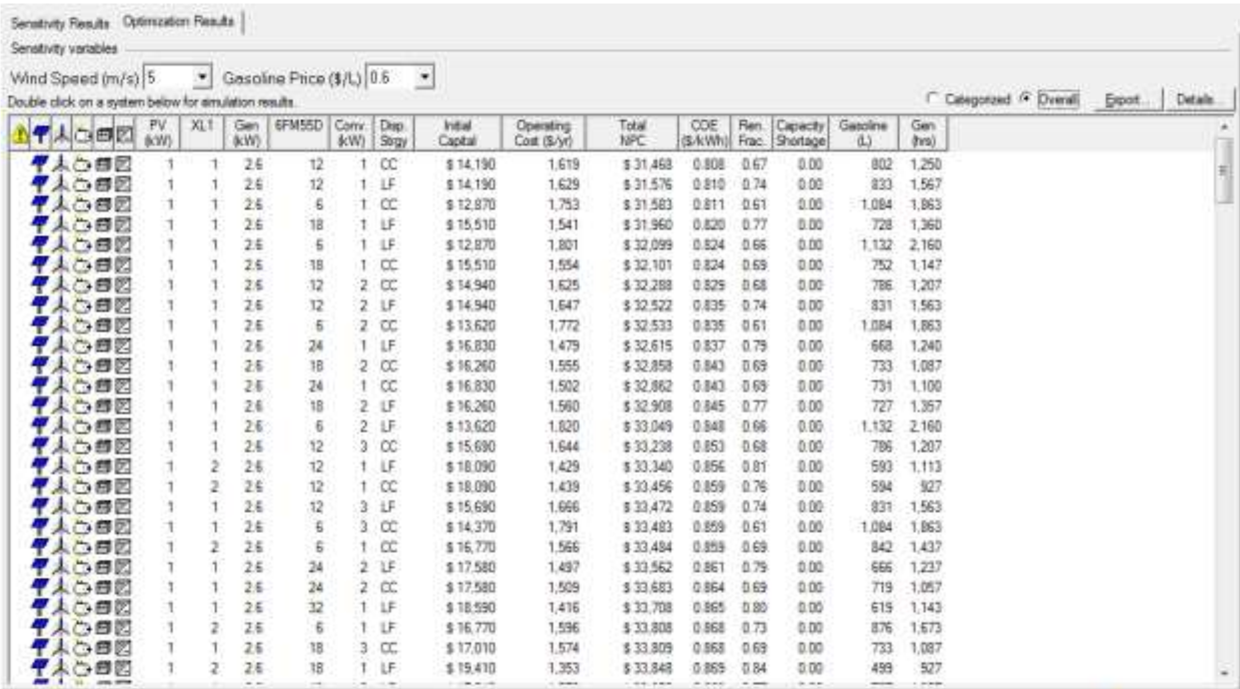
Annual real interest rate:	8%
Project lifetime:	25 yr
Capacity shortage penalty:	$ 0/kWh
System fixed capital cost:	$ 0
System fixed O&M cost:	$ 0/yr

CHAPTER 5 RESULTS & DISCUSSION

The RE potential and techno economic analysis of electricity generation with a hybrid RET system in the village *Mathania* in the Indian state of Rajasthan were performed in this study. Different scenarios have been considered and future developments in the fuel price and in the costs for RETs (which can be expected to sink due to technical progress) have also been taken into account. The sizing of the various components paid regard to the necessity of an operation reserve to enable the system to provide reliable energy supply and also allows for a rising energy demand in the future.

5.1 Optimization results

For the off-grid electrification various combinations have been obtained of hybrid systems with SPV, wind turbines, batteries and convertors from the HOMER Optimization simulation. This is shown in fig. 13



PV (kW)	XL1	Gen (kW)	6FM55D	Conv. (kW)	Disp. Strgy	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Capacity Shortage	Gasoline (L)	Gen (hrs)
1	1	2.6	12	1	CC	$ 14,190	1,619	$ 31,468	0.808	0.67	0.00	802	1,250
1	1	2.6	12	1	LF	$ 14,190	1,629	$ 31,576	0.810	0.74	0.00	833	1,567
1	1	2.6	6	1	CC	$ 12,870	1,753	$ 31,583	0.811	0.61	0.00	1,084	1,863
1	1	2.6	18	1	LF	$ 15,510	1,541	$ 31,960	0.820	0.77	0.00	728	1,360
1	1	2.6	6	1	LF	$ 12,870	1,801	$ 32,099	0.824	0.66	0.00	1,132	2,160
1	1	2.6	18	1	CC	$ 15,510	1,554	$ 32,101	0.824	0.69	0.00	752	1,147
1	1	2.6	12	2	CC	$ 14,940	1,625	$ 32,288	0.829	0.68	0.00	786	1,207
1	1	2.6	12	2	LF	$ 14,940	1,647	$ 32,522	0.835	0.74	0.00	831	1,563
1	1	2.6	6	2	CC	$ 13,620	1,772	$ 32,533	0.835	0.61	0.00	1,084	1,863
1	1	2.6	24	1	LF	$ 16,830	1,479	$ 32,615	0.837	0.79	0.00	668	1,240
1	1	2.6	18	2	CC	$ 16,260	1,555	$ 32,858	0.843	0.69	0.00	733	1,087
1	1	2.6	24	1	CC	$ 16,830	1,502	$ 32,862	0.843	0.69	0.00	731	1,100
1	1	2.6	18	2	LF	$ 16,260	1,560	$ 32,908	0.845	0.77	0.00	727	1,357
1	1	2.6	6	2	LF	$ 13,620	1,820	$ 33,049	0.848	0.66	0.00	1,132	2,160
1	1	2.6	12	3	CC	$ 15,690	1,644	$ 33,238	0.853	0.68	0.00	786	1,207
1	2	2.6	12	1	LF	$ 18,090	1,429	$ 33,340	0.856	0.81	0.00	593	1,113
1	2	2.6	12	1	CC	$ 18,090	1,439	$ 33,456	0.859	0.76	0.00	594	927
1	1	2.6	12	3	LF	$ 15,690	1,666	$ 33,472	0.859	0.74	0.00	831	1,563
1	1	2.6	6	3	CC	$ 14,370	1,791	$ 33,483	0.859	0.61	0.00	1,084	1,863
1	2	2.6	6	1	CC	$ 16,770	1,566	$ 33,484	0.859	0.69	0.00	842	1,437
1	1	2.6	24	2	LF	$ 17,580	1,497	$ 33,562	0.861	0.79	0.00	666	1,237
1	1	2.6	24	2	CC	$ 17,580	1,509	$ 33,683	0.864	0.69	0.00	719	1,057
1	1	2.6	32	1	LF	$ 18,590	1,416	$ 33,708	0.865	0.80	0.00	619	1,143
1	2	2.6	6	1	LF	$ 16,770	1,596	$ 33,808	0.868	0.73	0.00	876	1,673
1	1	2.6	18	3	CC	$ 17,010	1,574	$ 33,809	0.868	0.69	0.00	733	1,087
1	2	2.6	18	1	LF	$ 19,410	1,353	$ 33,848	0.869	0.84	0.00	499	927

Figure 13: - Optimization result details

HOMER uses the total NPC as its main selection tool. All the possible hybrid system configurations are listed in ascending order of their total NPC in the figure shown above. The technical and economical details of all the configurations of the hybrid systems from the optimization process are shown in detail in fig., where the best possible combination of SPV, a BDG and batteries is highlighted in blue and the next best possible combination is marked with a red colored box. The blue highlighted combination is able to fully meet load demands at the lowest possible total NPC.

5.2 Sensitivity Results

Sensitivity analysis eliminates all infeasible combinations and ranks the feasible combinations taking into account uncertainty parameters. HOMER allows taking into account future developments, such as increasing or decreasing load demand as well as changes regarding the resources, for example fluctuations in the river's water flow rate, wind speed variations or the biodiesel prices. Here, the various sensitive variables are considered to select the best suited combination for the hybrid system to serve the load demand. Figure 14 shows the sensitivity analysis detail. It can be observed that with change in the sensitive variables, the configuration of the system changes. Even in this analysis, HOMER ranks the configurations in descending order of their total NPC.

Sensitivity Results | Optimization Results

Tabular | Graphic

Export... | Details...

Double click on a system below for optimization results.

Wind (m/s)	Gasoline ($/L)		PV (kW)	XL1	Gen (kW)	6FM55D	Conv. (kW)	Disp. Strgy	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Capacity Shortage	Gasoline (L)	Gen (hrs)
3.000	0.200		1		2.6	6	1	CC	$ 8,970	1,661	$ 26,697	0.685	0.33	0.00	1,911	3,343
3.000	0.400		1		2.6	6	1	CC	$ 8,970	2,059	$ 30,948	0.794	0.33	0.00	1,808	3,050
3.000	0.600		1		2.6	6	1	CC	$ 8,970	2,434	$ 34,956	0.897	0.33	0.00	1,770	2,930
4.000	0.200		1		2.6	6	1	CC	$ 8,970	1,661	$ 26,697	0.685	0.33	0.00	1,911	3,343
4.000	0.400		1		2.6	6	1	CC	$ 8,970	2,059	$ 30,948	0.794	0.33	0.00	1,808	3,050
4.000	0.600		1	1	2.6	6	1	CC	$ 12,870	2,052	$ 34,775	0.893	0.52	0.00	1,320	2,230
5.000	0.200		1	1	2.6	6	1	CC	$ 12,870	1,253	$ 26,245	0.674	0.60	0.00	1,186	2,137
5.000	0.400		1	1	2.6	6	1	CC	$ 12,870	1,502	$ 28,908	0.742	0.61	0.00	1,115	1,960
5.000	0.600		1	1	2.6	12	1	CC	$ 14,190	1,619	$ 31,468	0.808	0.67	0.00	802	1,250

Figure 14: - Sensitivity analysis details.

In fig14 the least cost configuration is marked in blue, further suitable configurations are marked in red. These red boxes show how the configuration changes with changing sensitivity variables. In the first red box there is no SHP in the configuration due to a zero flow design; hence the component sizes, number of batteries and the costs related to the system increase rapidly.

The second and third red box adds wind turbines to the configuration when the wind speed increases from 3.5m/s to 5m/s. Hence with an increasing number of components the related capital cost and total NPC also increase. .

Figure 15 shows how the system configuration changes due to changes in wind speed and biodiesel price if the design flow rate is fixed at zero-

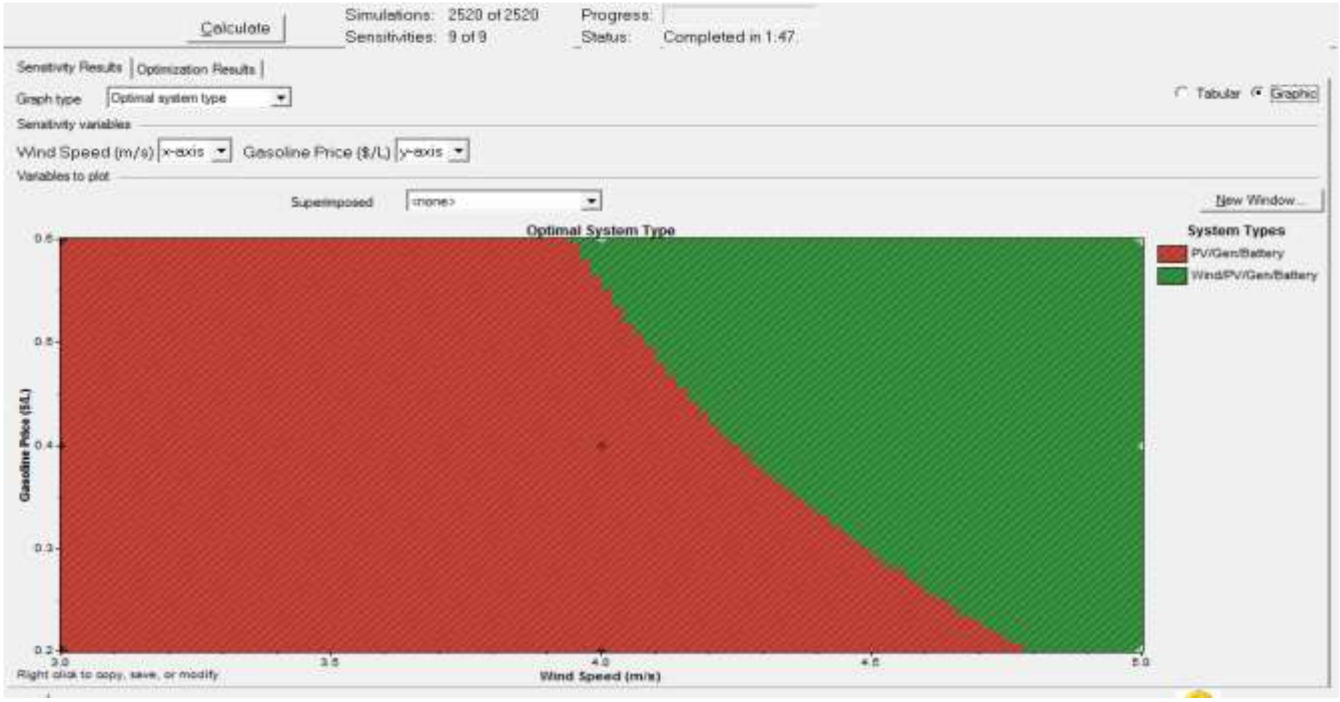


Figure 15: - Optical System graph.

It can be clearly see from the above figure that as the wind speed increase above 3.8m/s, the system configuration changes from SPV, Biodiesel, Battery to Wind, SPV, Biodiesel, and Battery.

The total net present cost is HOMER's main economic output. All systems are ranked according to net present cost, and all other economic outputs are calculated for the purpose of finding the net present cost. The result obtained from the optimization gives the initial capital cost as $14190 while operating cost is 1619 $/year. Total net present cost (NPC) is $31468 and the cost of energy (COE) is 0.808 $/kWh.

CHAPTER 6 CONCLUSION

Even though the initial investment required is comparatively high, the LCC analysis shows that for a remote village with low energy demand, a hybrid system can be cost-competitive due to the high costs for a grid extension. Electricity from the grid as such might be cheap, yet the costs for grid extension and the T&D losses connected with it add up to result in a high cost per unit electricity, especially where the grid has to be extended over a considerable distance. Furthermore, the hybrid system has – once it has been implemented – low O&M costs. For these reasons, a stand-alone/mini-grid hybrid system can be the most financially attractive and reliable solution in these cases.

In this study, a resource assessment and demand calculation have been carried out and the COE per unit has been ascertained for different systems and configurations. A combination of PV, wind, biodiesel and batteries has been identified as the cheapest and most dependable solution with a COE of $0.808/kWh.

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