Optimization and Sizing of Spv-Biomass Renewable Energy System for a Smart Village Using Homer Software

A THESIS SUBMITTED TOWARDS PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE

of

Master of Technology

In

Energy Science and Technology

Course affiliated to

Faculty of Engineering &Technology

Under

Faculty Council of Interdisciplinary Studies Law & Management

Jadavpur University

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2022

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CERTIFICATE OF RECOMMENDATION

This is to certify that the thesis entitled "**Optimization and Sizing of Spv-Biomass Renewable energy system for a smart village using Homer Software**" is a bonafide work carried out by **SOHAG SAHA** under the supervision and guidance for partial fulfilment of the requirement for Post Graduate Degree of Masters of Technology in Energy Science & Technology,during the academic session of 2020-2022.

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The foregoing thesis is hereby approved as a creditable study of a technological subject carried out and presented in manner satisfactory to warrant its acceptance as a pre-requisite to the degree for which it has been submitted.It is understood that by this approval the undersigned persons do not necessarily endorse or approve the thesis only for the purpose for which it has submitted.

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DECLARATION OF ORIGINALITY AND COMPLIANCE OF ACADEMIC ETHICS

I hereby declare that this thesis contains literature survey and original research work by the undersigned candidate, as part of his Master of Technology in Energy Science and Technology studies during academic session 2020-2022.All the information in this document have been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all materials and results that are not original to this work.

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ACKNOWLEDGEMENT

I would like to convey my sincere gratitude and regards to my project supervisor and thesis guide Dr. Ratan Mondal,Professor & Director, School of Energy Studies, Jadavpur University, Kolkata, for his brilliant guidance,encouragement and untiring support throughout the program,which has been a major factor that lead to the successful completion of this thesis.The thesis would not have culminated into the present from without his invaluable suggestion and generous help.I am particularly indebted to him for meticulously monitoring my day to day progress,providing me with important documents,facilities and useful suggestion for the successful completion of the thesis work.

I would especially thankful to the staff members of School of Energy Studies for rendering their help during the experimentation.

I am highly grateful to my institute Jadavpur University,Kolkata for providing me an opportunity to study here and to use the institutes facilities for carrying out thesis work smoothly.

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Abbreviations

Nomenclature

HRES	Hybrid Renewable Energy System
HOMER	Hybrid Optimization of Multiple Energy Resources
HDI	Human Development Index
SPV	Solar Photovoltaic
WT	Wind Turbine
DG	Diesel Generator
COE	cost of energy
NPC	Net present cost
RF,	Renewable Fraction
LCE	Life Cycle Emission
CFL	Compact Fluorescent Lamp
GHI	Global Horizontal Irradiance
Wp	Watt peak
P_{spv}	Daily energy generated (kWh) by single SPV module
P_{mo}	Peak output power of SPV module;
d	Derating factor of SPV module
S_G	Global Irradiance Occurrence on the PV Surface
S_I	Incident Radiation at STC
γ	Temperature Coefficient
θ_{ref}	SPV module temperature at STC;
θ_c	SPV module temperature
ρ	Air density
A	Area swept
C_p	Performance coefficient
η_w	Wind Turbine efficiency
q_b	Battery Charge
IV	Inverter

F_{DG}	Fuel Consumption in DG
SOC_b	Battery of State of charge
q_{bm}	Maximum Battery Charge
$E_{ex}(r)$	Excess Energy
5_{ch}	Battery Charging Efficiency
5_c	Charge Controller Efficiency
E_o	Electric Output (Kw)
F_S	Fuel Curve Slope (0.251 L/H/Kw),
F_I	Fuel Curve Intercept Coefficient (0.625 L/H),
R_c	Rated Capacity of DG (Kw).
ð$_i$	Lifetime equivalent CO_2 emissions of components
N	Number of start-stop
E_o	Energy Generated by DG
E_m	Energy Generated or Stored.
E_c	Energy Produced by the Conventional System
E_r	Energy Produced by the Renewable Source.
E_l	Electricity Consumption (Kwh/Yr/Person)
β_{ms}	Factor For Maximum Surplus Energy Utilized For AC Additional Load
β_{ml}	Factor For Annual Increase In AC Load To Utilized The Surplus Energy
E_L	Surplus Energy (Kwh/Yr)
N_h	Number of human consumer for HRES.
JC_{pv}	Job/MWp by SPV in number Job/MWp
$JC_{biomass}$	by Bio in number Job/MWh/yr
$JC_{battery}$	Job/Mwh by BS in number
LTE	Local Transport based Employment
P_{PV}	Generated Peak Power by SPV in MWp
P_{Bio}	Power by Biomass plant in MW
$E_{battery}$	Battery capacity in MWh

CONTENT

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION OF RENEWABLE ENERGY:

Renewable energy is derived from natural sources that are replenished at a higher rate than they are consumed. Sunlight and wind, for example, are such sources that are constantly being replenished. Renewable energy sources are plentiful and all around us.Fossil fuels - coal, oil and gas - on the other hand, are non-renewable resources that take hundreds of millions of years to form. Fossil fuels, when burned to produce energy, cause harmful greenhouse gas emissions, such as carbon dioxide.Generating renewable energy creates far lower emissions than burning fossil fuels. Transitioning from fossil fuels, which currently account for the lion's share of emissions, to renewable energy is key to addressing the climate crisis.Renewables are now cheaper in most countries, and generate three times more jobs than fossil fuels.[1]

1.2 COMMON SOURCES OF RENEWABLE ENERGY:

1.2.1 SOLAR ENERGY:

Solar energy is the most abundant of all energy resources and can even be harnessed in cloudy weather. The rate at which solar energy is intercepted by the Earth is about 10,000 times greater than the rate at which humankind consumes energy.Solar technologies can deliver heat, cooling, natural lighting, electricity, and fuels for a host of applications. Solar technologies convert sunlight into electrical energy either through photovoltaic panels or through mirrors that concentrate solar radiation.Although not all countries are equally endowed with solar energy, a significant contribution to the energy mix from direct solar energy is possible for every country.The cost of manufacturing solar panels has plummeted dramatically in the last decade, making them not only affordable but often the cheapest form of electricity. Solar panels have a lifespan of roughly 30 years, and come in variety of shades depending on the type of material used in manufacturing.[1]

Fig 1.1 Solar Energy

1.2.2 WIND ENERGY:

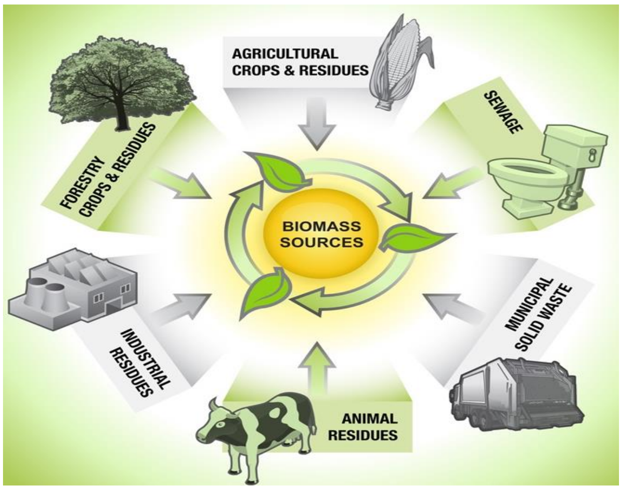
Wind energy harnesses the kinetic energy of moving air by using large wind turbines located on land (onshore) or in sea- or freshwater (offshore). Wind energy has been used for millennia, but onshore and offshore wind energy technologies have evolved over the last few years to maximize the electricity produced - with taller turbines and larger rotor diameters.Though average wind speeds vary considerably by location, the world's technical potential for wind energy exceeds global electricity production, and ample potential exists in most regions of the world to enable significant wind energy deployment.Many parts of the world have strong wind speeds, but the best locations for generating wind power are sometimes remote ones. Offshore wind power offers tremendous potential.[1]

Fig 1.2 Wind Energy

1.2.3 BIO ENERGY

Bioenergy is produced from a variety of organic materials, called biomass, such as wood, charcoal, dung and other manures for heat and power production, and agricultural crops for liquid biofuels.

Most biomass is used in rural areas for cooking, lighting and space heating, generally by poorer populations in developing countries.Modern biomass systems include dedicated crops or trees, residues from agriculture and forestry, and various organic waste streams.Energy created by burning biomass creates greenhouse gas emissions, but at lower levels than burning fossil fuels like coal, oil or gas. However, bioenergy should only be used in limited applications, given potential negative environmental impacts related to large-scale increases in forest and bioenergy plantations, and resulting deforestation and land-use change.[1]



. **Fig 1.3 Bio Energy**

1.2.4 GEOTHERMAL ENERGY

Geothermal energy utilizes the accessible thermal energy from the Earth's interior. Heat is extracted from geothermal reservoirs using wells or other means.Reservoirs that are naturally sufficiently hot and permeable are called hydrothermal reservoirs, whereas reservoirs that are sufficiently hot but that are improved with hydraulic stimulation are called enhanced geothermal systems.Once at the surface, fluids of various temperatures can be used to generate electricity. The technology for electricity generation from hydrothermal reservoirs is mature and reliable, and has been operating for more than 100 years.[1]

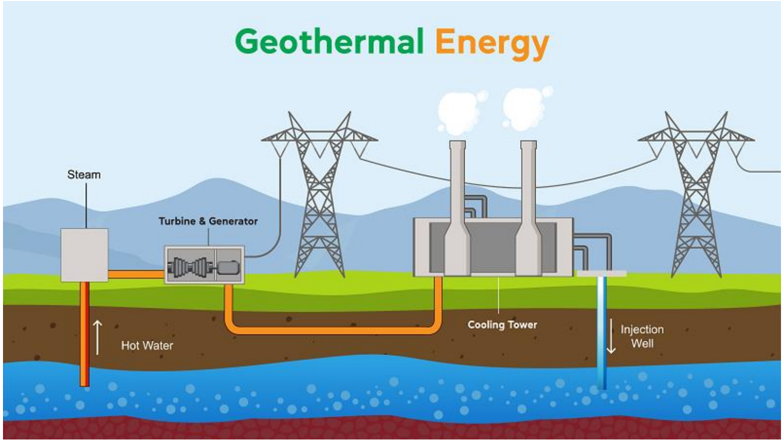


Fig 1.4 Geothermal Energy

1.2.5 HYDROPOWER

Hydropower harnesses the energy of water moving from higher to lower elevations. It can be generated from reservoirs and rivers. Reservoir hydropower plants rely on stored water in a reservoir, while run-of-river hydropower plants harness energy from the available flow of the river.Hydropower reservoirs often have multiple uses - providing drinking water, water for irrigation, flood and drought control, navigation services, as well as energy supply.Hydropower currently is the largest source of renewable energy in the electricity sector. It relies on generally stable rainfall patterns, and can be negatively impacted by climate-induced droughts or changes to ecosystems which impact rainfall patterns.The infrastructure needed to create hydropower can also impact on ecosystems in adverse ways. For this reason, many consider small-scale hydro a more environmentally-friendly option, and especially suitable for communities in remote locations.[1]

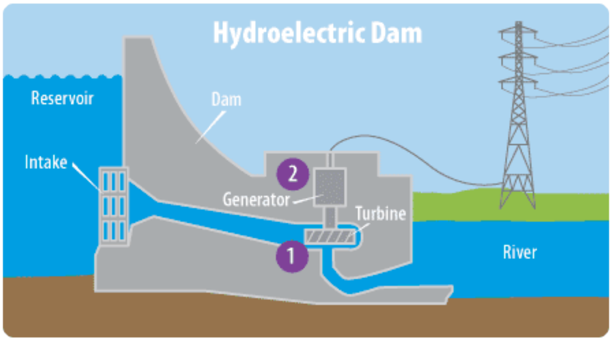


Fig 1.5 Hydropower

1.2.6 OCEAN ENERGY

Ocean energy derives from technologies that use the kinetic and thermal energy of seawater - waves or currents for instance - to produce electricity or heat.Ocean energy systems are still at an early stage of development, with a number of prototype wave and tidal current devices being explored. The theoretical potential for ocean energy easily exceeds present human energy requirements.[1]

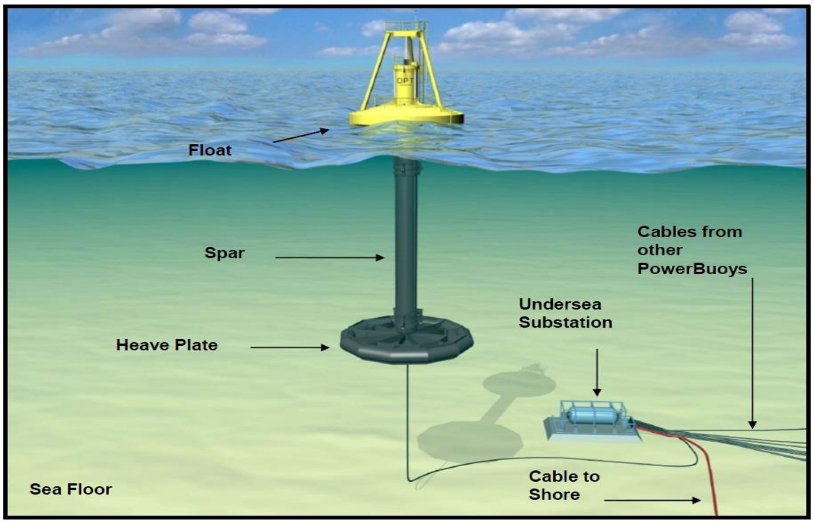


Fig 1.6 Ocean Energy

1.3 WHY DO WE NEED RENEWABLE ENERGY:

1.3.1 Fossil Fuels Are Limited

The first and main reason for why governments and businesses are keen to move to renewable energies as soon as possible is that fossil fuels are a finite resource. We may or may not have reached peak oil - the point at which demand outstrips supply -and by current figures, many experts seem to agree we did so around 2008 with only external factors creating fluctuations in demand making it difficult to predict precisely when it will run out. That is another debate entirely that our politicians and economists have argued for decades, and will continue to argue for many years to come. Whichever way we look at it, fossil fuels will run out eventually and it will take some 10,000,000 years to replenish what we have used in around 150 years.

As the human population increases, our *rate* of consumption of these fossil fuels also increases. Geologists and others whose job it is to locate and access these pockets of crude oil are finding it increasingly difficult to locate and extract new sources. Whether we have 1 year or 100 years left of oil, many argue that what is left should remain in the ground because it is not sustainable it will run out eventually and so we should prepare for a post-fossil fuel world now.[2]

1.3.2 Carbon Emissions & Climate Change

The most immediate problem, particularly in light of the COP21 agreement of 2016, and the changes we have seen to the climate in the last 150 years, is climate change and the carbon emissions that are forcing it.In the last few years especially, no part of the world has been untouched by freak weather conditions. Most continents have recorded record high temperatures in summer, record lows in winter and increased frequency of typhoons and hurricanes, record dry spells, drought and flooding. There is no doubt that these freak weather conditions are affecting every country.

Most renewable energy sources, and the technology used to harness them, are low carbon emission. In most cases, once installed they have minimal or no carbon output and can still provide our energy needs. We can never go fully carbon neutral as it takes resources to make a solar panel, build a dam and so on, but it is a critical and significant reduction of our carbon output. What we do need to do, is to take the steps we can to reduce our carbon footprint for international regulations, to help those in the developing world, and to protect ourselves against the freak weather. We also know that the ice caps are melting and the sea levels are rising which creates food shortages and national instability as well as being an expensive situation for our insurance.[2]

1.3.3 Environmental Damage

As fossil fuel supply gets harder to acquire, and prospectors search for new pockets of oil and have to drill longer and deeper to acquire it, there has been conflict between environmental groups and industry and between governments and both groups when local wildlife and environmentally sensitive areas are threatened. Here in the US, public consciousness and the need to protect our wildlife and natural landscapes means that many new developments are protested with concerns of environmental damage. Ongoing protests against fracking and new drilling in Europe and North America and recent examples. Though *some* renewables will have an environmental impact, many do not and when built, have no further impact - unlike ongoing drilling.[2]

1.3.4 Public Health

Oil, gas and coal drilling and mining have high levels of pollution that are pumped into local environments and the wider atmosphere, so while protestors attempt to prevent the building of pipelines or new prospecting in virgin areas and wilderness, it is as much about public health as it is about conservation. We have known for decades about the knock on effect of industrial processes for public health. Few renewables are entirely emission-free, but their output is much lower than conventional fossil fuel acquisition and processing.[2]

1.4 RENEWABLE HYBRID ENERGY SYSTEM RECENT TRENDS IN INDIA:

The energy requirement has been rising exponentially due to the high population growth and industrialization across the world. In the present time, energy utilization is one of the basic parameters used for defining economic development and the country's advancement.[3] Worldwide, most of the energy demand is fulfilled by fossil fuel-based conventional resources[4-5].The increase in environmental degradation and limited availability of fossil fuels has advanced the need for alternate energy resources[6-8] .

In developing countries like India, the increasing demand and rural electrification require additional energy sources. India has stretched out the power network to most of the residents, yet, millions of families cannot access the grid supply[9-12]. The power transmission and distribution sector in India is still facing several constraints like financial crises, transmission losses, unreliable irregular supply, billing issues and power theft. The present power generation (370 GW) in India shares 62.8% fossil fuel-based capacity and 23.6% from renewable resources[13-14].It is expected that India's power demand would be triple by2040 . The major issues faced by developing countries are providing clean electricity to the millions of rural people those have no access to electricity. Grid extension is an enormously expensive approach due to the land acquirement, installation of extensive infrastructure and socio-technical constraints. Apart from these, disturbance of the village eco-system and huge carbon emission is also demoralizing grid extension factors Therefore, an alternative arrangement of power generation is needed for rural electrification. In a developing country, development and improvement of millions of rural peoples' socio- economic condition become a considerable challenge[15]. Renewable energy becomes an encouraging option for rural natives. The utilization of renewable resources make the villagers' energy independent, improves agricultural productivity and, creates better agroindustrial structures.

September 10, 2019 India recently conducted two auctions for wind/solar hybrid projects. Both the auctions were under-subscribed, with bids totaling 1.56 gigawatts (GW) awarded to SB Energy, Adani Green Energy and ReNew Power, against a total of 2.4 GW on offer. The discovered prices were marginally below the ceiling tariff of 2.70 Indian Rupees. Although the initial response from industry appears guarded, we believe that renewable hybrids can play a key role in helping India accelerate the decarbonization of power generation and lowering the cost of electricity in the medium term.

India has added 65-70 GW of wind and solar capacity so far, with wind and solar contributing 9.5 percent of generated energy in May 2019. If the government target of 175 GW is achieved by 2022, this share could exceed 15-16 percent. Renewable energy has three inherent challenges. First, it relies on intermittent sources, producing energy only when the sun is shining, or wind is blowing; second, its output is constrained to specific hours of the day; third, its use leads to lower utilization of transmission lines. This can create issues in matching peak power demand with renewable output (e.g. in evening hours when solar energy is not available), and raise costs of transmission. Experience in countries which have achieved renewable energy penetration of over 15 percent indicates that some flexible energy resources which can rapidly ramp up or down are needed. These could include hydro or gas-based power, or energy storage solutions.

Renewable hybrids can be one solution to the above issues. Simply put, a hybrid system can combine wind, solar with an additional resource of generation or storage. Let us take an example: in India, we observe that solar output is maximum between 11am and 3pm, while wind output is highest in late evening and early morning. Peak demand for power is reached in the evening hours of 6-9pm, which cannot be catered to by either wind or solar. If we can store some energy during excess renewable generation hours and release it into the grid during peak demand hours, the combined “hybrid” system can produce round-the-clock clean energy in response to varying levels of demand through the day. The storage can take many forms, such as batteries, pumped hydro or mechanical storage through flywheels. The intermittency of wind and solar could also be balanced by adding a fast ramping source of power; for example, an open cycle gas turbine. The overall output of the hybrid system can thus be matched against a required load on an hourly basis. In this way, it can provide both baseload and flexible power.

Hybrid systems are expected to become increasingly cost competitive, driven by reducing costs of battery storage and solar energy. An optimal combination of solar, wind and storage can deliver stable round-the-clock power even at today’s costs of around 6-7 Indian Rupees per kilowatt hour (kWh). Compared to baseload coal plants, this is significantly higher. However, lithium-ion battery costs are expected to fall from current $220-240/kWh to below $100 in next 3-4 years. Similarly, levelized costs of solar energy have plummeted from 4.63 Indian Rupees per kWh in 2016 to 2.50 Indian Rupees per kWh in the latest auctions and may fall as low as 2 Indian Rupees per kWh in the next three to five years.

McKinsey’s proprietary modelling suggests that that if the above improvements are factored in, wind-solar storage hybrid systems could generate round-the-clock power with cost as well as reliability levels comparable to existing coal-fired power plants in the next 4-5 years. For example, a hybrid system which is required to deliver a flat load of 250 megawatts (MW) could be designed by combining solar, wind and battery storage, at a levelized cost of energy at 3-4 Indian Rupees per kWh by 2025. This is, of course, dependent on the specific location and some seasonal variations.India’s ministry of new and renewable energy released a solar-wind hybrid policy in 2018. This provides a framework to promote grid-connected hybrid energy through set-ups that would use land and transmission infrastructure optimally and also manage the variability of renewable resources to some extent.

India is not the only country planning hybrid projects; 50-plus hybrid projects of MW-scale have already been announced or are under construction globally, with Australia and US being the leaders. For larger capacities or longer duration balancing, pumped hydro is a viable storage solution, but is restricted by the lack of suitable physical locations.If the economics of hybrid systems do approach the above levels, our analysis indicates that they can potentially be competitive with 30-40 percent of existing coal-fired stations in India. They can therefore become a viable solution to meeting future baseload power requirements, all at zero carbon emissions and future cost-inflation proof. Several leading Indian corporates are also showing active interest in increasing their usage of clean power if round-the-clock solutions are available[16].

1.5 AIM AND OBJECTIVE OF THE THESIS:

Hybrid renewable energy systems have been accepted as one of the most convenient approaches towards the green energy future. As the renewable penetration propagates throughout the world, benefits of those systems other than providing clean energy have been brought to light. The major objective of the present work is given below in brief.

A novel stand-alone Solar-Bio hybrid renewable energy system is developed for an individual consumer, located remotely. This work utilises solar energy as leading renewable resource and Bio energy into a supportive role. The optimisation and sizing analysis of HRES scheme is based on different parameters related to some diverse fields: economic, technical, environmental and social fields.A novel social analysis of HRES scheme based on the human development index and Social acceptance is specifically presented in this work. The unemployment of rural areas has been addressed in terms of Job formation and local transport based employment utilizing the excess energy. It is found that maximum recent techno economic research works lack in addressing the social aspects as presented in this work.The optimised system's robustness is evaluated .The robustness check found that optimal HRES is economically viable, technically feasible has social and environmental advantages.

1.6 OVERVIEW OF THESIS:

The present work intends to develop a rural hybrid renewable energy system and examines techno-financial, and social viability of the same system for rural sites in North24pgs Habra. This work analyses the performance of Solar Photovoltaic-Biomass renewable energy system for a Smart village demand of 1081.27 kWh/day with 102.80 kW peak in standalone application. In this thesis, different parameter based multi-target optimisation and sizing schemeis executed by HOMER PRO software. This work sequentially addresses the techno-economic and socio-environmental indicators for optimization analysis. The specification of technical and financial fields are availed from the Indian local market. Many feasible combinations of different resources are analysed for designing parameters and the optimized combination is selected by multiple criteria analysis. The Solar Photovoltaic-Biomass-battery storage is found best combination for consistent power supply. The net present cost and cost of energy are obtained as $ 0.144 and $734805 respectively. Moreover, the technical and commercial viability of the proposed system is assured by robustness check for satisfying the consumer demand.This thesis consist of 7 chapters.First chapters describes Introduction of renewable energy,Second chapter describes review of earlier work,Third chapter describes abour smart village configuration,fourth chapter describes about homer software,Fifth chapter describes about Methodology of present work,Sixth chapter describes the result and discussion of this thesis and Seventh chapter describes the conclusion and future scope of this thesis.

1.7 Conclusion:

This work presents an optimal techno-economic analysis for HRES system addressing the social and environmental factors more accurate and reliable results. The main objective of this work is to determine an optimized arrangement for Solar PV Biomass-Battery Hybrid System, to ensure a consistent and reliable power supply for a smart village. Identifying significant issues and parameters by studying many studies and addressed the problems in contrast to the recent work those are based on financial analysis only.Many specific parameters from Economic, Technical, Social and Environmental domains are adopted for the optimization and sizing of standalone HRES. A novel HRES scheme is presented here to fill the research gaps recognised from the available recent literature works. The work focuses on the minimization of cost of energy, capital cost, unmet load, renewable factors and social parameters simultaneously. The best optimal HRES arrangement is selected among different hybrid arrangements that have been analysed according to the designing parameters in HOMER.In the next chapter review of earlier work,gap of knowledge and probable solution is described thoroughly.

CHAPTER 2

REVIEW OF EARLIER WORK

2.1 INTRODUCTION:

Different renewable energy sourses have been discussed in the previous chapter. Renewable energy sources can be used to produce electricity with fewer environmental impacts. It is possible to make electricity from renewable energy sources without producing CO_2, the leading cause of global climate change.recent trends in renewable based hybrid system is also described in the previous chapter.

In this chapter a literature review is a search and evaluation of the available literature in Hybrid renewable energy system.A literature review has four main objectives

- It surveys the literature in Hybrid Renewable energy system.
- It synthesizes the information in that literature into a summary.
- It critically analyses the information gathered by identifying gaps in current knowlwdge,by showing limitations of theories and points of view,and by formulating the areas for further research and reviewing areas of controversy.
- It presents the literature in organized way.

Literatures reviews have been given in-depth graps of HRES models and have also been understudied where your own research fits into and adds to an existing body of agreed knowledge.

2.2 LITERATURE SURVEY:

Rodolfo Dufo-L_opez et,al[17] have investigated on PV-wind-diesel-battery stand-alone systems to minimise cost and maximise human development index and job creation. This work presents a new methodology for the multi-objective optimisation of stand-alone (off-grid) hybrid renewable systems (PV-wind-diesel-battery) to minimise net present cost and maximise human development index (HDI) and job creation (JC). The optimisation performed uses an MOEA in order to obtain the optimal Pareto set of the combinations of components consideringthe three objectives. The best control strategy for each combination of components used by the MOEA is obtained by means of a GA, which optimises the NPC.HDI and JC had not been considered previously in the optimisation of this kind of system. HDI depends in a logarithmic function on the annual electrical consumption per capita; thus we consider a minimum load to be covered (corresponding to a specific value of HDI) and consider that the excess energy generated by the renewable sources could be used by new extra loads (new businesses or services, with or without their own electricity storage systems), which would increase HDI. Each generation technology has a specific job creation factor,which includes direct and indirect jobs in manufacturing, installation and O&M. A review of the state of the art of JC has been conducted to obtain a high variation in the job creation factors for PV and wind. The number of jobs created by a hybrid system depends on the combination of components (mix of technologies).We present an example of application of the multi-objective optimisation (minimisation of NPC, maximisation of HDI and maximisation of JC) to obtain an optimal Pareto set in which none of the solutions is better for all three objectives than any other one.

Yashwant Sawle, S.C. Gupta, Aashish Kumar Bohre[18] have investigated Socio-techno-economic design of hybrid renewable energy system using optimization techniques. The optimal planning of diverse HRES with a multi-objective function applying GA, BFPSO, PSO and TLBO is presented for a remote location of district barwani. A summary of results obtained by considering hybrid system parameters and multiple objectives involving different cases I to VI are discussed including a new multi-objective function. Optimal configurations of parameters have been obtained using GA, BFPSO, PSO and TLBO for the new multi-objective function involving six separate objectives. The various parameters such as technical (LPSP, Renewable factor), economical (COE, Penalty & Fuel consumption) and social (Jobcreation, HDI & PM) attributes are explored in the optimal design of hybrid system. The results indicate that in all cases from I to VI the best solution is obtained using TLBO, then BFPSO, PSO and GA respectively. The comparative results analysis of hybrid system configuration parameters and objective parameters for different cases from I to VI are presented. The optimal design of a different hybrid system using GA, PSO, BFPSO and TLBO are given on the basis of the minimum value of the multi-objective function (Fmultiobjective) and optimal values of objective indices or parameters. The optimal values of COE for different hybrid system configuration cases I, II, III, IV, V & VI are 0.21352, 0.236098, 0.309075, 0.342012,0.22662 and 0.195166 respectively. Also, the optimal values of LPSP for different hybrid system configuration cases from I to VI are 0.021879, 0.023635, 0.040292, 0.043328, 0.018733 and 0.017638 respectively. Similarly, the comparative analysis can be given for PM, HDI, Job creation, Renewable factor, Emission, Penalty cost and Diesel operating hours etc. This investigation indicates that each case has the best solution using TLBO and case VI is the more optimal solution using TLBO technique as compared to other cases with respect to all objective (COE, LPSP, Renewable factor, PM, HDI, JCI & Emission) parameters consideration. In the case e VI for the hybrid system configuration COE is 0.195166 and LPSP are 0.017638which is the minimum solution obtained among all the cases considered. Similarly for Renewable factor, HDI, Emission, PM, job creation, Fuel cost, Penalty cost and Diesel operating hours etc. a comparative analysis can be presented. Finally, it can be concluded that the TLBO has the superior performance for each of the cases considered. The technical, economic and social parameters of hybrid system are successfully improved by using the proposed methodology.[]

A.N. Celik[19] has investigated on Optimisation and techno-economic analysis of autonomous photovoltaic–wind hybrid energy systems in comparison to single photovoltaic and wind systems. A techno-economic analysis for autonomous small scale photovoltaic–wind hybrid energy systems is undertaken for optimisation purposes in the present paper. The answer to the question whether a hybrid photovoltaic–wind or a single photovoltaic or wind system is techno-economically better is also sought. Monthly analysis of 8 year long measured hourly weather data shows that solar and wind resources vary greatly from one month to the next. The monthly combinations of these resources lead to basically three types of months: solar-biased month, wind-biased month and even month. This, in turn, leads to energy systems in which the energy contributions from photovoltaic and wind generators vary greatly. The monthly and yearly system performances simulations for different types of months show that the system performances vary greatly for varying battery storage capacities and different fractions of photovoltaic and wind energy. As well as the system performance, the optimisation process of such hybrid systems should further consist of the system cost. Therefore, the system performance results are combined with system cost data. The total system cost and the unit cost of the produced electricity (for a 20 year system lifetime) are analysed with strict reference to the yearly system performance. It is shown that an optimum combination of the hybrid photovoltaic–wind energy system provides higher system performance than either of the single systems for the same system cost for every battery storage capacity analysed in the present study. It is also shown that the magnitude of the battery storage capacity has important bearings on the system performance of single photovoltaic and wind systems. The single photovoltaic system performs better than a single wind system for 2 day storage capacity, while the single wind system performs better for 1.25 day storage capacity for the same system cost.

S.Diafa,D.Diafb,M.Belhamelb, M.Haddadic, A.Louchea[20] have investigated on A methodology for optimal sizing of autonomous hybrid PV/wind system. The optimal sizing of autonomous hybrid PV/wind system with battery storage, using an optimization model, has been developed in this work. The system configurations can be obtained in terms of a system power supply reliability requirement by using the LPSP concept. The one with the lowest levelized cost of energy is considered as the economical optimal configuration. The simulation results, for a LPSP of 0 and a defined profile, show that in order to obtain a total renewable contribution (RC ¼ 1), more than 30% of the energy production is unused unless the battery capacity is very large. On the other hand, while in a renewable contribution of about 85%, the energy excess percentage decreases to 5%, for a configuration with one wind generator and below 15% for that comprising two generators. The second important conclusion is that the system devices choice represents an important step in the optimal sizing of the hybrid PV/wind system. Including economical consideration, a 125W module configuration is found better than a 50W one. However, the configuration system comprising one wind generator (600 W), PV generator (using 125W modules) and batteries storage (using 253 Ah battery) is found as the optimal one from both the economical and technical point of view.Additionally, for different system configurations with 100% reliability, the lowest LCE happens with the same battery capacity (750 Ah), corresponding to the double daily capacity, and with an energy excess exceeding 40%. Finally, in order to reduce the energy excess, corresponding to the lowest LCE, the use of a third energy source (diesel) can bring benefit to the system.

Chong Li [21]et.al. have investigated on Techno-economic feasibility study of autonomous hybrid wind/PV/ battery power system for a household in Urumqi, China. In this paper, it is clear that insofar as the needs of a household in Urumqi, China are concerned, the autonomous hybrid wind/PV/ battery power system is more cost effective when compared to PV/battery and wind/battery power systems. The optimized hybridwind/PV/battery system with 5 kW of PV arrays (72% solar energypenetration), one wind turbine of 2.5 kW (28% wind penetration), 8unit batteries each of 6.94 kWh and 5 kW sized power converters can reduce the total net present cost (NPC) about 9% and 11% compared to a PV/battery and a wind/battery power systems, both of which have a similar consequence for the levelized cost of energy (COE). The suggested optimal hybrid systemwas found with an NPC of $ 53,296 and a COE of 1.045 $/kWh respectively. Given the economical analysis, it is clear that the bulk of the NPC is accounted for in PV modules, while the least of it is accounted for in converters.Furthermore, different system configurations will provide different variations of NPC and COE values against different numbers of batteries or wind turbines. Given the sensitivity analysis,we have found that the solar energy contributes more efficiently to the proposed hybrid wind/PV/battery power system than the wind energy. Furthermore, the NPC values of the proposed system increase with the increasing primary load, whereas the COE values of the system decrease before the 20 kWh/day of primary load and increase after the load. Given the PV module tilt angle analysis, the daily horizontal axis adjustment is used as the tracking system; the range of the PV module tilt angle of the proposedsystem. In addition, the total PV module generation from the hybrid system with the tracking system is greater than a system with an optimized PV module tilt angle.

Soumya Mandal [22] et.al have been investigated on Optimum sizing of a stand-alone hybrid energy system for rural electrification in Bangladesh The present study investigates the potential application of the hybridized system for the electrification of a remote community by simulating an effective hybrid energy system with optimum cost evaluation and control emission of harmful products. In this study, six different cases of hybrid systems are studied and an optimal configuration is selected on the basis of the lower Cost of Energy and pollutant emissions and is compared the relative advantages and disadvantages with the grid connected and Solar Home Systems (SHSs). This research also investigates the significant results of different configurations regarding Life Cycle Emissions, Duty Factors, Renewable Penetration, and other economic and environmental parameters. Among the various system configurations, a PV/Batt/Diesel generatorebased hybrid system with PV module capacity of 73 kW, a 57kW diesel generator set, and a 373 kWh battery bank is the most optimally sized configuration while meeting 88,354 kWh annual load demand. Social perspectives and challenges also discussed. The primary outcomes of this study are summarized as follows: In this sizing optimization, the Cost of Energy for optimal hybrid system configuration (Case I) is 0.37$/kWh with Net Present Cost of $357,284. Although the COE and the NPC are comparable with the Case II, the higher capital and replacement costs along with environmental pollutants emissions make less favourable than Case I. The proposed system is however costly than national grid connection but has a lower price compared to the Solar Home Systems (SHSs) installed in Bangladesh. From the analysis, it is also evident that the optimized system has lower operational CO2 emissions (13,720 kg/yr) than kerosene-based lighting (36,135 kg/yr) and the grid-connected electricity (41,085 kg/yr). Although Case III and Case IV have zero operational emissions and lower Life Cycle Emissions than Case I and Case II, these systems have much higher cost than Case I and Case II. The optimized system (Case I) has lower Duty Factor (DF) compared to the Case V and Case V. In relation to Renewable Penetration (RP), Case III and Case IV have higher RP (100%) among the system configurations. On the other hand, Case I and Case II have comparable renewable penetration (89%) whereas Case V and Case VI have almost zero renewable penetration. It is attributed to higher operational as well as the Life Cycle Emissions.Sensitivity analysis shows that the COE is highly sensitive to capital cost and discount rate. However, the variation of fuel price, PV module cost, battery cost, and diesel generator cost have less effect on the COE. A similar trend is also true for NPC but inversely for variation of the discount rate.

Anurag Chauhan et.al[23] have investigated on Techno-economic feasibility study on Integrated Renewable Energy System for an isolated community of India. In the present paper, a techno-economic feasibility study on Integrated Renewable Energy System has been carried out for 48 number of un-electrified village hamlets of the Chamoli district of Uttarakhand state (India). The data collected from the study area were used for the demand assessment and resource assessment. Small wind turbine models of different manufacturers were considered and compared based on the capacity factor. Whisper 500 wind turbine model was selected as this model offers the highest capacity factor of 25.79% at Harmal site of the study area.. Further, nine different combinations of renewable energy resources have been investigated using HOMER software. Among different combinations, MHP-Biogas-Biomass-Wind-PV array- Battery based configuration is found to be the most suitable option for the study area as it offers the minimum NPC of $ 825,408 LCOE at the estimated LCOE of $ 0.092 per kW h along with the highest jobs generation of 0.1792 per year. Optimum configuration of this combination consists of 50 kW MHP system, 50 kW biogas system, 40 kW biomass gasifier system, 33 kW wind energy system, 57 kW PV array, 427.20 kW h battery bank storage system and 47 kW converter. A sensitivity analysis has also been performed for variation in electrical energy demand, mean annual wind speed, maximum annual capacity shortage and biomass prices. It has been found that the considered system is very sensitive towards the fluctua- tion of biomass prices. With the biomass price variation from $ 15/ton to $ 50/ton, the LCOE has been deviated from $ 0.092 per kW h to $ 0.115 per kW h. The study carried out may be useful for the development of IRES in stand-alone mode for the electrification of other similar remote rural areas.

S. Bahramara et.al[24] have been investigated a review paper on Optimal planning of hybrid renewable energy systemsusing HOMER. HRESs are appropriate solution to meet the local loads in rural, remote, and special urban regions, e.g., universities and hospitals. Determining the optimal sizes of HRES's equipment is the major concern of researchers. HOMER software is a powerful tool used by many researchers around the world for optimal planning of HRES. According to the ability and widespread use of this software, the present paper reviewed those articles that have used HOMER for the optimal planning of HRES. The most remarkable conclusions from this review are listed as follows:The software has been used in developing countries more than other regions, especially in remote and rural areas.The software has been used for wide range of load from 0.626 kW to 2,213,000 kW.Many combinations of dispatchable/Non-dispatchable resources, storages and converters have been modeled in the articles. PV is the popular resource considered by many researchers.HRESs have been modeled in stand-alone mode more than grid connected mode.Wind speed, solar radiation, fuel price, component cost, and primary load are the most uncertain parameters referred to in the articles.

Madhumita Das , Ratan Mandal[25] have investigated on The effect of photovoltaic energy penetration on a Photovoltaic-Biomass-Lithium-ion off-grid system and system optimizationfor the agro-climatic zones of West Bengal. In this research work, the effect of the PV energy penetration on the PV/Biomass/Li-ion battery HRES and its optimization is studied for the nine places under the six agro-climatic regions of the West Bengal state of India. The impact of the penetration of PV energy into the HRES has been studied on the system's unmet load, capacity shortage, battery capacity, cost of the system, and CO_2 emissions the system. The study suggests a range of PV capacity with zero unmet load percentage and zero capacity shortage of the HRES for all nine places. The capacity of the battery increases as PV capacity increases, but after reaching a peak battery capacity, it decreases or remains constant. PV penetration lowers the NPC and COE of the system, as well as the amount of CO_2 emitted. The maximum CO_2 emission avoided in tonnes is 71 for Rangapur and Kharibari whereas a minimum of 69 for Hilli.The study finds suitability of the installation of the HRES for all the locations with COE in the range of 0.101 $/kWh-0.105 $/kWh except Rangapur with a high COE of 0.11 $/kWh. The COE may be reduced by decreasing the autonomy hours of the battery. This HRES would help the farmers and the rural communities to be energy secure and enhance their livelihood. The HRES is found sensitive to biomass price, biomass quantity, discount rate, and inflation rate.The designed system would help the policymakers to take the necessary steps to give priority to installing the PV-Biomass-Li-ion bat- tery HRES for the agricultural and community loads of different agro- climatic zones of West Bengal, India. Also, this study can be replicable throughout the agricultural districts of India and over the world.

Kenneth E. Okedu et.al[26] has intestigated on Optimization of Renewable Energy Efficiency usingHOMER.This paper presented the use of the hybrid optimization model for electric renewable (HOMER) for designing renewable system considering energy efficiency. A combination of different energy technologies was simulated by the HOMER system and a combination of different configurations were achieved, with the best result which gives the least net present cost selected as the most optimizedoutcome of the different technologies.Also, a model system consisting of wind turbine, PV system, diesel ac generator, battery and converter system wasinvestigated using different load profiles. The cash flow summary results demonstrates that increase load profile leadsto more capital, operating, replacement, increase fuel, and salvage value of the project for the wind turbine, PV, diesel and battery systems. However, the converter system was found to be independent of the load profiles.

Pronob Das et.al[27] have investigated on Evaluating the prospect of utilizing excess energy and creating employments from a hybrid energy system meeting electricity andfreshwater demands using multi-objective evolutionary algorithms. This study presents the sizing optimization of PV/WT/Batt/DG-based hybrid renewable energy system for meeting the commu- nity load demand while utilizing the excess energy generated by the system to run a reverse osmosis desalination plant for providing fresh water. Three evolutionary algorithms namely genetic algo- rithm, particle swarm optimization and a hybridization of these two algorithms are utilized for the optimization with the objectives of minimizing cost of energy, minimizing excess electricity, and maximizing job creation. TOPSIS method is used for selecting the solution with the best trade-off. The outcomes of this research are as follows:The optimum system configuration consists of 179.5 kW PV, 10 kW WT, 90 kW DG and 1013.2 kWh battery with 201 kW of inverter. The system offers the lowest COE of 0.234 $/kWh, produces 24,038 kWh/yr excess energy and creates 1.64 jobs in the community. The system also outperforms other options with the lowest payback period (8.13 years) and corresponding maximum internal rate of return (14.4%) and profitability index.Among the three algorithms, the GA-PSO hybrid optimization shows better convergence and provides the optimum system configuration. For the same combination of components, PSO optimization provides COE of 0.246 $/kWh and GA offers 0.265$/kWh, which is the maximum. However, the GA optimization exhibits the maximum number of jobs (1.79) while being the most reliable (99.79%) in terms of meeting the demands.The range of RPR and RF of the systems are between 91-98% and 88.9e96.3%. The optimal hybrid system (PV/WT/DG) has a renewable fraction of 88.9%, resource to production ratio of 91% and it emits 40,239 kg of equivalent CO_2 in a year.

Prajna Jandial[28] has investigated on Analysis and Scope of Hybrid Renewable Energy System. This paper established what Hybrid Renewable Energy Systems are, and analysed their potential. Thereis still a lot optimisation required in hybrid systems. Overall, these systems could make Renewable Energy Sources more reliable and help in their integration to the main grid. Rural India could benefit alot with HRESs and see immense growth and development. HRESs could be very beneficial for remoteregions, and can have further applications in water supply, desalination and rain-water harvesting. Systems that could integrate not just power generation, but also have more functionality (as mentionedabove: water supply, desalination and rain-water harvesting), can accelerate rural development in India.

Adel Brka et,al[29] has investigated onThe interplay between renewables penetration, costing and emissions in the sizing of stand-alone hydrogen systems. Several hybrid renewable energy systems are sized to mini- mise Net Present Cost (NPC), the Excess Energy (EE) and the Life Cycle Emissions (LCE). Sizing is formulated as a multi- objective optimisation problem and solved using a Genetic Algorithm. Loss of Power Supply Probability (LPSP) is used tomeasure load meeting reliability in the optimised solutions. In addition, experiments have been conducted to practically resolve the transient start-up time of PEM fuel cell stacks. It is believed such data is used for the first time to modify the LPSP formula in order to provide a more accurate estimate of load meeting reliability. Results show the proposed methodology can help systems designers to more accurately assess the reliability of stand-alone energy systems in meeting a target demand. The techno-economic feasibility and optimisation of renewable energy systems is however very location specific. As such, even though sizing results drawn from this paper are valid only for the location and the load demand profiles employed, more importantly, the sizing methodology used (multi-objective Genetic Algorithms) and techniques derived (modified LPSP) are believed to be more valuable as they are generic and adaptable to other scenarios.The following specific outcomes have been drawn from this research:Ignoring the transient response of fuel cell stacks results in hydrogen energy systems which are sized but overestimate their load meeting reliability.A modified index to evaluate the load meeting reliability of energy systems is introduced. This accounts for the tran- sient start-up characteristics of fuel cells.If the optimisation of a hydrogen system aims to reduce EE and LCE (in addition to NPC), the solutions obtained favour more hydrogen energy pathway equipment at the expense of battery storage.Because of the high cost of energy storage devices, a stand- alone energy system with greater renewables penetration (less dumped or excess energy) is more expensive than a system with high excess energy.Including limited battery storage, within hydrogen based stand-alone renewable energy systems, reduces the total cost and life cycle (environmental) impact.For the considered location and load profile, the WG-H2 has the best compromise between the objectives tested, compared to PV-H2 and WG/PV-H2.

H. El-houari et.al[30] have investigated on Energy, Economic, Environment (3E) analysis of WT-PV-Battery autonomous hybrid power plants in climatically varying regions.The energy, economic and environmental (3E) study for sustainable electrification was proposed on the national scale in Morocco. The feasibility of off-grid HRES for wind-PV system was evaluated exten- sively for a total 24 cities. These cities are distributed in twelve regions based on the geographical location of the country with two cities for each region.The NASA metrological data for wind speed and solar radiation was used. The simulations were performed by HOMER Pro software. Both key indexes performance for financial and environmental of HRES have been evaluated for different twelve regions of Morocco. Eddakhla and Laayoune cities have been demonstrated to the best site according to the lowest COE 0.171 and 0.172 $/kWh, respectively.The percentage of electrical energy production from wind turbine and solar PV technologies for these cites was varied depending on the prevailing weather data. Laayoune city has 40% of power production from WT and 59.3% power production from PV, while the Eddakhla city has 25.6% of power production from WT and 74.40% power production from PV. The amount of CO2 per year that can be saved in Laayoune and Eddakhla cities are about 154.21 and 128.21 tonnes, respectively. The Nador city shows the percentage of power production by WT is higherthan percentage of power production by PV, whereas, some sites are not suitable for wind energy production.This genre of projects is eco-friendly and will allow Morocco to in- crease its energy independence by relying on renewable energy re- sources.

Furthermore, generalizing the use of such systems in isolated towns and villages which are not connected to the electrical networks in the African continent can engender substantial social and economic benefits.

M. Das[31] et.al have investigated on Optimization, Sensitivity and Energy Management of a PV/Wind/Battery and PV/Wind/Supercapacitor Hybrid Renewable Energy System for the Climatic Conditions of Haldia using HOMER: A Case Study. This paper presents the effect of penetration of wind energy system on PV/Wind/Battery system and PV/Wind/SC system in an off-grid configuration to meet a typical agricultural load at Haldia, India. The effect of different ratios of PV/Wind electricity contribution on the techno-economic evaluation of the two systems is assessed using HOMER software. It is found that 80:20 and 73:27 share of the PV/wind energy genera- tion is optimum for PV/ Wind/battery and PV/Wind/SC system respectively. The optimum tilt angle is found to be 24° which is 2° more than the latitude of the site. The sensitivity analysis of the PV module temperature showed that with the increase of the panel temperature by 5 °C, the PV production rate decreases by 1.8-1.9 %. A module cooling or a temperature control system is recommended for the climatic conditions of Haldia. The PV, wind, and battery cost sensitivity on PV/Wind/ Battery system and SC cost sensitivity on PV/Wind/SC system are evaluated to predict future COE of the sys- tem. The cost sensitivity of the SC in the PV/Wind/SC showed that a reduction of the SC cost may make it at par with the battery-based system. The energy man- agement of the two systems shows that PV/Wind/SC system can serve peak loads better. It showed that the supercapacitor can deliver peak load, load during the day, and also load during the night. It also depicts that it can charge very fast with low values of available solar or wind energy. Also, a PV/Wind/SC system with low hours of autonomy can reduce the COE of the sys- tem which can deliver the peak loads of the system.

Daywes Pinheiro Neto et,al[32] have investigated on Risk analysis of Levelized Cost of Electricity toRenewable Energy in Brazil. The main objective of this paper is to present a risk analysisapproach of levelized cost of electricity to renewable energyin Brazil, considering hydro, wind, and photovoltaic energy.The LCOE results, provided as a probability distribution, allow investors to identify the expected value E[LCOE] and, mainly, the risk σ[LCOE], rather than a simple value provided by deterministic methods. In this way, investors have more information to aid the decision making process, especially in the energy market which is risky.When compared to the other sources, the photovoltaic powerplant has the highest value of E[LCOE] due to its high installation cost and mainly due to the low capacity factor.The results showed that the photovoltaic power plant has the lowest LCOE risk due to the low volatility of the historical dataof solar irradiance and ambient temperature (used to calculate panel temperature). Otherwise, the small hydro power plant presents the highest LCOE risk due to the water inflow presenting greater volatility than the other random variables.Stochastic modeling captured the generation characteristics based on the real behavior of the random variables, capturing uncertainties, and provided risk information, unlike determin- istic models that use a single capacity factor value.The methodology used in this paper is applicable to any country, serving as an important decision support tool, especially in relation to risk analysis.

W. Margaret Amutha et.al[33] have investigated on Cost benefit and technical analysis of rural electrification alternatives in southern India using HOMER. This paper considered available local energy resources and maximising the use of renewable energy resources. The simulation results show that the expansion of existing grid lines is not a suitable choice from both the cost effectiveness and environ- mental protection perspectives. The grid extension line also has high initial construction costs, maintenance cost.The simulation result also shows that the Solar/Wind/Hydro/ Battery and Solar/Wind/Battery system has a zero carbon emission and reduced NPC and COE. The electricity production in Solar/ Wind/Hydro/Battery system for different months of a year is also relatively more stable compared with Solar/Wind/Battery system. In Solar/Wind/Hydro/Battery system, the hydro power and wind power plays a major role in electricity production. The wind power is relatively poor from October to January. The water flow is relatively high from June to November. The solar power is also high from March to June. Therefore solar, wind, hydro-power provides a suitable complementary effect throughout the year. Thus according to simulation results, the hybrid renewable energy system combined with energy storage facilities does not only meet the load demand but also lower the COE and carbon emissions.

Mehdi Baneshi et.al [34]In this article, it was tried to design a hybrid energy system to meet the demand of a large electricity consumer in Shiraz, Iran. Several off-grid and on-grid configurations of diesel generator, wind turbine, PV panel, and battery storage were examined. The results can be concluded as follows: For off-grid systems the cost of electricity (COE) and the renew- able fraction of 9.3–12.6 ₵/kWh and 0–43.9%, respectively, are achieved with PV, wind turbine, and battery sizes of 0–1000 kW, 0–600 kW, and 1300 kWh, respectively.Adding batteries to the off-grid system reduces the excess elec- tricity and increases the renewable fraction in expense of increasing capital cost.Among the grid connected systems the one with PV, inverter, and wind turbine sizes of 400, 320, and 300 kW, respectively, shows the highest COE of about 0.084 $/kWh.The optimal grid connected configuration based on minimum COE has 1000 kW PV, 800 kW inverter, and 300 kW wind turbine capacities.Low interest loan increases the number of economically viable systems. Some of projects are not economically attractive even with interest free loans.Taxing carbon emission can be a suitable policy to encourage the investment in large renewable energy projects.Increasing the grid electricity price from 0.075 to 0.13 $/kWh makes a considerable number of systems studied in this article economically attractive.

Daniel Chade [35]Three scenarios of wind-diesel, wind-diesel-hydrogen and wind- hydrogen systems have been proposed for an implementation to support the Grimsey electrical grid. All the proposed systems reduced the system running costs during the lifetime of 20 years however, each of them required a substantial amount of the initial investment. For the current practical implementation, it is recom- mended to apply the wind-hydrogen-diesel system as it has the lowest operational cost from all the investigated configurations and it is characterised by the moderate costs of the initial investment.The wind-hydrogen infrastructure for the island can be intro- duced slowly step by step by firstly deploying wind turbines and then adding the hydrogen storage infrastructure. The third step of this road map would be switching for 100% renewable electricity generation, which is not advised for now. In the future it is probable, that renewable energy technology investment prices will decrease and oil prices will rise, so wind-hydrogen system might become more cost-effective. It is worth noticing, that when a 100% renewable energy system is examined, optimal storage is not able to consume a major part of the excess energy and some alternatives for using this excess electricity should be considered, for example an application of hydrogen for vehicles and/or boats across the community.Summarising, the described scenarios only take into account theelectrical load for Grimsey, which energy needs are dominated by space and water heating. Due to that before any practical implementation of the proposed systems, heating needs should be also carefully considered.Finally, achieved result of less than four year payback period of the entire system, should start serious discussion about hydrogen applications in the northern part of the globe. The Arctic area characteristic features are: excellent wind potential with seasonal variations, high energy prices that seem to be very similar to the modelled case. Due to that it might be worth to consider implementation of wind-hydrogen system also for other arctic remote communities.

Barun K. Das [36]et.al The present study is optimized a PV/Batt/Wind/Biogas/Diesel generator-based hybrid energy system for remote area application in Bangladesh. The study is covered all the renewable energy sources available in the studied area and is proposed a design for implementing the system with its relative merits and demerits compared to the existing system (e.g. SHSs and diesel only sys- tems). The study also investigates the economical and social perspective for this hybrid system. The simulation results show that the Cost of Energy of the hybrid system is high compared to the grid electricity. However, the system is economically feasible when it is compared to the Solar Home Systems (SHSs). Among the various categorized system configurations, a PV/Batt/Biogas/Diesel generator-based system containing a 10 kW PV module, a 9 kW biogas generator, two 10 kW diesel generators, and 72 battery units gives the most feasible solution considering both economically and environmentally for this study. The outcomes of this study are summarized as follows:The COE for the optimized system (Case A) is \$0.28/kWh. The NPC, capital costs, operating costs, and fuel costs for the system are \$612280, \$75688, \$116000, and \$323510, respectively. Although the Case C has a comparable COE and NPC, the oper- ating cost, fuel cost, and CO2 emissions are higher than Case A. It is also evident that the Case E has same COE (\$0.28/kWh) and better NPC (\$546216), and renewable energy fraction (100%); however, higher capital costs for large number of PV panels and batteries. This also needs more attention and manpower for maintenance.The major share of electricity in the optimal solution comes from the biogas generator and it provides power to the locality with comparatively lower cost using locally available bio- resources. The biogas generator, the PV modules, and diesel generator contribute 15%, 49%, and 36%, respectively, to elec- tricity generation with a renewable fraction of 60%.The system with including wind turbines (Case B) is economi- cally unfavorable because the system needs higher initial in- vestments compared to Case A, although the COE and the renewable fraction is quite comparable.The optimized configuration is economically feasible as compared to the solar home systems (COE, \$0.89/kWh) and diesel only systems (COE, \$0.40/kWh).This hybrid energy system has CO2 emissions of 34234 kg/yr andit reduces the emission of CO2 by 59.6% compared to diesel generator the only system and by 40.5% than the grid system. Taking the selling electricity price \$0.34/kWh, the payback period for the most feasible system is found as 13years. The results also show that increasing the selling price of electricity would increase the financial benefits and reduce the payback period.

Tao Ma et.al[37] The study shows that the island's existing diesel generator could be fully replaced by a 100% renewable energy power generation system. The combination of solar energy, wind energy and battery storage can supply continuous power to this island. The optimal system mainly comprises 145 kW PV array, 2 WTs, 168 batteries and a 30 kW converter. The result illustrates that 84% of the load was covered by the PV array and 16% by WTs. However, the dumped energy was as high as 100,883 kW h, about 48.6% of the total production, due to timing mismatch between power de- mand and generation. If a small percentage capacity shortage or some degreed of unmet peak load is allowed, the sizes of the system components could be greatly reduced and the system's eco- nomic performance could be enhanced. The results also demonstrate that the proposed hybrid solar and wind power system with battery storage is a practical and cost- effective solution for this remote island. The levelized cost of energy (COE) of this system is $0.595/kW h. With expected continuing rapid development in renewable energy industry and up- grades in storage technology, the system's cost will be reduced and hence off-grid RESs sited in remote places could be more promising. It can be expected that in the near future the transition from diesel to high renewable energy penetration will be increasingly popular in remote areas for power generation.

Hegazy Rezk et.al[38] This paper has investigated the use of renewable energy sys- tems for water pumping application in an Egyptian remote area. Different configurations of SHRS have been evaluated and com- pared for minimum cost of energy. The case study was represented as a remote area located in Egyptian deserts. An agricultural load profile was demanded to pump underground water for irrigation of olive trees farm. The optimization results indicated that PV/FC system performed the best choice among all the studied config- urations, followed by PV/WTG, PV/WTG/FC, and PV/BS in both of minimum COE and NPC. Considering the grid extension, all studied stand-alone systems are more economical viable than grid extension except stand-alone diesel generator system and wind/ battery system.

2.3 GAP OF THE KNOWLEDGE:

It is observed that most of the rural studies, either briefly considered the environmental and social concerns or ignored. This research work address the research gap identified in the different schemes. In the present scenario a cost effective and reliable HRES design is highly needed for the rural areas of developing nations. It can be seen that cost minimization and optimal solving HRES is performed by several authors in various domain and using different software tools. Various optimization and sizing studies have introduced many tools and software to perform similar investigations. These hybrid systems can overcome limitations of the individual generating technologies in terms of their fuel efficiency, economics, reliability and flexibility. One of the main concerns is the stochastic nature of photovoltaic (PV) and wind energy resources. Wind is often not correlated with load patterns and may be discarded sometimes when abundantly available. Also, solar energy is only available during the day time. A hybrid energy system consisting of energy storage, renewable and nonrenewable generation can alleviate the issues associated with renewable uncertainties and fluctuations. Large number of random variables and parameters in a hybrid energy system requires an optimization that most efficiently sizes the hybrid system components to realize the economic, technical and designing objectives. Authors have identified significant issues and parameters by studying many studies and addressed the problems in contrast to the recent work those are based on financial analysis only Most of the research did not consider social parameter, so social effect by this systems have not been analysed by the above literature. The technical robustness of optimised HRES has not been analysed by the researched papers in this chapter for the smooth and consistent supply of electricity in different weather conditions and diverse load profiles.

2.4 PROBABLE SOLUTION:

A techno-financial and social investigation will be done by utilizing real-time domestic load demand for accessible renewable resources and different components specifications. The designing parameters from different criteria of evaluations are utilized to resolve the research gap. Different combinations of renewable energy sources and backup devices are simulated in HOMER. To obtain the best suitable combination by comparative analysis. The optimization process of various HRES arrangements will be performed by the different parameters from four domains such as economic,technical,social,and to obtain more accurate and reliable results.Many researchers use different tools for analysing the system,but after reveiewing all the papers it can be seen that Homer is the best software for using the analysis.Sensitivity analysis,robustness analysis would be done for optimizing the system more precisely.

2.5 CONCLUSION:

From the above chapter it is clear that designing of HRES system is mainly based on software analysis and different parameters from some domain.In this chapter there have been gathered different technique of optimization for designing renewable energy based hybrid system. In the base of earlier work, gap of knowledge, possible solution have also been described in this chapter. Smart village overview has been described in next chapter.

CHAPTER 3

SMART VILLAGE CONFIGURATION

3.1 INTRODUCTION:

India is rapidly digitising and transforming itself into a smarter nation with smart cities and smart power transmission and distribution systems rapidly coming into the big picture (smart metering, smart grids etc.). With around 6, 00,000 villages in India and 68% of the Indians forming the rural population, it's of utmost priority to equip them with smart technologies, for actually transforming India into a smart nation. Smart energy-sufficient villages, using renewable energy sources, provided its abundance and feasibility in the region and using them in every possible sphere of work, along with hybrid models of 3-R's will bring about a green energy revolution across the country. A sustainable theoretical model of a smart village consist of integrating all basic requirements of energy demand like rooftop PV systems, biomass plants, wind energy utilisation for pumping and power generation, solar crop driers etc. and advanced requirements like passive architectures, solar water purification systems etc. together. The design based on a STERM (science, technology, engineering, regulations& management) framework is a way forward to achieve goals of inclusive growth. It will be replicable and will undoubtedly address the numerous issues prevailing within the country and also reduce causes of global problems like climate change. With villages integrated to contribute to the smartness of the nations, smart nations will be a reality soon.In this chapter a overview of smart village is portrayed below.[39]

3.2 SMART VILLAGE DESCRIPTION:

A smart village is a concept which refers to a set, series or even a bundle of services being delivered to a group of residents inhabiting that particular rural area and businesses effectively and efficiently (Viswanadham, 2011). India is rapidly digitising with a vision to transform itself into a smart nation. Also a worldwide smart community is gradually growing up (Coe et al., 2001; Lindskog, 2005), in which Indians can play a massive role by joining it actively. The first few stepping stones being, implementing a culture of using renewable energy sources, introduction of smart metering, development of automated infrastructure for creating the base for smart grids, 100 smart cities programme, variable tariff policies etc. The various flagship events like JNNSM, Smart Rural Aggregation Platform (SRAP), 100 smart cities, 500 AMRUT

(Atal Mission for Rejuvenation and Urban Transformation) cities etc. and recently launched Sansad Adarsh Gram Yojna are specifically being designed and implemented for marching towards a carbon free, sustainable, eco-friendly and energy-independent economy. Standing at this point of time, a well-designed model is of utmost importance to integrate various view-points together for delivering it to the service of the nation. While we look forward into a smart future, with a sense of energy independence and lesser carbon footprints, simultaneously we will have to focus on areas which need to be accounted, for giving the term "Smart Village", its complete meaning. Issues like clean metalled road, proper inter and intra village connectivity, dust free lanes & streets, hygienic and clean water supply and access to all, primary and secondary Schools with industry driven education, community Library with E-Library facility, professional institutions within an area of 10 km. , proper means for Health Check-up and treatment, access to multi-facility Hospital within an area of 10 km. and primary health centre in each village, empowered panchayats for settling disputes, if possible produce its own grains, vegetable, fruits and khadi, fixed place for evacuation along with proper disaster management planning, Wi-Fi/ Broadband connectivity, recreation and playgrounds for adults and children, village theatre, smart schools and public halls, cooperative activities, common place for grazing cattle, access to seeds, fertilizers, pesticides etc. within an area of 5 km., access to means for markets, industries and income maximization, access to best practices for agriculture, horticulture, sanitation etc. Solid waste management processes, sewage treatment plants and proper water harvesting and management techniques has to be added as per feasibility of the system.[39]

Also we need to develop a sound socio-economic parity for getting desired results. It is believed that the smart paradigm should cover smart homes as a way of enhancing the quality of life (Harper, 2003 & Kim et al., 2012). We need to constantly work on issues like literacy for all up to a certain basic course, ensuring an individual is working or have means to work, everyone is ensured of a pukka house along with availability of proper food, water and clothing for all seasons. All individuals must have a bank account, mobile phone and internet connectivity along with access to all basic facilities within the village premises. A society having proper scientific temper and a sound social basis free of discrimination is a must for achieving such targets. Thus, the model would account for a holistic change in people especially those in rural communities (Collins, 2012).

3.3 SMART VILLAGE MODEL:

The model will be based on a schematic idea, which is shown below

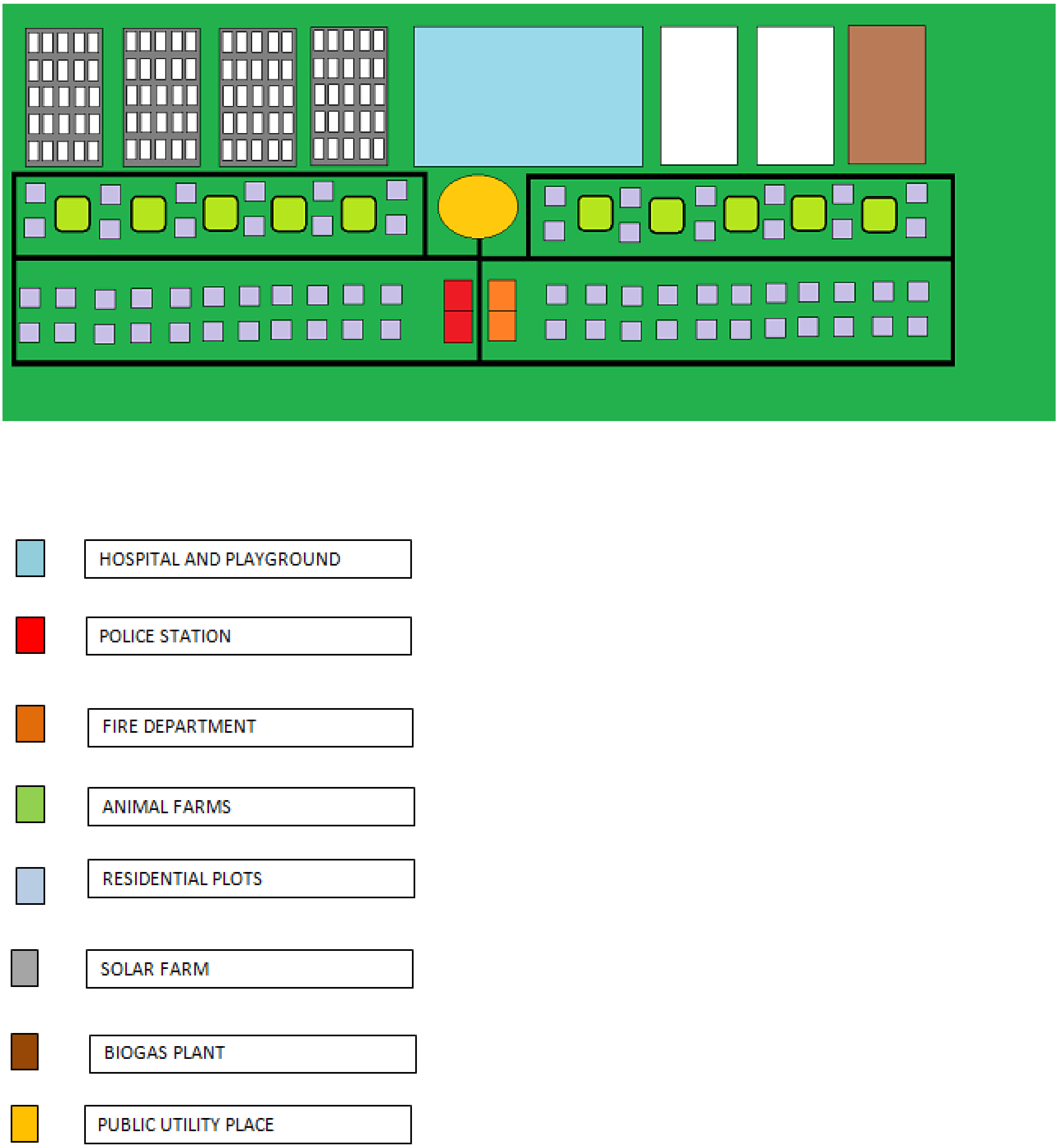


Fig 3.1 Schematic Diagram of Smart Village

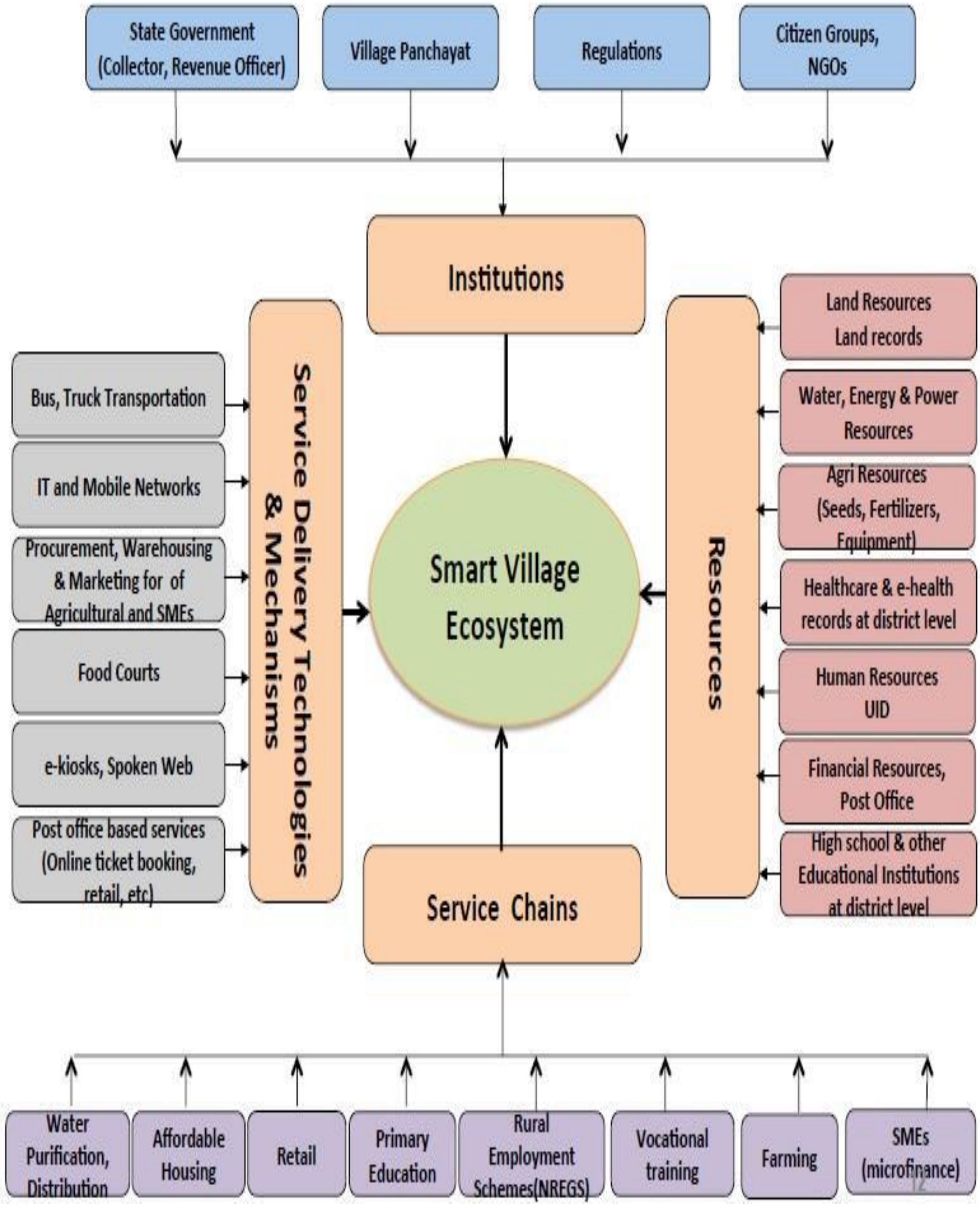


Fig 3.2 Ecosystem of a Smart Village

The basic requirement being power, the primary aim would be to construct a solar farm, provided there is no constraint of land availability, the other alternative being rooftop PV installation in each house. Since a solar farm would be much more cost-effective, it would be desirable to avoid the rooftop installations. Focussing into the solar farms, a typical solar farm based on flat panel crystalline PV (c-Si) takes at most 5 acres of land per MW, while 7-8 acres per MW for a thin film (a-Si/CdTe) solar PV with 12-18 % efficiency. Factors like ground-coverage ratio (0.45-0.65), topography, preferably plain land with rectangular or square shape and proximity to transmission lines. The modules used must qualify IEC PV module specification or equivalent BIS standards. Some typical specifications being IEC 61215 for crystalline Si, thin film modules – IEC 61646, concentrator modules – IEC 62108 etc. The overall workmanship, structures and electrical works must be warranted for a minimum 5-7 years. The module must be warranted for output voltage not less than 90% at the end of 10 years and 80% at the end of 25 years. A well-designed system for two way power transmission, to & from the grid as and when necessary, along with a database for keeping details of power consumption of each house is a must. The average payback time period, using standard numbers based on above considerations, assuming crystalline Silicon, under the NSM incentive structure, is 6 years. The cash flows will recover the equity capital in 6 years, though the loans could take longer to clear. Return on equity pre-tax would be about 20%. The revenue generated out of the surplus power generation can be used to pay off the overall cost of the village in the long run. Also, the revenue generated can be used as a common source of funding to all villagers, by developing a cooperative banking system and hence a nationwide network can be formed.[39]

In case of land constraints the only option is rooftop PV system installation.

PV Module efficiency (%)	PV Capacity Rating (watts)						
	100	250	500	1000	2000	4000	10000
4% , area in sq.ft	30	75	150	300	600	1200	3000
8%, area in sq.ft	15	35	75	150	300	600	1500
12%, area in sq.ft	10	25	50	100	200	400	1000
16%, area in sq.ft	8	20	40	80	160	320	800

Table 3.1 Pv capacity rating

The next addition, a biogas plant, a full waste to energy product technology, typically uses microbes under anaerobic condition to produce Biogas. Biogas can be used in similar to natural gas in gas stoves, lamps or occasionally as fuel for engines. Also 1kW of electricity produced by biogas prevents 7000 kg of CO_2 per year. It has a low running cost, cost-effective and energy efficient.

For The family size biogas plant (with a capacity of 2 m3) costs around Rs. 9000.
Assuming 0.2 kg of average waste produced per person per day, the total waste produced from the entire village is 200 kg. 5 kg of waste is required for production of 1 cubic metre of biogas, which is equivalent to 0.43 kg of LPG. So, per day production of biogas amounts to 40 cubic metres. This is equivalent to 18.9 kg of LPG. And the monthly production amounts to 567 kg approximately for the entire village, which is equivalent to 40 cylinders of LPG. Thus, meeting 1/10th fuel requirement of the households. The presence of following resources, depending upon availability, in and around the village area can maximise the production of biogas, enough to meet the requirements of 200 households. Also the welcome change it has brought in rural living is the job opportunities it has created.[39]

Max. potential of gas production per ton	
industrial food waste	120 cubic metre /ton
floating slurry	400 cubic metre /ton
waste food grease and oil	600 cubic metre /ton
loppings	110 cubic metre /ton
whey	55 cubic metre /ton
pig manure	36 cubic metre /ton
cow dung	25 cubic metre /ton

Table 3.2 Biomass max potential of gas production

3.4 CONCLUSION:

The vision for smart villages is that modern energy access can act as a catalyst for development education, health, food security, productive enterprise, clean water and sanitation, environmental sustainability and participatory democracy, which makes transformative change possible. – *Drs John Holmes and Terry van Gevelt.*

The conclusion is straight forward. An energy independent economy if established will help people to get permanent access to electricity, will help children and youth living in remote rural locations are literally disconnected from the world, excluded from the opportunities provided by global learning, will also help farmers to make their backbones strong by giving them alternate but unlimited source replacing their diesel gen sets etc. This vision to grow along with the whole of India, making the common people equipped at par with the other contrasting population sample, will give a new age to India, by extracting the best outputs from each person. This idea will help in holistic development of the rural India, giving them an equal platform to compete with the rest of the world with an open mind. But then, huge investments needed to practically implement the idea into reality, gives it a setback at one look. Dividing the geographical area to be covered in phases, Public- Private Partnership (PPP), along with contributions from the target population can limit the edge of huge investments. The corporates can contribute a lot to the society through proper utilisation of their CSR's. The stakeholders can play a very important role by providing innovative but cost-effective solutions to day to day problems, which can curb the investment to a great extent. The Indian rural community can be a great example to the world of how resources could be integrated to provide a holistic developmental approach to the society.In the next chapter homer software working has been dissussed throughly.

CHAPTER 4

HOMER SOFTWARE OVERVIEW

4.1 INTROUCTION:

Hybrid Optimization Model for Electrical Renewable (HOMER), is a micro power optimization model, that simplifies the task of evaluating designs of both off-grid and grid-connected power systems for a variety of applications. The HOMER Hybrid Optimization Modeling Software is used for designing and analyzing hybrid power systems, which contain a mix of conventional generators, cogeneration, wind turbines, solar photovoltaic, hydropower, batteries, fuel cells, biomass and other inputs.In this thesis all analysis are done using this Homer Software.[40]

4.2 HOMER:

HOMER is a free software application developed by the National Renewable Energy Laboratory in the United States. This software application is used to design and evaluate technically and financially the options for off-grid and on-grid power systems for remote, stand-alone and distributed generation applications. It allows you to consider a large number of technology options to account for energy resource availability and other variables. HOMER was first developed in 1993 for internal DOE (Department of Energy) use to understand the trade offs between different energy production configurations. A few years after the original design NREL made a version publically available for free to serve the growing community of system designers interested in Renewable Energy.In this chapter Homer software has been discussed in detail. Since then HOMER has remained a free software application which has evolved in to a very robust tool for modelling both conventional and renewable energy technologies**.**[41]

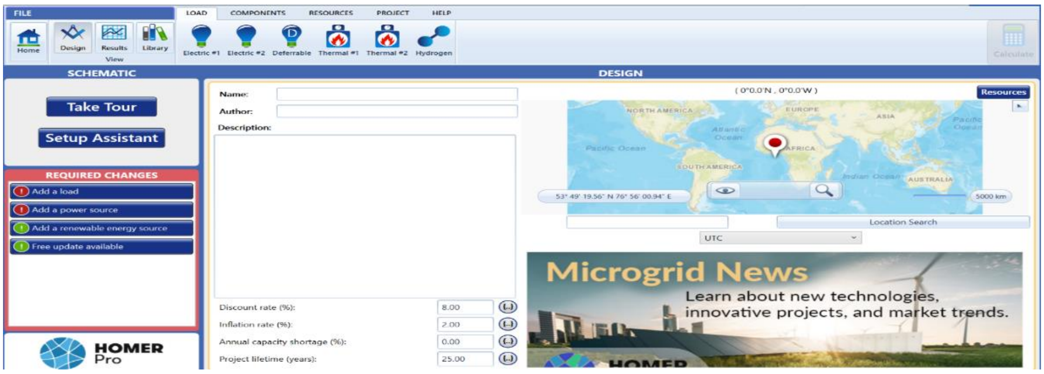


Fig 4.1 Homer Software

4.3 OBJECTIVE:

HOMER is one of the tools used by the GSMA for designing renewable energy base stations. This chapter goes through HOMER and the different elements within the system in detail to demonstrate the depth of the software application and instruct telecom operators on how to design renewable energy sites with HOMER and interpret the results.

4.4 STEPS FOR USING HOMER SOFTWARE:

Step 1. Downloading the Software

Step 2 Defining the Power System

Step 3 Defining the Site Load

Step 4 Specify Wind,Biomass and Solar Resources

Step 5 Specify Diesel Price

Step 6 Specify Economics

Step 7 Specify Equipment

Step 8 Calculate Results

4.5 ADVANTAGE AND DISADVANTAGE OF HOMER:

Merits	Limitations
Simulates a list of real technologies, as a catalogue of available technologies and components	Quality input data needed (sources)
Very detailed results for analysis and evaluation.	Detailed input data (and time) needed
Determines the possible combinations of a list of different technologies and its size.	An experienced criterion is needed to converge to the good solutions
It is fast to run many combinations.	HOMER will not guess key values or sizes if there are missed.
Results could be helpful to learn a system configuration and optimization.	Could be time consuming and onerous

Table 4.1 Merit and Limitations of Homer Software

4.6 CONCLUSION:

Hybrid Optimization Model for Electrical Renewable (HOMER), is a micro power optimization model, that simplifies the task of evaluating designs of both off-grid and grid-connected power systems for a variety of applications. The HOMER Hybrid Optimization Modeling Software is used for designing and analyzing hybrid power systems, which contain a mix of conventional generators, cogeneration, wind turbines, solar photovoltaic, hydropower, batteries, fuel cells, biomass and other inputs. This paper is divided basically into two sections. The first section investigates the energy efficiency of renewable energy system considering an isolated AC diesel generator. A model system consisting of a PV, three batteries and a converter system was considered. HOMER was able to calculate the best option that would give the best energy efficiency. In the second section, a further investigation was carried out considering two cases with two different load profiles to show that the load profiles affects the responses of the renewable energy system and the cash flow summary of some of the system equipments. In this section, a wind turbine is integrated into the PV, battery, converter and AC diesel generator system.In the next chapter by using homer software all the analysis is being done.In the next chapter methodology of this analysis using homer software is portrayed and all the parameters has been discussed thoroughly.[40]

CHAPTER 5

METHODOLOGY

5.1 Introduction:

The first phase of HRES designing scheme is started with collecting the meteorological and social information with the real-time load estimation of the selected site.In this chapter methodology of this HRES analysis for gaining a optimal system is described in detail. It is widely acceptedthat detailed information of rural sites and consumers are required to be carefully inspected tomake energy project successful. A thorough study of the site location, consumers demand, and available resource potential has performed. In addition, social and fincial conditions of the chosen site are also inspected in the first phase of designing.

5.2 Working scheme for proposed rural hybrid energy system Design:

A socio-economic investigation associated with dedicated technical viability is executed here in the light of available diverse literature on electrification of remote locations. The working scheme for the HRES design is outlined in Figure 5.1

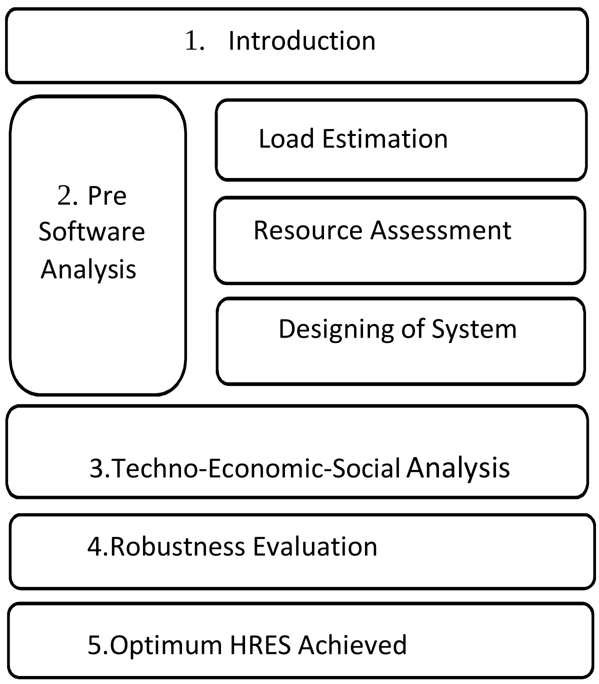


Fig 5.1 Working Scheme

5.3 Techno-Economic and Social analysis:

In the second phase, a techno-financial and social investigation by utilizing real-time domestic load demand for accessible renewable resources and different components specifications. The designing parameters from different criteria of evaluations are utilized to resolve the research objective. Different combinations of renewable energy sources and backup devices are simulated in HOMER. To obtain the best suitable combination by comparative analysis, results of each simulation are summarized and analysed in various tables and figures.

5.4 Robustness Assessment of optimized model:

The robustness evaluation of the optimised system performs three significant manners. The first assessment is applied for the power production test, whether it can meet the load demand. It is an essential step to ensure the constant supply in different weather conditions. These evaluations are imperative to make the HRES feasible for domestic usage and appealing to potential investors.

5.5 Flowchart to Determine the Optimal Design:

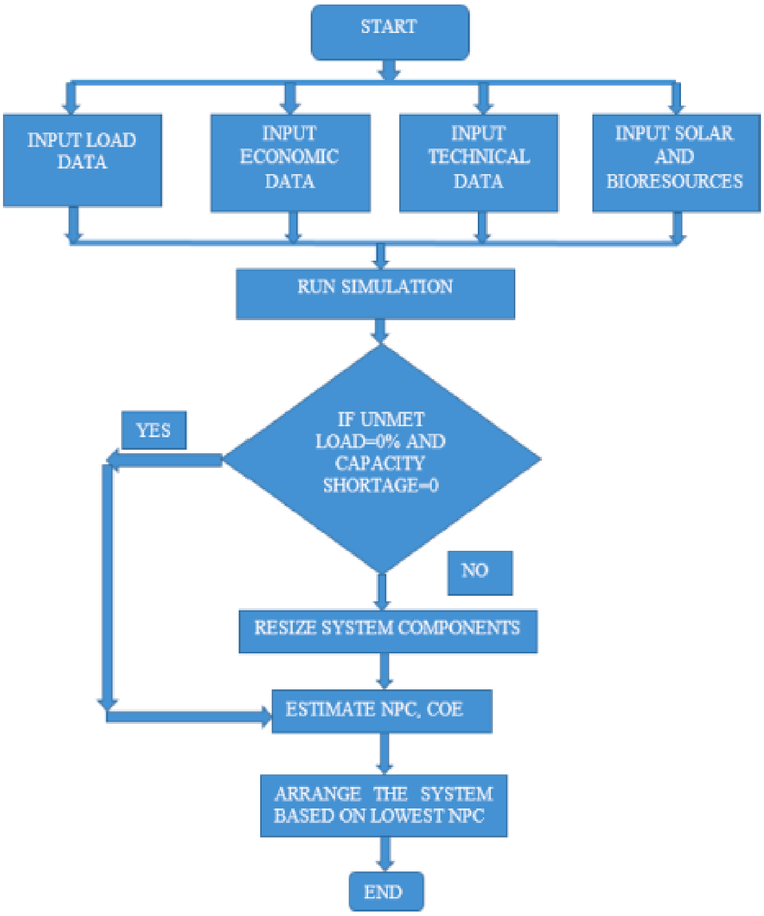


Fig 5.2 Flowchart to determine the optimal system

5.6 EXECUTION OF PROPOSED HRES SYSTEM :

5.6.1 Meteorological & social profile of the selected site:

The site chosen for study is located at the village under the West Bengal division in India's eastern region. The location is situated at 22°50.4' N, 88°39.2' E.

5.6.2 Load estimation in the selected site:

- Consider our smart village has 500 persons.
- Each family has at an average 5 invididuals.
- Smart Village is having 100 houses,around 700 sq.ft each.
- Each house is assumed to have 2 living rooms,one kitchen,one washroom.
- Each house is equiped with light source,Fan,Led tv,Refrigerator,Water Pump,Laptop.
- Smart village consists of 100 houses, a Government hospital,a government Office,a police station, a school,Agricultural load,Electric vehicle charging station.

5.6.2.1 Load Estimation for Houses in Summer Season:

Eqipment	Quantity	Power cons	Time	Enery cons/day	Running time(hour)
Light 1	200	40w	18.00-24.00	48	6
Light 2	200	20w	18.00-24.00	24	6
Fan	200	60w	18.00-9.00	180	15
Led Tv	100	60w	19.00-23.00,07.00-08.00	30	5
Laptop	100	65w	19.00-22.00	19.5	3
Refrizerator	100	150w	06.00-09.00,18.00-23.00	120	8
Water pump	25	746w	06.00-07.00	18.65	1
Water pump	25	746w	07.00-08.00	18.65	1
Water pump	25	746w	17.00-18.00	18.65	1
Water pump	25	746w	18.00-19.00	18.65	1
Light 3	100	10w	24.00-06.00	6	6
Fan	100	40w	09.00-17.00	32	8

Table 5.1 Load Estimation for Houses in Summer Season

5.6.2.2 Load Estimation for Houses in Winter Season:

Eqipment	Quantity	Power cons	Time	Enery cons/day	Running time(hour)
Light 1	200	40w	18.00-24.00	48	6
Light 2	200	20w	18.00-24.00	24	6
Led Tv	100	60w	19.00-23.00,07.00-08.00	30	5
Laptop	100	65w	19.00-22.00	19.5	3
Water pump	25	746w	06.00-07.00	18.65	1
Water pump	25	746w	07.00-08.00	18.65	1
Water pump	25	746w	17.00-18.00	18.65	1
Water pump	25	746w	18.00-19.00	18.65	1
Light 3	100	10w	24.00-06.00	6	6

Table 5.2 Load Estimation for Houses in Winter Season

5.6.2.3 Load Estimation For School in Summer Season:

Eqipment	Quantity	Power cons(w)	Time	Enery cons/day(kwh)	Running time(hour)
light 1	4	40	17.00-07.00	2.24	14
light 2	60	40	11.00-18.00	16.8	7
Fan	60	75	11.00-18.00	31.5	7
Water Pump 1	1	746	07.00-08.00	0.746	1
Water Pump 2	1	746	08.00-09.00	0.746	1
Water Pump 3	1	746	09.00-10.00	0.746	1
Water Pump 4	1	746	10.00-11.00	0.746	1
Desktop	4	100	11.00-15.00	1.6	4

Table 5.3 Load Estimation For School in Summer Season

5.6.2.4 Load Estimation For School in Winter Season:

Eqipment	Quantity	Power cons(w)	Time	Enery cons/day(kwh)	Running time(hour)
light 1	4	40	17.00-07.00	2.24	14
light 2	60	40	11.00-18.00	16.8	7
Water Pump 1	1	746	07.00-08.00	0.746	1
Water Pump 2	1	746	08.00-09.00	0.746	1
Water Pump 3	1	746	09.00-10.00	0.746	1
Water Pump 4	1	746	10.00-11.00	0.746	1
Desktop	4	100	11.00-15.00	1.6	4

Table 5.4 Load Estimation For School in Winter Season

5.6.2.5 Load Estimation For Government office in Summer Season:

Eqipment	Quantity	Power cons	Time	Enery cons/day(kwh/day)	Running time(hour)
Light(Type1)	10	40w	10.00-17.00	2.8	7
fan	8	60w	10.00-17.00	3.36	7
Water pump 1	1	746w	06.00-07.00	0.746	1
Water pump 2	1	746w	07.00-08.00	0.746	1
Water pump 3	1	746w	08.00-09.00	0.746	1
Water pump 4	1	746w	09.00-10.00	0.746	1
Light(Type2)	10	20w	17.00-06.00	2.6	13
Desktop	10	100w	10.00-17.00	7	7

Table 5.5 Load Estimation For Government office in Summer Season

5.6.2.6 Load Estimation For Government office in Winter Season:

Eqipment	Quantity	Power cons	Time	Enery cons/day(kwh/day)	Running time(hour)
Light(Type1)	10	40w	10.00-17.00	2.8	7
Water pump 1	1	746w	06.00-07.00	0.746	1
Water pump 2	1	746w	07.00-08.00	0.746	1
Water pump 3	1	746w	08.00-09.00	0.746	1
Water pump 4	1	746w	09.00-10.00	0.746	1
Light(Type2)	10	20w	17.00-06.00	2.6	13
Desktop	10	100w	10.00-17.00	7	7

Table 5.6 Load Estimation For Government office in Winter Season

5.6.2.7 Load Estimation For Police Station in Summer Season:

Eqipment	Quantity	Power cons	Time	Enery cons/day(kwh/day)	Running time(Hour)
light(Type 1)	10	40w	17.00-24.00	2.8	7
Fan(Type 1)	8	60w	08.00-24.00	7.68	16
Fan(Type 2)	4	55w	0.00-08.00	1.76	8
light(Type 2)	4	40w	0.00-06.00	0.96	6
Water Pump	1	746w	06.00-07.00	0.746	1
Desktop	4	100w	11.00-17.00	2.4	6

Table 5.7 Load Estimation For Police Station in Summer Season

5.6.2.8 Load Estimation For Police Station in Winter Season:

Eqipment	Quantity	Power cons	Time	Enery cons/day(kwh/day)	Running time(Hour)
light(Type 1)	10	40w	17.00-24.00	2.8	7
light(Type 2)	4	40w	0.00-06.00	0.96	6
Water Pump	1	746w	06.00-07.00	0.746	1
Desktop	4	100w	11.00-17.00	2.4	6

Table 5.8 Load Estimation For Police Station in Winter Season

5.6.2.9 Load Estimation For Hospital in Summer Season:

Eqipment	Quantity	Power cons(w)	Time	Enery cons/day	Running time(hour)
Light	15	20	18.00-24.00	1.8	6
Fan	30	60	0.00-24.00	43.2	24
water pump	2	746	8.00-12.00	5.968	4
computer	3	70	12.00-18.00	1.26	6
x ray machine	4	200	12.00-15.00	2.4	3
new born incubator	3	420	0.00-24.00	30.24	24
mechanical ventilator	3	200	10.00-20.00	6	10
Electrocardioram	3	60	12.00-14.00	0.36	2
Vaccine Refrizarator	2	200	10.00-14.00	1.6	4
light	10	10	24.00-06.00	0.6	6

Table 5.9 Load Estimation For Hospital in Summer Season

5.6.2.10 Load Estimation For Hospital in Winter Season:

Eqipment	Quantity	Power cons(w)	Time	Enery cons/day	Running time(hour)
Light	15	20	18.00-24.00	1.8	6
water pump	2	746	8.00-12.00	5.968	4
computer	3	70	12.00-18.00	1.26	6
x ray machine	4	200	12.00-15.00	2.4	3
new born incubator	3	420	0.00-24.00	30.24	24
mechanical ventilator	3	200	10.00-20.00	6	10
Electrocardioram	3	60	12.00-14.00	0.36	2
Vaccine Refrizarator	2	200	10.00-14.00	1.6	4
light	10	10	24.00-06.00	0.6	6

Table 5.10 Load Estimation For Hospital in Winter Season

5.6.2.11 Load Estimation For Electric Vehicle Charging Station:

Eqipment	Quantity	Power cons	Time	Enery cons/day	Running time(hour)
Light	10	40w	18.00-06.00	4.8	12
Electric E rickshaw	15	768w	00.00-06.00	69.12	6
Electric scooter	15	600w	06.00-11.00	45	5

Table 5.11 Load Estimation For Electric Vehicle Charging Station

5.6.2.12 Load Estimation For Agricultural Load in Summer Season:

Eqipment	Quantity	Power cons	Time	Enery cons/day	Running time(Hour)
Water irigation pump 1	10	3.73kw	10.00-15.00	186.5kw	5
Water irigation pump 2	10	2.238kw	6.00-17.00	246.18kw	11
Electric Grass cutter	10	1.5kw	6.00-12.00	90kwh	6
Electric bulb	20	60w	17.00-06.00	15.6kwh	13

Table 5.12 Load Estimation For Agricultural Load in Summer Season

5.6.2.13 Load Estimation For Agricultural Load in Winter Season:

Eqipment	Quantity	Power cons	Time	Enery cons/day	Running time(Hour)
Water irigation pump 1	10	3.73kw	10.00-15.00	186.5	5
Electric Grass cutter	10	1.5kw	6.00-12.00	90	6
Electric bulb	20	60w	17.00-06.00	15.6	13

Table 5.13 Load Estimation For Agricultural Load in Winter Season

This work analyses the performance of Solar Photovoltaic-Biomass renewable energy system for a Smart village demand of 1081.27 kWh/day with 102.80 kW peak in standalone application.

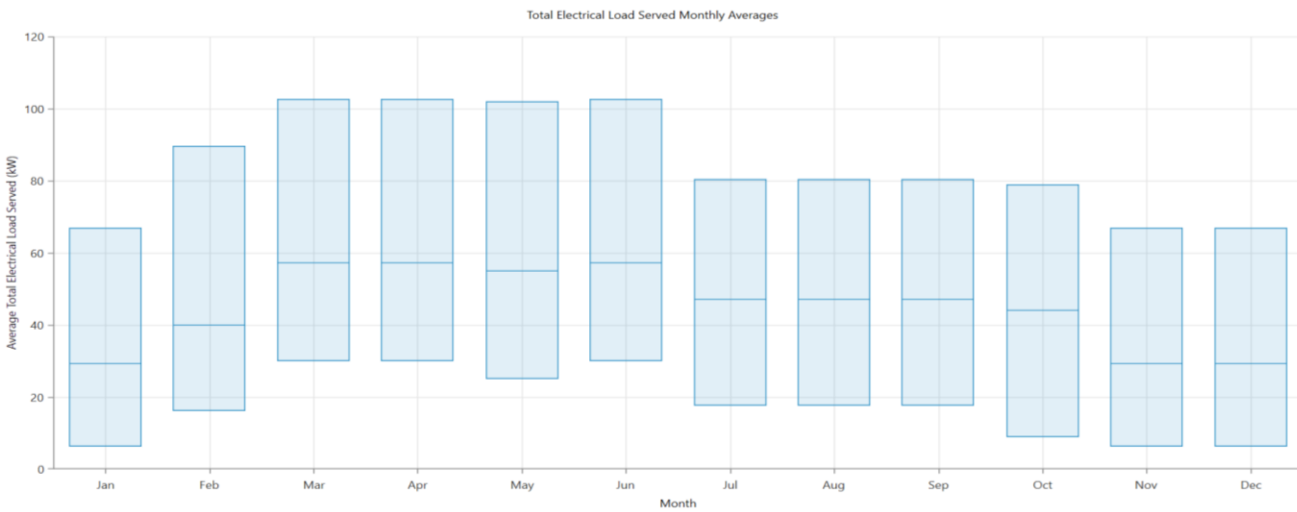


Fig 5.3 Total Electrical Load served monthly Average

5.7 RENEWABLE RESOURSES AT THE SELECTED SITE:

5.7.1 Solar Energy Resourses:

Monthly average Solar Global Horizontal irradiance data of the selected site is given in below fig 5.4.

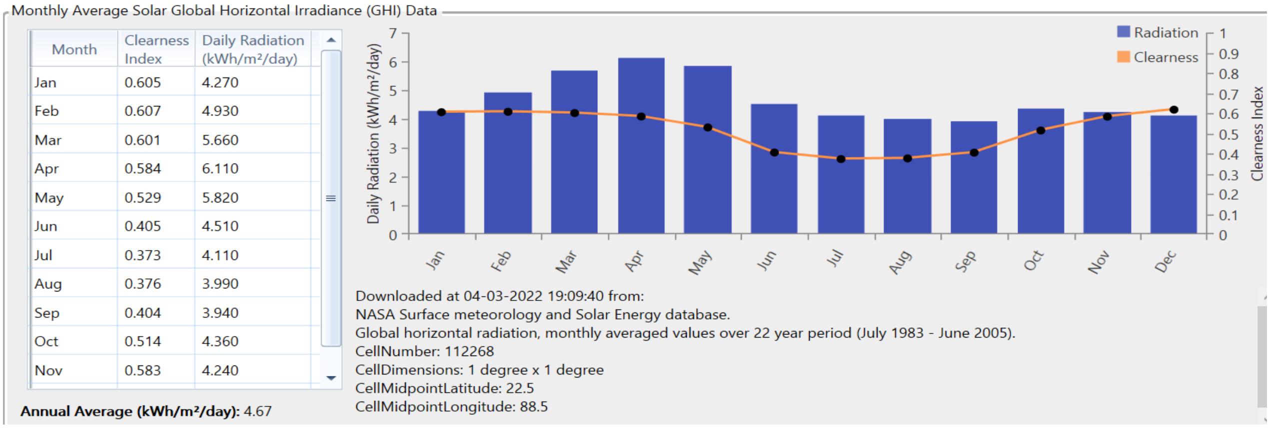


Fig 5.4 GHI data for selected site

5.7.2 Biomass Energy Resourses:

Monthly average available Biomass data is shown in the below fig5.5.Here 2.7 ton/day biomass resourses are considered for the analysis of HRES system.

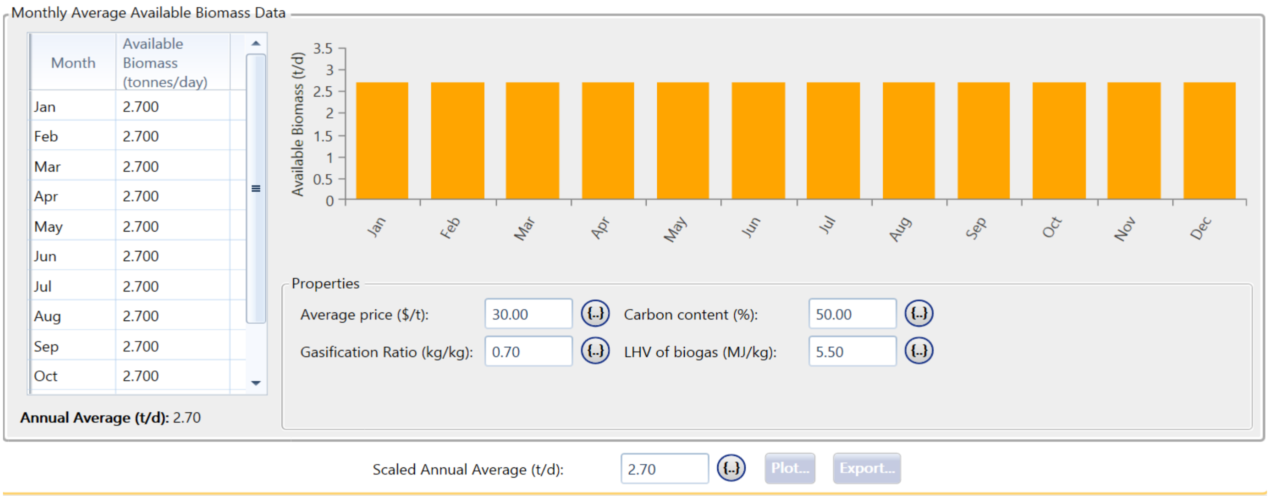


Fig 5.5 Monthly Average Biomass Data

Specification of biomass resourses are shown in the below table 5.14

Parameters	Units	Values
Annual Average	(ton/day)	0.13
Average Price	$/ton	30
Carbon content	(%)	50
Gasification Ratio	(Kg/Kg)	0.7
LHV of biogas	MJ/kg	5.50

Table 5.14- Specification of Biomass Resourses

5.8 SPECIFICATION AND MODELING OF HRES COMPONENTS:

5.8.1 Solar PV component:

In this research, the solar modules have been used in combination with biogas generators to meet the load requirement throughout the year. The PV modules are of polycrystalline silicon types with a maximum rated power of 1 kW with a lifetime of 25 years. The capital cost of 1 kW capacity of the solar PV module is considered 280 $ and the derating factor to be 80 %. Eq. (1) calculates the power generated by photovoltaic arrays[42-43].

$$P_{PV} = P_{STC} \times fd \times G/\ G_{STC} \times [1 + KT\ (Tc - T_{STC})] \qquad (1)$$

Where P_{PV} is the actual PV output power at site conditions, P_{STC},G_{STC} ,T_{STC} are the power output, solar irradiance, and temperature of the PV module under Standard Test Conditions (STC), T_C is the temperature of the PV module under climatic conditions of the site, KT is the temperature coefficient of the material of the PV module, and fd is the derating factor of the PV module.

5.8.2 Biomass energy:

Rice crop residues are available as biomass for bio-gasifiers in the state of West Bengal. Approximately 22 % of raw paddy contains rice husk. 10 % of the rice husk available is used as chicken feed and fodder. Immature paddy makes for about 3 % of the total paddy crop. The amount of rice crop biomass required for power generation is 1.26 kg per kW[44]. For an average runtime of the bio-gasifier be ‘n’ hours, the rice crop residues required as the fuel for the bio-gasifier is Breq in kg, then the power generated ‘PBio’ by the bio-gasifier in kW is given in Eq. (2).

$$P_{Bio} = 1.26 \times Breq \qquad (2)$$

The biomass required may increase depending on the solar radiation available for a period thus minimizing the unmet load during a cloudy or rainy day. A biogas-fueled generator with a capacity of 100 kW is chosen for the study with a capital cost of 410 $ per kW and 10 years of lifetime. The biomass properties such as the carbon content, gasification ratio, and the lower heating value of the biogas are considered as 50 %, 0.7, and 5.50 MJ/kg respectively.Specification of Biogas genset is shown below fig 5.6.

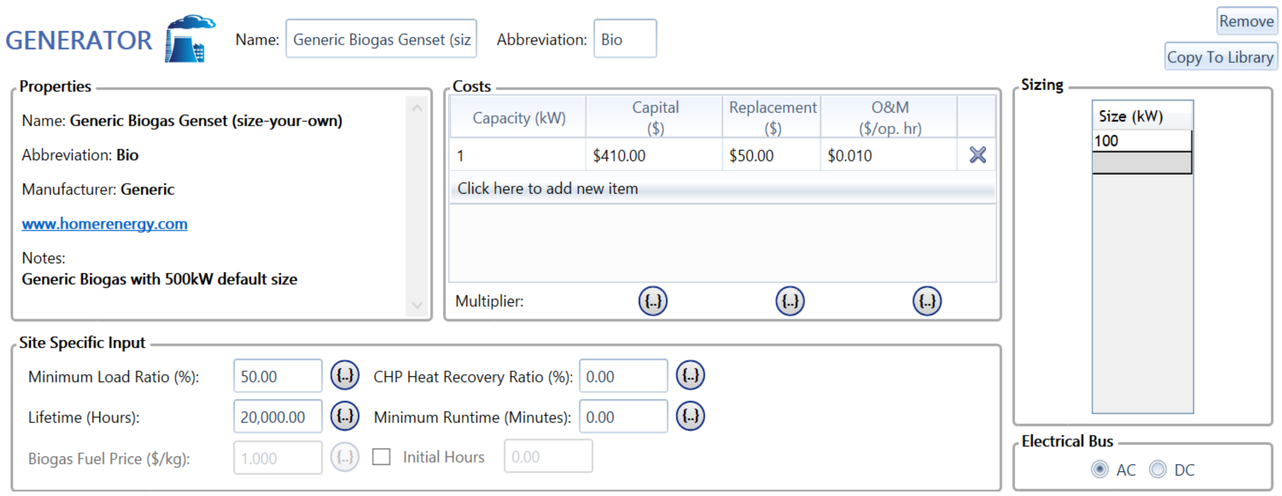


Fig 5.6 Specification Of Biogas Genset

5.8.3 Battery Storage:

The main utilization of the battery is to serve the load at night when the PV and wind energy are not available. Li-ion battery (1 kWhr, 167 Ah) is considered for the design of the systems. The capital cost of a 1 kWhr, Li-ion battery is considered to be 550 $ with 10 years of lifetime. Specifaction of battery is shown below figure 5.7.

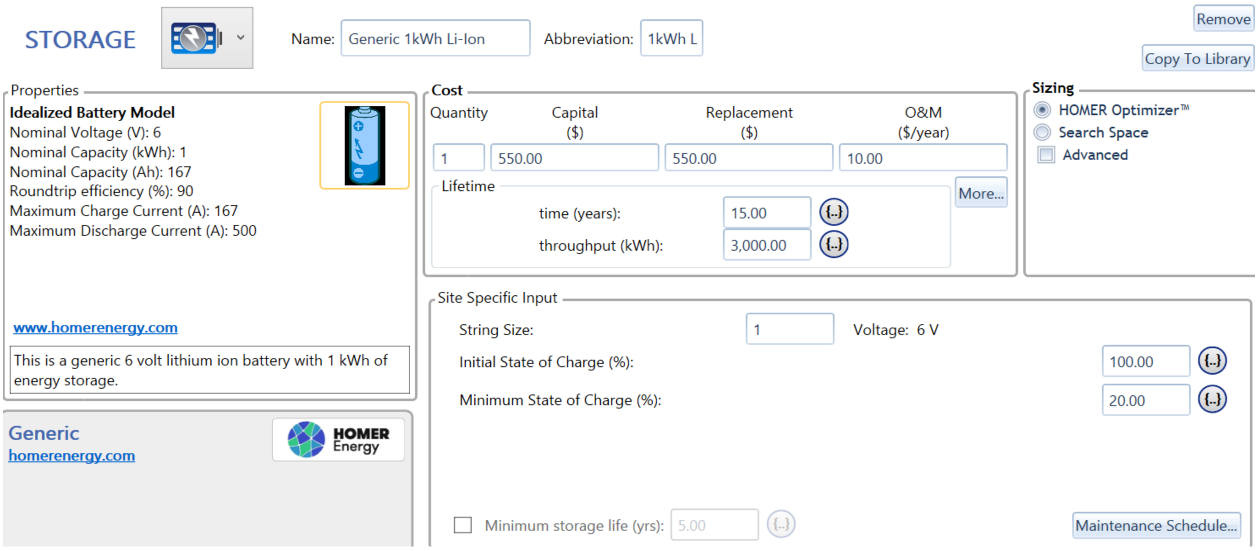


Fig 5.7 Specification of Battery

5.8.4 Converter system:

Considering the converter efficiency of 95 %, its initial capital cost is estimated at 300 $.Specification of converter is shown below fig 5.8.

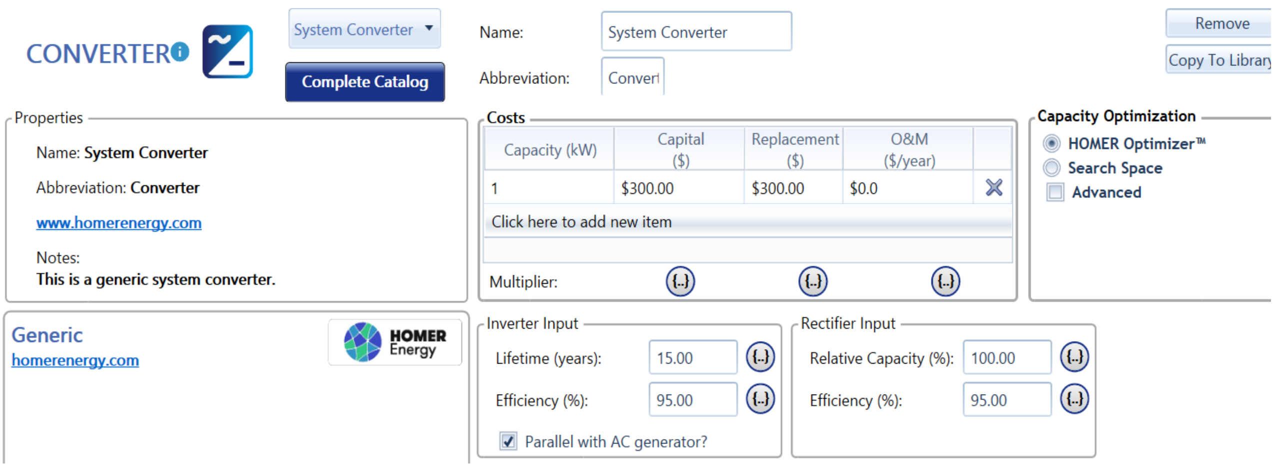


Fig 5.8 Specificaion of Converter

5.9 TECHNO ECONOMIC ANALYSIS OF PROPOSED HRES SYSTEM

The optimal-sizing of the HRES system is performed according to the design or sizing parameters used in HOMER. The primary design parameters are Capital Cost, Replacement Cost, Operation and Maintenance Cost and Life span of each components used in HRES.

5.9.1Criteria of Evaluation

The optimization process of various HRES arrangements is performed by the different parameters from different domains, as discussed below.

1)Net Present Cost 2)Cost of Energy 3)Capital Cost 4)Fuel Cost 5)Excess Energy 6)Unmet load 7)Human Development Index 8)Job formation Factor.

5.9.1.1 Net Present Cost:

The net present cost (NPC) is an essential parameter for the economic analysis of a system. It is the summation of initial cost (IC) of system, replacement cost (RC) of each component, and OMC of the entire lifetime as shown by equation (1) .

$$Net\ Present\ Cost = \frac{Total\ Annualized\ Cost(\$/year)}{Capital\ Recovery\ Factor(I_y,t)} \quad \textbf{(1)}$$

Here, t is the life-time of project, I_y is the annual real interest rate (%) that is calculated in terms of annual inflation rate (f) and nominal interest rate (I_n) by the equation (2)

$$I_y = \frac{I_n - f}{1+f} \quad \textbf{(2)}$$

The capital recovery factor is defined as the element used for calculating the present value of annual cash flows in number of years (k) and real interest rate (I_y) as shown by equation (3)

$$Capital\ Recovery\ Factor(Iy,t) = \frac{I_y(1+I_y)^k}{(1+I_y)^k - 1} \quad \textbf{(3)}$$

5.9.1.2 Cost of Energy

The cost of energy (COE) is defined as the average per-unit cost of electrical energy produced by a renewable hybrid system for the system's entire lifetime as shown by below equation (4)

$$COE = \frac{Total\ annualized\ cost\ of\ system(C_{an})}{Total\ Electricity\ consumption\ per\ year E_t\left(\frac{kWh}{year}\right)} \quad \textbf{(4)}$$

Where, the annualized cost (C_{an}) is summation of capital cost, replacement costs and annual operating cost for the entire lifespan and E_t is the annual electricity consumption[45].

5.9.1.3 Life Cycle Emission

The term Life Cycle Emission (LCE) represents the annual equivalent CO_2 emissions (kg-eq-CO_2/year and also used for hazardous emissions produced in various processes. The LCE emissions may be produced by individual components or whole HRES system and expressed as shown in equation for *n* number of components[46].

$$LCE = \sum_{i=1}^{n} ð_i \, E_m \qquad \textbf{(5)}$$

5.9.1.4 Renewable Penetration

Renewable Penetration (RP) is defined as the percentage of energy obtained from sustainable resources as presented in equation. This factor is used for determining the renewable fraction of energy produced by a generation system as shown by equation (5) [22]

$$\% \, RP = \left(1 - \frac{\sum E_c}{\sum E_r}\right) \times 100 \qquad \textbf{(6)}$$

5.9.1.5 Unmet Load

The unmet load is considered as the ratio of annual non served load to the entire yearly load, as given by the expression (6)[47]

$$Unmet\ Load = \left(\frac{Annual\ Non\text{-}served\ Load}{Annual\ Entire\ Load}\right) \qquad \textbf{(7)}$$

5.9.1.6 Human Development Index:

In general the socio-economic development of residents is represented by the human development index (HDI). It can also be observed by the electricity consumption pattern of consumers residing in a locality[48]. The excess energy, produced by the HRES system can be used for HDI improvement. In the present work the excess energy is required to be minimized, and the minimized quantity of excess energy is utilized for additional usages that can improve human development index[48-51]. Pasternak[51] introduces a logarithmic expression, for HDI estimation, based on 60 countries' data that was further elaborated inan improved form by analysing data of 128 nations[52].HDI is shown by the below eqution (7)(8)(9).

$$H_D = 0.091 \log_e[E_{ap}] + 0.072\,4 \qquad \textbf{(8)}$$

$$H_D = 0.0978 \log_e[E_{ap}] - 0.0319 \qquad \textbf{(9)}$$

In addition, Sawle et al[50] proposed a cumulative expression based on summation of specific elements(x) and their control approaches(y)[48-49] as shown in expression .

$$H_{Dxy} = 0.098 \log_e[(E_l + \min(\beta_{ms} \times E_{se} \times \beta_{ml} \times E_l) / n_h] - 0.031\beta_{ms} \qquad \textbf{(10)}$$

5.9.1.7 Particulate Matter:

Particulate matters are micro-size pollutants with an approximate diameter of 2.5 µm. $PM_{2.5}$and PM_{10} are the basic categorizations of particulate matter. It is emitted by carbon combustion, heavily injurious to human health and promotes environmental degradation.The expression for Particulate Matter (PMF) estimation in a HRES is shown by below equation (11)

$$PMF = \left(\frac{Total\ PM_{annual}}{Total\ Reference\ PM_{annual}}\right) \qquad \textbf{(11)}$$

5.9.1.8 Job formation factor

The progress of renewable energy resources may become an additional of job formation sector directly or indirectly for the developing nations. Few standard job formation calculation and parameters are established for each renewable resources respectively by numerous scholars[49]. The range of job formation factor for wind energy system and SPV power generation system are 0.39 to 0.8jobs/MW and 0.41 to 2.48jobs/MW[48]. The job formation factor by DG is estimated as 0.17 jobs/ (GWh/yr) in India. The combined expression for the job formation factor calculation is shown by below equation (12)

$$JFF=JC_{pv}*P_{pv} + JC_{battery*}E_{battery}+JC_{biomass*}P_{biomass} \qquad \textbf{(12)}$$

In the last few years, battery-based public transportation vehicles are introduced in India. It is a sustainable approach that creates better employment opportunity. Batteries of rating 48V-80Ah, 3.84kwh are used for regular battery rickshaw that requires twice charging in a single day[53] .According to the availability of excess energy of HRES, employment produced for one year (300 days) through local transport can be estimated by expression (13)

$$LTE = \frac{Annual\ Excess\ Energy}{Daily\ Charging\ requiredX\ 300} \tag{13}$$

5.10 CONCLUSION:

The optimal configuration is selected based on the different factors such as Net present cost,Cost of Energy,Capital cost,fuel cost,excess energy,Unmet load. Then calculate the Human development index,Job formation factor,LTE for better understanding of social impact of this HRES model.After assuming the load of all the equipments from different place such as School,hospital,office,home,agricultural load,ev charging station can estimate the overall load profile of that area,then put the load profile into the homer software and giving the different amount of resourses to check for which value can get low COE and NPE.In this chapter modelling of the HRES system is done and analysis is going on.This chapter concludes that HRES system modelling depends upon various factors which explained in the above description.In the next chapter results of all the analysis has been discussed and social analysis,robustness analysis is being analysed.

CHAPTER 6

RESULT AND DISCUSSION

6.1 INTRODUCTION:

An autonomous PV-Biomass-Li-ion battery HRES is developed to serve an electrical load of 102.80 kW peak and 1081.27 kWh/day for the locations under study. The systems are simulated for the locations using the HOMER software considering the input data. The discount and the inflation rate of the country are considered as 8 % and 2 % respectively. The effect of the PV energy penetration on the unmet load, capacity shortage, battery capacity, COE, and CO2 emission is studied. HOMER runs the simulations, identifies the HRES for zero capacity shortage and zero unmet load, and the HRES with the lowest COE is selected as the best fit for a certain location. The optimized HRES is analyzed for COE, NPC, excess energy generated, CO2 emissions avoided, and compared with the HRES designed by existing literature. System architecture, Economic result of HRES system, electrical summary of different component, fuel summary, emissions, social factor, cash flow graph, monthly electicity production by Solar Pv and Biogas genset,robustness analysis all are described in this chapter in details.

6.2 Optimal Model:

In this thesis, the desired system is designed using Solar photovoltaic, Biogas genset,li-on Battery,and convereter based hybrid renewable energy system.Schematic diagram of Pv Bio Battery Converter based HRES model is shown by the below fig 6.1.

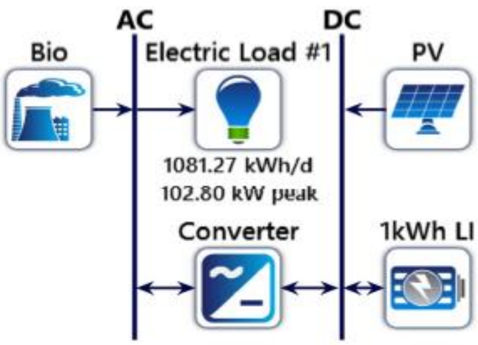


Fig 6.1 Schematic Diagram of Pv Bio Battery Converter based HRES Model

6.3 System Architecture:

After Optimization using homer software optimal system architecture is being achieved.Optimal architecture of Solar pv,Biogas genset,Battery,Converter for our designed system is shown by the below table 6.1.

Component	Name	Size	Unit
Generator	Generic Biogas Genset (size-your-own)	100	kW
PV	Generic flat plate PV	150	kW
Storage	Generic 1kWh Li-Ion	104	strings
System converter	System Converter	88.0	kW
Dispatch strategy	HOMER Load Following		

Table 6.1 System Architecture

6.4 Economic Result of HRES Arrangement:

Economic result of HRES system divides into two parts,Net presents cost and Annualized cost. Capital, Operating, replacement, salvage cost of the analysed system is shown by below table 6.2 for Generic flat plate pv.Biogas genset,System Converter,and Li-ion battery.

Net Present Costs

Name	Capital	Operating	Replacement	Salvage	Resource	Total
Generic 1kWh Li-Ion	$57,200	$13,445	$76,245	-$9,997	$0.00	$136,892
Generic Biogas Genset (size-your-own)	$41,000	$67,223	$14,898	-$598.89	$339,727	$462,249
Generic flat plate PV	$42,000	$58,174	$0.00	$0.00	$0.00	$100,174
System Converter	$26,398	$0.00	$11,200	-$2,108	$0.00	$35,491
System	$166,598	$138,842	$102,343	-$12,704	$339,727	$734,805

Table 6.2 Net present cost of overall component

Annualized cost of overall components are shown below table 6.3.

Annualized Costs

Name	Capital	Operating	Replacement	Salvage	Resource	Total
Generic 1kWh Li-Ion	$4,425	$1,040	$5,898	-$773.33	$0.00	$10,589
Generic Biogas Genset (size-your-own)	$3,172	$5,200	$1,152	-$46.33	$26,279	$35,757
Generic flat plate PV	$3,249	$4,500	$0.00	$0.00	$0.00	$7,749
System Converter	$2,042	$0.00	$866.38	-$163.06	$0.00	$2,745
System	$12,887	$10,740	$7,917	-$982.72	$26,279	$56,840

Table 6.3 Annualized cost of overall component

6.5 Electrical Summary:

The PV-Biomass-Li-ion Battery HRES is optimized with 0 % unmet load and 0 % capacity shortage, excess energy 70961 kwh/yr with the lowest possible NPC and COE as shown in below Table 6.4.

Excess and Unmet

Quantity	Value	Units
Excess Electricity	70,961	kWh/yr
Unmet Electric Load	0	kWh/yr
Capacity Shortage	0	kWh/yr

Table 6.4 Excess energy and Unmet load of the System

Generic flat plate pv produces 199255 kwh/yr and Generic biogas genset produces 28052 kwh/yr, as shown in the below table 6.5 ,which is 41.5 % and 58.5 % enery produced by the system.

Production Summary

Component	Production (kWh/yr)	Percent
Generic flat plate PV	199,255	41.5
Generic Biogas Genset (size-your-own)	280,592	58.5
Total	479,847	100

Table 6.5 Production summary of Components

Ac primary load consumes 394,664 kwh/yr.Consumption summary of the anayzed system is shown by the below table 6.6.

Consumption Summary

Component	Consumption (kWh/yr)	Percent
AC Primary Load	394,664	100
DC Primary Load	0	0
Deferrable Load	0	0
Total	394,664	100

Table 6.6 Electricity Consumption Summary

Generic biogas genset consumes 876 tons/year fuels,specific fuel consumptions 2.19 kg/kwh,Fuel energy input 936810,mean electricity efficiency 30 as shown in the below table 6.7.

Generic Biogas Genset (size-your-own) Fuel Summary

Quantity	Value	Units
Fuel Consumption	876	tons/yr
Specific Fuel Consumption	2.19	kg/kWh
Fuel Energy Input	936,810	kWh/yr
Mean Electrical Efficiency	30.0	%

Table 6.7 Fuel summary of biogas genset

Generic biogas genset has 5200 hrs/yr operation per year,number of stats 1340 starts/yr,operaional life 3.85 yr,capacity factor 32%,fixed generation cost 1.68 $/hr,marginl generation cost 0.0857 $/kwh as shown in the below table 6.8.

Generic Biogas Genset (size-your-own) Statistics

Quantity	Value	Units
Hours of Operation	5,200	hrs/yr
Number of Starts	1,340	starts/yr
Operational Life	3.85	yr
Capacity Factor	32.0	%
Fixed Generation Cost	1.68	$/hr
Marginal Generation Cost	0.0857	$/kWh

Table 6.8 Statistics of Biogas Genset

Generic flat plate Pv has maximum output 123 kw,pv penetration 50.5%,hours of operation 4399 hrs/yr,and levelized cost is shown below table 6.9.

Generic flat plate PV Electrical Summary

Quantity	Value	Units
Minimum Output	0	kW
Maximum Output	123	kW
PV Penetration	50.5	%
Hours of Operation	4,399	hrs/yr
Levelized Cost	0.0389	$/kWh

Table 6.9 Electrical Summary of Pv

After the electrical analysis,homer shows rated capacity of Generic flat plate pv is 150kw,mean output 22.7 kw,mean output 549 kwh/day,capacity factor 15.2 %,and total production 199,255 kwh/yr as shown in the below Table 6.10

Generic flat plate PV Statistics

Quantity	Value	Units
Rated Capacity	150	kW
Mean Output	22.7	kW
Mean Output	546	kWh/d
Capacity Factor	15.2	%
Total Production	199,255	kWh/yr

Table 6.10 Statistics of Flat plate Pv

Generic 1kwh li-ion battery shows its energy input is 42969 kwh/yr,energy output is 38720 kwh/yr,storage depletion 51.1,losses 4299 kwh/year,and annual throughput 40815,Storage wear cost is .193 $/kwh.nominal capacity 104 kwh,usable nominal capacity 83.2,lifetime throughput 312000 kwh,and expeced life 7.64 yr.all are shown by the below table 6.11(a),(b).

Generic 1kWh Li-Ion Result Data

Quantity	Value	Units
Average Energy Cost	0	$/kWh
Energy In	42,969	kWh/yr
Energy Out	38,720	kWh/yr
Storage Depletion	51.1	kWh/yr
Losses	4,299	kWh/yr
Annual Throughput	40,815	kWh/yr

Table 6.11 (a) Electrical summary of li-ion battery

Generic 1kWh Li-Ion Statistics

Quantity	Value	Units
Autonomy	1.85	hr
Storage Wear Cost	0.193	$/kWh
Nominal Capacity	104	kWh
Usable Nominal Capacity	83.2	kWh
Lifetime Throughput	312,000	kWh
Expected Life	7.64	yr

Table 6.11(b) Statistics of Li-ion Battery

System Converter of this analyzed system has operation hour 5156 hrs/yr,enery input 171982 kwh/yr,energy out is 163383 kwh/yr,losses are 8599 kwh/yr as shown in the below table 6.12.

System Converter Electrical Summary

Quantity	Value	Units
Hours of Operation	5,156	hrs/yr
Energy Out	163,383	kWh/yr
Energy In	171,982	kWh/yr
Losses	8,599	kWh/yr

Table 6.12 Electrical Summary of Converter

6.6 Fuel Summary:

Fuel summary of the designed system is shown by the below table 6.13.Total biomass consumption is 876 tons,average feedstock per day is 2.40 tons/day,and average feedstock per hour is .100 tons/hour as shown by the below table 6.13.

Biogas Consumption Statistics

Quantity	Value	Units
Total feedstock consumed	876	tons
Avg feedstock per day	2.40	tons/day
Avg feedstock per hour	0.100	tons/hour

Table 6.13 Fuel summary

6.7 Emissions Summary:

1603 kg/yr Carbon Dioxide,1.75 kg/yr Carbon monoxide,and1.09 kg/yr Nitrogen Oxides are emitted through this analyzed system over the year which is shown below by the table 6.14.

Emissions

Pollutant	Quantity	Unit
Carbon Dioxide	1,603	kg/yr
Carbon Monoxide	1.75	kg/yr
Unburned Hydrocarbons	0	kg/yr
Particulate Matter	0	kg/yr
Sulfur Dioxide	0	kg/yr
Nitrogen Oxides	1.09	kg/yr

Table 6.14 Emissions by the system

6.8 Overall Summary of Optimal HRES System Analysed Parameters:

By the below table 6.15 overall summary of all analyzed parameters of the optimal HRES system are shown.

Selected System	Capital Cost	Net present cost	Replacement cost	COE($/kwh)	Fuel cost
1)	**$ 166598**	**$ 734803**	**$102343**	**$ 0.144**	**$ 339726**

Table 6.15 Overall Analysed parameter

Selected System	PV(Kw)	Bio(Kw)	BS(Kw)	IV(kw)	Excess Energy(KW)	Unmet load(KW)
1)	**150**	**100**	**104**	**88**	**70961**	**0**

Table 6.15 (Continued)

6.9 SOCIAL FACTOR ANALYSIS OF THE HRES SYSTEM:

A novel social analysis of HRES scheme based on the human development index and Social acceptance is specifically presented in this work. The unemployment of rural areas has been addressed in terms of Job formation and local transport based employment utilizing the excess energy.Using eq 5 in the Chapter 5 Human development index is calculated,its value is .6239,using eq 11 in the chapter 5 job formation factor is calculated.JFF is 1.53,using eq 12 local transport based employment is analysed and 61.59 jobs/year is coming after the calculation.The summary of all the social factors are shown by the below table 6.16.

Selected System	HDI	JFF	LTE(jobs/year)
1)	**.6239**	**1.53**	**61.59**

Table 6.16 Social Factors

6.10 Monthly Electric Production Sharing by each component:

Monthly electricity production by the all component Flat plate pv and Biogas genset is shown by the below fig 6.2.

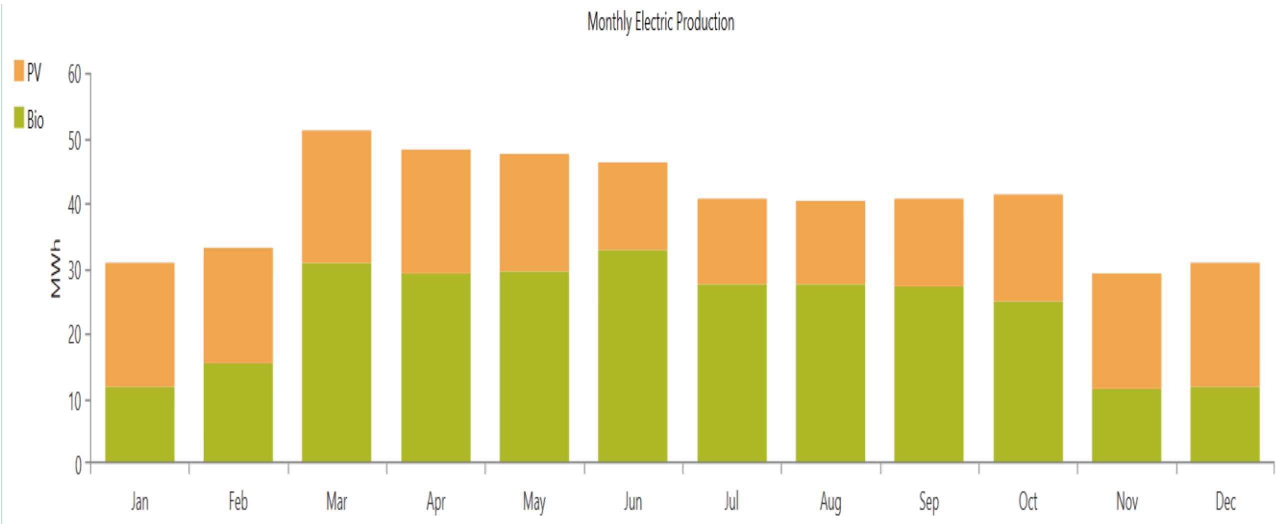
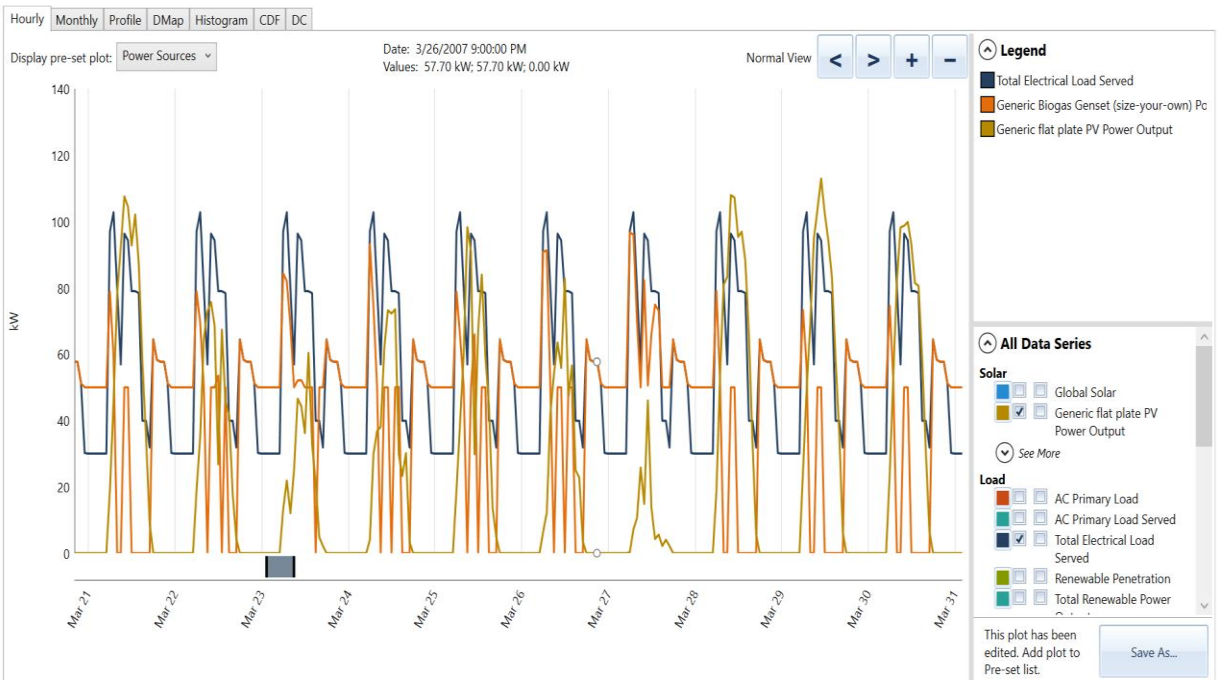


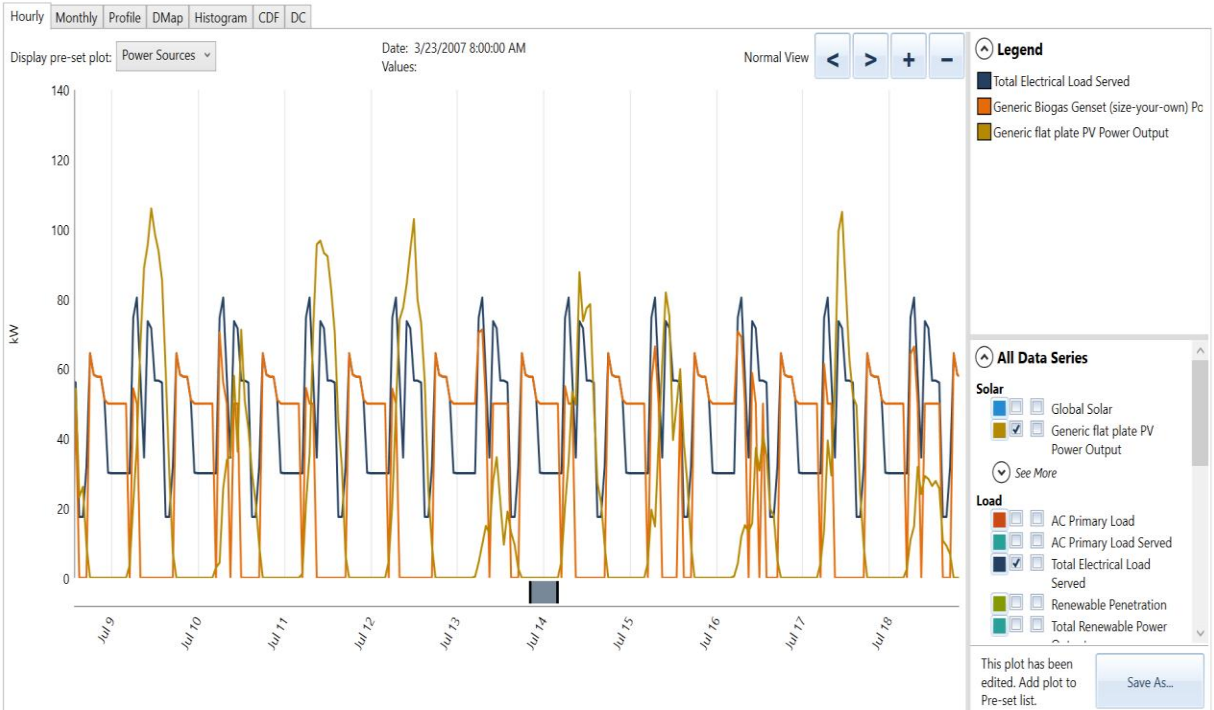
Fig 6.2 Monthly Electric Production

6.11 Robustness Analysis:

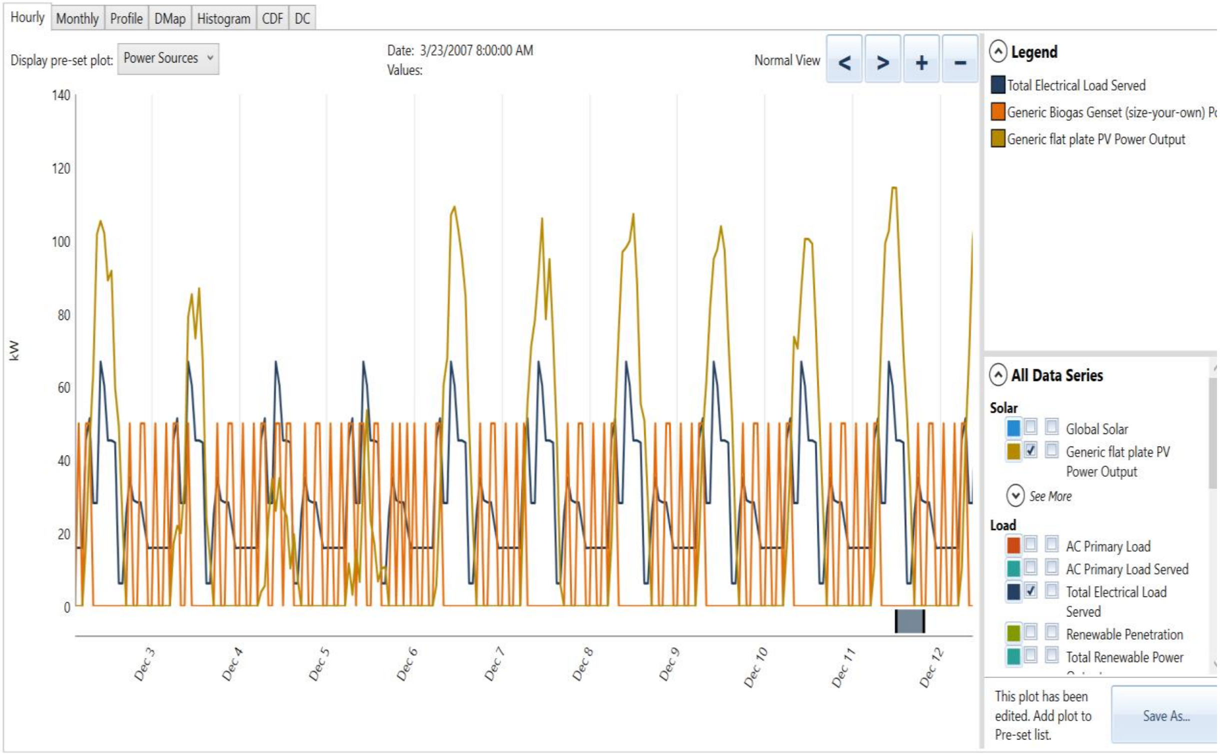
The technical robustness of optimised HRES is analysed for the smooth and consistent supply of electricity in different weather conditions and diverse load profiles. In addition, the feasibility of the HRES system is ensured by robustness analysis for domestic usage and appealing to potential investors. Figure 6.3 shows that the cumulative electricity generation of HRES is always greater than or equal to the load demand. In summer season (e.g. march), the renewable energy is sufficient for the load demand , here Pv generates the maximum power and Bio supports the Spv as shown in figure 6.3(a).. In moonson season (e.g.july), the renewable energy is sufficient for the load demand , here also Pv generates the maximum power and Bio supports the Spv as shown in figure 6.3(b). In winter season renewable resources gives good response for the load demand an pv generates max power .The seasonal generation demonstrated that no capacity shortage and unmet load is found here with least excess energy generation. It is clear that this HRES system is a technically robust arrangement that can meet the load demand in different seasons load demand effectively.



(a) Electricity generation in Summer



(b) Electricity generation in Monsoon



(c) Electricity generation in Winter

Fig 6.3 HRES Electricity generation pattern

6.12 CONCLUSION:

In this chapter, all the analysing data is shown in the table format for the optimal HRES system.Different parameters are considered for evaluating the optimal system like COE,NPE,Excess energy,Unmet load,environmental factors such as total CO_2 emmisions,different social factors Human development index,Job formation factor,Local transport based employment etc which are properly analysed and discussed in this chapter.After all parameters analysing, a Spv-Bio-Battery-Converter based HRES system is considered as the optimal design.In the next chapter the conclusion and future scope of this thesis is described in detail.

CHAPTER 7

CONCLUSION, FUTURE SCOPE,&LIMITATIONS

7.1 CONCLUSION:

This thesis introduces an optimal design and assessment of standalone HRES for a rural area. Initially, resource assessment, socio-economic profile, and load demand of the consumers are carefully studied. Later on, the socio-economic and technical feasibility of the HRES is carried out for electrification of remote rural consumers. The HOMER-PRO software is used for the optimisation and sizing procedure. In this study, One HRES configurations is analysed to accomplish the different parameters related to the different domains. The major results of the present work are summarizedas follows.

1) The obtained optimal size of the HRES is combination of 150 kW of PV, 100 kW of BIO, 104 unit of Battery System and 88 kW of inverter for 1081.27 kWh/day electricity load demand. The COE and NPC of the optimized HRES are 0.144 $/kWh and $734803 respectively.

2) The optimum HRES are obtained as zero capacity shortage less excess energy producing element. The particulate matters are not found in this analysis.

3) The social parameter indicators for optimum arrangement like human development index, Job formation factor and Local transport based employment indicator are obtained as 0.6239, 1.53 and 61.59 respectively.

4) The electricity production of the optimum system is illustrated in different seasons and also elaborated for the share of each components energy production.

5) The optimal hybrid configuration is further assessed through robustness evaluation.

This work's findings are financially and technically robust and successfully analysed for continuous and reliable power supply to the consumer. This HRES can also improve the way of life and financial activities of the rural inhabitants. The HRES system can play an essential role in mitigating future energy crises, and unemployment. The utilisation of the HRES in rural consumers, can creates many job opportunities and improvement of HDI. The hybrid renewable system proposed in present work can be applicable in similar climatic and economic rural regions, worldwide.

7.2 FUTURE SCOPE:

India is a country where 75% of the population lives in rural areas. These areas do not have adequate electricity, water supply, education, and transport. With HRES, electricity can become easily accessible in rural India.Developing villages has been a challenge for India for a very long time. HRESs can be the solution to many of the problems. Here is the location-wise suitability of HRES as shown in below figure 7.1.

Geographical feature	Type of HRES	Recommendation
High Altitude	Biomass-wind-fuel cell, photovoltaic-wind, photovoltaic-biomass	Photovoltaic-biomass
Mountain	Biomass-wind-fuel cell, photovoltaic-wind, photovoltaic-biomass	Photovoltaic-biomass
Plain	Photovoltaic-biomass, hydro wind, solar flower, combined HRES plant, biomass wind, photovoltaic-wind	Combined HRES plant
Semi Desert	Wind-fuel cell, wind-photovoltaic, wind biomass, photovoltaic-biomass, photovoltaic wind-biomass	Photovoltaic-Wind-Biomass
Desert	Wind-fuel cell, wind-photovoltaic, wind biomass, photovoltaic-biomass, photovoltaic wind-biomass	Photovoltaic-Wind-Biomass

Table7.1 Location wise HRSE recommendation

- In this thesis,after estimating and surveying the load profile for different area in a small village all the analysis is being done.So If load profile is collected from any meterological place in future,the overall analysis will be done more precisely.
- By using another renewable energy sources, the analysed parameters may be less compared to the analysis being done by this thesis.
- Sensitivity analysis is not done here.In future, The sensitivity analysis will be performed by the varying the components cost and micro-economic variables separately for this arrangement.
- Grid extension is not done here.A offgrid HRES system is analysed here.In furure,this arrangement will be connected to the grid and excess energy would supply the grid from the HRES system and net metering will be observed.

India with its diversity in weather conditions could benefit a lot with such systems, specially in remote areas where installation and the reliability of the national grid is often not feasible. These systems can independently function and because of their increased reliability can power regions effectively. HRES also exploit India RES potential more effectively, and utilisation of such systems could benefit in long term sustainability of the country.

7.3 Limitations:

- The design and implementation of a hybridized power system is a complex one and a relatively challenging task because of the system topology. Additionally, the hybridized system needs higher capital investment costs .

- Implementation of the hybrid system is not possible by going beyond the ongoing rules and regulatory but can be done by reconstructing the new law. Political commitment from governments crucial for the rural electrification with the renewables.

- Economic consideration is one of the significant factors to implement such a system in the rural areas, as it is not practically possible without financial assistance. The primary challenge of the developing countries like ours is to manage the high installation cost for the hybrid system compared to the conventional power generation technologies.

- The acceptance of a technology which involves complexity in it also depends on the socio-cultural freedom as it requires the level of understanding of such technology In this regard, members of the society and their cultural background has a strong influence to establish the hybrid system in the remote area. However in many cases, the local people feel confused to come forward for help because of the superstitions, the cultural barrier to accept the new technology.

REFERENCES

[1] https://www.un.org/en/climatechange/what-is-renewable-energy.
[2] https://www.environmentalscience.org/renewable-energy.
[3] Ahiduzzaman, M. and A.S. Islam, Greenhouse gas emission and renewable energy sources for sustainable development in Bangladesh. Renewable and Sustainable Energy Reviews, 2011; 15(9): 4659-4666.
[4] Aziz AS, Tajuddin MFN , Adzman MR, Azmi A, Ramli MAM, Optimization and sensitivity analysis of standalone hybrid energy systems for rural electrification: A case study of Iraq. RenewableEnergy ,2019;138: 775-792
[5] Li, G., et al., Study on effect factors for CO2 hydrate rapid formation in a water-spraying Apparatus. Energy & Fuels, 2010; 24(8): 4590-4597.
[6] Li, G and X Zheng, Thermal energy storage system integration forms for a sustainable future. Renewable and Sustainable Energy Reviews 2016; 62: 736-757.
[7] Singh, A, Baredar P, and Gupta B, Techno-economic feasibility analysis of hydrogen fuel cell and solar photovoltaic hybrid renewable energy system for academic research building. Energy Conversion and Management, 2017; 145: 398-414.
[8] Khan FA, Pal N, Saeed SH, SPV/Wind Hybrid Energy System: Future of Rural India, 21st National Power Systems Conference (NPSC), 2020; IEEE Xplore: 1-6. DOI: 10.1109/NPSC49263.2020.9331871
[9] Bhattacharyya SC, Palit D, Gopal KS, Vivek S, Prerna S, "Solar PV mini-grids versus large-scaleembedded PV generation: A case study of Uttar Pradesh (India) Energy Policy 128 (2019) 36–44.
[10]https://www.google.com/publicdata/explore?ds=d5bncppjof8f9_&met_y=sp_pop_totl&idim=count ry:IND:CHN&hl=en&dl=en (Accessed on 18/06/2020).
[11] Samanta PK, A Study of Rural Electrification Infrastructure in India, IOSR Journal of Businessand Management 2015; 17(2): 54-59. DOI: 10.9790/487X-17245459
[12] https://mercomindia.com/electricity-demand-india-triple-2018-2040.
[13] https://powermin.nic.in/en/content/overview-1 (Accessed o\n 17/06/2020).
[14] Chauhan A, Saini RP. Discrete harmony search based size optimization of Integrated RenewableEnergy System for remote rural areas of Uttarakhand state in India. Renew Energy 2016; 94:587-604.
[15] Human Development Report 2014, Sustaining Human Progress: Reducing Vulnerabilities and Building Resilience, United Nations Development Programme, 2014, 978-992-1-126340-4.
[16]https://www.mckinsey.com/business-functions/sustainability/our-insights/sustainability blog/renewable-hybrid-energy-systems-as-a-game-changer-in-india.
[17] Rodolfo Dufo-L_opez ,, Iv_an R. Crist_obal-Monreal , Jos_e M. Yusta , Optimisation of PV-wind-diesel-battery stand-alone systems to minimise cost and maximise human development index and jobcreation, Renewable Energy 94 (2016) 280-293.
[18] Yashwant Sawle*, S.C. Gupta, Aashish Kumar Bohre Socio-techno-economic design of hybrid renewable energy system using optimization techniques Renewable Energy 119 (2018) 459-472.
[19] A.N. Celik Optimisation and techno-economic analysis of autonomous photovoltaic–wind hybrid energy systems in comparison to single photovoltaic and wind systems Energy Conversion and Management 43(2002) 2453–2468.
[20] S. Diaf, D. Diaf, M. Belhamel, M. Haddadi, A. Louche A methodology for optimal sizing of autonomous hybrid PV/wind system Energy Policy 35 (2007) 5708–5718.
[21] Chong Li , Xinfeng Ge , Yuan Zheng , Chang Xu , Yan Ren , Chenguang Song , Chunxia

Yang Techno-economic feasibility study of autonomous hybrid wind/PV/battery power system for a household in Urumqi, China, Energy 55 (2013) ,263-272.
[22] Soumya Mandal , Barun K. Das , Najmul Hoque, Optimum sizing of a stand-alone hybrid energy system for rural electrification in Bangladesh, Journal of Cleaner Production 200 (2018) ,12-27.
[23] Anurag Chauhan , R.P.Saini, Techno-economic feasibility study on Integrated Renewable Energy System for an isolated community of India, RenewableandSustainableEnergyReviews59(2016)388–405.
[24] S. Bahramara,M.ParsaMoghaddam , M.R.Haghifam, Optimal planning of hybrid renewable energy systems using HOMER: A review, RenewableandSustainableEnergyReviews62(2016)609–620.
[25] Madhumita Das , Ratan Mandal, The effect of photovoltaic energy penetration on a Photovoltaic-Biomass-Lithium-ion off-grid system and system optimization for the agro-climatic zones of West Bengal Sustainable Energy Technologies and Assessments 53 (2022) 102593.
[26] Kenneth E. Okedu, Roland Uhunmwangho, Optimization of Renewable Energy Efficiency using HOMER, INTERNATIONAL JOURNAL OF RENEWABLE ENERGY RESEARCH Kenneth E. Okedu et al. ,Vol. 4, No. 2, 2014.
[27] Pronob Das , Barun K. Das , Mushfiqur Rahman , Rakibul Hassan, Evaluating the prospect of utilizing excess energy and creating employments from a hybrid energy system meeting electricity and freshwater demands using multi-objective evolutionary algorithms, Energy 238 (2022) 121860.
[28] Analysis and Scope of Hybrid Renewable Energy System Prajna Jandial 2020 IOP Conf. Ser.: Mater. Sci. Eng. **937** 012030.
[29] Adel Brka*, Yasir M. Al-Abdeli, Ganesh Kothapalli, The interplay between renewables penetration, costing and emissions in the sizing of stand-alone hydrogen systems, internationl journal of hydrogen energy 4 0 (2 0 1 5) 1 2 5 - 3 5.
[30] H. El-houari , A. Allouhi , T. Salameh, T. Kousksou., A. Jamil , B. El Amrani, Energy, Economic, Environment (3E) analysis of WT-PV-Battery autonomous hybrid power plants in climatically varying regions, Sustainable Energy Technologies and Assessments 43 (2021) 100961.
[31] M. Das, R. Mandal, Optimization, Sensitivity and Energy Management of a PV/Wind/Battery and PV/Wind/Supercapacitor Hybrid Renewable Energy System for the Climatic Conditions of Haldia using HOMER: A Case Study, *JOURNAL OF NANO- AND ELECTRONIC PHYSICS*, Vol. 13 No 3, 03011(5pp) (2021).
[32] Daywes Pinheiro Neto, Elder Geraldo Domingues, Luane Schiochet Pinto, Risk analysis of Levelized Cost of Electricity to Renewable Energy in Brazil.
[33] W.Margaret Amutha, V.Rajini , Cost benefit andtechnicalanalysisofruralelectrification alternatives
in southernIndiausingHOMER, RenewableandSustainableEnergyReviews62(2016)236–246.
[34] Mehdi Baneshi , Farhad Hadianfard, Techno-economic feasibility of hybrid diesel/PV/wind/battery electricity generation systems for non-residential large electricity consumers under southern Iran climate conditions, Energy Conversion and Management 127 (2016) 233–244.
[35] Daniel Chade , Tomasz Miklis , David Dvorak, Feasibility study of wind-to-hydrogen system for Arctic remote locations e Grimsey island case study, Renewable Energy 76 (2015) 204e211.
[36] Barun K. Das , Najmul Hoque , Soumya Mandal , Tapas Kumar Pal , Md Abu Raihan, A techno-economic feasibility of a stand-alone hybrid power generation for remote area application in Bangladesh, Energy 134 (2017) 775e788.

[37] Tao Ma, Hongxing Yang, Lin Lu, A feasibility study of a stand-alone hybrid solar–wind–battery system for a remote island, Applied Energy 121 (2014) 149–158.
[38] Technical and economic analysis of different configurations of stand-alone hybrid renewable power systems – A case study Hegazy Rezk n, Gamal M.Dousoky, RenewableandSustainableEnergyReviews62(2016)941–953.
[39] Saptam Ganguly, Vagisha Nandan, Namwar Anjum, SMART VILLAGES: A SUSTAINABLE MODEL, https://www.researchgate.net/publication/311453293.
[40] Kenneth E. Okedu Roland Uhunmwangho, Optimization of Renewable Energy Efficiency using HOMER, INTERNATIONAL JOURNAL OF RENEWABLE ENERGY RESEARCH Kenneth E. Okedu et al. ,Vol. 4, No. 2, 2014.
[41] HOMER Software Training Guide for Renewable Energy Base Station Design, chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2012/06/HOMER-Software-Training-Guide-June-2011.pdf.
[42] Nyeche EN, Diemuodeke EO. Modelling and optimisation of a hybrid PV-wind turbine-pumped hydro storage energy system for mini-grid application in coastline communities. J Cleaner Prod 2020;250:119578.
[43] Razmjoo A, Davarpanah A. Developing various hybrid energy systems for residential application as an appropriate and reliable way to achieve energy sustainability. Energy Sources Part A 2019;41(10):1180–93.
[44] Ghosh B. Towards Modernized Bio-Energy. Ministry of New and Renewable Energy, Govt. of India. 2004.
[45] Hiendro A, Techno-economic analysis of photovoltaic/wind hybrid system for onshore/remote area in Indonesia. Energy 2013; 59: 652-657.
[46] Brka A, Al-Abdeli YM, Kothapalli G. The interplay between renewables penetration, costing andemissions in the sizing of stand-alone hydrogen systems. International Journal of Hydrogen Energy, 2015. 40(1): 125-135.
[47] Khalid, F, Dincer I, Rosen MA, Thermo economic analysis of a solar biomass integrated multi generation system for a community. Applied Thermal Engineering, 2017. 120: 645-653.
[48] Dufo-Lopez R, Ivan R, Cristobal M, Yusta JM, Optimisation of PV-wind-diesel-battery stand- alone systems to minimise cost and maximise human development index and job creation, Renew. Energy 2016; 94: 280-293.
[49] Ramanathan R., Ganesh LS, Energy resource allocation incorporating qualitative and quantitativecriteria: an integrated model using goal programming and AHP, Socio-Economic Plan. Sci. 1995; 29(3): 197-218.
[50] Sawle Y, Gupta SC, Bohre AK, “Socio-techno-economic design of hybrid renewable energy system using optimization techniques. Renewable Energy 2018; 119: 459-472
[51] Pasternak AD, Global Energy Futures and Human Development: a Framework for Analysis, U.S. Department of Energy, 2000. UCRL-ID-140773, http:// www.geni.org/globalenergy/issues/global/qualityoflife/HDI-and-electricityconsumption. Pdf.
[52] United Nations Development Program, Human Development Report – 2009 Overcoming Barriers: Human Mobility and Development, 2009, http:// dx.doi.org/10.1016/S0883-153X(98)80004-0.
[53] https://www.luminousindia.com/ (Accessed on 18/04/2020).