Use of Renewable Energy Technologies for Energy Self Sufficient Community in Remote Areas- Pakistan

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Dedication

To my Parents, my wife, family and friends who have been supporting me round the clock.

Acknowledgement

I would like to thank ALLAH ALMIGHTY, the most Beneficent and the most merciful who made me able to complete my thesis. I have no words to express my gratitude to my loving parents, my wife and other family members for exemplary patience, understanding and cooperation during my studies. I would like to thank my supervisor Dr. Parvez Akhter for his guidance, understanding and encouragement during this work. Special thanks to Dr. Adeel Waqas, AP Ahmed Sohail, Dr. Majid , my friends Gusaan Mufti, Kamran Ashraf, Imran Yousaf, Naveed Ahmed & Asif Shahzad for their advices and help in my work gave me great boost in my work and I put myself in a right direction I could never be able to complete this work without their help.

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Abstract

Renewable energy resource utilization can address the both most emerging issues of the world in the current era: rapid depletion of conventional fossil fuel reserves and drastic climate changes. The main theme of this work is Pakistan being an energy deficient country facing major issues in its economic development due to the current power crisis. Pakistan is naturally benefitted with different renewable energy resources; out of which solar and wind energy are the main highlighted technologies. This research work will provide an assessment of the renewable energy potential of the Baluchistan region. A comparison of the economic and financial analysis for a centralized hybrid renewable energy system has been simulated by using Homer software. Three cases have been proposed in which centralized & decentralized solar PV system, wind energy system and a hybrid combination of both solar and wind energy system have been studied. Homer software has been used to devise the most optimal solution. The simulations confirm that the best optimal solution is the hybrid renewable energy system for the rural electrification of the proposed region.

Keywords: AC Micro grids, Centralized Hybrid Renewable Energy Systems, Hybrid Renewable Energy Systems, Rural Electrification, Stand Alone Systems

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I. *“Techno-Economic Evaluation of the Centralized Hybrid Renewable Energy Systems for off-grid rural electrification” Atif Naveed Khan, Dr. Parvez Akhter presented in International Conference on Recent Trends in Computer Science and Electronics(RTCSE), 2-3 January 2016,At Malaysia.

List of Abbreviations

COE……………………..……………………………….………Cost of Equity

NPC………………………………..……………………….…….Net Present Cost

INC……………………………………………………………………….Initial Cost

DOD…………………………………………………………...Depth of Discharge

C.F………………………………………………………….........Capacity Factor

KW……………………………………………………………….……...Kilo Watt

KWh……………………………………………………...…...……Kilo Watt hour

HRES…………………………………………......Hybrid Renewable Energy System

CRES…………………………………...…...Centralized Renewable Energy System

DRES…………………………………..… Decentralized Renewable Energy System

NREL ……………………………….…..............National Renewable Energy Laboratory

HOMER………………….………Hybrid Optimization Model for Electric Renewable

NOCT ……………………………………...Nominal Operating Cell Temperature

η.……………………..…………………………………..................Efficiency [%]

β………………………………………………………………………...Slope [º]

γ ……………………………………………………………………Azimuth [º]

VOC ………………………………………………….........Open Circuit Voltage

RF ………………………………………………………...Renewable Fraction

Chapter 1

Introduction

1.1 Background

Roughly 17 % of the world's population still does not have access to electricity. International Energy Agency estimates that roughly 30% of the people without electricity live in peri-urban or remote rural areas (IEA, 2009b) [1]. Today, most of these people are found in sub-Saharan Africa and South Asia. The IEA predicts that in 2030, if no new policy to alleviate energy poverty is introduced, 1.3 billion people (some 16% of the total world population) will still be denied electricity most of whom in South Asia and Africa [2] .

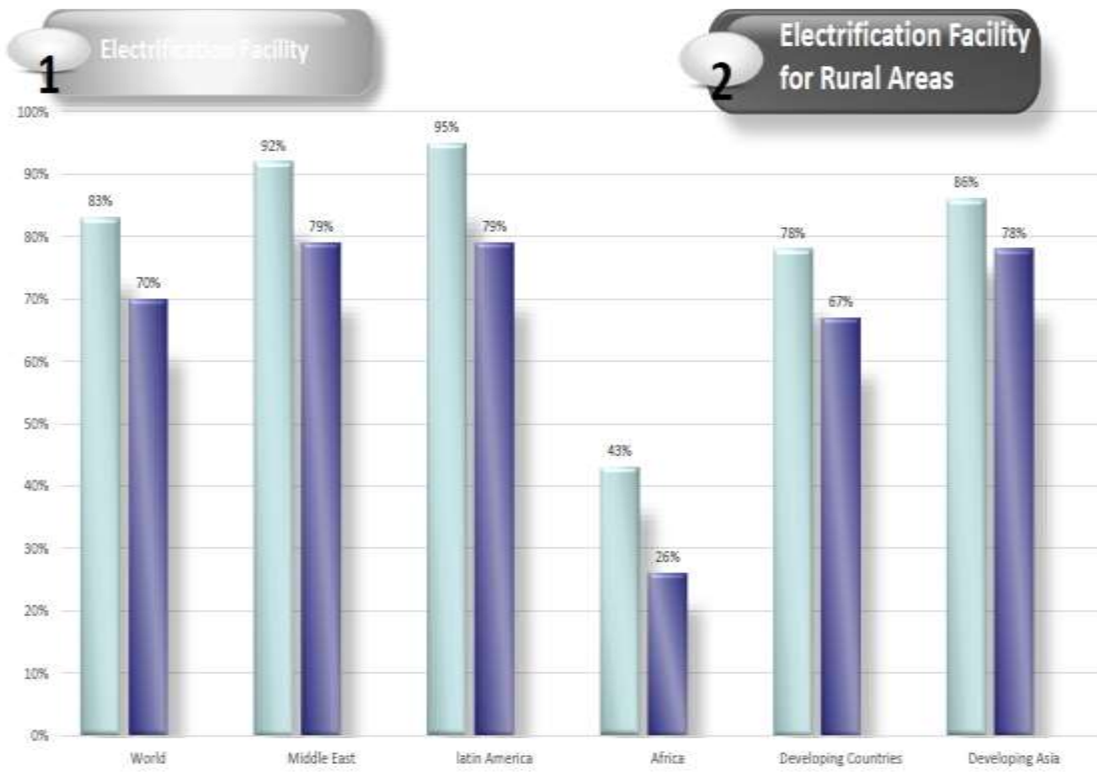

Figure 1.1: Energy Outlook of Globe and Rural Areas

As the graph clearly indicated that most of the non-electrified people of world lives in the remote areas especially the developing countries of Africa and South Asia. So rural electrification is one of the urgent need around the globe. By the term rural electrification we mean that provisioning of electricity to households or villages located in the isolated or remote areas. Generally it is not easy to electrify these villages because:-

- Lie at a reasonable distance from national.
- Difficult to access.
- Suffer harsh climatic conditions
- Dispersed population with low population density.
- Low load density.
- Low revenue generation.

Rural electrification is usually the main priority of emerging economies, but the main problem is the technology to be chosen for the purpose. The choice of a specific energy technology for RE depends upon the community or household that is to be benefited. Other than this there are various other issues like load density, relative distance from national grid, availability of alternate energy resources, socio-economic aspects, matured technology etc. All these factors must be catered before the selection of best possible technology for rural electrification in the areas to be benefitted.

1.2 Problem statement

Modern source of energy is very crucial in achieving a range of social and economic goals relating to basic necessities of life like poverty, health, education, equality and environmental sustainability etc. Modern concept of energy for all is far from being achieved.

If we focus on the situation of Pakistan, One of the great hurdles in the current economic growth of Pakistan is the enormous shortfall in the demand and supply of electricity. The gap between electricity demand and supply is increasing day by day. The difference between the electricity supply and demand had reached new heights of up to 50% in the summer of 2012. Extensive load shedding has been reported in the years passed. According to rough estimates about 12 hours a day in urban areas and 20 hours a day in rural areas have been reported. (NEPRA, 2012). Electricity power short fall during 2010 was observed up to 4522 Mega Watt (MW) and becoming worse with the passage of time. During 2011 Energy deficit up to 7000 MW was observed [3]. Overall energy shortage in Pakistan has adversely affected every aspect of life and around 40,000 villages are deprived of electricity in the country. According to WEO 2015, 38 % people of remote areas of Pakistan still have no access to electricity [4]. Connecting these villages to the national grid would be very costly. Some of the facts about the availability of electricity to the rural areas of Pakistan was revealed in a study conducted by Pakistan Bureau of Statistics.

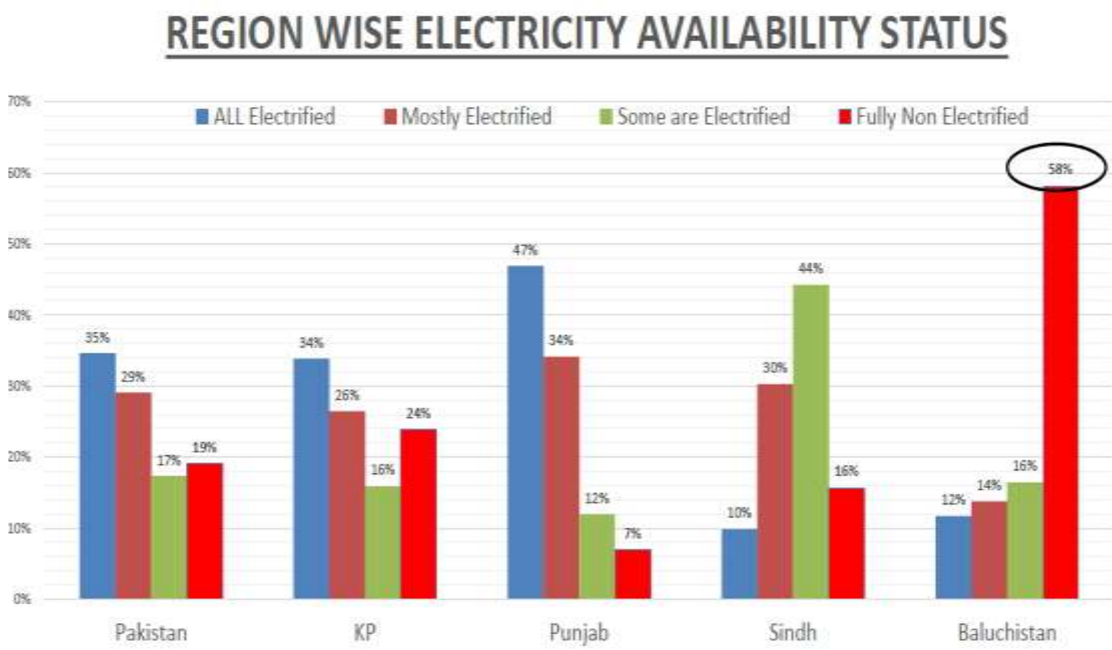

Figure 1.2: Region wise electricity availability status of Pakistan

On the other hand country is however rich in renewable energy sources and has vast potential for their exploitation. There are four main sources of renewable energy, namely hydel, solar, wind and biomass, which have substantial potential to overcome the energy shortage problem in the country. The total hydel power potential exceeds 100 GW, Solar power 2900 GW, wind power 120 GW and biomass 5.7GW [5]. Despite of such a huge renewable energy potential one some hundred Megawatts has been produced using renewable energy technologies. Keeping these facts and figures in view, rural electrification through Renewable Energy technologies has been considered as the best option.

1.3 Objective

The main objective of the research/ case study was basically to help the deprived community of Pakistan and device successful and sustainable Rural Electrification model. The main objective was sub categorized to the following sub tasks:-

- Collection of social, energy sources available and energy consumption data.
- Analysis of data on the basis of energy needs of the community.
- Based on the analysis, the energy needs of the community had been quantified.
- Analysis of the locally available energy sources.
- Based on the data collected for available energy sources, the best possible/ implementable energy source had been suggested.
- System sizing and Designing on the basis of the energy requirement and the available energy source.
- Actual system cost calculation based on the proposed system.
- Economic, Social Environmental and Financial analysis.
- Mechanism sustainability, operation and maintenance of the system had been recommended.

1.4 Methodology

Facts and figures already mentioned clearly shows that rural electrification is the area which had not been given importance in the country. First and foremost priority is the selection of suitable technology or model for electrifying far flung deprived communities. Based on the current energy crises, highly dispersed population, low population density, low load factor and low revenue generation in these remote areas, extension of national grid is considered a viable option. On the other hand we have huge potential of Alternate Energy resources. These Renewable Energy resources are present in enormous amounts and can be obtained free of cost. Since the last few decades, Renewable Energy technologies have received a huge amount of attention as a source of producing electricity. With the country's exceptional renewable energy potential, option of promoting renewable energy technologies especially (solar & wind) has the potential to become an affordable, long-term alternative to the grid and bring millions out of the dark while powering the country's economy.

Keeping the option for the renewable energy technologies, one can design Standalone energy system as well as Hybrid Renewable Energy System (HRES). Both have their own pros and cons. A stand-alone system comprises of an energy producing unit, a battery as a storage device, a charge controller, Inverter in case of AC loads. Stand-alone systems have been used widely in the world.

On the other hand Hybrid Renewable Energy Systems (HRES) consists of two or more renewable energy technologies working together or hybrid with conventional energy resource. HRES incorporates two or more electricity generation options based on the renewable energy or fossil fuel unit. Finding the suitable configuration of HRES is related to topography of the location, estimation of the load, available energy resources and devised energy solution.

In the study, stand alone and Hybrid renewable energy systems both for centralized and decentralized cases has been assessed and best system has been recommended.

With this objective in mind the selected village required has been surveyed. Survey of the villages has been carried out using Survey Questionnaires compiled for detailed village Profile and Household Survey to conclude the energy requirement of the community. The detailed questionnaire prepared in this context has been attached separately as Annex. After accomplishing the survey, the data received through the Questionnaires was examined and daily load profile for the community has been finalized with consent with the stakeholders involved.

1.5 Area selected

As the main theme of the research was to devise the electrification solution for the most deprived community of the country, so on the basis of facts and figures already mentioned, the area of Baluchistan has been selected.

Geographically, the province of Baluchistan is the largest in the country, spanning 347,190 sq kms, making up 44% of the country's total land mass. It is situated in the southwest of the country, sharing borders with Iran and Afghanistan, as well as a coastline to the Arabian Sea. Baluchistan has the lowest indicators for electricity availability in Pakistan. The province is one of the most energy deficient and backward regions of Pakistan. A large number of remotely located villages are without electricity. Kerosene lamps and small scale solar lanterns has been used for night time lighting produce undesirable gases and pollutants which are harmful for the humans and also damage the environment. Another big issue is the availability of clean drinking water close to the villagers as women need to travel for hours to fetch water to fulfill their family requirements. The poor are particularly vulnerable in this context.

The situation is further worse in Noshki and Chagai districts of Baluchistan area, where the prevailing poverty and vulnerability rates in relatively higher due to drought prone districts. Majority of the areas in these districts have no access to the electricity. In this context, the research aims to address the major constraints and challenges for providing the basic necessities of life to these deprived communities.

Chagai District, area-wise is the largest district, of Baluchistan and even of Pakistan. Total area of the district is 45,444 square kilometer. The terrain of district consists of highlands, plains and deserts with ground elevation ranges between486 to 2,800 meters above Mean Sea Level (MSL). The climate of Chagai District is extremely hot in summer and mild in the winter. The rainfall is irregular and scanty due to the district falls outside the sphere of monsoon currents. Rainy season is mostly in the month of January. However, a little rainfall is also recorded in the months of February, July and December. Electricity is not available to the most of the rural areas whereas the facility of drinking water is also not accessible to half of the population. The water of ponds, at some areas even, is used by both human and animals. Consequently, water borne diseases are common and preventive measures are needed to be taken. The picture depicted below showing the worse condition of the area.

Figure 1.3: Picture of a remote area of Chagai District

Keeping the disastrous situation of the Chagai area, there is an urgent need for using alternate means to supply sufficient electric power in these villages so that their requirements for night time lighting can be adequately met. A small mauza of the district named "Killi A.Majeed" near Dalbandin area has been taken as the case study for providing the best possible solution to these deprived communities. However almost all of the areas in Chagai has same topography, so the research work can be implement anywhere for the betterment of the community.

1.6 Significance/Importance

Since, the energy crises of Pakistan is the major issue being faced which is effecting every chapter of life. Energy is considered as the backbone of economy of any country. Energy crises affects adversely the socioeconomic affairs of any country. In the current modern age, it is essential for any country to be strong in energy sectors because without making reasonable achievements in energy sector any country can't get success in any field. There has been enormous increase in demand of energy due to advancement in technology and industry. There is very fast increase in demand of energy as compare to supply of energy. So, due to this difference between supply and demand of energy causes energy crisis and it will be fatal for economy of any country. So, it is necessary that one country should have to increase its production of energy according to increase in demand of energy. The current energy scenario of Pakistan, the relevant departments have failed in providing the energy demands of the domestic users. The industrial sector of Pakistan has been affected very badly resulting in dramatic decrease in the imports. In that situation, there is an energy need to rely more on renewable energy resources especially in the far flung areas where there is no access to the national grid lines. It has been tried to focus on the same lines and to device a rural electrification model that can be replicated in any of the remote area.

1.7 Organization of Thesis

This study will be structured into five chapters.

Chapter 1 gives the Introduction to the study and answers of pre-requisites required for starting research and describes background of the study, problem statements, objective, methodology, significance and its importance.

Chapter 2 gives relevant literature review from starting point describing the need of rural electrification, successful rural electrification models adopted around the world and its relevance with the current situation of Pakistan.

Chapter 3 is concerned almost detailed description of the methodology. The thesis thoroughly deliberates the forecasting technique in this chapter.

Chapter 4 is presents analysis of the obtained through simulation analysis.

Chapter 5 this chapter discusses the results of each topology simulated and also cover the conclusions and findings.

Summary

This chapter introduces almost initial pre-requisites required for starting research work i.e. motivation, what to do in this work, objectives to be attained and work methodology adopted for current study. The following chapter is concerned almost the literature study of constituent parts of system to be developed and studied in current work. It will also serve as a basis for further study and uses of other methods in this field. This chapter is about the introduction and the importance of solar and wind energy. Limited supply of natural resources diverts researcher's attention towards alternative energy resources. Increase in global warming from ejective pollution from conventional power production. Researchers are now focusing on renewable energy technologies; Wind turbine converts the kinetic energy of wind into electrical energy. Solar Photovoltaic PV is a technology which converts the sunlight energy into electrical energy. Hybrid (solar/wind) system increase the system reliability due to different operational hours of solar PV and wind. Operation hours of wind are higher than solar PV. There are different kinds of hybrid energy system PV/wind, PV/Wind/Diesel, Wind/Diesel, PV/Wind/Grid etc.

References

[1] Comparative study on Rural Electrification Policies in Emerging Policies; Key to Successful Policies. Information paper by Alexandera Niez.

[2] International Energy Agency Outlook, 2009.

[3] A. Malik "Power Crisis in Pakistan: A Crisis in Governance?," Pakistan Institute of Development Economics, No. 2012: 4, 2012.

[4] World Energy Outlook, 2015

[5] Suhail Zaki Farooqui, "Prospects of renewables penetration in the energy mix of Pakistan," Renewable and Sustainable Energy Reviews 29(2014)693–700

Chapter 2

Literature Review

2.1 Successful Rural Electrification Models

Providing the facility of electricity to their citizens is always on the leading agendas of the governments [1]. How they provide the facility and which technology or method is used varies from country to country. The choice of a specific energy technology for rural electrification naturally depends on the targeted country, community, business, and farm or household that is to benefit from the process. Other than this there are various other issues like load density, relative distance from national grid, availability of alternate energy resources, socio-economic aspects, matured technology etc. [2]. All these factors must be catered before the selection of best possible technology for rural electrification in the areas to be benefitted. Technologies normally used for rural electrification programs generally involve:-

- National grid extension.
- Diesel generators
- Liquefied petroleum gas (LPG)
- Standalone Renewable Energy Systems
- Hybrid Renewable Energy Systems.

2.1.1 National or Regional Grid Extension

The policy of electrifying any community generally considers the first question of its distance from national grid lines and the load factor. If the region is near to the grid with reasonable load, than the option of grid extension is considered as cost competitive with respect to other local auto generators. The most viable and economical solution for providing the facility of these deprived communities can be extension of national grid lines. But if we compare this case for Pakistan, based on the energy crises, the energy needs of the already electrified areas are not been fulfilled how we can electrify more far flung areas through national grid. In addition to energy crises, other factors like highly dispersed remote population, low load factor, high transmission losses and last but not the least low revenue generation from these remote areas nullifies the option of extension of national grid for electrification of far flung remote areas.

2.1.2 Renewable Energy Systems

Keeping the promotion of renewable energy technologies, the RE solutions are considered most viable in these far flung areas. These alternate energy resources had received a significant amount of consideration due to the decreasing supplies of fossil fuels, the unpredictable price factor, the growing demand for power and the increasing adverse factor of global warming. [3].

Considering the Renewable Energy technologies the viable solution, there can further be two classification of RETs.

- Standalone Renewable Energy Systems (SRES)
- Hybrid Renewable Energy Systems (HRES)

Both SRES & HRES have their own pros and cons which have been discussed in detail one by one.

2.1.2.1 Standalone Renewable Energy Systems

A standalone system consists of any of the renewable energy technology like solar, wind etc. as the energy producing technology, a storage device, a control unit and inverter in case of AC load. Standalone systems have been widely used in both developing and under developed countries [4]. R.K Akikur in his research paper compared various SRES and HRES systems and compiled some pf the SRES systems introduced in recent years.

Table2.1: Standalone Renewable Energy Systems

S.No	Location	Load Type	Design Capacity	Reference
1.	Kerman, Iran	50 typical rural households with an annual load of 24.4 MWh	19 kW solar-PV, 12 components (2 V, 3000 AH) battery	[5]
2.	Rural area, India	219 kWh/yr load consisting of 3 lamps, 1 TV, 1 Radio	150W solar-PV, 60 Ah battery	[6]
3.	Rural areas, southern Iraq	A health clinic load of 11,534 kWh/yr.	6 kW solar-PV, 80 pieces (6 V, 225 Ah) with a battery	[7]
4.	Rural area, Bangladesh	A load of operating 2 fluorescent and 2 WLED lamps.	25W solar-PV, 12 V, 30 Ah battery	[8]
5.	Tunisia, located in North Africa	Small remote communities, 24 h load approximately 83,161.6 kWh/yr	41.6 kW (260 pieces at 160W) solar-PV, 228 kWh battery bank	[9]
6.	Village in the north east of Thailand	Rural house load including 3 lights, 1 fan, 1 radio, 1 TV, for a total of 197.83 Wh/yr	220W solar-PV, 250 Ah BD125 battery	[10]

2.1.2.2 Hybrid Renewable Energy Systems

Hybrid energy system is the settings associated with several alternative as well as non-renewable powers because primary causes of power era so the capability deficit of energy from resource will certainly replace through some other accessible resources in order to accommodate lasting energy. It really is suitable ways to offer electrical power through in your area accessible powers with regard to locations where main grid expansion is actually funds rigorous, geographically separated locations which is why electrical power transmitting through central power is actually hard. Normally talented alternative resources could be controlled to create electrical power within a lasting method to offer energy and create comfy the actual residing regular of individuals. You will find various value and downsides of just alternative resources with regard to electrical power era within countryside communities, value such as energy price slope, energy transportation price is actually higher, problems of worldwide heating as well as environment enhancements made on big. The actual disadvantages of alternative resources because off-grid/standalone energy techniques, they have intermittence character which makes hard to control the ability outcome to handle using the masse wanted. To ensure for your dependability as well as cost from the provider, mixing traditional diesel powered power generator along with nonconventional power generators may resolve the issue noticeable whilst working separately. A few of the benefits mixing both causes of power creation tend to be mentioned the following.

- Diesel powered power generator energy utilization as well as greenhouse fuel decrease
- Ingenious utilization of in your area accessible sources
- Deducts/avoids energy shortfalls, improve durability power
- It offers electrical power accessibility in a nutshell intervals compared to awaiting main grid expansion as well as relieve in order to scale-up anytime

Hybrid standalone energy system has energy manage versatility as well as value associated with environment safety compared to diesel powered power generator alone. Hybrid techniques may increase the capability whenever load demand gets greater later on, through alternative techniques, diesel powered power generator ranked energy or even they are all. A few of the elements generate DC power as well as others AC power directly without any utilization of conversion.

R.K Akikur in his research paper compared various SRES and HRES systems and compiled some pf the HRES systems introduced in recent years.

Table2.2: Hybrid Renewable Energy Systems

S.No	Location	Load Type	Design Capacity	Reference
1.	Vadodara, India	AC home appliances, 1825 kWh/yr	2 kW solar-PV, 1 kW wind turbine.	[11]
2.	Juara village, Tioman island, Malaysia	The chalet loads are a refrigerator, air conditioner, TV and multimedia set, lighting and electrical oven, with a total load of approximately 181.04 MWh/yr	200 kW solar-PV, 40 kW wind turbine, 540 pieces, Surrette 6CS25P battery	[12]
3.	Two different sites: 1.Nice, France 2. Nicosia, Cyprusa	Both locations consider 500 houses with average daily load of 24 kWh.	10.98 kW solar-PV, 1.5 kW wind turbine.	[13]

4.	Dalajia Island in Guangdong Province, China	Ttelecommunications station including a 1300W GSM base station and 200W for microwave communication, for a total load of 1500W	7.8 kW solar-PV, 12 kW wind turbine, 5000 Ah, 24 V GFM-1000 (2 V) battery	[14]
5.	Sitakunda, Bangladesh	DC loads such as DC lights, fans and TVs, for a total load of 61,685 kWh/yr	27 kW solar-PV, 39 kW wind turbine, 370 pieces, (6 V 225 AH) battery	[15]
6.	Nabouwalu Vanua Levu Island, Fiji	The government hospital, institutions, school, shops, staff quarters and the village with 180 residents. The primary load is 360.985 MWh/yr	200 kW solar-PV, 64.8 kW wind turbine, 500 Hoppecke 12 OpzS 1500 battery	[16]

2.2 Review of Other Related Works

In Cameron analysis was conducted for the stand alone electric production system for remote area [17]. Basic requirement of the village was lightening, television, and radio. So the total requirement of energy for the village is from 0.2 to 1 kWh/day. Different hybrid systems were analyzed for the village requirement. Systems which were analyzed were (hydro/LPG generator/battery). (micro hydro/diesel generator/battery), (solar/LPG generator), (solar/diesel/battery). Simulation results show the different levelized cost of energy for different energy options. It was found that the 14 kW micro hydro generator, 36 kWh of battery storage and 15 kW LPG generator produce the energy at the rate of 0.296 €/kWh. In this analysis the second simulation shows that PV hybrid system which consist of 18 kW PV, 72 kWh of battery storage and 15 kW of LPG generator generates the energy at the cost of 0.576 €/kWh. The price of petrol and LPC price were 0.1 €/kWh and 0.7 €/kWh respectively. In this analysis micro hydro was the most optimal and cheapest system. So it was the best option for the southern part of the Cameroon. For the southern part of the country PV hybrid was the best option.

An analysis was carried out for the hybrid system which was designed for the power generation. Power generation was for the 100 domestic consumers, an elementary school and health clinic [18]. This hybrid system was hybrid of solar and wind. Research was conducted with the study of wind and solar potential of the site so either it is suitable for both resources or not. Different simulation results of the system shows that wind/PV/diesel generator/battery and converter configured system. So the levelized cost of energy for the system was 0.302 $/kWh and total net present cost NPC of the system is about $ 103,914. So the diesel fuel consumed per annum was 1955 litter and its operating hours were 633 hours/year.

A study for feasibility report was conducted by [19] for standalone hybrid (wind/solar) energy system. It was designed to supply electricity to the remote areas of Ethiopia. The simulations presented in paper were for wind/PV/diesel and battery to provide electricity requirement for 200 domestic consumer's model population. In this paper the most optimized and cost efficient system was hybrid (diesel generator/battery) and converter. There was no contribution of renewable source fraction. There were also other most optimized cost effectual combinations of PV/diesel generator and converter, following load strategy was applied in case of dispatch strategy.

A research carried out in which off grid system (wind/diesel generator) for Saudi Arabia is analyzed in [20]. This system was designed for the supply of energy to the hot coastal areas of Dhahran. In this paper it is considered that wind energy will be harvested for the 100 domestic consumers. As wind is a blinking resource of energy thus from energy fluctuation preservation wind/diesel and battery are considered for the hybrid system.

A renewable hybrid energy system of PV/wind/micro-hydro with diesel generator backup was simulated for Sundargarh district of Orissa State, India. In case study two different simulations were carried out. First one was wind/solar PV and diesel generator and the second study case was combining of wind/PV/small hydro and diesel generator. In this analysis author suggest that wind power fluctuation and demand of household difference is the only hamper influencing the structure [21].

In a research design is described and implementation of proficient renewable energy power-driven energy scheme for domestic use in Khartoum, the Sudan's capital. The simulation action was performing for entity domestic consumers and for a collection of 10 to 25 domestic consumers. The power delivered from PV/battery arrangement for the particular users was costly than wind/PV for collection of domestic consumers. To list a number of the expenses, the COE for solo residence is about 49.5 SP/Wh, for 10 household it is about 25.8 SP/Wh and for 25 household is concerning 20.1 SP/Wh [22].

A research of different system offered the viability learning of the wind turbines hybridizing to an accessible off grid diesel power plant in the northern countryside region of the Kingdom of Saudi Arabia. The research was principally to play down the operation costs of wind turbines by combining with diesel generator and for that reason to diminish environmental contamination. Sensitivity analysis was also completed by captivating sensitive parameter for example wind speed which can shape the power system all through its lifetime. The results of simulation shows that retrofitting wind turbine to the presented diesel generator was not reasonable for wind speeds not as much of 6m/s and petroleum price of $0.1/litter [23].

Research completed by researchers to judge the variety of off-grid electrification within the countryside communities within the Empire associated with Bhutan. The research had been happened within 4 various locations from the nation. In addition, the actual challenging masse had been regarded as with regard to illumination as well as conversation solutions just. The primary focus on from the papers had been optimization associated with hybrid energy producing models. PV/battery energy producing program is the least expensive technologies with regard to Muselina as well as Lunana, while the actual diesel/PV/battery hybrid program is the least expensive within Getena region. Execution associated with wind/battery program had been far better to use within Yangtse site [24].

Based on the papers analyzed that was dedicated to study regarding techno-economic facets of hybrid (wind as well as diesel powered generator) plans for any countryside local community within Algeria. The research had been carried out to include the wind generator in order to current diesel powered engine power techniques to lessen energy usage. The writer came to the conclusion with regard to wind pace beneath 5m/s the present diesel powered controlled flower along with 0.05-0.179 $/liter is actually inexpensive compared to hybrid program. The actual feasibility from the hybrid program guaranteed in wind pace associated with 5.48m/s, optimum yearly capability lack 0%, minimal alternative small fraction 0% as well as $0.162/liter energy cost [25].

In this paper investigated and looked into the actual use associated with hybrid alternative energy techniques because supply of main power with regard to cellular phone channels within the Democratic Republic associated with Congo. The research had been carried out for 3 place to place that are not really coupled to the main grid specifically; Kamina, Mbuji-Mayi as well as Kabinda. The actual feasible set-up choices carried out through the writers tend to be PV-wind generator, diesel powered power generator, genuine PHOTOVOLTAIC as well as genuine wind speed plans had been set up, furthermore techno-economic as well as environment impact had been analyzed. With regard to Kabinda the perfect hybrid program consists of two wind generators, 11kW photovoltaic, 82 battery 7.5kW converter, and also the NPC as well as COE tend to be $196, 975 and0.372 $/kWh correspondingly [26].

Different systems are analyzed for Urumqi, China. Different off grid systems are analyzed for optimum solution PV/wind/battery, PV/battery, Wind/battery. Atmosphere and climate of Urumqi is explained in the paper that has feasible and optimal solar radiation and wind speed. The actual hybrid wind/PV/battery system along with 5 kW associated with photovoltaic arrays (72% solar power penetration), 1 wind turbine generator of 2.5 kW (28% wind power penetration), 8 unit device battery all of 6.94 kWh as well as 5 kW sized energy conversion includes a good optimum energy program for your home; this decreases the entire net existing price (NPC) regarding 9% as well as 11% in contrast to PV/battery as well as wind/battery energy techniques, with a comparable result for your levelized cost of energy (COE) [27].

Even though authors explained over utilized HOMER being an optimization tool in order to actualize their own research, the actual hybrid systems setups had been analyzed utilizing various load demands and also the applications, area associated with research along with weather data's these people utilized had been various. A few of the research had been used in places which have absolutely no electrical power whatsoever while others within places which have electrical power accessibility that was supplied utilizing diesel powered power generator. Each and every hybrid energy system needs to be developed in the new way for your site in line with the accessible weather data's, amount of domestic consumers, support centers as well as customer load profile.

Summary

Energy is basic requirement for the betterment of the country and each nation strives to provide basic facilities to their nations. How they provide the facility and which technology or method is used varies from country to country. The choice of a specific energy technology for rural electrification naturally depends on the targeted country, community, business, and farm or household that is to benefit from the process. Other than this there are various other issues like load density, relative distance from national grid, availability of alternate energy resources, socio-economic aspects, matured technology etc. The literature review summarizes that extension of national grid is not a viable option for many far flung areas of Pakistan. On the other hand the country is naturally equipped with various alternate energy resources which can be utilized to fulfil the energy demands. Countries around the globe have implemented standalone as well as hybrid renewable energy systems for providing facility of electricity in the remote areas.

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Chapter 3

Methodology

3.1 Overview

The main theme of the research was to device an electrification solution for the most deprived community of Pakistan. As already discussed in the introductory chapter, energy is the main issue that has affected the lives of people of Pakistan. The whole country is facing the issue due to immense energy crises. Load shedding hours of up to 12 hours per day in urban areas and 20 hours per day in rural areas have been reported by NEPRA 2012 [1]. In the current developing era, when the nations are striving hard to take lead in the field of technology; there are still many parts of our country which are even not covered by the national grid lines [2]. Pakistan Bureau of Statistics published a report covering various aspects of life. In the report mauza wise electricity status for the domestic users had also been covered. The summary of the report covering overall scenario for availability of electricity for domestic users has been depicted in the table below.

Table 3.1: Mouzas reporting availability of electricity for domestic use.

Area	Pakistan	KP	Punjab	Sindh	Baluchistan
Rural Populated Mouzas	47482	11540	23941	5573	6428
ALL Electrified	16428 35 %	3902 34 %	11226 47 %	549 10 %	751 12 %
Mostly Electrified	13789 29 %	3053 26 %	8165 34 %	1686 30 %	885 14 %
None Electrified	9047 19 %	2752 24 %	1684 7 %	874 16 %	3737 58 %

The figures shows very alarming numbers according to which 19 % of the total mouszas of Pakistan have no access to the electricity where as 17 % have some of the time and 29 % people of Pakistan have most of the time access to the electricity. Only 35 % of the mouzas have full time availability of electricity. A mouza or mauza is a type of administrative district, corresponding to a specific land area with in which there may be one or more settlements. If we look in to the province wise electricity situation; 24 % mauzas of KPK, 7 % of Punjab, 16 % of Sindh and 58 % of Baluchistan are not electrified. [3] For Baluchistan, the situation is extremely dire: there are minimum sources available for the electricity production. As the main theme of the research was to devise the electrification solution for the most deprived community of the country, so the area of Baluchistan has been selected.

3.2 Proposed Solution for Provisioning of Electricity to the Deprived Communities

The most viable and economical solution for providing the facility of these deprived communities can be extension of national grid lines. Rural areas are normally located far away from national grid and the high cost of extending the transmission lines usually makes these projects unfeasible. [4]. Considering current energy crises, dispersed population, low load factor, low revenue generation and high transmission losses extension of far flung remote areas is not considered a viable option.

In chagai area, the population is vastly scattered so the extension of national grid lines is no more considered a viable option. Keeping the promotion of renewable energy technologies, the RE solutions are considered most viable in these far flung areas.

Considering the Renewable Energy technologies the viable solution, there can further be two classification of RETs.

- Standalone Renewable Energy Systems (SRES)
- Hybrid Renewable Energy Systems (HRES)

Hybrid Renewable energy systems has advantages over single source systems[5]. Hybrid energy system is the settings associated with several alternative as well as non-renewable powers because primary causes of power era so the capability deficit of energy from resource will certainly replace through some other accessible resources in order to accommodate lasting energy. It really is suitable ways to offer electrical power through in your area accessible powers with regard to locations where main grid expansion is actually funds rigorous, geographically separated locations which is why electrical power transmitting through central power is actually hard. Normally talented alternative resources could be controlled to create electrical power within a lasting method to offer energy and create comfy the actual residing regular of individuals. You will find various value and downsides of just alternative resources with regard to electrical power era within countryside communities, value such as energy price slope, energy transportation price is actually higher, problems of worldwide heating as well as environment enhancements made on big. The actual disadvantages of alternative resources because off-grid/standalone energy techniques, they have intermittence character which makes hard to control the ability outcome to handle using the masse wanted. To ensure for your dependability as well as cost from the provider, mixing traditional diesel powered power generator along with nonconventional power generators may resolve the issue noticeable whilst working separately. A few of the benefits mixing both causes of power creation tend to be mentioned the following.

- Diesel powered power generator energy utilization as well as greenhouse fuel decrease
- Ingenious utilization of in your area accessible sources
- Deducts/avoids energy shortfalls, improve durability power
- It offers electrical power accessibility in a nutshell intervals compared to awaiting main grid expansion as well as relieve in order to scale-up anytime.

Hybrid standalone energy system has energy manage versatility as well as value associated with environment safety compared to diesel powered power generator alone. Hybrid techniques may increase the capability whenever load demand gets greater later on, through alternative techniques, diesel powered power generator ranked energy or even they are all. A few of the elements generate DC power as well as others AC power directly without any utilization of conversion.

3.3 Hybrid Renewable Energy System Configuration

Hybrid energy techniques could be created in line with the subsequent specialized topologies in order to control the actual accessible alternative resources and also to fulfill the load demand. This is often set up in various methods using the attention and also the load demand since the determinant aspects.

HRES can be classified further into two categories which are:-

- Centralized Hybrid Renewable Energy Systems
- De- Centralized Hybrid Renewable Energy Systems

3.3.1 Centralized Hybrid Renewable Energy Systems

The actual central system offers capacity of growing battery-life because of the existence associated with main control system for charging an overpriced charges and deep cycle discharging. Additionally it is suitable for power plants as well as allows in order exporting extra electrical power throughout minimal load demand occasions; furthermore electric battery can be charged through speed of wind as well as photovoltaic. Similar procedure from the elements enables additional growth from the program along with secure dependability.

3.3.2 Decentralized Hybrid System

Within this kind of structures all of the technology isn't linked to some of the bus, instead these individuals separately connect with the load directly. Figure 3.4 displays the actual combination of the device topology, currently noticeable through the number powers might not be located in one area or even near to each other plus they may connect with the load through anyplace the actual alternative sources can be obtained.

The actual value associated with this kind of settings could be that the energy producing elements may set up through the area wherever alternative reference can be obtained.

However it features a drawback because of the trouble associated with energy effects of the device. Therefore, evaluating both designs the actual central strategy is much better because of its controllability compared to dispersed program.

CHRES & DHRES can be further classified in to some categories, some of them are given below:-

- PV/ Wind/ Battery HRES
- PV/ Wind/ Battery / Diesel HRES
- Micro Hydro/ PV/ Diesel Battery
- Wind/ Hydro HRES
- Solar/ Hydro HRES
- Hydro/ PV/ Wind HRES
- PV/ Biogas HRES
- Wind/ PV/ Biomass/ Hydro HRES

3.4 HRES Considered for the subject Research

Baluchistan is blessed with the resources that can be helpful in easing the energy shortage. Different combination of HRES can be applied based on the available renewable energy resources. If we look in to the renewable energy potential of Baluchistan, there are two main renewable energy technologies i.e. Solar and Wind energy potential in that area. According to the data published on the website of Energy Department, Government of Baluchistan; Average Solar Global Isolation of 5-7 kwh/m^2/day, over 95% area (about 2300-2700 hr/annum) [6]. Secondly the province is blessed with seven wind corridors suitable for wind farms. Some of these corridors are at least 50% better and more efficient compared to that of Gharo in Sindh [7].

Based on the available renewable energy resources, six different options for renewable energy solutions has been considered for the subject study:-

1. Standalone or Decentralized Solar PV/ Battery System
2. Standalone or Decentralized Wind/Battery System
3. Decentralized Solar PV/Wind/Battery Hybrid Renewable Energy System

4. Centralized Solar PV/ Battery System
5. Centralized Wind/Battery System
6. Centralized Solar PV/Wind/Battery Hybrid Renewable Energy System

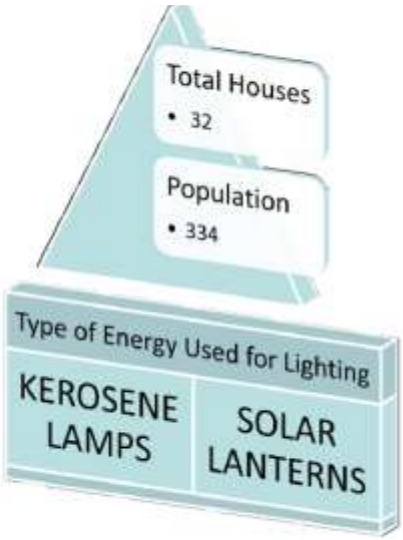
All the above mentioned RES has been considered and best possible solution from all the considered systems has been recommended.

3.5 Survey

If we consider the whole Chagai district, most of the people are deprived and going through the drought situation. The main capital of the district Dalbandin has been provided with the facility of national grid some three to four years ago. Most of the areas are deprived lacking basic facilities of life. To start with and to derive a model for one of the area that can be replicated in any part of the country, a small community named “Killi A.Majeed” has been selected. Questionnaire was developed for households and key informants interviews with consent and confidentiality assurance statement. Clear instructions for enumerator for each question, skip patterns and question codes were incorporated in the questionnaire to reduced enumeration errors.

A female local enumerators from local NGO was requested to accompany for the household survey. After initial orientation on questionnaire, enumerator was taken to the field to pre-test the tools in nearby villages/communities of area of both the districts. The filled questionnaires of enumerator was reviewed and discussed thoroughly. Based on feedback, some minor changes were made in questionnaire. The inputs from the household were collected using a questionnaire, which had modules regarding population, number of houses, source of energy, monthly expenditure etc. Each module comprise of close-ended questions ranging from general to specific. Interviews were held with the head of the family/ household to get the detailed and correct information. The questionnaire devised has been attached as Annex.

The data was processed with Microsoft excel. The data validation feature were applied through development of drop downs to ensure accurate data entry, reduce chances of spelling mistakes and ensure entry of only predefined answers. The key and relevant findings of the survey has been highlighted in below picture:-



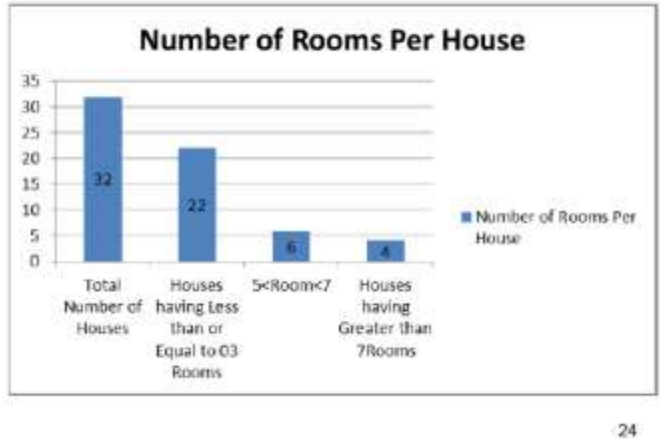


Figure 3.1: Survey summary

3.6 Load/ Energy Calculation

After going through the retrieved data it is concluded that the most suitable approach is to have a system design that could be implemented in all types of households. On the basis of which a central meeting was conducted in which the all the honorable of the community were invited and ensured their presence in the meeting. The participants were briefed about the importance and background of the survey. The local NGO rep helped in convincing the people for actively participation in the study.

Based on the requirements of the community and their feedback, the standard package comprise of 05 CFL Lights, three ceiling fans, a fridge and a TV. The proposed system will have two-day backup to cater for over cast days which are quite common during the winter and rainy season. Details related to a standard package of a Solar Home System along with the technical details are as follows:-

Table 3.2: Load Details for Single House

S.No.	Load	Wattage of each Load	Quantity for each house
1.	Energy Saver	25	5
2.	Ceiling Fan	100	3
3.	Fridge	200	1
4.	TV	100	1

3.7 Selection Of Simulation Software

Design, optimization and operation control of Hybrid Renewable Energy Systems (HRES) with two or more energy sources are complex with the high risk of failure.. Different softwares has been introduced by the researchers to provide support in the design of Hybrid Renewable Energy Systems. Some of the main softwares are HOMER, Hybrid 2, RETScreen, iHOGA, INSEL, TRNSYS, iGRYSO, HYBRIDS, RAPISM, SOMES, SOLSTOR, Hysim, HybSim,IPSYS, HySys etc [8]. The most used and best known of these software tools is HOMER [9].

3.8 Criteria for Selection of Best Renewable Energy System

HOMER software was used in order to determine the feasibility and the economic viability of different renewable energy systems. The technical feasibility of the simulated systems were assessed on the basis of lowest unmet load and capacity shortage factor whereas the economic viability was determined on the basis of the total NPC. The details has been covered in Chapter 5.

Summary

Pakistan being an energy deficient country facing major issues in its economic development due to the current power crisis. Pakistan is naturally benefitted with different renewable energy resources; out of which solar and wind energy are the main highlights. This research work will provide an assessment of the renewable energy potential of the Baluchistan region. A comparison of the economic and financial analysis for a centralized hybrid renewable energy system has been simulated by using Homer software. Three cases have been proposed in which centralized standalone solar PV system, centralized standalone wind energy system and a hybrid combination of both centralized standalone solar and wind energy system have been studied. Homer software has been used to devise the most optimal solution. The simulations confirm that the best optimal solution is the hybrid renewable energy system for the rural electrification of the proposed region.

Reference

[1] National Energy Power Regulatory Authority.

[2] Comparative study on rural electrification policies in emerging economies.

[3] Pakistan 2008 Mouza Statistics.

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[6-7] Department of Energy, Government of Baluchistan.

[8] Review of Software tools for Hybrid Renewable Energy Systems.

Chapter 4

Simulation Analysis

4.1 HOMER Software Overview

Hybrid Optimization Product with regard to Electrical Renewable (HOMER) is really a computer product created initially through the National Renewable Laboratory (NREL) which have various power producing elements inside the library. The consumer should choose the elements through the collection to symbolize the actual structures regarded as. This particular building device utilizes period stage through one moment to many hours. HOMER makes simple or even assists founder in order to numerous energy techniques choices depending on specialized as well as financial elements. This software can answer lot of questions like given below.

- Either the designed system can meet the required demand or not
- What kind of hybrid system is suitable for the required location (e.g. Wind, Solar, Hydro, all of them combined or single source etc.)
- How much batteries are required for the stand alone system
- How can we control the designed power system
- What will be the effect of fuel price change on the system

The software additionally selects between different techniques (cycle charging and load following) by causing comparison. Design as well as analysis associated with techniques could be difficult job since the big mixture of technique choices and also the addition associated with concerns. The method complexness as well as doubt improves whenever alternative resources tend to be within the program, as they are non-dispatch capable as well as irregular character. HOMER created in order to overcome these types of difficulties. HOMER operation method is shown in the figure, given figure shows clearly how homer simulate the systems to evaluate suitable system. Figure shown below indicates that how Homer simulates the systems, it performs sensitive analysis on the basis of sensitive input given by user. Sensitive inputs may be anyone according to project or user choice. Homer selects the most optimized system according to the given resources. Homer takes the energy balance on hourly basis, it need energy requirement for each hour of the whole day. It takes the seasonal variation into account for simulation process. It can simulate different combination of hybrid systems and calculates their fraction in the system and make a detail analysis.

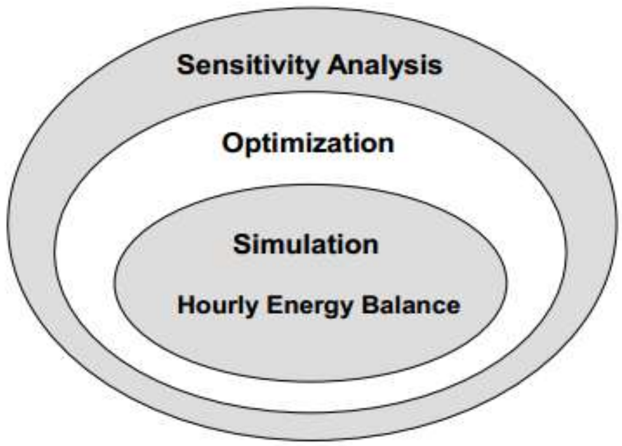

Figure 4.1: Simulation, Optimization, Sensitivity Analysis

4.1.1 Simulation

This even comes close the power provide through the system and also the load demand within one hour, from the 8760 hrs. During this period this makes a decision possibly to make use of load following or even dispatch technique to run battery as well as power generator. For any system which has electric battery as well as power generator needs getting dispatch strategy. Dispatch strategies are of two styles, load following as well as cycle charging techniques.

4.1.2 Optimization

Within this procedure this imitates every various system designs looking for the cheapest NPC as well as listings every energy techniques which fulfill the load demand. The objective of optimization would be to figure out the perfect system in line with the choice factors enforced through the developer. Choice variable is really a variable which has managed through the designer. HOMERs choice factors might include such as; photovoltaic variety dimension, amount of wind generators, power generator dimension, converter size, amount of battery dispatch technique, as well as and so on Looking the perfect program consists of determining the combination of energy elements such as size, quantity simultaneously the actual dispatch technique.

4.1.3 Sensitivity Analysis

This looks at the result associated with external variables and do optimization for every sensitivity factors. But initially defining the variables so as to influence the system over its total life is compulsory to input of the software. The actual optimization procedure is actually repetitive right after indicating the actual sensitive parametric factors being an input in the software program. The actual awareness factors could be weather information variants, elements as well as energy price, rate of interest, capability shortages, operating reserves as well as others. HOMER really does several optimizations utilizing numerous sensitive inputs to find out exactly how sensitive outcome from the energy system. The actual awareness outcomes through HOMER tend to be shown within listed as well as image form.

4.2 Solving Problems with HOMER

HOMER simplifies the task of designing distributed generation (DG) systems both on and off-grid systems. HOMER models with both conventional and renewable energy technologies. The sources that can be considered in HOMER for designing are solar photovoltaic (PV), wind turbine, Diesel Generator, Electric utility grid, etc.

HOMER Pro can be used to:-

- Evaluate off grid or grid connected system designs.
- Choose the system on the basis of technical reqs, cost and other environmental factors.
- Simulate design configurations under market price.

Solving the problem using HOMER Pro requires the following information from the designer:-

- Location
- Load Profile
- Components to be considered for System Design
- Local Resources available for the Energy Production.
- General Considerations for the Simulation.

Each of the above mentioned requirements have been discussed in detail.

4.2.1 Location

Baluchistan being the most vulnerable province of the country has been selected for the subject case study. Out of many districts of Baluchistan, Chagai district has been proposed. The Basis of the area selection has already been discussed in detail in Chapter 3.

4.2.2 Domestic Load

The HOMER consumer identifies some main load in kilo watts for every hour for the whole year, possibly through adding file that contains per hour information or even through permitting HOMER in order to synthesize per hour information through typical everyday load information. HOMER provides the user-specified quantity of randomness in order to produced load information to ensure that each and every day's load design is exclusive. HOMER may produce two individual main loads, all of which may be AC or even DC.

Annual average consumption (kWh) = ((appliances power rating × No. of appliances × operating hours × No. of days)/1000)/

As different kinds of simulations has been proposed for both centralized and decentralized systems; so on the same basis two different kind of load profiles has been defined as per the simulation requirement. Hourly load profile for both the Centralized and Decentralized systems has been defined.

As per the requirement of HOMER Software, after discussing the working hours of the local community and requirement of defined load in their houses, the hourly load profile has been defined. Based on the variation in usage of load in different seasons, the usage of load profiles has been categorized in three seasons which are:-

- Load usage during summer season (April-September)
- Load usage during winter season (November – February)
- Load usage between summer and winter season. (March & October).

The hourly load profiles for each of the categorized seasons have been covered below:-

4.2.2.1 Load usage during Winter season (November-February)

Table 4.1: Load usage during winter season for decentralized system

Description	Load 1	Load 2	Load 3	Load 4	Total Power (Watts)	Total Power (KW)
	Energy Savor	Ceiling Fan	Fridge	TV		
Power Consumption	25	100	200	100		
Qty.	5	3	1	1		
00.00 – 01.00	75	0	150	0	225	0.225
01.00 – 02.00	75	0	150	0	225	0.225
02.00 – 03.00	75	0	150	0	225	0.225
03.00 – 04.00	75	0	150	0	225	0.225
04.00 – 05.00	75	0	150	0	225	0.225
05.00 – 06.00	75	0	150	0	225	0.225
06.00 – 07.00	75	0	150	0	225	0.225

07.00 – 08.00	0	0	150	0	150	0.150
08.00 – 09.00	0	0	150	0	150	0.150
09.00 – 10.00	0	0	150	0	150	0.150
10.00 – 11.00	0	0	150	0	150	0.150
11.00 – 12.00	0	0	150	0	150	0.150
12.00 – 13.00	0	0	150	0	150	0.150
13.00 – 14.00	0	0	150	0	150	0.150
14.00 – 15.00	0	0	150	0	150	0.150
15.00 – 16.00	0	0	150	0	150	0.150
16.00 – 17.00	0	0	150	0	150	0.150
17.00 – 18.00	75	0	150	0	225	0.225
18.00 – 19.00	125	0	150	100	375	0.375
19.00 – 20.00	125	0	150	100	375	0.375
20.00 – 21.00	125	0	150	100	375	0.375
21.00 – 22.00	125	0	150	100	375	0.375
22.00 – 23.00	125	0	150	100	375	0.375
23.00 – 24.00	75	0	150	100	325	0.325
Total KW-Hrs per Day						5.500

4.2.2.2 Load usage during summer season (April-September)

Table 4.2: Load usage during summer season for decentralized system

Description	Energy Savor	Ceiling Fan	Fridge	TV	Total Power (Watts)	Total Power (KW)
Power	25	100	200	100		
Qty	5	3	1	1		
00.00 – 01.00	50	300	170	0	520	0.520
01.00 – 02.00	50	300	170	0	520	0.520
02.00 – 03.00	50	300	170	0	520	0.520
03.00 – 04.00	50	300	170	0	520	0.520
04.00 – 05.00	75	300	170	0	545	0.545
05.00 – 06.00	75	300	170	0	545	0.545
06.00 – 07.00	0	300	170	0	470	0.470
07.00 – 08.00	0	100	170	0	270	0.270
08.00 – 09.00	0	100	170	0	270	0.270
09.00 – 10.00	0	100	170	0	270	0.270

10.00 – 11.00	0	100	170	0	270	0.270
11.00 – 12.00	0	100	170	0	270	0.270
12.00 – 13.00	0	100	170	0	270	0.270
13.00 – 14.00	0	100	170	0	270	0.270
14.00 – 15.00	0	200	170	0	370	0.370
15.00 – 16.00	0	200	170	0	370	0.370
16.00 – 17.00	0	200	170	0	370	0.370
17.00 – 18.00	0	100	170	0	270	0.270
18.00 – 19.00	0	100	170	100	370	0.370
19.00 – 20.00	125	300	170	100	695	0.695
20.00 – 21.00	125	300	170	100	695	0.695
21.00 – 22.00	125	300	170	100	695	0.695
22.00 – 23.00	75	300	170	100	645	0.645
23.00 – 24.00	50	300	170	0	520	0.520
Total KW-Hrs						10.530

4.2.2.3 Load usage during Mild season (March &October)

Table 4.3: Load usage during Mild season for decentralized system

Description	Load 1	Load 2	Load 3	Load 4	Total Power (Watts)	Total Power (KW)
	Energy Savor	Ceiling Fan	Fridge	TV		
Power	25	100	200	100		
00.00 – 01.00	75	200	150	0	425	0.425
01.00 – 02.00	75	200	150	0	425	0.425
02.00 – 03.00	75	200	150	0	425	0.425
03.00 – 04.00	75	200	150	0	425	0.425
04.00 – 05.00	75	200	150	0	425	0.425
05.00 – 06.00	0	200	150	0	350	0.350
06.00 – 07.00	0	200	150	0	350	0.350
07.00 – 08.00	0	100	150	0	250	0.250
08.00 – 09.00	0	100	150	0	250	0.250
09.00 – 10.00	0	100	150	0	250	0.250

10.00 – 11.00	0	100	150	0	250	0.250
11.00 – 12.00	0	100	150	0	250	0.250
12.00 – 13.00	0	100	150	0	250	0.250
13.00 – 14.00	0	100	150	0	250	0.250
14.00 – 15.00	0	100	150	0	250	0.250
15.00 – 16.00	0	100	150	0	250	0.250
16.00 – 17.00	0	100	150	0	250	0.250
17.00 – 18.00	0	100	150	0	250	0.250
18.00 – 19.00	75	100	150	100	425	0.425
19.00 – 20.00	125	200	150	100	575	0.575
20.00 – 21.00	125	200	150	100	575	0.575
21.00 – 22.00	125	200	150	100	575	0.575
22.00 – 23.00	125	200	150	100	575	0.575
23.00 – 24.00	75	200	150	100	525	0.525
Total KW-Hrs						8.825

For the centralized system, the load for individual house is going to be multiplied with the number of houses in the community which are thirty two. So the total load considered for the centralized system for the whole community turns out to be:-

Table 4.4: Load details for Centralized system

S.No.	Load	Wattage of each Load	Qty. for each house	Total Houses	Total Watts (single Item)
1.	Energy Saver	25	5	32	800
2.	Ceiling Fan	100	3		3200
3.	Fridge	200	1		6400
4.	TV	100	1		3200

.

For the centralized systems, the hourly load profile for the three categories mentioned earlier are:-

4.2.2.4 Load usage during winter season (April-September)

Table 4.5: Load usage during winter season for centralized system

Description	Load 1	Load 2	Load 3	Load 4	Total Power (Watts)	Total Power (KW)
	Energy Savour	Ceiling Fan	Fridge	TV		
Power of	25	100	200	100		

each Item						
Wattage	800	3200	6400	3200		
Qty	160	96	32	32		
00.00 – 01.00	1600	9600	5440	0	16640	16.640
01.00 – 02.00	1600	9600	5440	0	16640	16.640
02.00 – 03.00	1600	9600	5440	0	16640	16.640
03.00 – 04.00	1600	9600	5440	0	16640	16.640
04.00 – 05.00	2400	9600	5440	0	17440	17.440
05.00 – 06.00	2400	9600	5440	0	17440	17.440
06.00 – 07.00	0	9600	5440	0	15040	15.040
07.00 – 08.00	0	3200	5440	0	8640	8.640
08.00 – 09.00	0	3200	5440	0	8640	8.640
09.00 – 10.00	0	3200	5440	0	8640	8.640
10.00 – 11.00	0	3200	5440	0	8640	8.640
11.00 – 12.00	0	3200	5440	0	8640	8.640

12.00 – 13.00	0	3200	5440	0	8640	8.640
13.00 – 14.00	0	3200	5440	0	8640	8.640
14.00 – 15.00	0	6400	5440	0	11840	11.840
15.00 – 16.00	0	6400	5440	0	11840	11.840
16.00 – 17.00	0	6400	5440	0	11840	11.840
17.00 – 18.00	0	3200	5440	0	8640	8.640
18.00 – 19.00	0	3200	5440	3200	11840	11.840
19.00 – 20.00	4000	9600	5440	3200	22240	22.240
20.00 – 21.00	4000	9600	5440	3200	22240	22.240
21.00 – 22.00	4000	9600	5440	3200	22240	22.240
22.00 – 23.00	2400	9600	5440	3200	20640	20.640
23.00 – 24.00	1600	9600	5440	0	16640	16.640
Total KW-Hrs						336.960

4.2.2.5 Load usage during summer season (November-February)

Table 4.6: Load usage during summer season for centralized system

Description	Load 1	Load 2	Load 3	Load 4	Total Power (Watts)	Total Power (KW)
	Energy Savor	Ceiling Fan	Fridge	TV		
Power of each Item	25	100	200	100		
Total number of Houses	32					
Wattage	800	3200	6400	3200		
Qty	160	96	32	32		
00.00 – 01.00	2400	0	4800	0	7200	7.200
01.00 – 02.00	2400	0	4800	0	7200	7.200
02.00 – 03.00	2400	0	4800	0	7200	7.200
03.00 – 04.00	2400	0	4800	0	7200	7.200
04.00 – 05.00	2400	0	4800	0	7200	7.200
05.00 – 06.00	2400	0	4800	0	7200	7.200
06.00 – 07.00	2400	0	4800	0	7200	7.200
07.00 – 08.00	0	0	4800	0	4800	4.800

08.00 – 09.00	0	0	4800	0	4800	4.800
09.00 – 10.00	0	0	4800	0	4800	4.800
10.00 – 11.00	0	0	4800	0	4800	4.800
11.00 – 12.00	0	0	4800	0	4800	4.800
12.00 – 13.00	0	0	4800	0	4800	4.800
13.00 – 14.00	0	0	4800	0	4800	4.800
14.00 – 15.00	0	0	4800	0	4800	4.800
15.00 – 16.00	0	0	4800	0	4800	4.800
16.00 – 17.00	0	0	4800	0	4800	4.800
17.00 – 18.00	2400	0	4800	0	7200	7.200
18.00 – 19.00	4000	0	4800	3200	12000	12.000
19.00 – 20.00	4000	0	4800	3200	12000	12.000
20.00 – 21.00	4000	0	4800	3200	12000	12.000
21.00 – 22.00	4000	0	4800	3200	12000	12.000
22.00 – 23.00	4000	0	4800	3200	12000	12.000

23.00 – 24.00	2400	0	4800	3200	10400	10.400
Total KW-Hrs						176.000

4.2.2.6 Load usage during Mild season (March & October)

Table 4.7: Load usage during mild season for centralized system

Description	Load 1	Load 2	Load 3	Load 4	Power (W)	Power (KW)
	Energy	Ceiling	Fridge	TV		
Wattage	800	3200	6400	3200		
Qty	160	96	32	32		
00.00 – 01.00	2400	6400	4800	0	13600	13.600
01.00 – 02.00	2400	6400	4800	0	13600	13.600
02.00 – 03.00	2400	6400	4800	0	13600	13.600
03.00 – 04.00	2400	6400	4800	0	13600	13.600
04.00 – 05.00	2400	6400	4800	0	13600	13.600

05.00 – 06.00	0	6400	4800	0	11200	11.200
06.00 – 07.00	0	6400	4800	0	11200	11.200
07.00 – 08.00	0	3200	4800	0	8000	8.000
08.00 – 09.00	0	3200	4800	0	8000	8.000
09.00 – 10.00	0	3200	4800	0	8000	8.000
10.00 – 11.00	0	3200	4800	0	8000	8.000
11.00 – 12.00	0	3200	4800	0	8000	8.000
12.00 – 13.00	0	3200	4800	0	8000	8.000
13.00 – 14.00	0	3200	4800	0	8000	8.000
14.00 – 15.00	0	3200	4800	0	8000	8.000

15.00 – 16.00	0	3200	4800	0	8000	8.000
16.00 – 17.00	0	3200	4800	0	8000	8.000
17.00 – 18.00	0	3200	4800	0	8000	8.000
18.00 – 19.00	2400	3200	4800	3200	13600	13.600
19.00 – 20.00	4000	6400	4800	3200	18400	18.400
20.00 – 21.00	4000	6400	4800	3200	18400	18.400
21.00 – 22.00	4000	6400	4800	3200	18400	18.400
22.00 – 23.00	4000	6400	4800	3200	18400	18.400
23.00 – 24.00	2400	6400	4800	3200	16800	16.800
Total KW-Hrs						282.400

4.2.2.7 Summarized Load Profiles

Average Daily load profile both for centralized and decentralized cases are summarized in table below:-

Table 4.8: Summary of Daily Energy for Centralized & Decentralized System

Season	Average daily energy consumption (kwh / day)	
	Decentralized system	Centralized system
Summer season (April-September)	10.53 kwh / day	337 kwh / day
Winter season (November – February)	5.5 kwh / day	176 kwh / day
Mild season (March & October)	8.82 kwh / day	282 kwh / day
Annual average (kwh / day)	8.59 kwh / day	274 kwh / day

4.2.2.7.1 Decentralized Hybrid Renewable Systems

Based on the calculations, daily energy requirement for decentralized renewable energy systems can be summarized as:

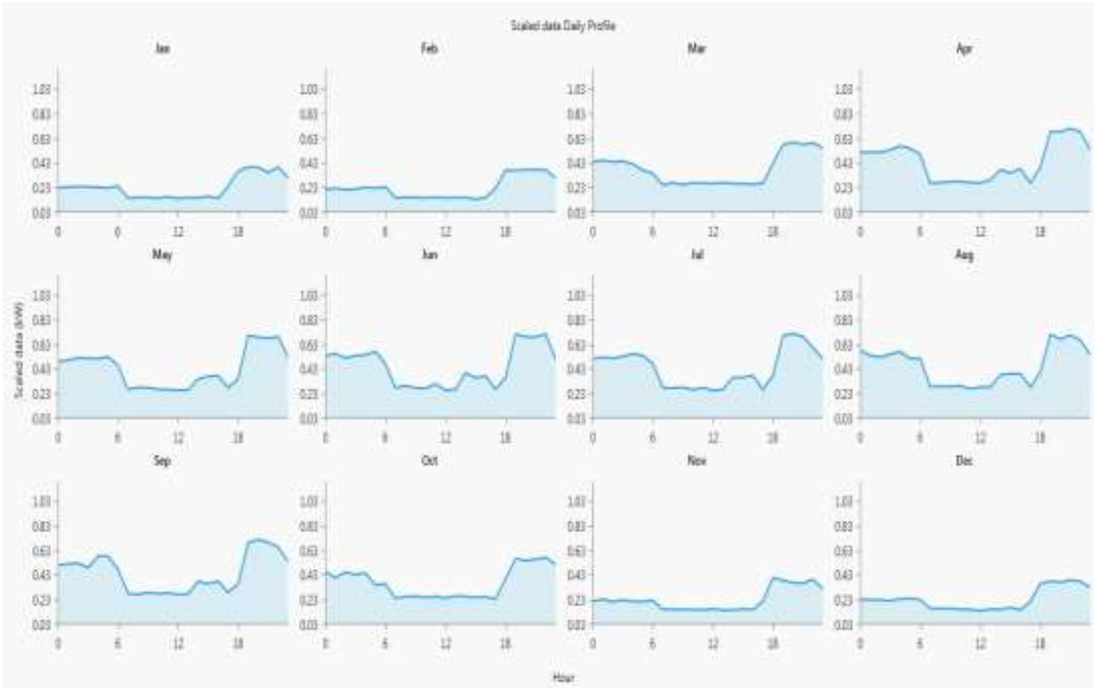

Figure 4.2: Decentralized Load Distribution

4.2.2.7.2 Centralized Hybrid Renewable Energy Systems

Based on the calculations, daily energy requirement for centralized renewable energy systems can be summarized as:

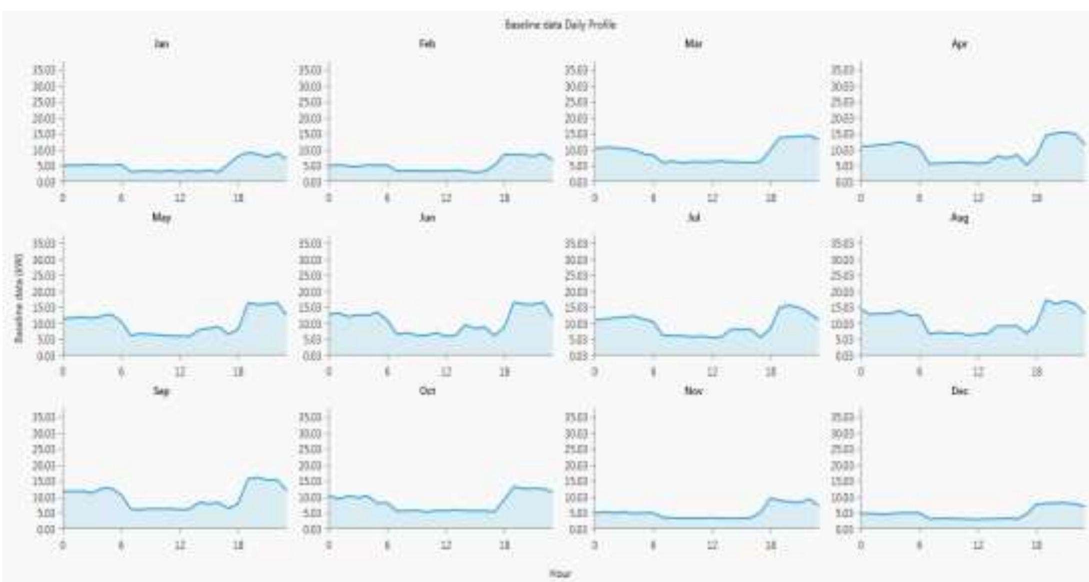

Figure 4.3: Centralized Load Distribution

4.3 Local Resources Available for Energy Production

In order to estimate the renewable energy resources available at the selected site the monthly daily solar radiation and the average wind speeds were obtained from NASA website. The values of the available solar resource and the wind speed thus obtained were then further used to carry out the simulations on the HOMER. It is important to mention here that the values of the available solar resource and the wind speed values of the NASA are accepted all over the world when carrying out the simulations of the proposed renewable energy projects. The month wise solar irradiation and wind speed is tabulated here:-

Table 4.9: solar irradiation and wind speed

S.No	Month	Solar Irradiation (KWh/m2/day)	Wind Speed @ 50 meter above the surface of Earth (m/s)
1.	January	3.8	5.08
2.	February	4.62	5.77
3.	March	5.26	5.81
4.	April	6.23	5.71
5.	May	6.76	6.32
6.	June	6.85	6.25
7.	July	6.56	5.44
8.	August	6.26	5.23

9.	September	5.95	5.23
10.	October	5.15	5.62
11.	November	4.12	4.91
12.	December	3.47	5.12

Both the available energy resources have been discussed in detail.

4.3.1 Solar Energy

In order to model a method that contains the photovoltaic array, the actual HOMER user should recommend photovoltaic resource information for your region. Photovoltaic resource information reveals the quantity of global radiation (beam rays arriving directly from sunlight, in addition dispersed rays of all areas of the sky) which attacks Earth's surface area within a typical year. The information could be in one of 3 types: per hour typical global solar rays within the horizontally surface area (kW/m^2), monthly average global solar radiation within the horizontally surface area ($kWh/m^2/day$), or even monthly clearness index. The clearness index catalog may be the proportion from the photo voltaic rays striking Earth's surface area towards the photo voltaic rays striking the atmosphere. Several among absolutely from zero to one, the actual quality catalog are really a way of measuring the actual quality of atmosphere clearness.

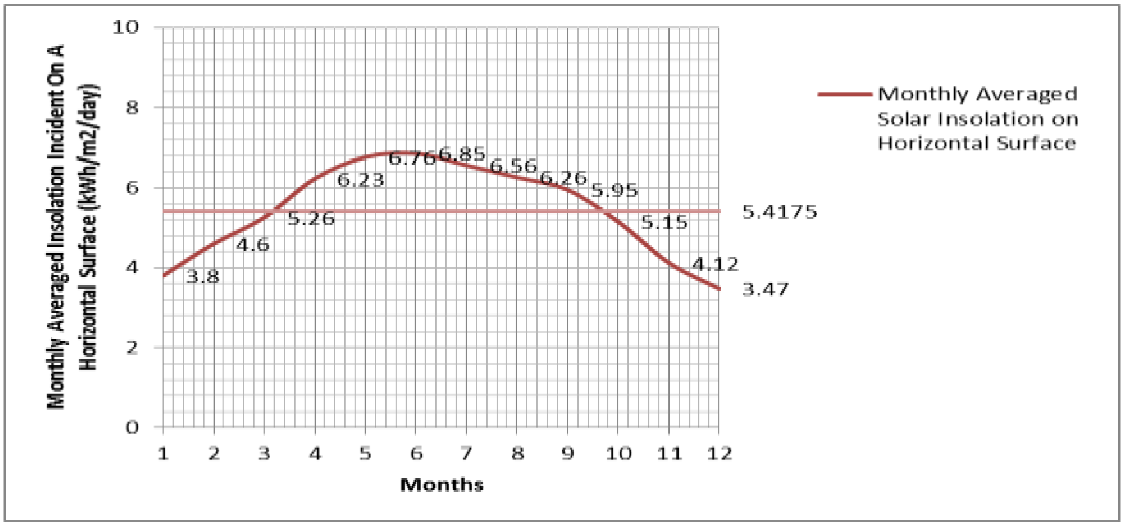

Figure 4.4: Monthly Averaged Solar Insolation on Horizontal Service

HOMER creates synthetic per hour global solar radiations information utilizing a formula produced by Graham as well as Hollands [8]. The actual input for this formula would be the monthly average solar radiations values and also the latitude. The outcome is definitely 8760-hour information arranged along with record features much like the ones from actual calculated information models. Among those record attributes is actually autocorrelation that is it tends for just one day to become just like the previous time, as it is for 1 hour to become just like the previous hours.

The potential of solar energy is immense in Baluchistan, with the average solar global isolations of 5-7 kwh/m2/day, over 95% area (about 2300-2700hr/annum). Fig 2 shows the average daily radiation at the “Killi A.Majeed“near Dalbandin area, for each month of the year. The annual average solar radiation predicted is about 5.42 kwh/m2/day which is considered very healthy for the feasibility of the solar energy systems.

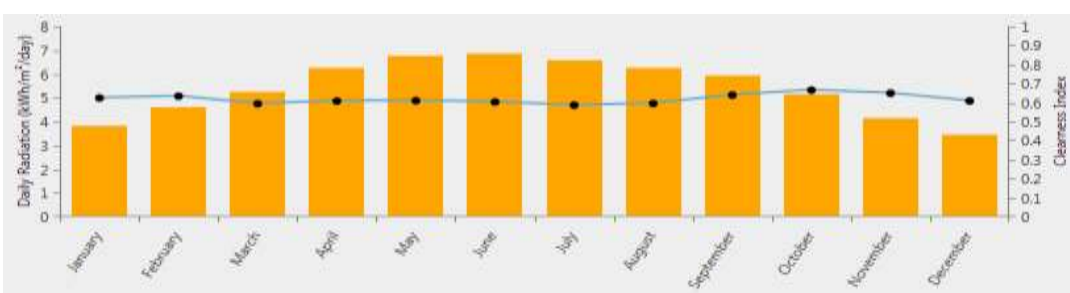

Fig.4.5 Average daily solar radiation at the proposed location for each month of the year

4.3.2 Wind Energy

Pakistan Meteorological Department (PMD) carried out a wind power potential survey of the coastal areas of Sindh and Baluchistan during 2002 to 2004.According to [2], [7]–[10]Pakistan possesses more than 20,000 MW of economically viable wind power potential Baluchistan is blessed with seven wind corridors suitable for wind farms. Fig 3 shows average wind speed predicted at the proposed location for each year. The annual average comes out to be 5.54 m/sec.

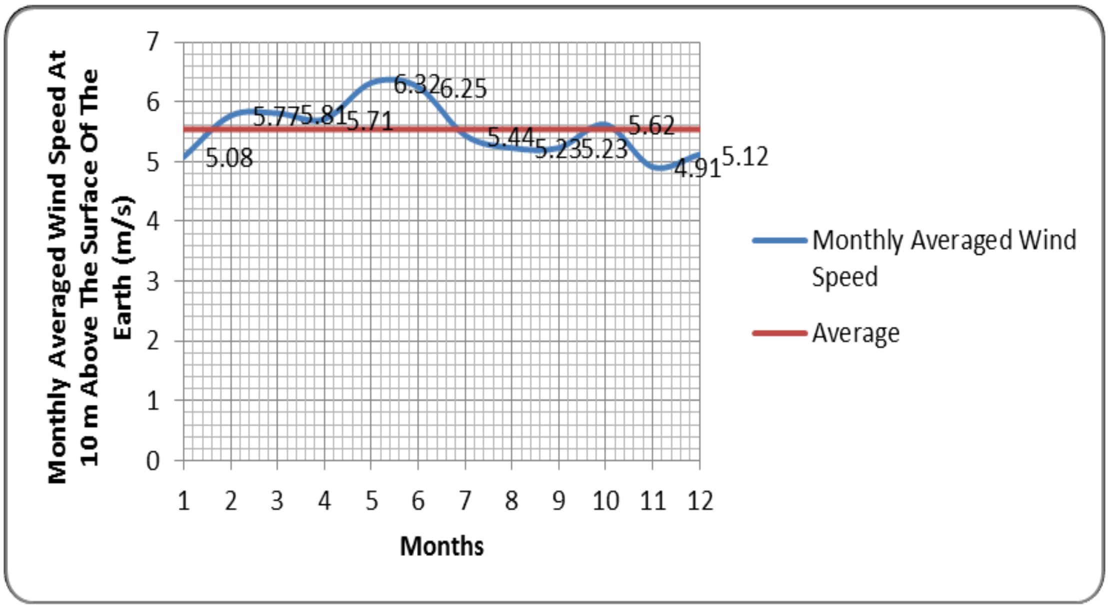

Figure 4.6: Monthly average wind speed.

In order to produce a method composed of a number of wind turbines, the actual HOMER consumer should offer wind resource information showing wind speed the turbine might encounter within a typical year. The consumer can offer calculated per hour wind speed information in case accessible. Or else, HOMER may produce synthetic per hour information through twelve month-to-month typical wind rates of speed and 4 extra parameters: the actual Weibull shape factor, the actual autocorrelation factor, the actual diurnal pattern strength, and also the hours associated with peak wind pace. Distribution measurement of wind speed over a year is called Weibull shape factor. The autocorrelation factor is a measure of how powerfully the wind pace in one hour tends to depend on the wind pace in the previous hour. The diurnal pattern strength and the hour of crest wind speed specify the amount and the phase, correspondingly, of the average daily pattern in the wind speed. HOMER offers default entities for all of these factors.

4.4 Components

Within HOMER, a component is actually any kinds of part of the micro power system which generate, provides, alter, or even store power. HOMER contains ten kinds of component. Three produce electrical power through irregular alternative resources: PV module, wind generators, as well as hydro generators. An additional three kinds of component, power generators, the actual main grid, as well as central heating boiler, tend to be dispatch able powers, which mean that the device may manage all of them as required.

The components for the required design depends on the system to be simulated. Based on the available renewable energy resources, six different options for renewable energy solutions has been considered for the subject study which are:-

- Standalone or Decentralized Solar PV/ Battery System
- Standalone or Decentralized Wind/Battery System
- Decentralized Solar PV/Wind/Battery Hybrid Renewable Energy System
- Centralized Solar PV/ Battery System
- Centralized Wind/Battery System
- Centralized Solar PV/Wind/Battery Hybrid Renewable Energy System

All the proposed systems have different components which are:-

4.4.1 Solar PV/ Battery System

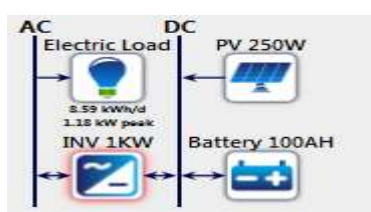

Figure 4.7: Components of Solar PV System

4.4.2 Wind/Battery System

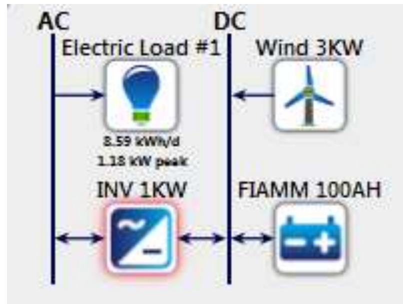

Figure 4.8: Components of Wind System

4.4.3 Solar PV/Wind/Battery Hybrid Renewable Energy System

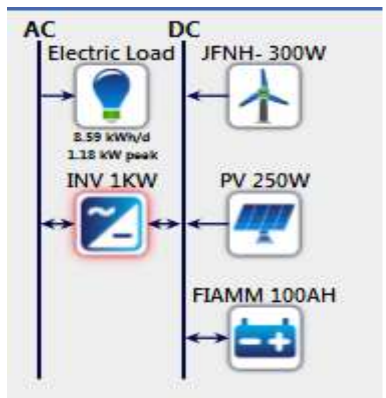

Figure 4.9: Components of HRES System

4.5 Costings Considered for Simulations

The Costs box includes the initial capital cost and replacement cost as well as annual operation and maintenance (O&M) costs. The capital and replacement costs includes all costs associated with the specific item including installation. So the designer must include the installation costs while putting these figures in the simulation softwares. Costings of all the items involved in the systems design (solar PV module, wind turbine, inverter, batteries etc.) needs to be specified separately. The technical specs and the costings of all the items has been discussed one by one:-

4.5.1 Solar PV Size and Cost

The PV inputs window allows to enter the cost, performance characteristics and orientation of an array of photovoltaic (PV) panels as well as choose the sizes to be considered by HOMER as it searches for the optimal system.

Costs bar contains the initial/capital cost, replacement and operation & maintenance cost. When specifying the capital and replacement costs, all costs associated with the PV system are also included, which may include:

- PV panels mounting structure inclusive of civil work
- Tacking system (if considered in the proposed design)
- Control system
- Wiring installation

Homer software use following equations to calculate the output of photovoltaic PV module array [kW] [8].

$$P_{PV} = Y_{PV} f_{PV} \left\{ \frac{\bar{G}_T}{\bar{G}_{T,STC}} \right\} [1 + \alpha_p (T_c - T_{c,STC})] \quad \text{.............(4.1)}$$

Y_{PV} This is the rated power of the Solar PV array, its power production under standard test conditions (STC).

f_{PV} It is Derating factor of PV module

$\bar{G}_T$ Incident solar radiations on solar PV panel in unit time step [kW/m²]

$\bar{G}_{T,STC}$ It is the incident radiations at STC

α_p Is the average temp coefficient of Power [% / ºC]

T_c Is the temperature of cell in unit time step [ºC]

$T_{c,STC}$ Is the cell temperature at STC [25ºC]

In case within the photovoltaic windowpane you select to not produce the result associated with temperatures within the photovoltaic array, HOMER will assumes that this temperatures coefficient of power is actually absolutely zero, so the over formula makes simple in order to

$$P_{PV} = Y_{PV} f_{PV} \left\{ \frac{\bar{G}_T}{\bar{G}_{T,STC}} \right\} \quad \text{……………………} \ (4.2)$$

Right after surveying various items concentrating on the price supplied the Canadian Solar 250 mono crystalline solar panel had been selected. The reason behind finding the item through the mentioned organization is a result of the affordable shipped so long as effectiveness is really a large issue right here. Considered solar panel was of 250W rating [8]. Efficiency of selected solar panel was 16% to 17% and the price of the selected solar panel was $1200/KW. Operation and maintenance cost of the solar panel is very much low it that's why it is considered as $10/yr.

Table 4.10: Solar PV Parameters

PV Size (KW)	Capital Cost ($)	Life (years)	Considered Size
1	1200	25	0,1,2,3,4

No tracking system is considered in this hybrid system, thus fixed system is modeled without any tracking mount at ground. The term derating factor is used for both solar PV panel efficiency and as well as charge controller efficiency as charge controller are not designed by HOMER. This derating factor term is used for dust, elevated temperature, shading effect, electric wiring losses, and so on. The size of the actual photovoltaic panel enter into HOMER is within kW, not really within m², so the efficiency is not really evaluated being enter additionally. The actual azimuth position or even direction as well as position associated with desire from the photovoltaic screen would be the 2 key elements that need to be regarded as throughout solar-system design. With regard to adequate quantity of electrical power production the perfect direction associated with photovoltaic array is due south, however nevertheless it can also be feasible to handle south-east or even south-west, there is little decline in performance because of the change associated with to the west or even eastern associated with south. Some factors had been considered as with regard to design of the power system such as; the derating factor had been used 80%, ground reflectance had been additionally regarded as 20%, slope equal to latitude and 45º and azimuth 0º.

4.5.2 Size and Cost of Wind turbine

The Wind Turbine inputs window allows to choose the wind turbine type, Power Curve, and turbine losses etc. Cost includes the capital cost which is the initial purchase price for a turbine, the replacement cost is the cost of replacing the wind turbine at the end of its life time and the operating and maintenance cost is the annual cost of operating and maintaining the turbine. During calculation of all costs, turbine rotor and tower costs, control system, wiring & installation costs must also be catered. Wind turbine selected for this thesis is 1 kW & 3 Kw wind turbine. O&M cost is estimated about 2% of the capital cost of wind turbine. Replacement cost is considered about 75% of initial cost of wind turbine.

Table 4.11: Wind Turbine Parameters

Size (kW)	Initial Capital Cost ($)	O&M Cost ($)	Replacement Cost ($)	Life (year)	Hub Height (m)
1	1500	100	1200	20	3

Specifications of 1 kW wind turbine are given below:-

- Start-up Wind Speed: 2.2 m/s
- Rated Wind Speed: 8 m/s
- Rated Power: 1000 watts
- Type: 3 Blade Upwind
- Rotor Diameter: 2.5 m (8.2 ft.)
- Blade Pitch Control: None, Fixed Pitch
- Over speed Protection: AUTOFURL
- Gearbox: None, Direct Drive
- Temperature Range: -40 to +60 Deg. C (-40 to +140 Deg. F)

- Generator: Permanent Magnet Alternator
- Output Form: 12 – 48 VDC Nominal.

4.5.3 Batteries Size and Cost

Batteries store direct current electrical energy in chemical form for later use. In a photovoltaic system, the energy is used at night and during periods of cloudy weather. Batteries also serve as a portable power source for appliances, such as flashlights and radios. Since a photovoltaic system's power output varies throughout any given day, a battery storage system can provide a relatively constant source of power when the PV system is producing minimal power during periods of reduced insolation. Batteries can even power the loads when the PV array is disconnected for repair and maintenance. Batteries can also provide the necessary amounts of surge power required to start some motors.

Batteries are not one hundred percent efficient. Some energy is lost, as heat and in chemical reactions, during charging and discharging. Therefore, additional photovoltaic modules must be added to a system to compensate for battery loss.

Costs includes the INC, replacement cost per battery, and annual O&M cost per battery. HOMER use following equation to calculate the size of battery bank.

$$A_{batt} = \frac{N_{batt} V_{nom} Q_{nom} \left(1 - \frac{q_{min}}{100}\right)\left(\frac{24h}{d}\right)}{L_{prim,ave}\left(\frac{1000Wh}{kWh}\right)} \quad \text{.................................(4.3)}$$

N_{batt} Is total No. of batteries in battery bank

V_{nom} Is single battery's nominal voltage [V]

Q_{nom} Is nominal capacity of battery [Ah]

q_{min} Is the lowest state of charge for battery bank [%]

$L_{prim,ave}$ Is average primary Load [kWh/d]

Within HOMER, 2 self-employed aspects might restrict the actual duration of the actual electric battery: the actual life time throughput and also the electric battery float life.

Quite simply, battery may expire possibly through use or even through old age. Whenever one have to develop a brand new electric battery, you can choose if the electric battery life time is restricted through time, throughput, or even both. The life of battery bank is calculated by Homer through following equation.

$$R_{bat} = \begin{cases} \frac{N_{batt} \cdot Q_{lifetime}}{Q_{thrpt}} & If\ Limited\ by\ throughput \\ R_{bat,f} & If\ limited\ by\ time \\ MIN\left(N_{batt} \cdot \frac{Q_{lifetime}}{Q_{thrpt}}, R_{bat,f}\right) & If\ limited\ by\ time\ and\ throughput \end{cases} \quad \text{……..(4.4)}$$

R_{bat} Is life time of the battery bank [yr]

N_{batt} Is the total number of batteries in battery bank

$Q_{lifetime}$ Is single battery's throughput [kWh]

Q_{thrpt} Is annual throughput of the battery [kWh/yr]

$R_{bat,f}$ Is floating life of the battery [yr]

Such as the some other aspects of the energy system, enter variables placing in to the software program tend to be price as well as amount of battery may be the condition associated with cost beneath that the electric battery will certainly not be released to avoid through damage. Through 30-50 % may be the suggested minimal condition associated with cost. Round-trip electric battery effectiveness may be the flow of energy in to the electric battery which can be removed or extracted for further use. The selected battery contain the nominal capacity of 3000 Ah and having the nominal voltage of 2V for Centralized System and 12 Volt, 150 Ah for Decentralized system. Batteries round-trip efficiency is about 85%. Minimum state of charge for the selected batteries is 30 %. Battery's life time is 5 years. Replacement cost of the batteries is considered same as capital cost of the batteries.

4.5.4 Size and Cost of Power Converter

Alternating current is easier to transport over a long distance and has become the conventional modern electrical standard. Consequently, most common appliances or loads are designed to operate on AC. As you know, photovoltaic modules generate only DC power. In addition, batteries can store only DC power. AC and DC are, by nature, fundamentally incompatible. Therefore, a "bridge" - an inverter - is needed between the two.

The fundamental purpose of a PV system inverter is to change DC electricity from PV modules (when connected with the utility grid) and batteries (in stand-alone or grid¬ tied/battery backup) to AC electricity, and finally to power AC loads.

Converter capital cost is taken as $ 500 per KW and its replacement cost is also the same of the initial cost. Efficiency of the power converter is taken as 98 %. Power converter life time is considered as 20 years.

4.6 Summarized Technical and Financial Parameters Considered for the Simulations

Table 4.12: Simulation Parameters

S.No	Item	Parameters	Unit	Value
1.	Solar PV	Slope	Degree	28
		Ground reflectance	%	20 %
2.	Wind Turbines	Rated power	kW	1 KW
		Hub height	Meter	3 meter
		Blade	No.	3
3.	Battery	Nominal Voltage	Volt	12 Volt
		Nominal Capacity	Ah	150 Ah
		Round trip efficiency	%	85 %

		Min. state of charge	%	30 %
		Float life	Years	5 years
		Batteries per string	Nos	4
4.	Inverter	Efficiency	%	98 %

4.7 Selection Scenarios and System Optimization

Even though HOMER created various designs of energy system components, nevertheless it just shows the actual feasible energy strategy situations for extra comprehensive evaluation. The actual complexness as well as calculation period is influenced by the number of variables as well as number associated with possible values in the design. Energy plans (scenarios) along with much less NPC, much less COE, greater alternative fraction, much less capability shortage, smaller sized extra electrical power as well as minimal fuel usage will be recommended as an optimum system.

Summary

The actual HOMER optimization product is really a computer product produced by the U.S National Renewable Energy Laboratory (NREL) to aid within the type of micro power techniques and also to help the actual a comparison of energy technology throughout a range of different application. HOMER models an electrical system's actual physical behavior as well as its life price, which is the entire cost of installation as well as working the system over its life time. HOMER enables the modeler in order to a variety of design choices depending on their own specialized as well as financial value. Additionally, it helps understand as well as quantifying the consequence of doubt or even modifications in the inputs of power system. As discussed in the overview and methodology, the simulations for standalone solar PV, wind and solar PV/wind hybrid renewable energy systems both for centralized and decentralized systems has been done. In the above chapter all the basic requirements for the simulations in the HOMER softwares like Location, Hourly Load Profile, Components, Energy Resources & General Considerations for the Simulation has been defined.

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Chapter 5

Conclusion and Recommendations

5.1 Systems Simulated

The HOMER software performs several simulations in order to arrive at the optimum system for serving the desired loads. In the present investigation, the renewable energy systems comprised different combinations of PV modules (kW) and wind turbine power supplemented with a battery bank to define a feasible system configuration which is capable of meeting the required electrical load. Using the HOMER program, several configurations, such as PV/bat, wind/bat and hybrid PV/wind/bat were examined in order to find the best renewable energy configuration. Six different options for renewable energy solutions has been considered for the subject study which are:-

- Decentralized Systems
    - ✓ Solar PV/ Battery System
    - ✓ Wind/Battery System
    - ✓ Solar PV/Wind/Battery Hybrid Renewable Energy System
- Centralized Systems
    - ✓ Solar PV/ Battery System
    - ✓ Wind/Battery System
    - ✓ Solar PV/Wind/Battery Hybrid Renewable Energy System

Techno economic analysis of all these six cases and their comparison has been discussed in detail.

5.2 System Analysis for Decentralized / Standalone Systems

5.2.1 Solar PV/Battery System

Different systems are analyzed at the specific site to indicate the optimum system for the location considered for the subject case study. Analysis of Solar PV/Battery for the decentralized case is discussed here.

The main components involved in this systems are solar PV module, a battery backup system, inverter for DC to AC conversion and the AC load. The average daily load requirement for the decentralized system calculated is 8.59 KWh /day. Several simulations were carried out by considering different PV capacities, battery bank and different inverter ratings. The sizes considered for the simulation of decentralized Solar PV/ Battery system are:-

Table 5.1: Solar PV input Parameters

S.No	Items	Sizes Considered for Analysis
1.	Solar PV Module (KW)	1.25, 1.5, 1.75, 2, 2.25, 2.5, 2.75, 3.0
2.	Number of Battery bank (with four batteries in each bank)	1,2,3,4,5,6
3.	Number Inverter (1 KW)	1,2,3

The best Solar PV/ battery configuration for the required load requirement was obtained at the PV panel of 2.5 KW, eight batteries and inverter of 1 KW. The daily average output of the proposed system will be 11.83 Kwh / day with the capacity factor of 19.72 and annual average production of 4,318 KWh / yr.

Different combination for achieving optimum output on the specific location were simulated. The cost summary of best possible system is summarized as with total initial cost of 5,900 $, cost of energy of 0.24 $ per unit and the net present of 13,847 $. Note that the price calculations has been done on the basis of individual component prices as already defined in the chapter 4.

5.2.2 Wind/Battery System

The main components involved in this systems are off grid wind turbine, a battery backup system, inverter for DC to AC conversion and the AC load. The average daily load requirement for the decentralized system calculated is 8.59 Kwh /day. Several simulations were carried out by considering different capacities, battery bank and different inverter ratings. The sizes considered for the simulation of decentralized Solar Wind/ Battery system are:-

Table 5.2: WT input Parameters

S.No	Items	Sizes Considered for Analysis
1.	Wind Turbine (KW)	0,1,2,3,4
2.	Number of Battery banks (with four batteries in each bank)	1,2,3,4,5,6
3.	Number of Inverters (1 KW)	1,2,3

The wind speed and duration of wind is not properly aligned with the duration of running load. As a result when we use small size wind turbine of 300 Watt, there was a huge capacity shortage and when the size of turbine has been increased to 1 KW, 2 KW & 3 KW the capacity shortage and the unmet load decreases respectively but the excess electricity increases. All the parameters for the considered sizes has been summarized here:-

Table 5.3: Off grid decentralized Simulation results for Wind Energy System

	1 KW Wind Turbine	2 KW Wind Turbine	3 KW Wind Turbine
Annual Production (Kwh / yr)	3,739	5,968	11,217
Excess Electricity (%)	14.6 %	44.2 %	70 %
Unmet Load (%)	16.2 %	7.2 %	4.2 %
Capacity Shortage (%)	20.3 %	10 %	6.8 %

The best Wind/ battery configuration for the required load requirement was obtained at the 2 KW, eight batteries and inverter of 1 KW with reasonable amount of unmet load but still the excess electricity is 44 %. The annual output of the proposed system will be 5,968 Kwh / yr with the capacity factor of 33 %.

Different combination for achieving optimum output on the specific location were simulated. The cost summary of best possible system is summarized as with total initial cost of 6,000 $, cost of energy of 0.319 $ per unit and the net present of 16,808 $. Note that the price calculations has been done on the basis of individual component prices as already defined in the chapter 4.

5.2.3 Solar PV/Wind/ Battery Hybrid Renewable Energy System

The main components involved in this systems are solar PV module, off grid wind turbine, a battery backup system, inverter for DC to AC conversion and the AC load. The average daily load requirement for the decentralized system calculated is 8.59 Kwh /day. Several simulations were carried out by considering different PV capacities, battery bank and different inverter ratings. The sizes considered for the simulation of decentralized Solar PV/ Battery system are:-

Table 5.4: Solar PV/Wind input Parameters

S.No	Items	Sizes Considered for Analysis
1.	Solar PV Module (KW)	1.25, 1.5, 1.75, 2, 2.25, 2.5, 2.75, 3.0
2.	Wind Turbine (KW)	0,1,2,3,4
2.	Number of Battery banks (with four batteries in each bank)	1,2,3,4,5,6
3.	Number of Inverters	1,2,3

Due to difference in resources availability and density capacity factor may also change. Higher wind speed availability increases the capacity factor of wind turbine while lower solar radiation may decrease the capacity factor of solar PV modules. All these factors affect the individual production of each component of the system which may contribute in the overall production of the system. This difference make system either reliable or not. Individual contributions to the overall system and total production from the system are different. Production from each component of the system is given bellow in the table.

Table 5.5: Solar PV/Wind Output Parameters

Component	Production (kWh/ yr)	Fraction
PV array	3,455	53.65%
Wind turbine	2,984	46.35%
Total	6,439	100%

In overall production of electricity or energy from the different components of hybrid renewable energy are given in the table. Solar produce 53.65 % of the total production and wind contribution is 46.35 %.

The best Solar PV/Wind/ battery HRES configuration for the required load requirement was obtained at the PV panel of 2 KW, 1 KW wind turbine, four batteries and inverter of 1 KW. The cost summary of best possible system is summarized as with total initial cost of 5,650 $, cost of energy of 0.208 $ per unit and the net present of 12,010 $. Note that the price calculations has been done on the basis of individual component prices as already defined in the chapter 4.

5.2.4 Comparison of Decentralized systems

After simulating all of the three systems for decentralized case, the results are being summarized in the table.

Table 5.6: Comparison of Decentralized Systems

S. No	System	Solar PV	Wind	Battery	Inverter
1.	Solar PV	2.5 KW		8	1 KW
2.	Wind		2 KW	8	1 KW
3.	Hybrid	2 KW	1 KW	4	1 KW

The Cost of Equity (COE) and Net Present Cost (NPC) of hybrid solar PV-Wind-Battery system is $ 0.2/ KWh and $ 12,010, of the standalone solar PV system is $ 0.24/ KWh and $ 13,847 and of standalone wind energy system is $ 0.319/ KWh and $ 18,845. It can therefore concluded that the hybrid renewable energy system is more cost competitive, eco-friendly, low maintenance alternative power solution for rural electrification in the researched area.

5.3 System Analysis for Centralized Systems

5.3.1 Solar PV/Battery System

Different systems are analyzed at the specific site to indicate the optimum system for the location considered for the subject case study. Analysis of Solar PV/Battery for the centralized case is discussed here.

The main components involved in this systems are solar PV module, a battery backup system, inverter for DC to AC conversion and the AC load. The average daily load requirement for the Centralized system calculated is 274 Kwh /day. Several simulations were carried out by considering different PV capacities, battery bank and different inverter ratings. The sizes considered for the simulation of decentralized Solar PV/ Battery system are:-

Table 5.7: Solar PV input Parameters for Centralized System

S.No	Items	Sizes Considered for Analysis
1.	Solar PV Module (KW)	10,20,30,40,50,60,70,80,90,100
2.	Number of Battery banks (with four batteries in each bank)	1,5,10,15
3.	Number of Inverters (1 KW)	35,40,45,50

The best Solar PV/ battery configuration for the required load requirement was obtained at the PV panel of 78 KW, 120 batteries and inverter of 40 KW. The daily average output of the proposed system will be 382.59 Kwh / day with the capacity factor of 19.72 and annual average production of 139,645 KWh / yr.

Different combination for achieving optimum output on the specific location were simulated. The cost summary of best possible system is summarized as with total initial cost of 250,600 $, cost of energy of 0.285 $ per unit and the net present of 521,457 $. Note that the price calculations has been done on the basis of individual component prices as already defined in the chapter 4.

5.3.2 Wind/Battery System

The main components involved in this systems are off grid wind turbine, a battery backup system, inverter for DC to AC conversion and the AC load. The average daily load requirement for the decentralized system calculated is 274 Kwh /day. Several simulations were carried out by considering different capacities, battery bank and different inverter ratings. The sizes considered for the simulation of decentralized Solar Wind/ Battery system are:-

Table 5.8: WE input Parameters

S.No	Items	Sizes Considered for Analysis
1.	Wind Turbine (KW)	10,20,30,40,50
2.	Number of Battery banks (with four batteries in each bank)	1,5,110,15
3.	Number of Inverters (1 KW)	35,40,45,50

The best Wind/ battery configuration for the required load requirement was obtained at the 42 KW, 192 batteries and inverter of 40 KW. The annual output of the proposed system will be 98,659 Kwh / yr with the capacity factor of 35.26 %.

Different combination for achieving optimum output on the specific location were simulated. The cost summary of best possible system is summarized as with total initial cost of 301,800 $, cost of energy of 0.343 $ per unit and the net present of 642,053 $.

5.3.3 Solar PV/Wind/ Battery Hybrid Renewable Energy System

The main components involved in this systems are solar PV module, off grid wind turbine, a battery backup system, inverter for DC to AC conversion and the AC load. The average daily load requirement for the decentralized system calculated is 274 Kwh /day. Several simulations were carried out by considering different PV capacities, battery bank and different inverter ratings. The sizes considered for the simulation of decentralized Solar PV/ Battery system are:-

Table 5.9: Solar PV/Wind input Parameters

S.No	Items	Sizes Considered for Analysis
1.	Solar PV Module (KW)	10,20,30,40,50,60,70,80,90,100
2.	Wind Turbine (KW)	10,20,30,40,50
2.	Number of Battery banks (with four batteries in each bank)	1,5,110,15
3.	Number of Inverters (KW)	35,40,45,50

In overall production of electricity or energy from the different components of hybrid renewable energy are given in the table. Solar produce 52 % of the total production and wind contribution is 48 %. Production from each component of the system is given bellow in the table.

Table 5.10 Component wise energy production

Component	Production (kWh/ yr)	Fraction
PV array	68,033	52%
Wind turbine	64,855	48%
Total	132,887	100%

The best Solar PV/Wind/ battery HRES configuration for the required load requirement was obtained at the PV panel of 38 KW, 21 KW wind turbine, 120 batteries and inverter of 40 KW. The cost summary of best possible system is summarized as with total initial cost of 239,000 $, cost of energy of 0.255 $ per unit and the net present of 471,806 $.

5.3.4 Comparison of Centralized systems

After simulating all of the three systems for decentralized case, the results are being summarized in the table.

Table 5.11: Solar Comparison of Centralized System

S. No	System	Solar PV	Wind	Battery	Inverter
1.	Solar PV	78 KW		192	40 KW
2.	Wind		42 KW	120	40 KW
3.	Hybrid	38 KW	21 KW	192	40 KW

The Cost of Equity (COE) and Net Present Cost (NPC) of hybrid solar PV-Wind-Battery system is $ 0.255 / KWh and $ 471,806, of the solar PV system is $ 0.28/ KWh and $ 521,457 and of wind energy system is $ 0.34/ KWh and $ 642,053.

5.4 Comparison of Centralized & Decentralized systems

Different configurations of Centralized and Decentralized systems are analyzed at the proposed location. Technically hybrid system (wind/solar) are strong enough to produce reliable power & economically these systems are also feasible due to low storage due to multiple generation systems.

5.4.1 Initial Cost Comparison

Initial cost of the system is calculated on the basis of the component wise cost defined earlier. The cost of solar PV was taken as 1200 $ per KW, for wind turbine cost was 1500 KW, for batteries $2 / Ah and for invert $ 500 / KW. Graph given below shows initial cost of the wind/solar/grid hybrid system for each system both for centralized and decentralized system. The cost of centralized systems is bit higher as the cost of infrastructure is also included for transmission and distribution to each house.

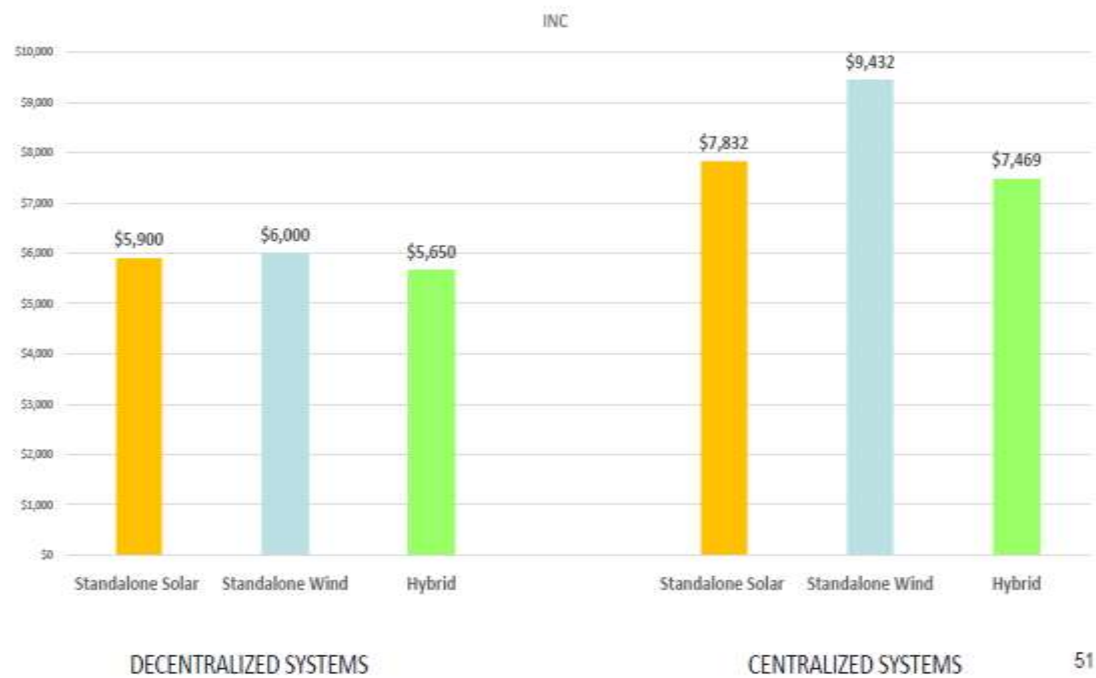

Figure 5.1: Graph of Hybrid systems INC

5.4.2 Comparison of Levelized Cost of Energy

The actual levelized cost of power is actually which means typical price for each kilowatt hour associated with useful energy created by the system. HOMER energy system use following given equation for levelized cost calculation [5]. Even though levelized cost of power is usually a handy metric which in order to the expenses various techniques, HOMER utilizes the entire NPC rather because it is main financial number associated with value. Hybrid (Wind/Solar) systems are analyzed at different wind speed areas to obtain the feasible system for the location, behavior of wind speed in the economic analysis of the hybrid systems are also analyzed.

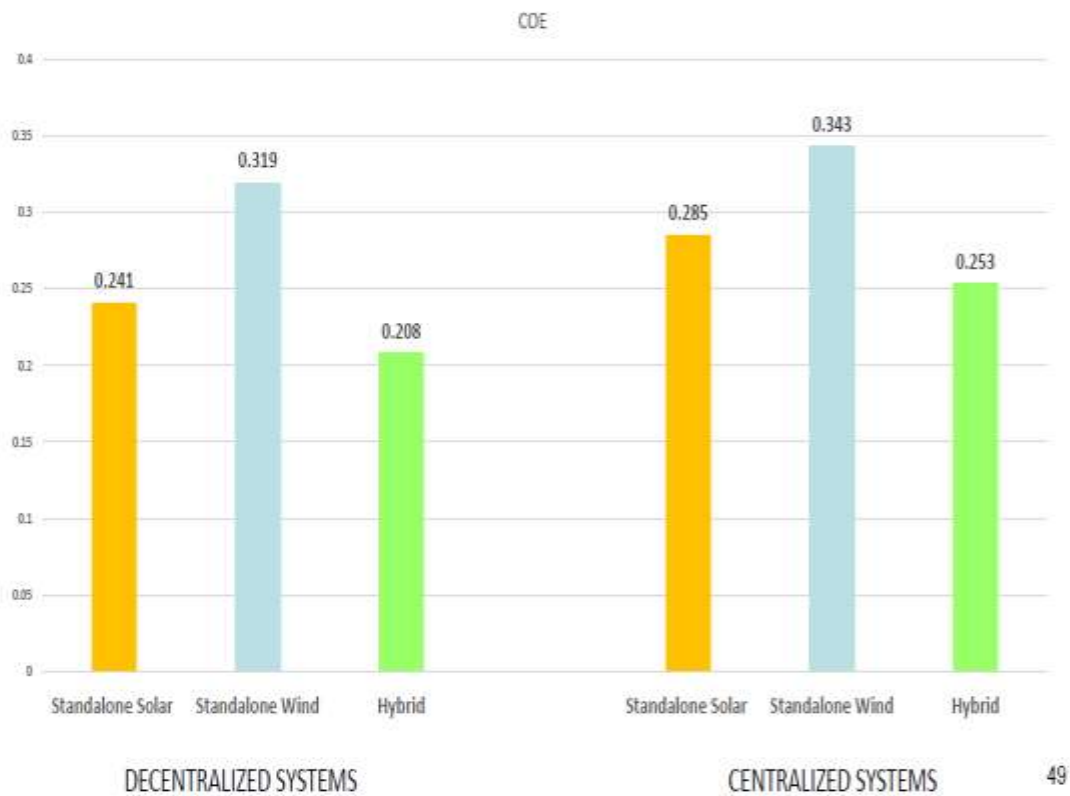

Figure 5.2: Graph of Levelized COE

5.4.3 Net Present Cost

HOMER rates the system designs based on NPC instead of levelized cost of power. The reason being the definition from the levelized expense of power is actually disputable in a manner that the definition from the complete NPC is not really. HOMER utilizes the entire net present cost (NPC) to symbolize the actual cycle expense of a system. The entire NPC condenses all of the expenses as well as profits which happen inside the task life time as one time within modern day currency, along with upcoming money moves reduced returning to the current utilizing the low cost price. The actual designer identifies the actual low cost price and also the task life time. The actual NPC consists of the expenses associated with preliminary building, element replacement, servicing, energy, as well as the expense of purchasing energy through the main grid as well as assorted expenses for example fines caused by pollutant emissions etc. Solar PV has low operation and maintenance cost and long life which make it suitable in Hybrid system.

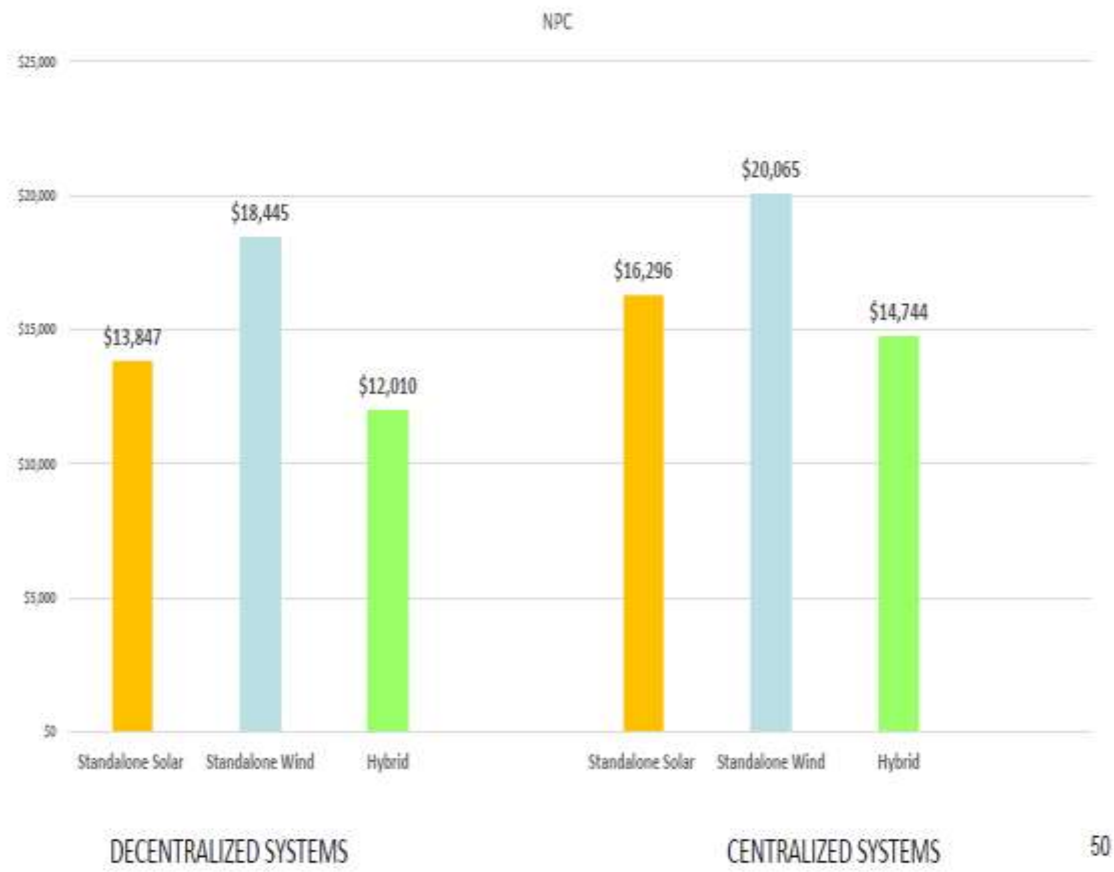

Figure 5.3: Graph of NPC

5.5 Conclusion

This particular thesis function is actually dedicated to design a technically as well as economically feasible off-grid alternative system with regard to household customers. Rural places electrification is currently and can stay difficult project with regard to developing nations such as Pakistan. To satisfy the power dependence on area hybridizing power technology may accommodate as long-term options.

Throughout the design of the actual off-grid system set-up it had been carried out an optimization procedure in line with the electrical power load, weather data resources, and the economics from the energy elements where the NPC needs to be decreased to pick a fiscal achievable energy system. HOMER simulation outcome shown probably the most affordable and achievable systems categorized through NPC through best in order to straight decreasing way.

Various designs had been simulated; nevertheless the choice might be carried out by providing because of focus on each evaluation variables individually. The outcomes revealed which numerous achievable hybrid system setups with various efforts created by renewable fractions.

Comparison between the solar PV, Wind and hybrid renewable energy systems both for centralized and decentralized cases has been discussed in detail. The COE and NPC of HRES is minimum for both cases. Hence we can easily conclude that HRES are best as compared to single generation sources. For centralized and decentralized cases, the cost of centralized system is bit higher as it also includes the infrastructure cost for distribution system or mini grid. But centralized systems has many advantages over decentralized systems like there will be one giant system which can be maintained, secured and stabilized easily. Based on these findings, therefore, the hybrid renewable energy system was recommended for supplying the electrical load requirements of the present study.

5.6 Recommendations

Different sites of Pakistan have lot of renewable resources which can be harvested. Resources availability changes from one location to other according to its latitude and climatic conditions of the site. To enhance the power insufficiency in nationwide and on the provincial level, main grid or grid connected systems and off-grid power technologies techniques needs to be advertised, utilizing various systems such as subsidized system by government. By strengthening the agricultural communities' earnings to develop renewable systems which produced electrical power buying energy can also is basic. In case attention should be given to land degradation, environment air pollution and bad residing standard from the rural local community, alternative resources hybrid energy system should be promoted to raise their standard, nevertheless the present electrification tendency of Pakistan's federal government is through building big hydropower dam and in some way available wind energy facilities. In addition within an uncommon situation photovoltaic standalone systems for separate houses are also installed but main drawback of these systems are their reliability and durability. Therefore hybridizing associated with wind energy and solar photo voltaic should be promoted because of price, durability and clean energy as compared to fossil fuels and hybrid system can give a 24 hour high quality electrical power.

The main recommendations are highlighted below:-

- ✓ Feasibility of Standalone and HRES both for Centralized and Decentralized has been investigated.
- ✓ Technical feasibility was determined on the basis of minimum capacity shortage and unmet load.
- ✓ Economic Viability was determined on the basis of COE & NPC.
- ✓ COE & NPC of HRES are minimum as compared to Standalone Renewable Energy Systems
- ✓ Most Feasible solution both for Centralized & Decentralized cases is Hybrid Renewable Energy Systems (HRES)

- ✓ Capital cost of Centralized Systems is greater as compared to Decentralized systems.
- ✓ Standalone Wind Energy systems for Decentralized case is not considered feasible due to excess energy issues.
- ✓ HRES are cost-competitive, eco-friendly, low maintenance, and alternative power solution for any load in rural locations far from the grid.
- ✓ By using Hybrid Renewable Energy Systems Remote areas around the country can be electrified to a large extent.
- ✓ Energy supply sources can be diversified as a result we can:-
    - ➢ Reduce our dependence on imported fuels
    - ➢ Improve the quality of the air we breathe,
    - ➢ Reduce the pressure on national grid
    - ➢ Stimulate our economy
- ✓ Govt. Sector as well as NGO's working for the betterment of deprived community can be approached for early deployment of these systems.

Annexure I

Techno-Economic Evaluation of the Centralized Hybrid Renewable Energy Systems for off-grid rural electrification

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Abstract

Pakistan being an energy deficient country facing major issues in its economic development due to the current power crisis. Pakistan is naturally benefitted with different renewable energy resources; out of which solar and wind energy are the main highlights. This research work will provide an assessment of the renewable energy potential of the Baluchistan region. A comparison of the economic and financial analysis for a centralized hybrid renewable energy system has been simulated by using Homer software. Three cases have been proposed in which centralized standalone solar PV system, centralized standalone wind energy system and a hybrid combination of both centralized standalone solar and wind energy system have been studied. Homer software has been used to devise the most optimal solution. The simulations confirm that the best optimal solution is the hybrid renewable energy system for the rural electrification of the proposed region.

Keywords: AC Micro grids, Centralized Hybrid Renewable Energy Systems, Hybrid Renewable Energy Systems, Rural Electrification, Stand Alone Systems.

1. Introduction

Energy is considered as the crucial element in the development of any country. The importance of energy in financial growth is recognized by the world and recent studies have established a direct relation between availability of energy and economic growth [1].According to International Energy Agency (IEA) report[2], there would be a 53% increase in the global primary energy consumption up to 2030 and 70% of this value is expected to come from developing nations[3].Currently, renewable energy contributes to only 11% of the world primary energy and this is expected to increase to 60% by 2070[4].To counter these environmental and energy problems there is a need to explore cleaner and environmental friendly energy resources.

Like other developing countries, Pakistan is also facing energy deficit of about 4GW in spite of the fact that Pakistan has huge potential of renewable energy resources[5].The gap between energy demand and supply is increasing with the passage of time. The energy demand of Pakistan is increasing at an exponential rate as shown in Fig 1, whereas on the other hand there is hardly any increase in the energy generation capacity of Pakistan. The installed electric power generation capacity of Pakistan is 21 GW, but the actual generation remains limited between 9 GW to 13 GW[5].

Fig.1 Projected Power Demand of Pakistan

Pakistan has a huge renewable energy potential which can easily overcome the energy crisis of Pakistan but still the renewable energy resources have hardly any percentage in the energy mix of Pakistan. The purpose of the study is to propose the most feasible renewable energy system for the deprived community having no access to the electricity. The area selected for the subject study is a small village of Baluchistan province which is considered as the most deprived area all over Pakistan.

2. Topography of the location

Baluchistan is the largest Province of Pakistan which covers a large area of about 347,190 Sq Km[6]. The selected area is one of the small communities of the district Chagai which is the largest district of Baluchistan. The terrain of the the Chagai district consists of highlands, plains and deserts with the vast arid zone having very little rainfall. The climate is very hot in summer and cold in the winter. The rainfall is irregular and scanty.

2.1 Estimation of the Available Energy Resources:

In order to estimate the available renewable energy resources available at the selected site the monthly daily solar radiation and the average wind speeds were obtained from NASA website. The values of the available solar resource and the wind speed thus obtained were then further used to carry out the simulations on the HOMER. It is important to mention here that the values of the available solar resource and the wind speed values of the NASA are accepted all over the world when carrying out the simulations of the proposed renewable energy projects.

2.1.1 Solar Energy

The potential of solar energy is immense in Baluchistan, with the average solar global isolations of 5-7 kwh/m^2/day, over 95% area (about 2300-2700hr/annum). Fig 2 shows the average daily radiation at the "Killi A.Majeed" near Dalbandin area, for each month of the year. The annual average solar radiation predicted is about 5.42 kwh/m^2/day which is considered very healthy for the feasibility of the solar energy systems.

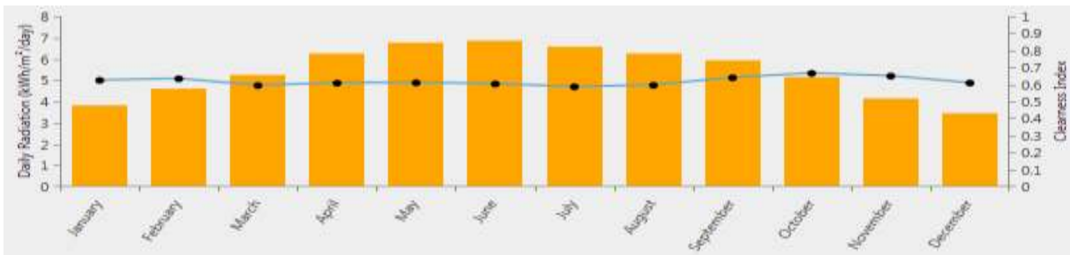

Fig.2 Average daily solar radiation at the proposed location for each month of the year

2.1.2 Wind Energy

Pakistan Meteorological Department (PMD) carried out a wind power potential survey of the coastal areas of Sindh and Baluchistan during 2002 to 2004.According to [2], [7]–[10]Pakistan possesses more than 20,000 MW of economically viable wind power potential Baluchistan is blessed with seven wind corridors suitable for wind farms. Fig 3 shows average wind speed predicted at the proposed location for each year. The annual average comes out to be 5.54 m/sec.

Fig.3 Average wind speed at the proposed location for each month of the year

3. Methodology

A Hybrid Renewable Energy System (HRES) incorporates two or more electricity generation options based on the renewable energy or fossil fuel unit. Finding the suitable configuration of HRES is related to topography of the location, estimation of the load, available energy resources and devised energy solution[11]–[16]. Topography of the area and the analysis on the available energy resources has already been explained. Electric load profile and the analysis on the proposed solutions would be explained in the subsequent sections.

4. Electric Load Demand Profile

In order to estimate the load requirements of the one of the selected locality named “Killi A.Majeed“near Dalbandin area, district Chagai , a survey was being conducted in the community. It was found that Killi A. Majeed has no access to the electricity and all the houses are having almost the same structure and the covered area. According to the survey conducted in the area and the response of the community a common load necessary for the functioning of a single major house was being proposed. The proposed load considered for each home is summarized in the table given below. Daily load profile of the community is presented in Fig 4.

S.No.	Load	Wattage of each Load	Quantity for each house
1.	Energy Saver	25	5
2.	Ceiling Fan	100	3
3.	Fridge	200	1
4.	TV	100	1

Table.I Load characteristics for the proposed renewable energy systems

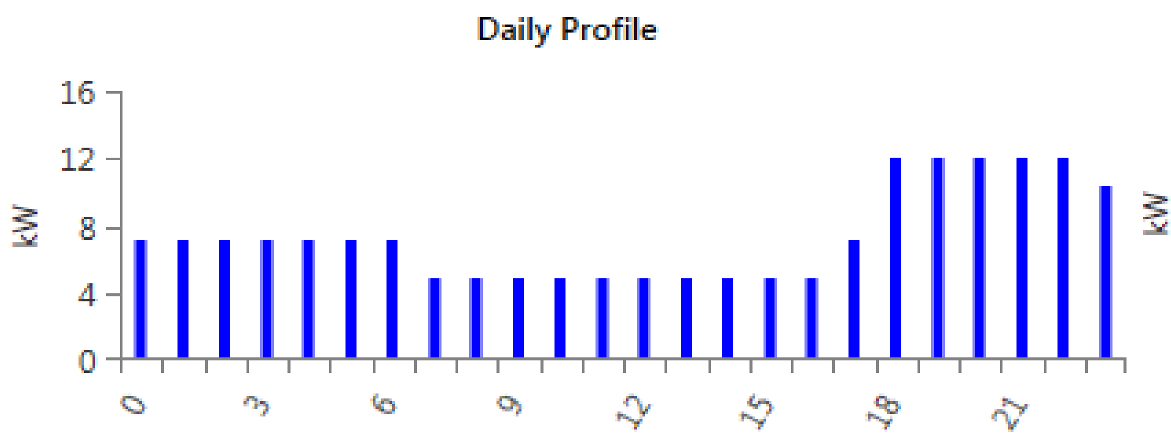

Fig.4 Average daily load profile

In order to estimate the load requirements the load usage was thus divided into three case scenarios as being plotted and shown in Fig: 5.

- Load usage during summer season (April-September)
- Load usage during winter season (November – February)
- Load usage between summer and winter season. (March & October).

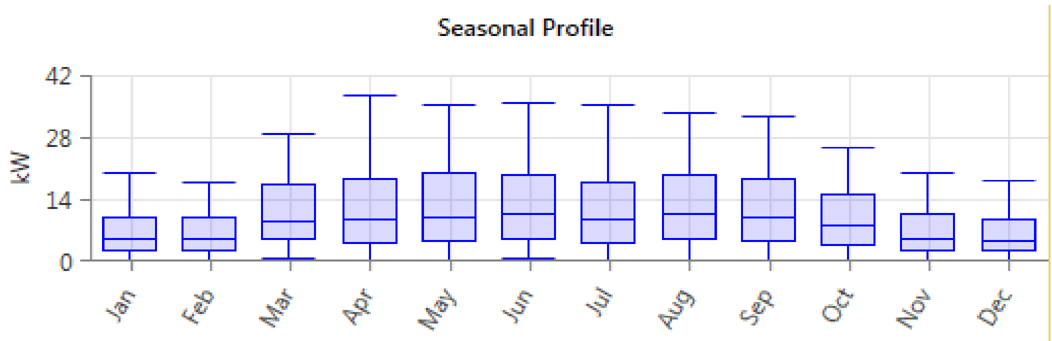

Fig.5 Seasonal load profile

5. Devised Energy Solution

HRES are more reliable, better efficient and a source of minimum levelized life cycle electricity generation cost. All these benefits can be availed when optimum design techniques are used. In [4],different software's tools which are being used for systems design and analysis of HRES have been analyzed and HOMER was found to be most widely used tool as it has maximum combination of renewable energy systems and performs optimization and sensitivity analysis which makes it easier and faster to evaluate the many possible system configurations[17]–[21].

5.1 System Design

The systems consist of PV module, wind turbine, battery and converter. The system schematic has been shown in fig:

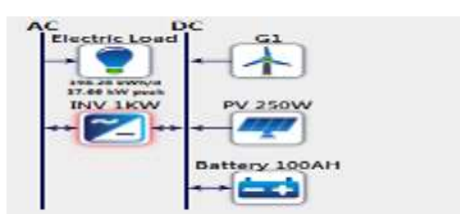

Fig.6I Schematic of the proposed system

5.2 Simulation Procedure

Three different renewable energy combinations standalone and Hybrid Renewable Energy systems have been simulated and analyzed by using HOMER software. Due to the non-availability of the national grid only off grid centralized systems have been considered and simulated. The options which are being simulated in the study are:-

- Standalone Solar PV/ Battery System
- Standalone Wind/Battery System
- Solar PV/Wind/Battery Hybrid Renewable Energy System

5.3 Results & Discussions:

After simulating all of the three systems the results are being summarized in the table V.The Cost of Equity (COE) and Net Present Cost (NPC) of hybrid solar PV-Wind-Battery system is $ 0.381/ KWh and $ 326,657, of the standalone solar PV system is $ 0.4/ KWh and $ 335,962 and of standalone wind energy system is $ 0.771/ KWh and $ 603,132.It can therefore concluded that the hybrid renewable energy system is more cost competitive, eco-friendly, low maintenance alternative power solution for rural electrification in the researched area.

Systems	PV	Wind	Battery			Converter	Capital Cost	Replacement Cost	Total NPC Cost	Annualized COE
			battery	Total batteries	Bus Voltage					
PV-Battery System	55 KW	NA	100 Ah	768	48	30 KW	$234,783	$141,041	$335,962	0.4 $ / KWh
Wind-Battery System	NA	90 KW	100 Ah	768	48	30 KW	$409,968	$218,512	$603,132	0.771 $ / KWh

PV-Wind-Battery System	51 KW	10 KW	100 Ah	640	48	30 KW	$230,743	$127,839	$326,657	0.381 $ / KWh

Table.II Comparison of the proposed Hybrid Renewable Energy Systems (HRES)

The combinations which are being analyzed are based on the available renewable energy resource of the area. Estimated cost of energy per kW h (LCOE) has been one of items that are roughly comparable. The cost analysis of the proposed hybrid system is provided in Table II, whereas the net present cost and annualized cost of the best possible HRES has been shown in fig 7 and Fig 8 respectively.

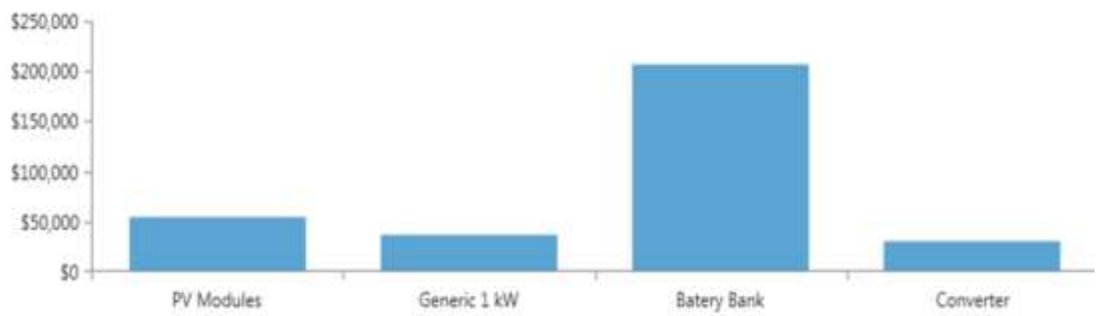

Fig. 7 Net present cost of PV/Wind/Battery HRES

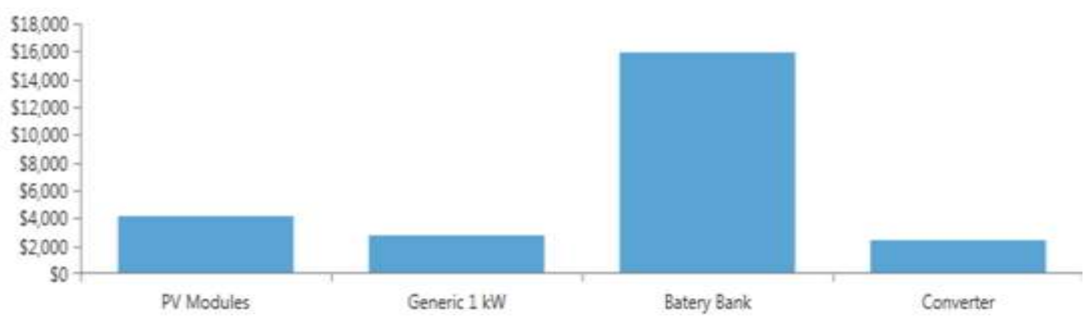

Fig. 8 Annualized cost of PV/Wind/Battery HRES

6. Conclusion

Analysing the energy crises of Pakistan and the depletion of global fossil fuel reserves, it is evident that there is an urgent need of increasing the ratio of renewable energy resources in the energy mix of Pakistan. To meet the anticipated energy demand, hybrid renewable energy systems are considered as the best possible solution for the researched area. This research paper confirms the utility and the cost effectiveness of the HRES as compared to the stand alone Solar PV systems and the wind energy systems. The simulations and results of the HOMER showed that the rural electrification using hybrid renewable energy system can act as a reliable solution for the community having no access to the electricity.

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