



Optimal Combination and Sizing for Standalone System for Remote Areas of Balochistan

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Abstract— Pakistan faces significant energy challenges, particularly in remote areas of Baluchistan, despite abundant renewable resources. This study evaluates the techno-economic viability of hybrid renewable systems for two locations in Baluchistan: Jiwani and Sibi. Using Homer Pro Software, we model and optimize various hybrid configurations combining solar, wind, and conventional energy sources for both on-grid and off-grid scenarios. The study aims to provide electricity to these sites at lower costs than current rates. Homer Pro simulates multiple load-satisfying solutions, employing two algorithms to compute the lowest feasible cost. The software analyzes system performance over time, providing outputs including Cost of Electricity (COE), Net Present Cost, Operating Cost, annual energy production and consumption, excess electricity, losses, and model lifetime. Results indicate that hybrid systems offer the most reliable and cost-effective solutions for remote areas without access to transmission lines. The most feasible solutions for each site are selected based on these outputs, demonstrating the potential of renewable hybrid systems to address Pakistan energy crisis in remote regions.

Keywords— Remote Areas, Baluchistan, Homer Pro, Techno-economic Feasibility, Optimization.

I. INTRODUCTION

Electricity is one of the biggest blessings in the world, transforming human life in many categories over the last few centuries, especially in the last century. As per report by International Energy Agency (IEA), twenty years ago 1.6 billion people were in no position to access electricity while in 2019 this was estimated to be 761 million people around the globe [1]. Countries in South Asia have shown an impressive reduction. For example, India has shown great reduction in these numbers from 475 million to 30 million in less than 20 years and in Bangladesh this number is reduced from 87.61 million to 12.72 million [1]. Contrary these numbers have increased from 40 million to 56 million in Pakistan, affecting remote areas significantly. Mostly remote areas' income is from agriculture and agriculture needs electricity for water extraction. Nearly 20% of the country's GDP is based on farming and agricultural farms, which are largely located in remote locations, Pakistan's Gross Domestic Product (GDP) has plummeted to 2% from 8% because of not delivering

enough energy to remote areas [2]. Also, Pakistan is showing great dependency on traditional resources like fossils and hydro in the energy sector. The growth in energy in April 2020 showed an increase of 7.5% of electricity compared to April 2019 from 33,452 MW to 35,972 MW [3] Fig. 1 shows the contribution of different shares to total electricity generation in 2019 and 2020. The hydroelectric has shown an increase of 5.1% from 28.5% to 30.9% and a decrease of 4.6% in thermal from 63% to 58.4%.

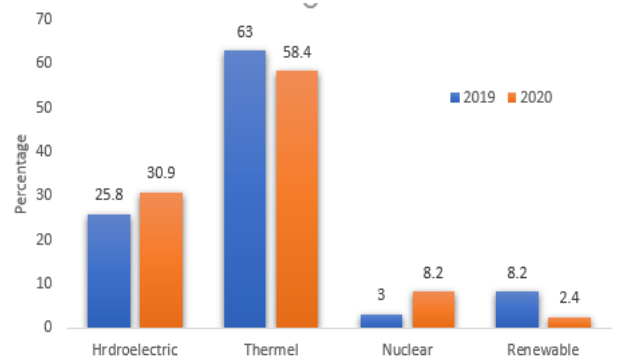


Fig 1 Share in Electricity Generation (%)

The indigenous thermal resource isn't enough to produce electricity on such a humongous scale. Importing fossil fuel on such a large scale is a huge burden on Pakistan's economy, economic stability, unemployment, high electrical tariff, inflation, and poverty. Variable and rising oil prices on the international market result in an increase in the budget deficit, inflation, and downward pressure on the exchange rate, making imports more expensive. Rising oil prices are a key source of anxiety for all developing countries, and Pakistan is no exception. Fuel prices are likely to rise higher until demand growth is slowed and other technologies such as solar and wind power, which are abundant in Pakistan, are deployed to lessen reliance on oil. Thermal energy has also many other adverse impacts on the environment like smog, drought, acid rain, recurring heatwaves, riverine and flash floods, sea storms, and landslides. Pakistan is presently planning to create 18 Gigawatts (GW) of power from non-conventional resources,

which will account for 5 to 6 percent of its total grid-connected generation. [4]. To accomplish this, the Pakistani government is supporting private division investment in renewable energy generation. According to the (see Wu et al., 2011), Pakistan has a vast amount of wind energy potential of around 346 GW for power generation, according to a report by the National Renewable Energy Laboratory (NREL) in the United States in 2012. Fig. 2 depicts a full wind map of Pakistan's wind pathways [5].

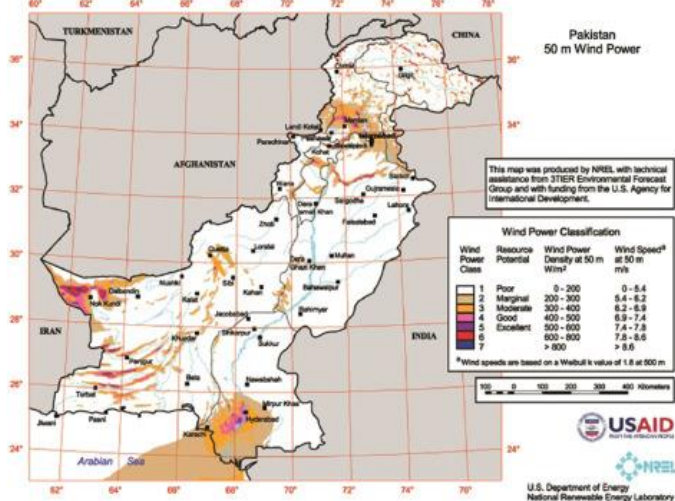


Figure 2 National renewable energy laboratory survey report map.

It can be seen Pakistan is very rich in case wind energy same as the case with solar energy throughout the year, most parts of Pakistan are exposed to direct sunshine. The lowest solar radiation intensity was 76.49 Wm⁻² in Cherat in December, while the maximum was 339.25 Wm⁻² in Gilgit. In the country, the average monthly solar radiation intensity ranges from 136.05 to 287.36 Wm⁻². The results show that solar radiation intensities of more than 200 Wm⁻² were detected in Sindh between Feb and Oct, in practically wholly regions of Baluchistan between Mar to Oct, in KPK, Northern Areas, and Kashmir from Apr to Sep, and in Punjab from Mar to Oct [6]. These resources are infinite, and the use of these resources can help to bring a better lifestyle, can help in a clean environment, and strengthen the country's economy, with the use of this we can save our natural combustible resources from fading and can provide low cost of electricity.

A. Problem Statement

They have never filled the supply and demand imbalance even with conventional resources. Supposedly the supply and demand imbalance is filled still the transmission lines can't transfer this power not to mention the transmission losses. Pakistan's population is growing at a growth of 2% per year. The increase in population will lead Pakistan to generate more electricity. The share of conventional electricity in Pakistan is more than half of total electricity. The use of conventional resources harms the economy and environment. Indigenous resources aren't sufficient to please the demand for energy of the rising economy. As a consequence, Pakistan must import a huge amount of fuel, as well as fuel-based goods from the Middle East and other countries to meet its energy needs.

Pakistan's economy is growing steadily for some reason as it couldn't show itself as a growing economy as other subcontinent nations. One of the main reasons is electricity as it's dragging the economy either by shortage in supply and demand or meeting the required demand through imported fuel. Load shedding or low voltage supply is currently used in Pakistan to bridge the gap between demand and supply of power. The industries in Pakistan can't produce their maximum capacity due to load shedding or low voltage supply. Because of the imported fuel the per unit price is dear which has a direct effect on inflation and unstable prices. Imported fuel is a burden on the economy. The other disadvantage of using fuel energy is on environment. Pakistan is one in those countries which is vilest caused by global warming.

To become independent of foreign oil price increases and to address the severe energy problem, we must transition from traditional energy sources to renewable energy sources. There is a huge potential for renewable resources in Pakistan. The important factor of renewable energy is that its site can be installed anywhere. The potential of two things is very important when site selection is solar irradiance and wind speed. As a result, to get the most out of the resources, they must be adequate at the threshold level. To this end, we shall describe in our paper how such a cost-effective hybrid system of renewable resources for remote places might be implemented is economical and feasible. For this system, we will use a standalone off-grid system as some advantages play key roles like cost, lifetime span of different apparatus, and the availability of components. To diminish the ensnarement and the multifaceted nature of the control, related upkeep and viable working, unbroken and supported control stream, exquisite spruce, control instrument and reasonable fetched play a critical part. To solve different problems of electrification in remote areas on a large scale it is necessary to use these renewable resources at their maximum in the province of Baluchistan knowledgeably and carefully.

B. Objectives

The purpose of this paper is to provide electricity on a small scale to different remote areas from renewable resources with the help of a stand-alone off-grid system as a long-term eradication of energy crises from the country and to provide neat and clean energy to make the environment clean. Off-grid systems are chosen to reduce the burden on transmission lines and to reduce losses. The transmission line still doesn't have the power to supply continuously 24/7. There are many locations available for this research due to the non-availability of electricity. While in this research, we have chosen two different locations Jiwani and Sibi. A techno-economic analysis is then done to extract the most feasible and economical solution using Homer Pro software. The main objective is to design a hybrid system of renewable resources for congested areas in the province of Baluchistan. Following are some of the main objectives of this research: (1) Conduct cost and sensitivity analyses for various hybrid systems at the proposed locations. (2) Determine the system's commercial viability by comparing the system's electricity cost to the government tariff. (3) Calculate the system's annual energy

production and consumption. (4) Check and analyze the viability and performance of renewable resources in various places, both jointly and independently. (5) To handle various restrictions and difficulties for practical implementation to improve the accuracy and precision of the system. (6) To investigate the many components of renewable energy generation.

II. LITERATURE REVIEW

The researchers have been using several different software and procedures to make a self-sustained hybrid system for electrifying of an area by integrating different renewable and non-renewable resources. Homer Pro is one such tool recently used by a lot of researchers for optimization and cost analysis. The software has been developed by the National Renewable Energy Laboratory USA (NREL). This software is capable of handling new renewable technologies of solar, wind, biogas, fuel cells, etc., and also non-renewable resources like diesel generators, and hydropower plants. Renewable systems are considered to be the best solution for remote area electrification but high initial capital cost due to expensive instruments poses difficulty in the slow growth of these renewable systems according to Ibtouen et. al [7]. Renewable resources are the best means to provide electricity to different communities and agricultural farms to make these independent from the central grid station and provide low-cost uninterrupted electricity according to Rohit and Subhes [8]. Previously a lot of different hybrid renewable systems were designed at different locations where the objective was to reduce the cost of operations. Ajitha k. et al. [9] performed a cost comparison analysis of two different systems where one was grid-based based the other was fuel cell based on a hospital located in a rural area of India using Homer Pro software. Another hybrid system comparison was made by Ankit Bhat et al. [10] who performed a feasibility analysis for a remote rural community in India and considered three different renewable resources.

The resources considered were photovoltaic, biomass, and hydro with a backup of conventional resources of diesel engines to generate electricity using Homer Pro. One another study by Kamilu et al. [11] concludes the result for Nigeria where he carried out a feasibility study of different composite renewable systems. Different resources like solar and wind were used for such purposes. These resources were used to supply to a transceiver that was mobile-based. For this purpose, a PV array of 10 Kilowatts was used. The diesel generator used for this purpose was 5.5 kilowatts. Trojan L16P, 64 unit's battery system was used for backup purposes. Using an economic study, it was found that the capital cost of the project was \$69,811 and that of the single unit of electricity will cost up to \$0.409. According to Ohunakin et al. [12] when the inspection of different arrangements of different hybrid systems of photovoltaic/Diesel Engine/Battery is done to obtain a superlative result it was found that the best solution was obtained for the sensitivity case of \$1.3/liter and \$1.1/liter of diesel.

Hosseinalizadeh et al. [13] performed optimization simulation in Iran for different renewable resources like solar, wind and fuel cells. It concluded with the results that wind and solar system with batteries as a backup was a most feasible

solution for the area. Fuel cell was not a feasible solution for the area. Al-falahi et al [14] conducted a detail comprehensive economic optimization analysis for different renewable resources like Solar, wind, batteries, hydro power, diesel generator and fuel cell. Moreover according to one another study conducted in 2019 by Assaf and Shabani [15], a continuous heat and power supply to a remote area load with the help of solar and fuel cell with high reliability can be obtained using Homer Pro. Shahzad et al. [16] conducted a techno-economic feasibility analysis of a hybrid system of solar and biogas for an agricultural farm and a small residential community in a remote district of Pakistan. The cost of energy and capital cost was obtained as a result which was quite feasible considering local market prices. According to Gautum [17] a load of 480.58 kWh/day can be satisfied using a hybrid system of solar and biomass. The results obtained as a result of this study were the most feasible. According to one another study by Ekren et al. [18] a hybrid system was made of Solar and wind for the electrification of electric vehicle charging stations. The sizing of the components was done using Homer Pro.

Another study was performed by Islam et al. [19] in 2021 to investigate a PV/Wind/micro-hydro for the electrification of the coastal community. The system made was an off-grid one. The most optimized solution cost of electricity was \$0.136/kWh as compared to the grid-connected one that cost \$0.12/Kwh. The system required batteries also. Another study performed in 2020 was by Elkadeem et al. in which an optimized solution with minimal environmental hazard was proposed for a newly constructed airport in new capital of Egypt. The system made was to provide the airport with daily electricity and water requirements. The cost of electricity to be calculated was around \$0.08/Kwh. The proposed hybrid system produced 58.5% less carbon dioxide than a conventional resource. The payback time for the proposed system was 1.2 years. Ramesh et al. [20] performed another feasibility analysis for remote areas of India. The system was able to load shifts based on Demand side management. Lithium-ion batteries were used with different renewable and nonrenewable resources alongside load management. The capital cost of the system and cost of electricity was \$467,644 and 0.106 \$/kWh respectively without demand side management and \$153,080 and 0.034 \$/kW respectively with demand side management.

In another study performed by Ahmed et al [21], a hybrid system was made up of solar, wind, battery, and converter for the remote area electrification of Baluchistan. The most feasible system capital cost was calculated as \$127,345. The cost of energy is calculated as \$0.137. Different hybrid systems were made for different sites. PV/Wind/MGT/Li-ion-based hybrid system was considered to be the most economical and feasible for the proposed site. For remote sites in India, Rajasthan a study was performed by Nijhawan [22], the study concluded that MHD, solar, wind and fuel cells combine to give an optimized solution.

III. METHODOLOGY

A. Sites

Two sites Sibi and Jiwani are chosen for this case study. The rural population in Jiwani is 31.6% and urban is 68.4%. (https://www.citypopulation.de/en/pakistan/distr/admin/gwadar/20604__jiwani/). while the urban population of Sibi is 64% and the rural population is 36%. The load has been assumed for 30 houses for Jiwani and 60 houses for Sibi. The average energy consumption by Jiwani is 448.5 kWh/day with a peak load of 77 kW in summer. The average energy consumption by Sibi is 1042 kWh/day with a peak load of 98 kW in summer.

B. Components Details

1) Batteries;

Storage is a constant component of the production of renewable energy. As a result, the system's storage is provided by batteries. When there is a shortage of generation capacity or during peak loads, it helps to manage and maintain a consistent voltage. excellent capacity, power, short depth of discharge, and excellent round-trip efficiency are all characteristics of a good battery.

2) Diesel Generator;

In two modes the diesel Generator has been used with the reduction of solar panels and wind turbines. Diesel generators will provide electricity in the absence of renewable resources during peak hours

C. Grid Connected

Electricity cannot be generated in exact alignment with demand; there will consistently be an excess of electricity. This surplus can be sold back to the electrical grid and procured during emergencies, maintenance, or peak load situations if feasible. The disparity between the purchased electrical energy and the electrical energy sold back to the grid constitutes the net electrical energy supplied by the grid.

D. Components and Parameters

The project life is estimated to be twenty-five years. Capital costs for flat plate solar PV, wind turbine batteries, and converters are shown in Table 1 along with operation and maintenance costs.

TABLE 1 Components and cost estimation.

Components name	Capital Cost (\$)	O & M Cost / Year (\$)
Solar PV Panel / kW	660	10
Wind Turbine / 10 kW	40000	200
Battery / 142 kWh	4400	20
Converter	40	8

E. Implementation using Homer Pro

A total of six different models were designed for two distinct locations, with three designs created for each location. Models one, two, and three correspond to the Jiwani location, while models four, five, and six correspond to Sibi. Model one

and model four exclusively utilize renewable resources. Model Two and Model five incorporate diesel generators. Model three and model six are identical to models one and two respectively, but with an additional grid connection. The components utilized in the various models are outlined in Table 2.

TABLE 2. Components utilized in each models.

Model	PV	Solar	Battery	Converter	Generator	Grid
Model one	✓	✓	✓	✓	×	×
Model two	✓	✓	✓	✓	✓	×
Model three	✓	✓	×	✓	×	✓
Model four	✓	✓	✓	✓	×	×
Model five	✓	✓	✓	✓	✓	×
Model six	✓	✓	×	✓	×	✓

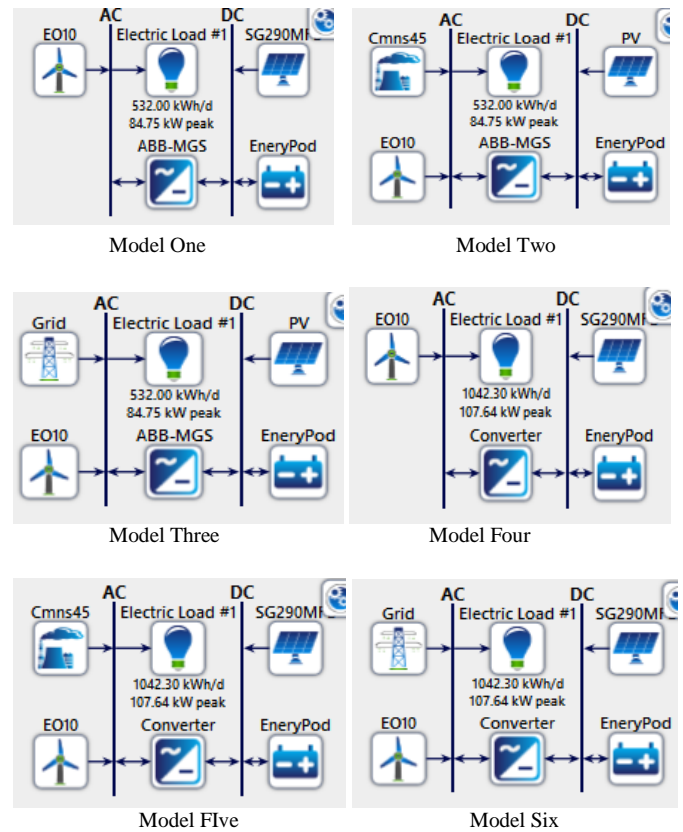


Fig.3 All the proposed Six models

IV. RESULTS AND DISCUSSION

Techno-economic feasibility analysis is performed by Homer Pro and results are established for each site. The results of different simulations are as follows:

A. Model One Simulation Results

In this model, we want to make a renewable model the combinations of both wind and solar energy. Through search space we provided PV panel of 85kW, 90kW, 95kW, 100kW, 105kW, 110kW, 115kW and 120kW and quantity of wind turbine 2,3,4,5,6 and one quantity is equal to 10kW. The Homer Pro. Simulated 9775 solutions in which 4777 were feasible and 4998 were not feasible due to shortage constraints. In these 4998 1819 were omitted due to lacking of converter and the other 4777 were omitted.

Architecture							Cost			
PV (kW)	EO10	EnergyPod	ABB-MGS (kW)	Dispatch	NPC (\$)	COE (\$)	Operating cost (\$/yr)	Initial capital (\$)		
90.0	4	7	76.0	LF	\$251,489	\$0.100	\$2,001	\$225,340		
90.0	4	7	76.0	CC	\$251,420	\$0.100	\$2,001	\$225,340		
90.0	4	7	76.0	LF	\$251,839	\$0.100	\$2,001	\$225,340		
90.0	4	7	76.0	CC	\$251,211	\$0.100	\$2,013	\$225,340		
90.0	4	7	77.3	LF	\$251,420	\$0.100	\$2,013	\$225,393		
90.0	4	7	77.3	CC	\$251,420	\$0.100	\$2,013	\$225,393		
90.0	4	7	77.3	LF	\$251,420	\$0.100	\$2,013	\$225,393		
90.0	4	7	77.3	CC	\$251,420	\$0.100	\$2,013	\$225,393		
90.0	4	7	80.0	LF	\$251,839	\$0.100	\$2,037	\$225,500		
90.0	4	7	80.0	CC	\$251,839	\$0.100	\$2,037	\$225,500		
95.0	4	7	68.0	CC	\$252,349	\$0.101	\$1,979	\$226,770		
95.0	4	7	68.0	LF	\$252,349	\$0.101	\$1,979	\$226,770		
95.0	4	7	68.0	CC	\$252,349	\$0.101	\$1,979	\$226,770		
95.0	4	7	68.0	LF	\$252,349	\$0.101	\$1,979	\$226,770		

Fig. 4 Homer Pro Optimization of Model 1.

The most feasible solution of the model is the one that is at the top of the Table. The results are arranged in ascending order based on feasibility. The total net present cost of the most feasible solution is \$ 251,420 and the cost of energy of the system is \$0.10. The operating cost of the feasible solution is \$2013.

B. Model Two Simulation Results

This model is the same as the previous one except for one change. Here we have added a diesel generator which will help the model to meet load peak hours. This model is not made entirely of renewable energies so there will be emissions. After the modeling, the model is optimized using Homer Pro. 17,276 results were simulated of which 12,107 were feasible. 5,169 were infeasible due to shortage capacity of constraints in which 2,652 were omitted and 2,148 for lacking converter. The few most feasible solutions out of 12,107 are shown in Table 3.

Architecture							Cost			
PV (kW)	EO10	EnergyPod	ABB-MGS (kW)	Dispatch	NPC (\$)	COE (\$)	Operating cost (\$/yr)	Initial capital (\$)		
75.0	4	45.0	5	70.7	LF	\$241,259	\$0.0961	\$2,079	\$214,377	
75.0	4	45.0	5	70.7	LF	\$241,259	\$0.0961	\$2,079	\$214,377	
75.0	4	45.0	5	70.7	LF	\$241,468	\$0.0961	\$2,079	\$214,377	
75.0	4	45.0	5	69.3	LF	\$241,525	\$0.0961	\$2,088	\$214,323	
75.0	4	45.0	5	69.3	LF	\$241,317	\$0.0962	\$2,088	\$214,323	
75.0	4	45.0	5	70.0	LF	\$241,333	\$0.0962	\$2,092	\$214,350	
75.0	4	45.0	5	68.0	LF	\$241,376	\$0.0962	\$2,112	\$214,270	
75.0	4	45.0	5	72.0	LF	\$241,468	\$0.0962	\$2,092	\$214,430	
75.0	4	45.0	5	72.0	LF	\$241,468	\$0.0962	\$2,092	\$214,430	
75.0	4	45.0	5	66.7	LF	\$241,525	\$0.0962	\$2,112	\$214,217	
75.0	4	45.0	4	69.3	LF	\$241,531	\$0.0962	\$2,445	\$209,923	
75.0	4	45.0	4	69.3	LF	\$241,531	\$0.0962	\$2,445	\$209,923	
75.0	4	45.0	4	70.7	LF	\$241,562	\$0.0962	\$2,443	\$209,977	

Fig. 5 Homer Pro Optimization of Model 2.

The total net present cost of the most feasible solution is \$241,376 and the cost of energy of the system is \$0.96. The operating cost of the feasible solution is \$2097.

C. Model Three Simulation Results

This model has been connected to main grid. This model is just to see how it affects the prices of the cost of electricity (COE) as it connects with the grid. Through search space, we provided a PV panel of 90 kW and 4 wind turbines each turbine is equal to 10 kW. The Homer Pro. Simulated 190 solutions in which 190 were feasible and zero were not feasible. Of these 26 were omitted due to lacking of a converter. The feasible solutions are shown below in Table 3.

Architecture							Cost			
PV (kW)	EO10	EnergyPod	Grid (kW)	ABB-MGS (kW)	Dispatch	NPC (\$)	COE (\$)	Operating cost (\$/yr)	Initial capital (\$)	
90.0	4		999,999	68.0	CC	\$136,196	\$0.0259	-\$4,488	\$194,220	
90.0	4		999,999	68.0	CC	\$136,196	\$0.0259	-\$4,488	\$194,220	
90.0	4		999,999	68.0	CC	\$136,196	\$0.0259	-\$4,488	\$194,220	
90.0	4		999,999	68.0	CC	\$136,196	\$0.0259	-\$4,488	\$194,220	
90.0	4		999,999	68.0	CC	\$136,196	\$0.0259	-\$4,488	\$194,220	
90.0	4		999,999	68.0	CC	\$136,196	\$0.0259	-\$4,488	\$194,220	
90.0	4		999,999	68.0	LF	\$136,196	\$0.0259	-\$4,488	\$194,220	
90.0	4		999,999	68.0	LF	\$136,196	\$0.0259	-\$4,488	\$194,220	
90.0	4		999,999	68.0	LF	\$136,196	\$0.0259	-\$4,488	\$194,220	
90.0	4		999,999	68.0	CC	\$136,196	\$0.0259	-\$4,488	\$194,220	
90.0	4		999,999	68.0	CC	\$136,196	\$0.0259	-\$4,488	\$194,220	
90.0	4		999,999	68.0	CC	\$136,196	\$0.0259	-\$4,488	\$194,220	
90.0	4		999,999	68.0	CC	\$136,196	\$0.0259	-\$4,488	\$194,220	

Fig. 6 Homer Pro Optimization of Model 3.

The total net present cost of the most feasible solution is \$136,196 and the cost of energy of the system is \$0.026. The Initial cost of the feasible solution is \$194,220.

D. Model Four Simulation Results

Through search space, we provided PV panels of 150 kW,155 kW, 160 kW,165 kW, and 170 kW and several wind turbines 8,9,10,11, and each of them equal to 10 kW. The Homer Pro. Simulated 4,924 solutions of which 1,932 were feasible and 2,992 were not feasible due to shortage constraints. In these infeasible, 808 were omitted due to lack of converter, and the other 988 were omitted. The feasible solutions are shown in Table 4. The results are arranged in the ascending orders of cost of electricity (COE).

Architecture							Cost			
SG290MFB (kW)	EO10	EnergyPod	Converter (kW)	Dispatch	NPC (\$)	COE (\$)	Operating cost (\$/yr)	Initial capital (\$)		
190	4	25	93.9	LF	\$397,431	\$0.0808	\$2,533	\$364,681		
190	4	25	93.9	CC	\$397,431	\$0.0808	\$2,533	\$364,681		
190	4	25	94.2	LF	\$397,526	\$0.0809	\$2,535	\$364,749		
190	4	25	94.2	CC	\$397,522	\$0.0809	\$2,535	\$364,749		
190	4	25	94.4	LF	\$397,626	\$0.0809	\$2,547	\$364,826		
190	4	25	94.4	CC	\$397,626	\$0.0809	\$2,542	\$364,826		
190	4	25	94.7	LF	\$397,756	\$0.0809	\$2,540	\$364,923		
190	4	25	94.7	CC	\$397,756	\$0.0809	\$2,540	\$364,923		
190	4	25	95.0	LF	\$397,847	\$0.0809	\$2,542	\$364,826		
190	4	25	95.0	CC	\$397,847	\$0.0809	\$2,542	\$364,991		
190	4	25	95.6	LF	\$398,100	\$0.0810	\$2,547	\$365,178		
190	4	25	95.6	CC	\$398,100	\$0.0810	\$2,547	\$365,178		
190	4	25	95.9	LF	\$398,203	\$0.0810	\$2,549	\$365,255		
190	4	25	95.9	CC	\$398,203	\$0.0810	\$2,549	\$365,255		

Fig. 7 Homer Pro Optimization of Model 4.

The total net present cost of the most feasible solution is \$397,431 and the cost of energy of the system is \$0.81. The operating cost of the feasible solution is \$2533.

E. Model Five Simulation Results

This model is not made entirely of renewable energies so there will be emissions. After the modeling, the model is optimized using Homer Pro. 5,920 results were simulated in which 3,726

were feasible. 2,194 were infeasible due to shortage capacity of constraints in which 1,000 were omitted and 800 for lacking converter. The few most feasible solutions out of 3,726 are shown in Table 4.

Architecture							Cost		
SG290MFB (kW)	EO10	Cmms45 (kW)	EnergyPod	Converter (kW)	Dispatch	NPC (\$)	COE (\$)	Operating cost (\$/yr)	
170	7	45.0	10	86.1	LF	\$439,619	\$0.0894	\$2,089	
170	7	45.0	10	86.1	LF	\$439,619	\$0.0894	\$2,089	
170	7	45.0	10	86.1	LF	\$439,619	\$0.0894	\$2,089	
170	7	45.0	10	84.4	LF	\$439,841	\$0.0894	\$1,835	
180	7	45.0	10	86.1	LF	\$439,841	\$0.0894	\$1,835	
180	7	45.0	10	86.1	LF	\$439,840	\$0.0894	\$2,138	
170	7	45.0	10	84.4	LF	\$439,841	\$0.0894	\$1,835	
170	7	45.0	10	84.4	LF	\$439,841	\$0.0894	\$2,145	
170	7	45.0	10	86.7	LF	\$439,861	\$0.0895	\$2,093	
170	7	45.0	10	86.9	LF	\$439,959	\$0.0895	\$2,095	
180	7	45.0	10	84.4	LF	\$439,969	\$0.0895	\$1,884	
180	7	45.0	10	84.4	LF	\$439,969	\$0.0895	\$1,884	
170	7	45.0	10	87.7	LF	\$439,984	\$0.0895	\$2,078	

Fig. 8 Homer Pro Optimization of Model 5.

The total net present cost of the most feasible solution is \$439,691 and the cost of energy of the system is \$0.89. The operating cost of the feasible solution is \$2033.

F. Model Six Simulation Results

The model has been connected to the main grid and the batteries have been removed. This model is just to see how it affects the prices of the cost of electricity (COE) as it connects with the grid. Through search space, we provided a PV panel of 160 kW and 10 wind turbines each turbine is equal to 10 kW. The Homer Pro. Simulated 236 solutions in which 236 were feasible and zero were not feasible. 36 were omitted due to lacking a converter. The feasible solutions are shown in Table 4. The results are arranged in the ascending orders of cost of electricity (COE).

Architecture							Cost		
SG290MFB (kW)	EO10	EnergyPod	Grid (kW)	Converter (kW)	Dispatch	NPC (\$)	COE (\$)	Operating cost (\$/yr)	Initial capital (\$)
160	9	999.999	108	CC		\$332,152	\$0.0330	-\$8,992	\$448,400
160	9	999.999	108	CC		\$332,152	\$0.0330	-\$8,992	\$448,400
160	9	999.999	108	LF		\$332,152	\$0.0330	-\$8,992	\$448,400
160	9	999.999	108	LF		\$332,154	\$0.0330	-\$8,992	\$448,400
160	9	999.999	108	LF		\$332,154	\$0.0329	-\$8,992	\$448,400
160	9	999.999	108	CC		\$332,152	\$0.0329	-\$8,992	\$448,400
160	9	999.999	109	LF		\$332,154	\$0.0329	-\$8,992	\$448,653
160	9	999.999	109	LF		\$332,154	\$0.0329	-\$9,012	\$448,653
160	9	999.999	109	CC		\$332,154	\$0.0329	-\$9,012	\$448,653
160	9	999.999	109	CC		\$332,154	\$0.0329	-\$9,012	\$448,653
160	9	999.999	107	LF		\$332,160	\$0.0330	-\$8,972	\$448,147
160	9	999.999	107	CC		\$332,160	\$0.0330	-\$8,972	\$448,147
160	9	999.999	110	CC		\$332,168	\$0.0329	-\$9,030	\$448,906
160	9	999.999	110	CC		\$332,168	\$0.0329	-\$9,030	\$448,906

Fig. 9 Homer Pro Optimization of Model 6.

The total net present cost of the most feasible solution is \$332,152 and the cost of energy of the system is -\$0.033. The initial cost of the feasible solution is \$448,400.

V. CONCLUSION AND DISCUSSION

Deciding and selecting cost-effective energy generation models to power off-grid settlements in remote places is a complex procedure with a variety of positive and negative aspects. Different hybrid models based on renewable energy are being developed. The impact of altering load requirements and production from various resources such as wind, solar, and fuel generators is examined. The main goal is to find an energy generation system with the lowest COE. Model three and model six are connected to the main grid station with no excess of electricity, making it most economical for site-1 and site-2, respectively. The excess of electricity is being sold to the government or any other organization. Model two and model five are connected to a fuel generator, which will turn on only when the demand exceeds a certain limit. Model one and model four are purely fed up by renewable resources that as wind and solar which makes it the most expensive. If we look at the trend of different models for both sites, we can see that the most economical is grid-connected then hybrid and the last is renewable.

TABLE 3 Comparison of Model 1, 2 and 3.

Results	Model one	Model two	Model three
Cost of Energy (COE)	\$ 0.0441	\$ 0.04045	-\$ 0.000817
Net present Cost (NPC)	\$ 110,711	\$ 101,509	-\$ 4,304
Operating cost	\$ 2,001	\$ 2079	-\$ 4,488
Annual Electricity Production	372,044 kWh/year	384,400 kWh/year	416,084 kWh/year
Annual electricity consumption	194,100 kWh/year	194,180 kWh/year	194,180 kWh/year
Fuel Consumed	---	445	---
Emission (COx+SO2 +NOx)	---	868.98 Kg/Year	27,954 Kg/Year
Excess of electricity	151,720 kWh/year	127,689 kWh/year	213,283 kWh/year
Wind contribution	225,656 kWh/year	225,659 kWh/year	225,659 kWh/year
PV contribution	146,385 kWh/year	121,988 kWh/year	146,385 kWh/year
Batteries quantity	7	5	---
Diesel contribution	---	754 kWh/year	---
Converter (Converter-Inverter)	76kW-45kW	70.7kW-42.7kW	68kW-40.8kW
Renewable fraction	100%	99.6 %	89.2%
Losses	26,244	26,531	7,251 kWh/year

	kWh/year	kWh/year	
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However, the main theme of this research is to provide electricity where people do not have access to electricity. The grid-connected model was just to see the impact of the cost of electricity. It can be seen that hybrid is the best solution for people of Baluchistan with no access to electricity.

The comparison of Model one, Model two and Model three at Jiwani, and Model four, Model five and Model six at Sibi are given in Table 3 and Table 4 respectively.

Table 4 Comparison of Model 4, 5 and 6.

Results	Model four	Model five	Model six
Cost of Energy (COE)	\$ 0.0484	\$ 0.0410	-\$0.0000338
Net present Cost (NPC)	\$ 237,790	\$ 210,619	-\$359.33
Operating cost	\$ 8,864	\$ 9,089	-\$11,507
Annual Electricity Production	742,527 kWh/year	625,381 kWh/year	854,102 kWh/year
Annual electricity consumption	380,428 kWh/year	380,381 kWh/year	380,428 kWh/year
Fuel Consumed	---	445 m ³	---
Emission (CO _x +SO ₂ +NO _x)	---	3,878.1 Kg/Year	65,246 Kg/Year
Excess of electricity	301,555 kWh/year	180,430 kWh/year	9,268 kWh/year
Wind contribution	462,046 kWh/year	323,432 kWh/year	462,046 kWh/year
PV contribution	280,481 kWh/year	298,011 kWh/year	280,481 kWh/year
Batteries quantity	16	10	---
Diesel contribution	---	3,937 kWh/year	---
Converter (Converter-Inverter)	91kW—91kW	86.1kW-86.1kW	108kW-108kW
Renewable fraction	100%	99.0 %	87.5%
Losses	60,544 kWh/year	64,570 kWh/year	13,432 kWh/year

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