International Journal of Engineering Works
https://www.ijew.io/
ISSN-p: 2521-2419
ISSN-e: 2409-2770
Vol. 11, Issue 06, PP. 111-123, June 2024
https://doi.org/10.34259/ijew.24.1106111123

Techno-Economic Evaluation of Hybrid Off-Grid Renewable Energy System

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Received: 18 May, Revised: 11 June, Accepted: 20 June

***Abstract*—**With the increase in globalization and population there is an increase in the supply and demand gap in the electricity sector. This gap is increasing day by day and expected to be considerably more in the foreseeable future. The conventional sources used for generation of electricity are depleting and hazardous to environment. Third world countries such as Pakistan are facing a huge problem to lessen the demand and supply gap. There is need to find an alternative that can provide remedy for this alarming situation. Solar renewable energy and biogas are the two sources that are available in abundance in this part of the world which can be used for good effects. Solar renewable energy is relatively new and is adequate to provide electrical energy to the entire world. Pakistan is one of the luckiest countries in the world where sun has the highest numbers of radiations hence lots of solar energy potential. Major components of solar PV system comprise of solar panels, inverters, charge controller, cables and batteries. It is very easy to install and can be upgraded based on the change in the load demand. Bio gas has also lots of potential in this part of the world. This research is focused on the making a system that is economically and environmentally feasible to tackle the load shedding problems in the province of Khyber Pakhtunkhwa. Peshawar is selected for this research study and Homer is software used for simulation. Results generated from Homer shows that there is a considerable advantage of using a mix of solar renewable energy system, batteries, bio gas plant along with generator to turn the gas produced into electrical energy. There is also a section on the environmental benefits of renewable energy system and according to simulations obtained from Homer the mixture of solar energy and bio gas is much more environmental friendly than the conventional sources.

***Keywords*—** Renewable energy, Pakistan energy crisis, Solar energy, Biogas, Solar PV system, Load shedding, Homer software, Economic feasibility, Renewable energy systems, Energy storage, Batteries, Generator.

I. INTRODUCTION

Due to modernization there is a rapid increase in the advancement of technology. Many machines which were operated by man, machine integration is turned into man, machine and power integration. Electrical power is absolutely essential for almost all the machineries to operate [1]. Electricity is not only essential to operate the heavy machinery but also utmost necessary to operate household's appliances. The demand for electricity is increasing day by day and it is expected to increase a lot more in the foreseeable future [2]. The progress of a country or region depends on the supply of electricity and abundance supply of electricity ensures that there are adequate opportunities for the dwellers to have a prosperous life.

It is established that electricity is very vital for a comfortable life and developed countries have abundance electrical energy. Third world countries are struggling to meet the electricity demands, hence unable to provide comfortable lifestyle to the residents. Governments do not have the necessary resources to meet the demand supply gap which requires lots of investment in the third world countries [3]. A conventional method of electricity i.e. from hydro and coal are very expensive and requires facilities that cost millions of dollars and are not very much environmental friendly [4]. These are the two main reasons scientists were looking to find the alternatives.

Solar energy is available in abundance in most part of the worlds and can be converted in electrical energy. The conventional sources are finite and are depleting rapidly due to the increase in the demand, on the other hand solar energy is infinite and it cannot be depleted [5]. Solar energy has gain great popularity in recent times as it is much cheaper and environmental friendly [6]. There was utmost need to find an alternative and solar energy seems to be a great replacement for the conventional sources. This study is focused on the electrical needs and supply and demand gap of Pakistan.

Pakistan is a third world country and struggling to meet up to a large extent to meet the supply and demand gap. Not only government is struggling to decrease the demand and supply gap but it is increasing rapidly [7]. This increase in gap has a huge impact on the economy of Pakistan. In remote areas there are roughly 10 to 12 hours of load shedding on daily basis which has adverse effect on domestic and commercial lives [8]. Solar renewable energy has proven it worth of being very useful to lessen the supply and demand gap over a period of time. Solar PV is useful during day time as sun emits radiations which can be turned into electrical energy so most of the load can be shifted to solar renewable energy during day time [9]. There are many advantages of solar renewable energy system such as low maintenance. Solar renewable energy requires very low maintenance and can be operate ion its own for considerable amount of time. On the other hand conventional sources requires lots of maintenance and have high operating cost while solar renewable energy system have almost none operating cost [10]. Another advantage of solar renewable energy system is that if the demand is increased it is fairly very easy to install extra machinery to meet the demand.

Pakistan is blessed with abundance of solar energy and is more than sufficient to meet all the demand. Pakistan is located in a region which receives the highest number of rays from the sun throughout the year. Pakistan has recent trends of installing solar renewable energy system to meet the domestic demands. According to a research Pakistan has the highest potential for solar energy in the whole world [11].

Many developed countries have installed solar PV systems in their electrification plan. Solar renewable energy has a considerable portion in their energy mix [12]. Solar renewable energy manufacturing organizations produces solar renewable energy system has increased the manufacturing capacity as the demand for the solar PV is increasing day by day. Not only there is a considerable increase in the production capacity but lots of work is done on the advancement of technology and keeping the cost down so it is affordable by the masses.

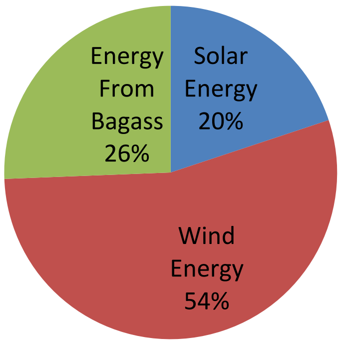


Figure 1 Electricity Generation from Renewable Energy in Pakistan

This study is also focused on the electrical energy generation from biogas resources. Pakistan is one of the greenest country in the region and mostly dependent on agriculture. This research study is based in the province of Khyber Pakhunkhwa. As it is previously mentioned it is one of the greenest regions and there are numerous forests located in this province. Due to the lack of supply of fossil fuels for cooking and other domestic purposes deforestation has taken place. People cut out trees and use them as a fuel for cooking and heating purposes. Most of the rural population does not have easy access to government pipe lines for gas etc [13]. To prevent this problem bio gas can be very useful as it will results in decrease in the deforestation and is considered a green source of energy. Bio gas is very much environmental friendly and sustainable as compared to the conventional sources [14]. Bio gas can also be converted into electrical energy so it can be mixed with solar energy to tackle the demand and supply gap. Both are available in abundance in the province of KP.

With the increase in technology and population there is a significant gap between the demand and supply of electricity. This gap is increasing day by day especially in the third world countries such as Pakistan and have adverse effect on the economy. Conventional source used for generation of electricity are depleting rapidly and are not environmental friendly. There is utmost need to find alternatives that are efficient and can lessen the supply and demand gap and also it is very important that they are environmental friendly.

Pakistan is struggling up to a larger extent to meet the supply and demand gap and this gap is increasing rapidly. Government does not have the required funds to build facilities and resources to tackle this problem. This research study aims to explore different alternatives that are cheaper, provide rapid solution to the existing problems and are environmental friendly.

This research study aims to assess the financial feasibility of a hybrid power plant, evaluating its potential for cost-effectiveness and sustainability. Additionally, it seeks to quantify the reduction in carbon dioxide emissions that would result from the implementation of such a plant, thereby contributing to environmental benefits. By analyzing both the economic viability and environmental impact, this study aims to provide valuable insights into the feasibility and potential benefits of integrating hybrid power technologies.

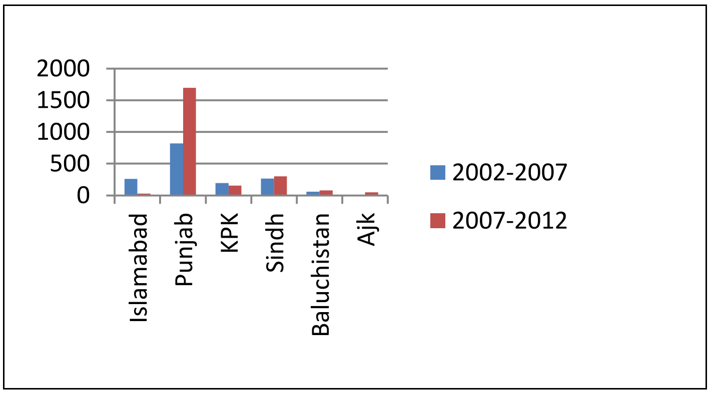


Figure 2 Biogas Plants in Pakistan

II. METHODOLOGY

A. Selected Area for the feasibility study

The area selected for the techno-economic study is located in Peshawar. The concept is to run a plaza on renewable energy as there is a shortage of power in specified area. Plaza consists of a total number of 22 stores. The shops in plaza ranges from general stores to barbers to tailors. There is availability of grid power source in desired location but the problem being shortage of electricity and second reason is commercial unit is very expensive and going in upward direction in a rapid pace. As this is a closed confined location therefore distribution of power will not be a major headache. That is why finances regarding distribution costs are ignored.

B. HOMER

HOMER stands for Hybrid Optimization Model for Electric Renewables. Homer runs on programming prepared by National Renewable Energy Laboratory (NREL). HOMER is used for optimization and simulation of different scenarios for a given set of data and pathways and it choose the best one in terms of production and finances [32]. HOMER can make hybrid models ranging from conventional to modern renewable techniques like Solar PV, Wind, and Biomass to identify the most economic cost model to meet the demand power needed. Below are some of the key factors why HOMER software was used in this study.

1) To run simulation for each hour of the project tenure. This project is set for tenure of 25 years. This is a long period. HOMER has the capability to run simulation for maximum time period keeping in mind all the seasonal changes. As solar radiation varies upon arrival of different seasons.
2) Calculation of results for all input data of different resources and gives the best optimum results.
3) Find economical results for all the input like pay back, IRR, NPC, total investment required, fuel, maintenance and operation

C. DATA and Modeling Approach

The location for the desired project was visited and different aspects were observed. Initial plan was to introduce Solar PV and Wind hybrid stand-alone system but wind power was not sufficient to carry on the project. This is the reason initial plan was shifted to Solar PV and Biomass. Data was gathered which include availability of biogas, space required for installation of Solar Panels, total load demand, peak load demand etc.

Technical data is also summed which include devices or parts which were to be installed to initiate the project. Some of the parts are Solar Panels, Batteries, Converter to convert DC power into AC, Generator, Fuel and technical capability required to complete the project.

D. Data Survey and analysis of load demand

Load demand was 190 KW which was a rare jump. It occurs minutely while next peak was at 173 KW. 190 KW load was normalized and peak load was set at 173 KW. Average load demand per hour is 50.52 KWh. Average KWh per day is 1212.6.

Metric	Baseline	Scaled
Average (kWh/d)	1,212.6	1,212.6
Average (kW)	50.53	50.53
Peak (kW)	172.86	172.86
Load Factor	.29	.29

Load Type: AC DC

Figure 3 Load Demand

This data is set for a period of 25 years that is why it is necessary to provide some slack in load and demand supply because there is a chance more load will be added in foreseeable future. HOMER reads data from note pad. The hourly data of whole year is taken which is then replicated 25 times for the project life time.

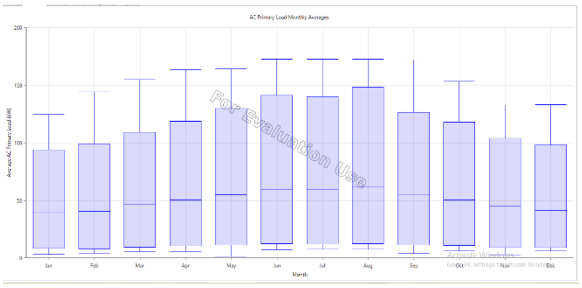


Figure 4 Load Demand for whole Year

The above figure shows AC primary load monthly averages. As it can be seen from figure August is the peak month for the load. While December has the minimum load demand. The reason being it is winter in December and there are no fans and air conditioner in winter which decrease the load demand considerably.

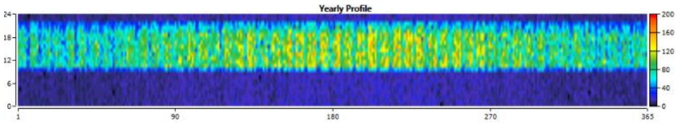


Figure 5 Load Demand Yearly Profile

The above figure shows yearly profile of load demand. Each color represents a load value. This figure is for whole years. Dark blue stands for lower limit of load and as we go in upward direction the load intensifies. Red stands for the maximum load.

E. Analysis of technological and financial resources

The following section describes the technological resources needed for this project along with cost associated with it.

1) Solar PV

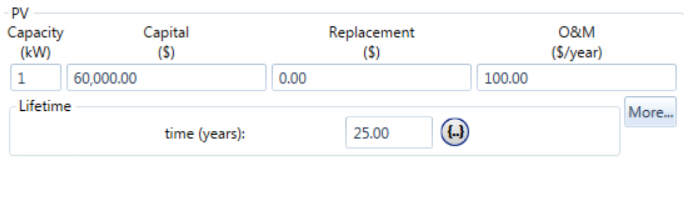


Figure 6 Solar PV Input

Cost of Solar PV is calculated per KW. Licensed Solar Panels that are easily available in this market cost usually around 60,000 rupees per kilowatt. The upper limit is set at maximum so HOMER knows there is no shortage of this resource. This will let HOMER decide for its own what should be the upper limit.

The life of Solar Panel can easily exceed past the project life time which is twenty five years so there is no replacement cost. Derating Factor is at eighty percent. Solar Panel once installed does not require much maintenance. The only maintenance they require is cleaning.

The operation and maintenance cost is set at 100 rupees per year. These are usually paid to the worker for the mere purpose of labor cost.

2) Storage System

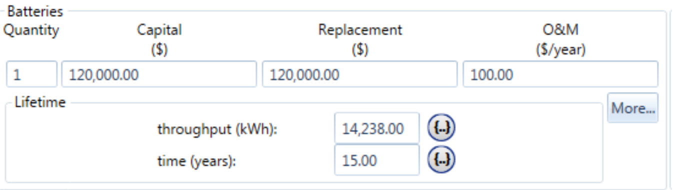


Figure 7 Storage Syetem Input

This project is supported by storage system i.e. batteries. The concept is Solar Panel will provide power during day time and will store some power for night time. One battery is estimated at a cost of 120,000. Battery has a life time of 15 years. This means battery will be replace and the replacement cost is kept the same at 120,000.

Figure 8 Battery State of Charge Settings

The battery state of charge determines when the battery will start and turn off. Battery will start powering the project when initial state of charge is at 100 percent but there is a constraint set on it till the limit it can power. The lower limit is set at 20 percent. The battery will shut down at 20 percent automatically.

3) Converter

The Solar PV power output is in DC so to turn that into alternating current to provide power to the end user this current should be converted. Converter is used for this purpose. We have let the HOMER decide the size of the converter.

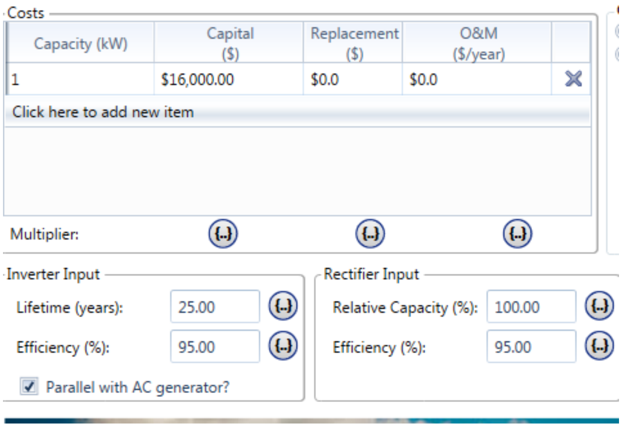


Figure 9 Converter Input

Per kilowatt rate of converter is 16,000 rupees. Life time of converter is 25 years which is in alignment with project life time. Efficiency of converter is set at 95 percent which is normal for today's converters.

4) Generator

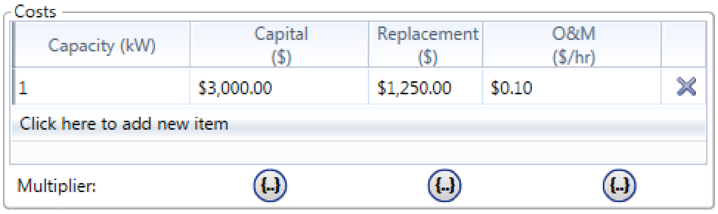


Figure 10 Generator Input

The HOMER has an option for generator i.e. size your own. For this project that option was selected which let HOMER size his own generator based on load and demand. It was given option from 10 KW to 200 KW with range of 10 KW each. Cost of 1 KW generator is 3000 rupees.

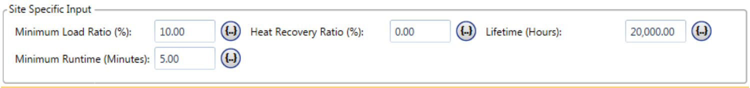


Figure 11 Generator Settings

The above figure shows some key aspects settings of the generator. The generator will start when the load exceeds our current capacity by 10 percent. The generator will start for minimum of 5 minutes and its lifetime is twenty thousand hours.

5) Fuel

The generator works on fuel generated from biogas. Different elements have the property to emit biogas.

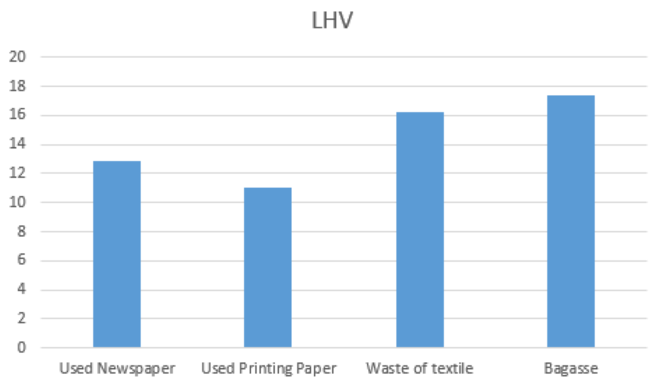


Figure 12 Heating Value of different available resources

The above figure shows some common elements which are easily available in our society along with their lower heating values.

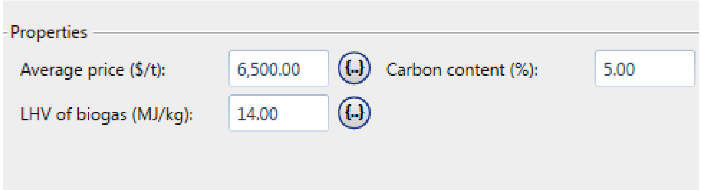
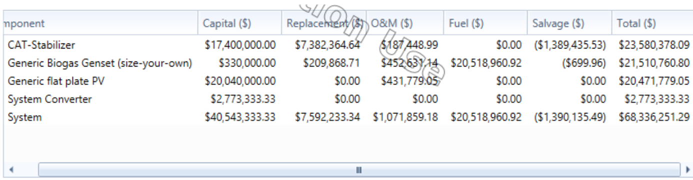


Figure 13 Biogas Inputs

As it can be seen in figure Lower Heating Value is taken at 14.00 MJ/Kg. Bagasse is easily available here and also in abundance to meet the needs of the project.

LHV value is taken 14 because fuel can also be extracted from those other three substances mentioned in graph based on availability of bagasse. From local market inquiry it has come to understanding that price of Bagasse is 6500 rupees per ton.

F. *Net Present Cost*



nponent	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
CAT-Stabilizer	$17,400,000.00	$7,382,364.64	$187,448.99	$0.00	($1,389,435.53)	$23,580,378.09
Generic Biogas Genset (size-your-own)	$330,000.00	$209,868.71	$452,631.14	$20,518,960.92	($699.96)	$21,510,760.80
Generic flat plate PV	$20,040,000.00	$0.00	$431,779.05	$0.00	$0.00	$20,471,779.05
System Converter	$2,773,333.33	$0.00	$0.00	$0.00	$0.00	$2,773,333.33
System	$40,543,333.33	$7,592,233.34	$1,071,859.18	$20,518,960.92	($1,390,135.49)	$68,336,251.29

Figure 14 NPV of the Project

The above figure shows the net present cost for this project. Every component capital cost is given in table along with replacement cost, operation and maintenance cost and salvage value. Salvage value is the remainder amount in terms of money of every component at the end of the project. This is the money which goes into investors pocket so it a plus. The net present cost of this project is 68,336,251 rupees. The major calculation in results section is done at net present cost of 68300000.

III. RESULTS AND DISCUSSION

A. *Optimization and Modeling*

As discussed in chapter 3 all the inputs data were provided to the HOMER software which then generates lots of simulations for the given data and gives the best optimized results. In this chapter results generated from HOMER will be discussed. There is some limitation to HOMER software so some calculations are done in Excel sheet.

B. *Hybrid Energy System Configuration*

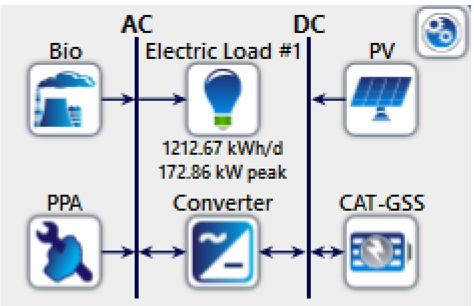
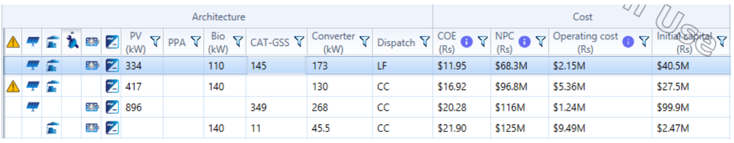


Figure 15 Schematic diagram of the Hybrid System

The schematic diagrammed shows the overall structure of the project. This run various different simulations for each hybrid and individual results and choose the best one based on generating capacity, financial costs, solar radiations in a given set of data.

C. *Results obtained in simulations*



Architecture						Cost			
PV (kW)	PPA	Bio (kW)	CAT-GSS	Converter (kW)	Dispatch	COE (Rs)	NPC (Rs)	Operating cost (Rs)	Initial capital (Rs)
334		110	145	173	LF	$11.95	$68.3M	$2.15M	$40.5M
417		140		130	CC	$16.92	$96.8M	$5.36M	$27.5M
896			349	268	CC	$20.28	$116M	$1.24M	$99.9M
		140	11	45.5	CC	$21.90	$125M	$9.49M	$2.47M

Figure 16 Simulations of the Hybrid Modal

The above figure shows various simulations to meet the project load demand. There are four cases in these figures. Below each case is discuss one by one.

1) *Case 1*

The first case discussed has Solar PV, biogas, batteries and converter. Net present cost is 68.3 million. Following are the few attributes of this scenario.

- Cost of Electricity is 11.95 rupees.
- Solar PV has total capacity of 334 KW
- Biogas has total capacity of 110 KW
- There are 145 batteries while converter is 173 KW.
- Production from biogas resource is 67960 KWh while that from Solar PV is 578909 KWh per year.
- Biogas works for 3185 hours per year.
- Operation and maintenance cost of biogas is 35,013 rupees while total fuel cost is 1,587,232 rupees.

2) *Case 2*

The second case discussed has Solar PV, biogas and converter. There are no batteries. Net present cost is 96.8 million. Following are the few attributes.

- Cost of Electricity is 16.92 rupees.
- Solar PV has total capacity of 417 KW
- Biogas has total capacity of 140 KW
- There are no batteries while converter is 130 KW.
- Production from biogas resource is 220658 KWh while that from Solar PV is 723203 KWh per year.
- Biogas works for 8009 hours per year.
- Operation and maintenance cost of biogas is 112126 rupees while total fuel cost is 5139098 rupees.

3) *Case 3*

The third case discussed has Solar PV, batteries and converter. There is no biogas. Net present cost is 116 million. Following are the few attributes.

- Cost of Electricity is 20.28 rupees.
- Solar PV has total capacity of 896 KW
- There are 349 batteries while converter is 268 KW.
- Production from Solar PV is 1552894 KWh per year.

We have discussed three scenarios above. Each case has one component missing. HOMER runs lots of simulations and these three are the best cases. Out of these three case 1 is the best one.

We will use this case for our project as it is more feasible economically.

D. Cash flow

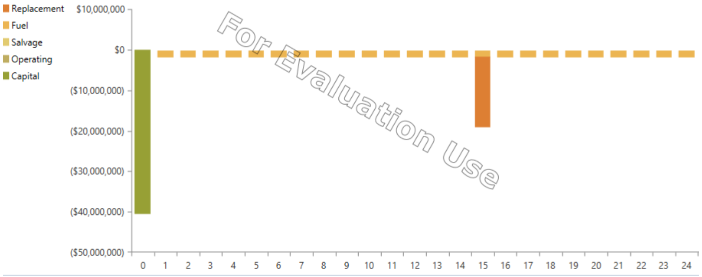


Figure 17 Cash Flow Diagram

The above figure shows the cash flow for the best optimum case. As it can be seen in above figure capital amount of 40 million is spent at time zero. Each period has fuel cost associated with it. Replacement cost will occur at year 15 which is roughly about 20 million. At the end of tenure of the project there is a salvage value.

E. Output by Components

Below section explains outcome of every component. Different components used in this project are Solar PV, Generator, Converter, Battery etc.

1) Solar PV

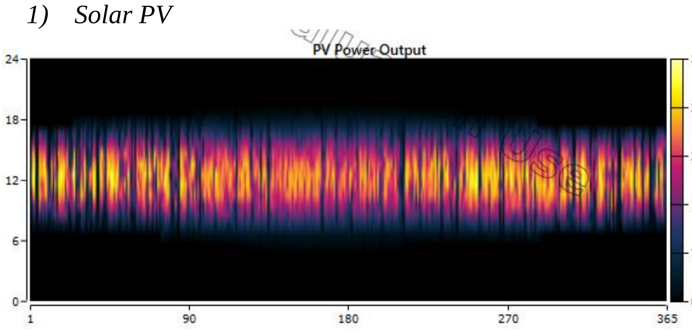


Figure 18 Solar PV Output

The above figure shows the usage of Solar PV. Black spots represents no production from Solar PV. This is during night time when the sun sets. As we go up the figure is more colorful showing production from Solar PV. Each color represents different range of production from solar. On the left of figure hours is given. It shows a full 24 hour cycle. At the bottom days are given. It runs from 1st day to the last date of the year. On the right hand side production from Solar PV is given in terms of KW.

Quantity	Value	Units
Rated Capacity	334	kW
Mean Output	66.1	kW
Mean Output	1,586	kWh/d
Capacity Factor	19.8	%
Total Production	578,909	kWh/yr

Figure 19 Solar PV key aspects

The above figure shows some key aspects related to production of Solar PV. Capacity Factor refers to energy generated over a period of year divided by total installed capacity.

Quantity	Value	Units
Minimum Output	0	kW
Maximum Output	335	kW
PV Penetration	131	%
Hours of Operation	4,383	hrs/yr
Levelized Cost	2.74	$/kWh

Figure 20 Output deatils of Solar PV

Minimum output from Solar PV is 0 KW which is during night time. Maximum output from PV is 335 KW. PV Penetration is 131 % which refers to total peak load power divided by peak load apparent power. Solar PV will be in production for 4383 hours per year. Cost of electricity from Solar PV is 2.74 rupees per KWh.

2) Generator

Biogas is extracted from biomass which then through generator is used to make electricity. HOMER has option to size your own generator which gives its capacity to pick the size of generator according to project need.

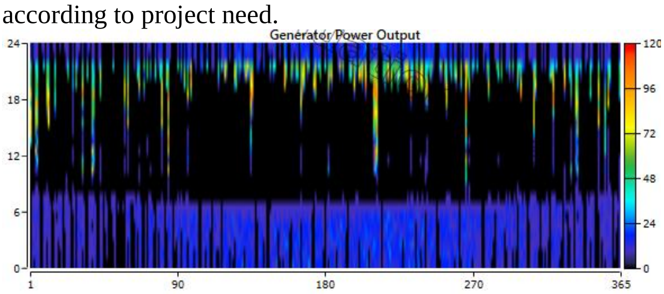


Figure 21 Generator Power output

The above figure shows the production from generator. The left side of the figure is showing hours starting from 0 to 24 hours i.e. complete day cycle. The right hand side of the figure shows production intensity. The bottom of figure has number of days marked on it. It has shown a full year circle. The different color schemes shows the production in terms of KW. Black color shows there is no production from biogas. The black color is in center of figure means during day time biogas will not generate electricity. Red color represents maximum generation from biogas which is during sun off hours.

Quantity	Value	Units
Electrical Production	67,960	kWh/yr
Mean Electrical Output	21.4	kW
Minimum Electrical Output	11.0	kW
Maximum Electrical Output	110	kW

Figure 22 Production Capacity

Quantity	Value	Units
Hours of Operation	3,183	hrs/yr
Number of Starts	335	starts/yr
Operational Life	6.28	yr
Capacity Factor	7.05	%
Fixed Generation Cost	120	$/hr
Marginal Generation Cost	18.6	$/kWh

Figure 23 Generator Details

Quantity	Value	Units
Fuel Consumption	244	tons/yr
Specific Fuel Consumption	2.52	kg/kWh
Fuel Energy Input	664,738	kWh/yr
Mean Electrical Efficiency	10.2	%

Figure 24 Fuel Details

The above figures shows some key aspects and performance indicators of generator. Biogas is responsible to produce 67,960 KWh/year. Average electrical output from generator is 21.4 KW. Generator will be in operation for 3183 hours out of 8760 hours for whole circle of year. Generator will start approximately 335 times per year. Cost of electricity from generator is 18.6 rupees per KWh. Fuel consumption details are also given in figure.

3) Battery

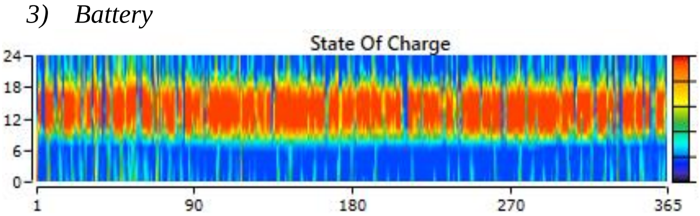


Figure 25 Battery Output

State of charge refers to the percentage of charge the battery has at certain point. Percentage ranges from 0 to 100. The blue color indicate the battery charge is low while the red color indicate battery charge is maximum. This figure shows battery charge level for whole year.

Quantity	Value	Units
Batteries	145	qty.
String Size	1.00	batteries
Strings in Parallel	145	strings
Bus Voltage	51.5	V

Figure 26 Battery Details

Quantity	Value	Units
Autonomy	7.99	hr
Storage Wear Cost	8.65	$/kWh
Nominal Capacity	505	kWh
Usable Nominal Capacity	404	kWh
Lifetime Throughput	1,985,086	kWh
Expected Life	15.0	yr

Figure 27 Battery Lifetime

Quantity	Value	Units
Average Energy Cost	0	$/kWh
Energy In	135,363	kWh/yr
Energy Out	128,988	kWh/yr
Storage Depletion	404	kWh/yr
Losses	6,778	kWh/yr
Annual Throughput	132,339	kWh/yr

Figure 28 Battery cost details

These three figures gives idea about the output of the battery. Total number of battery required will be one hundred and forty five. These batteries will provide power for the time period of 8 hours. 404 kWh power can be contributed by the batteries to the load demand. These figures also given idea about lifetime and through put of these batteries.

F. Power Purchase Agreement

From the simulation cost of electricity is found. That cost of electricity is now used to find various financial parameters which is crucial in deciding the feasibility of the project. Power Purchase Agreement refers to the contract between the producer and end user. This consists of time period of the contract, payment method, tariff and some other key parameters like who will be responsible for the maintenance etc.

For this project different parameters have been checked at four different power purchase agreement tariff. These tariffs are 11.95, 15, 20 and 25.

1) Break Even

Break Even or payback period is the time required for the investors to collect the amount he has invested. Break Even point will change according to tariff. The higher the tariff lower will be the breakeven point. HOMER calculates the breakeven point keeping the discount rate at consideration. Break Even point has also be calculated in excel without discount rate.

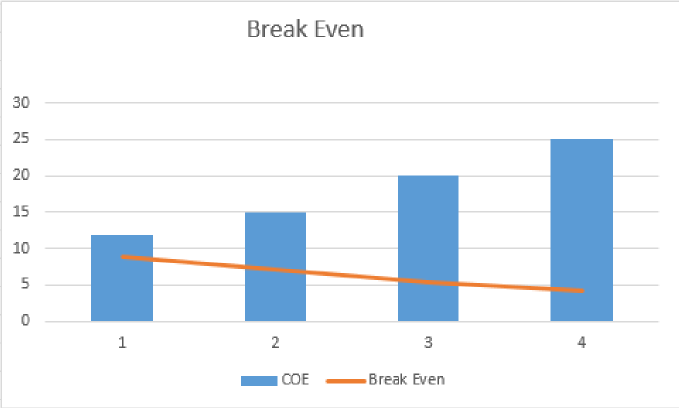


Figure 29 Breakeven Graph

To find the breakeven net present cost is divided by the revenue from a single year keeping in mind that the revenue from each year is a constant and there is no increment in tarrif. The above graph shows breakeven point. As there is increase in tarriff the breakeven point decreses. It has inversly proportional reltionship.

Table 1 Breakeven Table

COE	Break Even
11.95	8.83
15	7.03
20	5.28
25	4.22

As mentioned previouly we have set 4 different tarrifs at which breakeven will be checked. The aboce table shows tarrif level along with breakeven points. Breakeven points are given in years. Higher the tarrif lower will be the breakeven point.

1) Investors Profit

The whole purpose of independent power producers is to produce profit for invetors. Profit is key factor which attract private investors to invest in independent power producers.

Figure 30 Investor Profit Graph

The graph above shows profits for every tarrif level. When the tarrif level rises the profit increases. When the tarrif is 11.95 the profit is 124952114 ruppes. When the tarrif is 15 the profit is 174275875. When the tarrif is 20 the profit for the investors is 255134500. When the tarrif is set at 25 he profit for investors is 335993125. Tarrif has directly propoistional relationship to the profit.

1) Customer Savings

The reason why end users opts for indepednet power producers is if they see some sort of savings or advantage from grid power source. Commercial unit in Pakistan is set at round about 26 rupees per unit along with taxes.

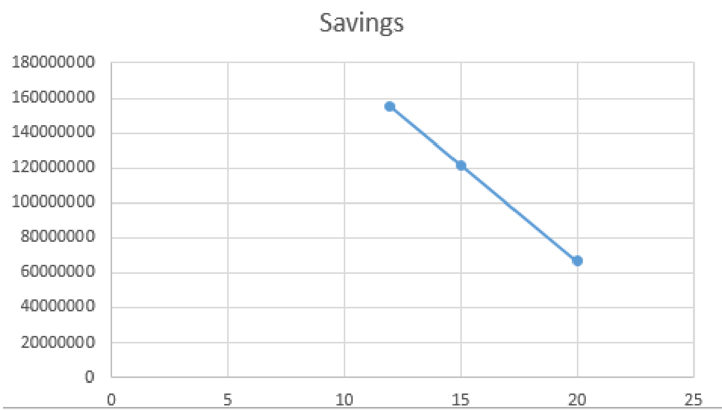


Figure 31 Total Savings Graph

The above graph shows savings with respect to every tarrif level. When the tarrif level is 11.95 rupees the savings for the end user is 155472383 rupees. When the tarrif is 15 the savings for the customer is 121722150. When the tarrif is set at 20 the consumer savings are 66393900. As the tarrif increases savings for consumers decreases. Tarrif has inversely proposrtional relationship to the savings. Remember savings can be much higher than shown figures. The commercial tarrif will not remain constant for a period of 25 years. It is expected to be much higher at the end of tenure of the project. Therefore real time savings is much higher than shown data.

2) Utilization

Independent power producers are investing money into these type of projects for the mere purpose of making money. Profits are depending on units utilized by the end consumers. Maximum the utilization more will be the profit for investors. If utilization level decrases profit decreases for the investors. This section reflects light onto how utilization affects the financial feasibility of the project.

Table 2 Utilization Levels at 11.95

Percentage	Units Consumed	PPA	Revenue	Greater Or less	Total Cost
100%	442626	11.95	132234518	>	68300000
90%	398363	11.95	119011066	>	68300000
80%	354101	11.95	105787614	>	68300000
70%	309838	11.95	92564162	>	68300000
60%	265576	11.95	79340711	>	68300000
50%	221313	11.95	66117259	<	68300000

The above table shows utilization economics based on when the tarrif is 11.95 rupees. Lets suppose all units produced are

utilized then utilization level is at 100 percent. That utilization level is multiplied with total demand units along with power purchase agreement per unit number and multiply it with 25 which is tenure of the contract. This will give us revenue. Now compare the revenue with total net present cost. If total revenue is greater than net present cost the project at that utilization level is feasible. But as we look down the table utilization level at 50 percent total revenue is less than net present cost. It can be said that project is not financially feasible at that level. To find the threshold where above that point project is in profit and below that point project is at loss interpolation is done.
Utilization level at which the revenue from Power Purchase Agreement is equal to the net present cost of the project can be calculated as

$$\frac{X - X1}{X1 - X2} = \frac{Y - Y1}{Y1 - Y2}$$

When Power Purchase Agreement is set at 11.95 PKR then utilization level at which revenue collected equals net present cost is calculated as

Table 3 Interpolation for 11.95

X = 60%	Y = 79340711
X1=	Y1 = 68300000
X2 = 50 %	Y2 = 66117259

$$\frac{60 - X1}{79340711 - 68300000} = \frac{X1 - 50}{68300000 - 66117259}$$

After solving this Equation the value of X1 = 51.65%.

Table 4 Utilization Level at 15

Percentage	Units Consumed	PPA	Revenue	Greater Or less	Total Cost
100%	442626	15	165984750	>	68300000
90%	398363	15	149386275	>	68300000
80%	354101	15	132787800	>	68300000
70%	309838	15	116189325	>	68300000
60%	265576	15	99590850	>	68300000
50%	221313	15	82992375	>	68300000
40%	177050	15	66393900	<	68300000

Process is repeated again to find the utilization level at which revenue is less than the net present cost. The utilization level at which the revenue dip below the net present cost is at 40 percent.
When Power Purchase Agreement is set at 15 PKR then utilization level at which revenue collected equals net present cost is calculated as

Table 5 Interpolation at 15

X = 50 %	Y = 82992375
X1=	Y1 = 68300000
X2 = 40 %	Y2 = 66393900

$$\frac{50 - X1}{82992375 - 68300000} = \frac{X1 - 40}{68300000 - 66393900}$$

After solving this Equation the value of X1 = 41.2%.

Table 6 Utilization Level at 20

Percentage	Units Consumed	PPA	Revenue	Greater Or less	Total Cost
100%	442626	20	221313000	>	68300000
90%	398363	20	199181700	>	68300000
80%	354101	20	177050400	>	68300000
70%	309838	20	154919100	>	68300000
60%	265576	20	132787800	>	68300000
50%	221313	20	110656500	>	68300000
40%	177050	20	88525200	>	68300000
30%	132788	20	66393900	<	68300000

The utilization level at which revenue dips down below net present cost at 20 power purchase agreement is at 30 percent. To find exact threshold interpolation is done.
When Power Purchase Agreement is set at 20 PKR then utilization level at which revenue collected equals net present cost is calculated as

Table 7 Interpolation at 20

X = 40 %	Y = 88525200
X1=	Y1 = 68300000
X2 = 30 %	Y2 = 66393900

$$\frac{40 - X1}{88525200 - 68300000} = \frac{X1 - 30}{68300000 - 66393900}$$

After solving this Equation the value of X1 = 30.2%.

Table 8 Utilization Level at 25

Percentage	Units Consumed	PPA	Revenue	Greater Or less	Total Cost
100%	442626	25	276641250	>	68300000
90%	398363	25	248977125	>	68300000
80%	354101	25	221313000	>	68300000
70%	309838	25	193648875	>	68300000
60%	265576	25	165984750	>	68300000
50%	221313	25	138320625	>	68300000
40%	177050	25	110656500	>	68300000
30%	132788	25	82992375	>	68300000
20%	88525	25	55328250	<	68300000

The utlization level at which revenue dips down below net present cost at 25 power purchase agreement is at 20 percent. To find exact threshold interpolation is done.

When Power Purchase Agreement is set at 25 PKR then utilization level at which revenue collected equals net present cost is calculated as

Table 9 Interpolation at 25

	Y = 82992375
X1=	Y1 = 68300000
X2 = 20 %	Y2 = 55328250

$$\frac{30 - X1}{82992375 - 68300000} = \frac{X1 - 20}{68300000 - 55328250}$$

After solving this Equation the value of X1 = 24.68 %.

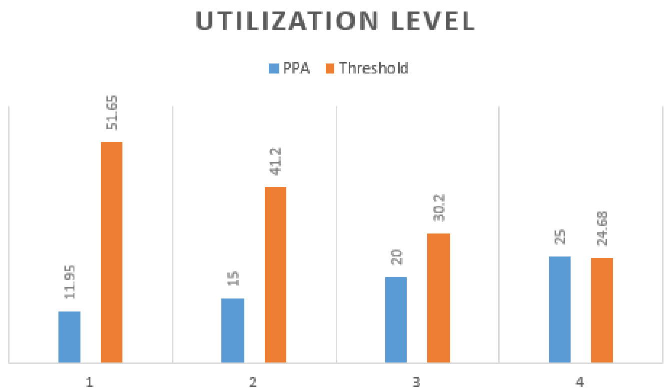


Figure 32 Utilization Level Graph

The above graph shows threshold for every power purchse agreement contact value. Lower the value higher will be the threshold utilization level. As the power purchase agreement contract value increases the investors will be able to recover its money in quick time.

3) Minimum Payment

As discussed previouly the mere purpose for the independent power producers is to make money. There can be a scenario where power is generated by independent producers cannot be utilized by the end consumers which will make the project non feasible in terms of finances. To avoid this situtaion some amount should be standard which the consumer will pay irrespective of units being utilized.

Net Present Cost = 68300000
Total tenure for the project= 25 years
Convert this into months= 25 * 12 = 300 months
To find Net Present Cost per month = NPC/Months
Npc= 68300000/ 300
Npc= 227667
Where as Npc is Net Present Cost per month.

The minimum amount required by the end consumer is 227667. There are 22 shops in plaza.
Payment per shop = 227667/22
= 10349
Each shop will pay 10349 rupees irrespective of how much units they consume.

NPC Per Month	227667
COE	11.95
Units Consumed	19052

Figure 33 Minimum Unit Consumed for Breakeven at 11.95 Tariffs

NPC Per Month	227667
COE	15
Units Consumed	15178

Figure 34 Minimum Unit Consumed for Breakeven at 15 Tariffs

NPC Per Month	227667
COE	20
Units Consumed	11383

Figure 35 Minimum Unit Consumed for Breakeven at 20 Tariffs

NPC Per Month	227667
COE	25
Units Consumed	9107

Figure 36 Minimum Unit Consumed for Breakeven at 25 Tariffs

Net present cost per month is calculated. To find units need to be consumed for every power purchase agreement net present cost per month is divided by power purchase agreement contract value.

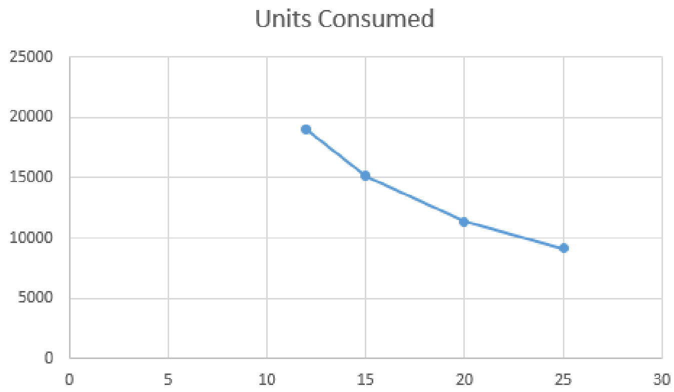


Figure 37 Units Consumed Graph

The above graph shows units consumed at every level. When the tarrif is 11.95 the unit cosumed should be 19052. When the tarrif is 15 the units consumed should be 15178, for tarrif at 20 units consumed should be 11383, for tarrif at 25 units consumed should be 9107 to meet the minimum payment. This is necessary to keep the minimum constraint value to avoid loses for investors.

G. *Reduction in carbon dioxide*

It is known that electricity generated from conventional methods produce harmful gases. These gases cause ozone layer to deplete which is casing various dieseases. One research claims that almost 40 % carbon dixode emmission occurs from generated electricity through conventional methods. These greenhouse gas emissions are responsible for global warming.

To calculate the reduction in carbon dioxide the load profile was uploaded to HOMER. The mere purpose for this is to find reduction carbon dioxide.

Carbon Dioxide (g/kWh):	417.35
Carbon Monoxide (g/kWh):	0.00
Unburned Hydrocarbons (g/kWh):	0.00
Particulate Matter (g/kWh):	0.00
Sulfur Dioxide (g/kWh):	2.74
Nitrogen Oxides (g/kWh):	1.34

Figure 38 Composition of gases

The input of others gases doesnot matter. According to united states electricity study carbon dixode emission per kilowatt is 0.92 pounds. To convert this into gram the figure becomes 417 gram per kilowatt.

Architecture		Cost				System		Grid	
Grid (kW)	Dispatch	COE (Rs)	NPC (Rs)	Operating cost (Rs)	Initial capital (Rs)	Ren Frac (%)	CO_2 (kg/yr)	Energy Purchased (kWh)	Energy (kW
999,999	CC	$0.100	$572,205	$44,263	$0.00	0	184,730	442,626	0

Figure 39 Carbon dioxide emission from Grid

The carbon dixode emission from grid power source is 184, 730 kg/ year. Factor which can contribute to this number depends on how electricity is produced. Electricity can be produced from fossil fuels, hydro, nucelar resource etc. Each source contribute different towards emission of carbon dixoide. In Pakistan electricity is generated from different resources i.e. hydro, nuclear, fossil fuel etc.

COE (Rs)	NPC (Rs)	Operating cost (Rs)	Initial capital (Rs)	Ren Frac (%)	CO (kg/
$11.95	$68.3M	$2.15M	$40.5M	100	44.0

Figure 40 Emission from Renewable Energy Sources

urce

The above figure shows emission from renewable energy source. Total emission from solar pv and biomass hybrid is 44 kg per year. Renewable energy source reduce the emission of carbon dixoide upto large extent. With the world population growing each day it is necessary to protect the environment for future generation.

To calulate reduction in emission of carbon dioxide emission from renewable source is deducted from emission from grid sources.

Reduction of carbon dioxide per year = emission of co2 from grid – emission of co2 from renewables = 184730 – 44 = 184686 kg/year

This is for single year. As discussed above the project life span is 25 years. To find total reduction for the project life span that number is multiplied by 25.

Reduction for co2 per year = 184686 kg / year

Project life span = 25 years

Total reduction = project life span * reduction for one year

= 184686 * 25

= 4617150 kg / year

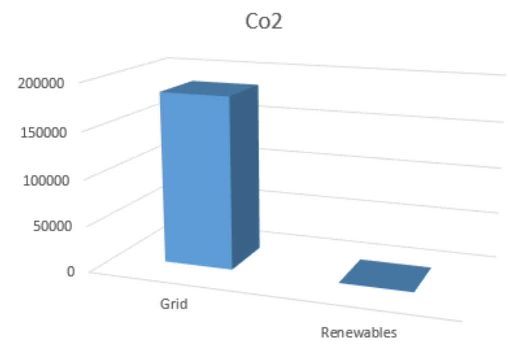


Figure 41 Reduction in Carbon dioxide

CONCLUSION AND RECOMMENDATION

Conclusion

World is facing electrical energy shortages and these shortages are more prominent in third world countries. This research study is focused on electrical energy shortages in Pakistan which has resulted in load shedding for majority part of the day. Pakistan government does not have the necessary funds to add facilities to cope with the increase in demands of electricity. This is one of the primary reasons there is increase in supply and demand gap and it is expected that this gap will increase considerably in foreseeable future. There is a need to find alternative to the fossil fuels and hydro resources which can provide remedy to the existing electrical problems. This research study focused in solar renewable energy and bio gas. Peshawar which is the capital of KP was selected for the study. HOMER is the software which was used for the simulation. In the first phase load of the desired location was calculated and system was designed on the calculated load. HOMER ran multiple simulations and a hybrid of solar renewable energy system and biogas plant along with generator and batteries was considered to the most viable option. Best viable option was taken into considerations and multiple economical calculations were carried out at different levels on Tariffs. Cost per unit for the installed facility is 11.95 which is way lower than the commercial unit cost in the province of KP so it can be considered that hybrid system is the most viable option. In the next step economical study was done to check the benefits of installing hybrid system from both investors and consumers side. It is established from the calculations that hybrid system is a very best option for both the parties. Higher the tariff will be lower will be the breakeven point for the investors and higher the profits and vice versa. If the tariff is low higher will be the savings for the consumers relatively to conventional grid source. There is also a question for the investors on how to making their investment secure and to provide security minimum payment per store has been calculated which will provide surety to the investors. Minimum payment is the payment consumers pay whether they use units below the threshold required by the investors to breakeven. Due to increase in technology pollution has increased vastly and greener technologies are more preferred. Hybrid renewable energy system designed in this research study is far more greener and will eliminate ill effects of pollution risen from the conventional sources.

Recommendations

As it is established that renewable energy discussed in this research study is very feasible both economically and environmentally but there are certain flaws associated with it. The major flaw is the capital cost required to procure the system components. It requires a very large sun of finances and unfortunately most of dwellers from Pakistan are deprived from it. Therefore it is highly recommended that government should invite independent power producers that can install the renewable energy plants and provide them security so they are less vulnerable and make sure their investments will be secured. If locals have the capability to procure the system they should opt for it because it will not only ensure electricity all the time and it is much cheaper source than the grid so it also has economic advantages. Due to worst economic conditions of Pakistan is the inflation is very high and dollar rate is at all-time high. This has resulted in increase in tariffs of electricity and it is expected that inflation will be higher in the future. It will also results in the increase in the tariffs it is wise to install a renewable energy plant which do not have operating cost and can last up to 25 years.

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How to cite this article:

Muhammad Naeem, Zohaib Rehman, "Techno-Economic Evaluation of Hybrid Off-Grid Renewable Energy System" International Journal of Engineering Works, Vol. 11, Issue 06, PP. 111-123, June 2024. https://doi.org/10.34259/ijew.24.1106111123.