Article

Techno-Economic Analysis of Hybrid Renewable Energy Based Electricity Supply to Gwadar, Pakistan

Muhammad Sharjeel Ali [1], Syed Umaid Ali[2], Saeed Mian Qaisar[3] , Asad Waqar[1, 2*], Faheem Haroon[1], Ahmad Alzahrani[4*]

[1] Department of Electrical Engineering, Bahria School of Engineering and Applied Sciences, Bahria University, Islamabad 44000, Pakistan; 01-244202-014@student.bahria.edu.pk; (M.S.A.), faheemharoon.buic@bahria.edu.pk; (F.H.)
[2] Center of Excellence in Artificial Intelligence (CoE-AI), Department of Electrical Engineering, Bahria University, E-8 Shangrilla Road, Islamabad 44000, Pakistan; sumaid.buic@bahria.edu.pk; (S.U.A.)
[3] College of Engineering, Effat University, Jeddah 22332, Saudi Arabia; sqaisar@effatuniversity.edu.sa; (S.M.Q.)
[4] Electrical Engineering Department, College of Engineering, Najran University, Najran 11001, Saudi Arabia
* Correspondence: asadwaqar.buic@bahria.edu.pk (A.W.); asalzahrani@nu.edu.sa (A.A.)

Abstract: Gwadar is essential for Pakistan's financial stability. The third deep-water port in Pakistan, Gwadar, plays a significant part in trade between the Gulf countries, Africa, China, United Arab Emirates, and Cordillera Administrative Region. However, the load Shedding of 12-16 hours in Gwadar is the most concerning issue. Pakistan imports 70 MW of electricity from Iran. The wind and solar system are already installed but for a limited residential area. In Gwadar, there are enough renewable energy resources that can be utilized for electricity generation. In this context, a Techno and Economic Analysis is performed using the Hybrid Optimization Model for Multiple Energy Resources (HOMER) Pro. Two models are considered for this study. Model-1 includes PV/Wind Turbine/ and Battery while Model-2 consists of PV/Wind Turbine/Converter and Grid. The yearly energy generated by Model-1 and Model-2 is 57.37 GWh and 81.5 GWh, respectively. The levelized cost of electricity (LCOE) for Model-1 and Model-2 is respectively $0.401/kWh and $0.0347/kWh. It is shown that the simple payback of Model-1 is of 6.70 years, and the simple payback of Model-2 is 7.77 years. Due to the high LCOE of Model-1, its payback year is lesser than model-2. All of these facts indicate that Model 2 is the most optimal solution.

Keywords: Techno-Economic Analysis, Gwadar, Renewable Energy, Homer Pro, Feasibility Analysis

1. Introduction

After the current upheaval, which consumed a significant quantity of non-renewable energy sources, scientists had long expected that Earth's temperature will rise. Because of the impact of human behavior on the organization of energy, environmental changes may now be felt throughout the planet due to a rise in the planet's mean temperature. [1]. One of the main proponents of an increase in the average temperature of the Earth is the electrical phase, which frequently depends on fossil fuel. Many ozone-depleting chemicals are released into the atmosphere by these petroleum derivatives. The ongoing confrontation between Russia and Ukraine has made this worse. The price of petroleum derivatives has skyrocketed, therefore now is the ideal time for nations that import non-renewable energy sources to seriously pursue sustainable power plans. The use of environmentally friendly energy as a substitute for petroleum products and the management of an unnatural weather shift that has been effectively implemented in industrialized countries can assist emerging nations. [2]. There is no other option besides ecologically friendly power. Despite the fact that it was conducted a while ago, it has become more well-known as the

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Middle East crude oil ban in the 1970s. Later then, ecologically friendly energy has advanced significantly as well as mostly taken the position of petroleum derivatives. [3]. The most well-known sustainable energy source in the past was hydropower, which requires the construction of a dam, a significant project. Hydropower can be utilized to lessen floods, as demonstrated by the Itaipu Dam in Paraguay and the Three Gorges Dam in China. Although hydropower requires a large initial investment, the Levelized cost of energy is less expensive in the long run. Microscale hydropower operations are also possible. The issue that micro-scale hydropower runs into is temperamental power age. Levelized energy is pricey relative to even low-cost fossil products like coal since solar photovoltaic and wind turbines systems are presently the most recognized renewable energy sources. [4-6]. To make solar energy competitive, a lot of research has been done, including employing nanofluid [7] and enhancing performance with a compound explanatory concentrator and a heated dryer powered by the sun [8]. Several nations have adopted this network-related structure, particularly the clever city [9]. Implementing independent and framework-related half-and-half energy frameworks has been indicated as being feasible via techno-economic analysis. [10].

According to recent studies [11-13], the execution of serious and sustainable energy arrangements is beneficial to move beyond conventional energy utilization. This is especially true for the development of energy that incorporates ozone-depleting substances. According to the International Energy Agency's 2019 specialized report, there will be a 55 percent increase in power age by 2040 related to 2018; 30 percent of that growth should be produced by wind and solar energy [14]. The Colombian Caribbean region benefits from the ability of solar panels and wind turbines to utilize sunlight-based illumination and wind speed separately. Research focuses on demonstrating that the public energy needs of Colombia could be met solely by installing wind turbines in 20 percent of the La Guajira division's domain and 10 percent of the ocean, leaving 40 percent unfinished [15]. Since petroleum products are still widely used in the area and despite the effort to carry out deep oil drilling to rise the utilization of non-renewable energy sources for a few more years, only a small portion of the potential for power creation through wind turbines and sunlight-based chargers in the Colombian Caribbean district is utilized [16,17]. However, taking everything into account, using non-renewable energy sources and emitting ozone-depleting substances will soon be subject to financial penalties [18], and the security of wind turbines and solar chargers will be improved. Implementing hybrid power systems will greatly aid in the transformation, education, and age of work for sustainable power systems while gradually shifting the entire activity of conventional non-renewable energy source to systems powered by wind and solar energy. [19,20]. Another benefit of using environmentally friendly energy is that it anticipates continuous employment rates of 16 percent in the manufacturing sector, 29 percent in the development sector, and 50 percent in activity and maintenance by 2050 [21]. The Hybrid Optimization for Multiple Energy Resources (HOMER) programming is used to support this research project. Since HOMER has the reenactment equipment to conduct research with altered energy sources, which enables evaluating the presentation of force age plants with one or a few inexhaustible sources, it is incredibly helpful for the estimation of a half breed energy supply framework [21].In adding to energy performance, HOMER can deliver info from a financial and environmental standpoint [23].

A challenging energy planning problem is combining multiple sustainable power systems into a single system [24]. However, introducing environmentally friendly power into power grids offers prospective solutions to several present issues, such as increasing environmental change and ozone-depleting chemical emissions, dependence on petroleum derivatives, and extremely fluctuating energy prices [25]. Clean energy is becoming more well-known on a global scale. Sustainable power developments are typically essential for long-term improvement, energy security, and environmental assurance [26,27]. Particularly viable options for reducing fossil fuel byproducts and creating a cleaner, safer society are wind and solar-based energy sources. Recent studies on sustainable power resources in Thailand have focused on solar-based [28], and hybrid environmentally friendly power sources [29] to promote a cleaner energy age and increase the energy security of this Southeast Asian nation with a developing economy. However, there are certain drawbacks to using ecologically friendly power sources, one of which being their erratic nature. Additionally, sporadic geographic and environmental factors have an impact on the age of the breeze and the sun [30]. To increase productivity, crossbreed sustainable power frameworks (HRES) have been developed [31–33]. These frameworks combine various energy resources, which has several benefits, including lower capital costs, an extended power age limit, increased steadfastness and general effectiveness, and more prominent adaptability in the plan streamlining. Additionally, the instability of the organic market and the vulnerability of environmentally friendly power sources affect the dependability of the power age framework. Utilizing energy storage systems (ESS) can aid in resolving these difficulties [34,35]. The expansion of environmentally friendly power-based power age in the public portfolio is at the center of Thailand's 2018 Power Development Plan (PDP), which aims to support cleaner creation as a route to energy security and carbon neutrality. Depending on the spatial circulation and the capacity of the sustainable power assets, dispersed power age is a characteristic of several developments in sustainable power, such as PV, wind power, biomass, hydropower and biogas. A HRES may be designed to combine solar, wind, hydro, biogas and diesel generator (DG) reinforcement with a battery power capacity framework (BESS), depending on the application [36]. Energy units (FC) with H2 innovation (HT) have more recently been incorporated into HRES frameworks [37,38].

Keeping in view following is the summary of literature review:

1) The Absence of national grid in Gwadar is a hindrance for Gwadar in becoming the economic hub of the country.

2) Furthermore, the limitation and cost for importing the power is also a concerning parameters.

3) No new plant can be established because of power limitation. The power situation in Pakistan is examined in this study because load shedding is impeding the nation's development. The creation of net-zero energy in the upcoming economic center of Pakistan, the city Gwadar, is suggested as a solution to this issue.

4) At the chosen location, the renewable resources are examined. Different wind and solar resource scenarios are examined, and the one with the lowest net present value, levelized cost of electricity (LCOE), and greenhouse gas emissions is chosen as the optimum scenario.

2. Approach for Techno-economic analysis:

A methodology was created and used throughout the research to ensure practical work was accomplished. Figure 3 shows the plan of the methodology used. The methodology focused research on the importance and electricity short fall issue of Gwadar, renewable energy sources. The following steps involved collecting data on solar and wind energy so that data help to identify how much power can be generated. This was then used to produce the demand profile that could be implemented into the model. To model this HOMER (Hybrid Optimization Model for Multiple Energy Resources). This study used the following analytical framework [39]. Figure 1 show methodology flow chart.

1) Specification of location.

2) The data needed for modelling.

   a) average electric load demand.

   b) The area's everyday radiation and clarity index;

   c) The site's normal everyday temperature.

3) Architecture of System.

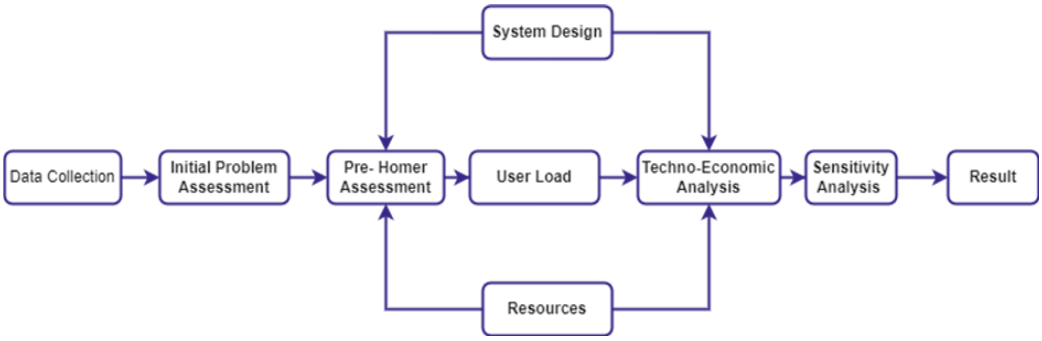

Figure 1: Flow Chart of Methodology

2.1 Location:

Pakistan is an undeveloped nation and is struggling to speed up its financial expansion and meet the rate of expansion of the area's rapidly expanding economies. The environment is a major problem in Pakistan. Exclusively in form of the energy crisis, water scarcity, water pollution, air pollution and dwindling natural resources. Pakistan need to work on different projects to overcome the crisis. As one project is already started which is Project like China Pakistan Economic Corridor (CPEC). The authors of [40] show the road map of CPEC and tell this project will help Pakistan to reinforce their financial, political and vital relations with the progression of time. This will help Pakistan and China to connect with other region. By applying the predictive methodology objective can be achieved. This research conclude that this project will be game changer for Pakistan. This project will help Pakistan to grow and will face challenges. Challenges should be overcome. Big Challenge is to full fill power demand for Gwadar as Gwadar will be main hub for this project. Gwadar has many renewable energy resources from which power demand can be full filled. In Gwadar region solar, wind, tidal and wave energy are present and power can be generated from these sources. In Gwadar there is no national grid and electricity is imported from Iran [41] . Gwadar map is presented in Figure 2.

Figure 2: Gwadar Map

2.2: Modelling Statistics

2.2.1: Average Electric Load Demand

70MW electricity is imported from Iran to fulfill the demand of Gwadar. But due to Iran's own electricity demand it don't give complete 70MW. Due to which there is load shedding of 12-16 hours. People use generator to fulfill the demand of electricity. The daily and seasonal load profile is shown in figure 3 and 4 correspondingly.

Figure 3: Daily Load Profile of Gwadar

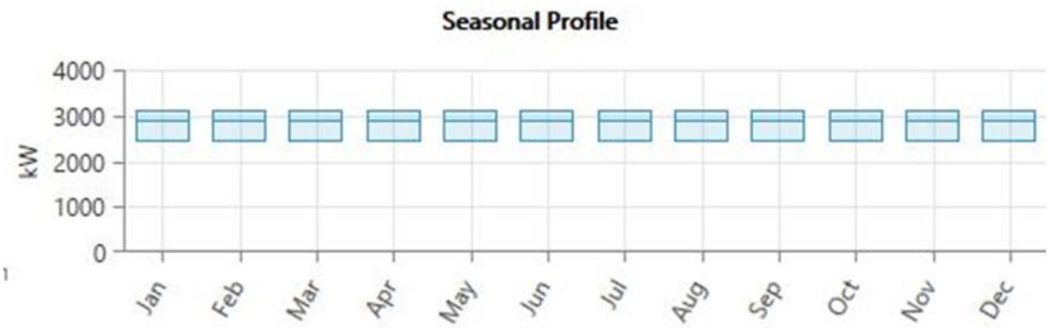

Figure 4: Seasonal Load Profile of Gwadar

2.2.2: Everyday Radiation and Clarity Index at the site

Indicators of the clarity of the atmosphere include the daily indexes for radiation and clarity numbers. The portion of solar energy that reaches the Earth's surface through the atmosphere. To calculate it, surface radiation is divided by extraterrestrial radiation, yielding a one-dimensional number between 0 and 1. The clarity index has a significant value while it is sunny and clear outside and a low value when it is cloudy. Figure 5 shows the location's everyday solar radiation and clarity index and Figure 6 displays the location's average wind speed.

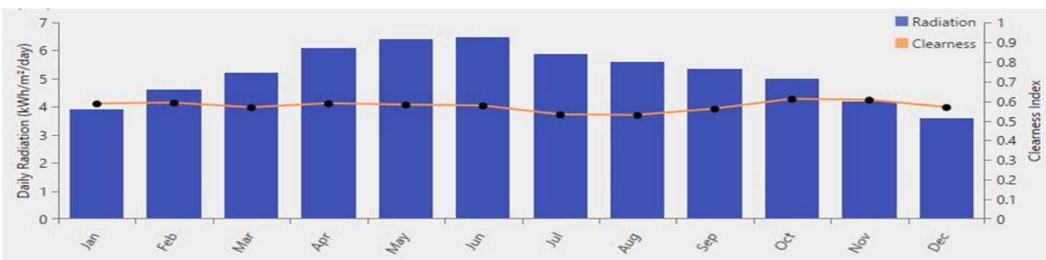

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Figure 5: Annual daily radiation and clarity index[42]

Figure 6: Average Wind Speed (m/s) [42]

2.3: Proposed System Architecture

It is necessary to initially build the system architecture in order to mimic the renewable energy system. There are two models in this instance, each of which includes the Photovoltaic, windmill, batteries, grid connections, and capacity that was previously mentioned. Figures 7 and 8 exhibit the schematic representations of the two distinct model designs, respectively. Table 1 lists the cost of components and Table 2 outlines the economic analysis of the proposed system. The proposed system's location is 4867+5Q Gwadar, Pakistan (25′ 6.6′′N, 62′18.9′′E). Solar panels, wind mills, battery bank, and grid connectivity make up the scenario of the recommended renewable energy system.

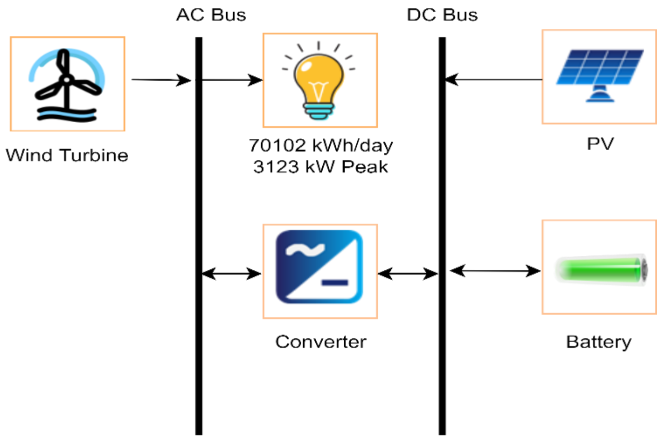

Figure 7: Model 1

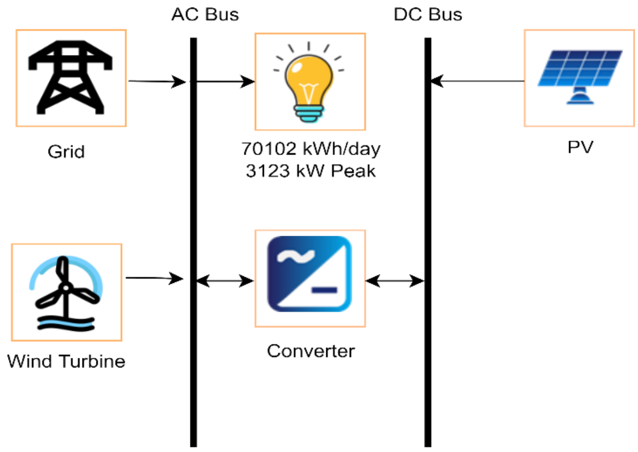

Figure 8: Model 2

Table 1: Cost of Component

Component	Name	Capital Cost ($)	Replacement Cost $	O&M Cost ($)	Lifetime
Solar	Flat-plate PV	641.75	437.50	5.80/year	25 year
Wind	Generic 10 kW	33,640.00	23,640.00	360.20/year	20 year
Storage	1 kWh Lead Acid	300	300	10/year	10 year
Converter	System Converter	300	300	0	15 year
Grid	Simple Tariff	0.06 kWh	-	-	

2.3.1: PV

The variants that are made use standard flat-plate photovoltaic. The lifespan and efficiency of generic PV panels are 25 years and 14%, respectively. One kW is the rated capacity of each PV plate. A photovoltaic system is expected to cost US$641.75/kW to buy, US$437.50/kW to replace, and US$5.80/kW to run. De-rating factor for the solar array is about 80%. Equation (1) [43]

$$P_{pv} = f_{pv} \ x \ Y_{pv} \ x \ \frac{IT}{IS} \qquad (1)$$

determines the module's output power under ideal operating circumstances. The average horizontal irradiance is 5.19 kWh/m². Figure 5 show the Annual daily radiation and clearness index for Gwadar.

2.3.2 Wind Turbine

For this project, a generic wind turbine with a 10 kW rated power has been chosen. Generic wind turbine has a 20-year lifespan and a 24 m hub height. Knowing the hub height wind speed allows one to compute the wind turbine's output by using the power curve. The power curve shows the anticipated power production of the windmill when estimated under typical pressure and temperature conditions. The Output can be calculated by Equation 2 [44].

$$P(V_{hj.}) = \frac{P(V_2) - P(V_1)}{V_2 - V_1} \ x \ (V_{hj} - V_1) + P(V_1) \qquad (2)$$

2.3.3 Battery

A "battery bank" is referred as a grouping of a few different batteries. A solo battery is modelled by HOMER as a component with a fixed energy efficiency that can store a certain amount of DC power, depending on limitations on how fast it can be charged or discharged and the maximum amount of energy it can handle before needing to be replaced. Battery used in this design is a generic 12 Volt Lead-acid Battery with 1 kWh of energy storage. Its efficiency on returns is 80%. Maximum currents for charging and discharging are each 16.7 A and 24.3 A respectively. Its capital and replacement cost is $300 respectively, and it's operating and maintenance cost is $10.

2.3.4 Converter

With this model, a Generic system converter from the Homer Pro software is utilized. It has both rectifier and inverter modes of process. When solar and wind resources are not available, the converter only operates in inverter mode; this typically occurs at night and in overcast weather. When there is enough renewable energy to charge the battery storage system, the converter solely operates in rectifier mode. The converter has a 95% efficiency rating. It is estimated that a kilowatt converter costs about $300. A replacement has a 15-year lifespan and costs roughly $300. The inverter's efficiency and selection will determine how well the power converter converts DC to AC. It is written as equation 3 [42]

$$P_{l,s(t)} = P_{input}(t) * \eta_{conv} \tag{3}$$

where $P_{input}(t)$ stands for the converter's input power and conv for its efficiency.

2.4. Economic Analysis

Calculating the techno-economic study of an engineering system requires certain economic statistics. The minimal discount rate, anticipated inflation rate, and project duration are just a few examples of the information included. The economic information needed for both model-1 and model-2is summarized in Table 2.

Table 2: Economic Analysis

Description	Value	Unit
Currency	US$1	$
Nominal discount rate	13.75	%
Predictable inflation rate	9.74	%
Project lifespan	25	Year

2.4.1. Interest Rate

The real rate of interest for the year, often known as the actual rate of interest or basic rate of interest, is one of the inputs utilized by HOMER. It is the discount rate used for converting one-time charges to annual costs overall. The following equation establishes a relationship between the minimal rate of interest and the annual real rate of interest [42]:

$$i = \frac{i' - f}{1 + f} \tag{4}$$

2.4.2. Levelised Cost of Energy

The normal price per kWh of usable the system produces electrical energy, which is what HOMER refers to as the levelised cost of energy (COE). The total annualized cost less the cost of feeding the load is the cost of producing power annually, which is then divided by HOMER's total output of usable electricity. Following is how the COE is determined [42].

$$LCOE = \frac{C_{ann.tot}}{E_{prim} + E_{def} + E_{grid.sales}} \quad (5)$$

The absolute annualized cost is the amount of every framework part's annualized costs in addition to the next annualized expenses. The levelized and total net present expenses of energy are calculated using it by HOMER, making it a crucial digit.

2.4.3. Net Present Cost (NPC)

The ongoing value of the various costs the combination framework incurred over the course of its declared useful life, less the recovery value at that period, is the net present cost of the combination framework. The expenses recalled for the net current expense are those for capital expense, replacement cost, activity, and maintenance cost as given in equation (4) in accordance with reference [42]. Each component of the newly introduced framework has its NPC determined by Homer expert programming. The total NPC is calculated using the formula below [42]

$$C_{NPC} = \frac{C_{ann.tot}}{CRF\left(i.R_{proj}\right)} \quad (6)$$

Throughout this case, the structure has a 25-year lifespan, and the investment recovery factor is a percentage used to calculate the annual present value (a progression of equivalent yearly incomes). The status of the capital recovery component is as follows [42].

$$CRF(i,N) = \frac{i(1+i)^N}{(1+i)^N - 1} \quad (7)$$

2.4.4. Salvage Value

Salvage value describes how much a power system component is worth if it's still functional at the expiration of a project's lifespan. Using this equation, HOMER determines the value of each part at the conclusion of the project's life cycle [42]:

$$S = C_{rep} \frac{R_{rem}}{R_{comp}} \quad (8)$$

2.4.5. Internal Rate of Return

The internal rate of return (IRR) is the discount rate where the net present cost of the reference case is alike to the net present cost of the optimized system. The IRR is calculated by HOMER by dividing the difference between the current values of the two cash flow sequences by the discount rate.

2.4.6. Return on Investment

Return on investment is the annual budget savings compared to the initial investment (ROI). By dividing the difference in capital costs by the typical yearly difference in

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nominal cash flows throughout the course of the project, the ROI is determined. The next equation is used to define the return on investment. [42]

$$ROI = \frac{\sum_{i=0}^{R_{proj}} C_{i,ref} - C_i}{R_{proj}(C_{cap} - C_{cap,ref})} \tag{9}$$

2.4.7. Simple Payback

In the optimal and baseline examples, the term "simple payback" refers to the amount of years required for the accumulated cash flow differential between the systems to become positive. The time required to recover the difference in investment costs between the optimal and baseline case systems is known as the payback period.

2.4.8. Total Annualized Cost

A component's full annualized cost is the amount that, if spread out equally over the life of the project, would result in a net present cost that is identical to the component's actual cash flow sequence. As shown in the following calculation, the capital recovery factor is divided by the net present cost to produce the annualized cost. [42].

$$C_{ann,tot} = CRF(i, R_{proj})\ x\ C_{NPC,tot} \tag{10}$$

3. Results and Discussion

The HOMER Pro was used for the techno-economic analysis and optimization of two distinct solar PV and wind turbine models for the entire Gwadar, Pakistan are included in this section's calculation findings. The outcomes of the optimization are reviewed first, and then the techno-economic analysis findings.

3.1. Optimization Results

3.1.1 Model 1

The optimization results for the plant location 4867+5Q Gwadar, Pakistan (25′ 6.6′′N, 62′18.9′′E). Show that all components are being used in system. The system with the lowest COE and highest proportion of renewable energy is chosen by the HOMER PRO after a cost analysis of a number of system capabilities and configurations. The simulation method determines the long-term feasibility of energy systems. Several configurations are generated after the hourly simulation, with the mentioned case system displayed in light blue. To find the optimum model of system that finest fits the Gwadar's configuration system out of several combinations to meet the Gwadar's load demand need, two different scenarios were assessed among diverse configured energy systems in this study. Figure 9 lists the details of the optimized component (the reference case is in light blue). Figure 10 displays the system that has been optimized the most. Table 3 summarizes the system information for the optimized components.

Architecture									Cost				System	
				PV (kW)	G10	1kWh LA	Converter (kW)	Dispatch	NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)	Total Fuel (L/yr)
				46,573	422	128,058	3,924	CC	$166M	$0.401	$5.09M	$83.7M	100	0
				54,634		150,829	8,493	CC	$176M	$0.423	$5.72M	$82.9M	100	0

Figure 9: The proposed system's optimization results of model 1

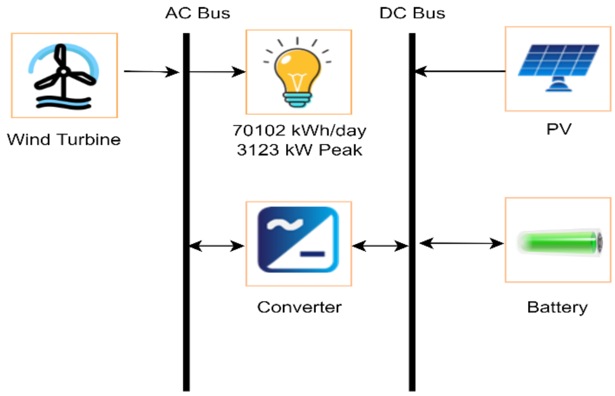

Figure 10: The optimized system architecture of model 1

Table 3: Optimized components detail of model 1

Component	Name	Size	Electricity Production (kWh/Year)
Solar PV	Generic flat-plate PV	46,573 kW	75,705,768
Wind Turbine	Generic 10 kW	422	5,859,989
System converter	System Converter	3924 kW	-
Battery	Generic 1kWh Lead Acid	128,058	12,733,506

With peak loads of 3123 kW, the total daily electricity usage in Gwadar is 70102 kWh. The following generating sources are used by the proposed system to meet the electrical load. The results showed that a model 1 system had the lowest COE (0.401/kWh) over the course of the project and the highest fraction of renewable energy (100%).

3.1.1.1 Electricity Generation, Consumption and Cost

As indicated in Table 3, the optimized system generates 100% renewable energy, with solar PV accounting for 75,705,768 kWh/year and wind turbines for 5,859,989 kWh/year. Figure 11 displays an overview of the monthly electric output from PV and GT10. Figure 12 shows the output of a solar photovoltaic system with a standard wind turbine. The Figure 13 show the cost analysis for model 1. Table 4 and Table 5 show the Net Present Costs and Annualized Costs of Model 1.

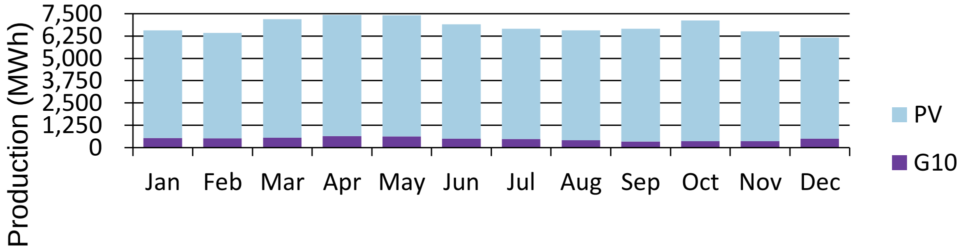

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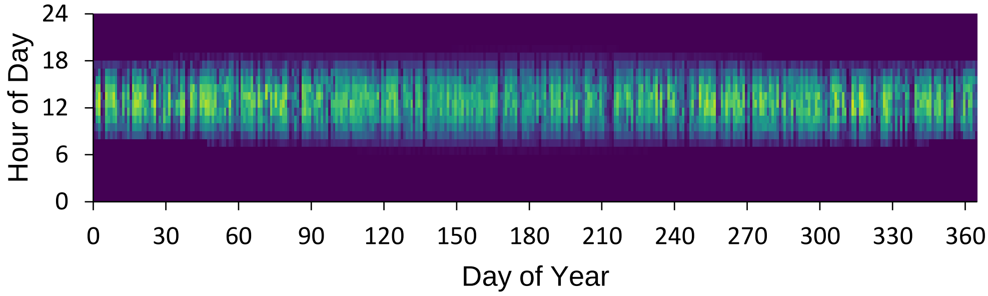
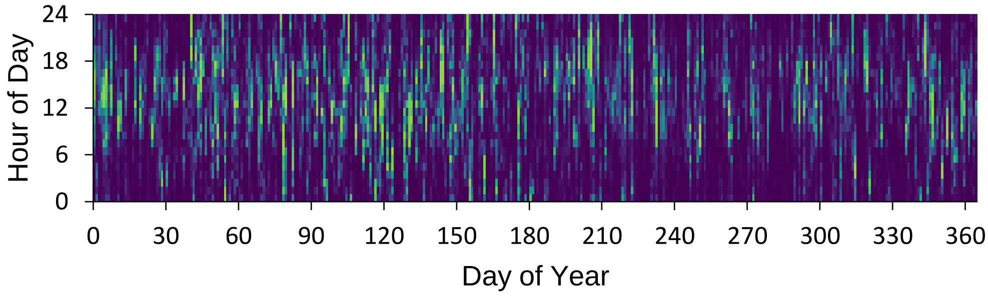
Figure 11: Monthly electric production of solar PV and GT10



Generic flat plate PV



Wind Turbine: Generic 10 kW

Figure 12: Solar PV output and generic wind turbine output.

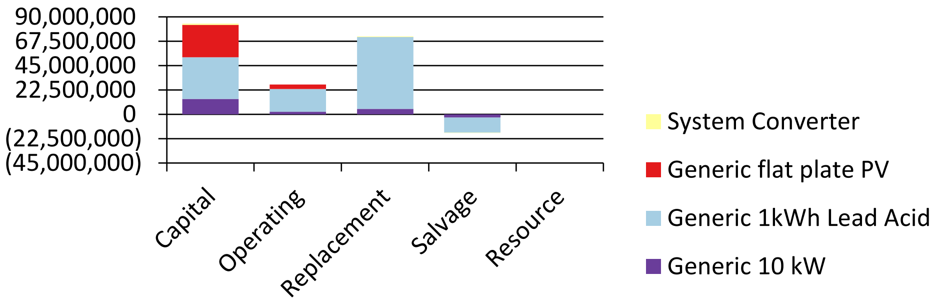


Figure 13: Cost Graph for model 1

Table 4: Net Present Costs of Model 1

Name	**Capital**	**Operating**	**Replacement**	**Salvage**	**Resource**	**Total**
Generic 10 kW	$14.2M	$2.46M	$4.87M	-$3.05M	$0.00	$18.5M

Generic 1kWh Lead Acid	$38.4M	$20.8M	$66.5M	-$14.0M	$0.00	$112M
Generic flat plate PV	$29.9M	$4.38M	$0.00	$0.00	$0.00	$34.3M
System Converter	$1.18M	$0.00	$687,111	-$159,971	$0.00	$1.70M
System	$83.7M	$27.6M	$72.1M	-$17.2M	$0.00	$166M

Table 5: Annualized Cost of Model 1

Name	Capital	Operating	Replacement	Salvage	Resource	Total
Generic 10 kW	$875,800	$152,004	$300,239	-$188,190	$0.00	$1.14M
Generic 1kWh Lead Acid	$2.37M	$1.28M	$4.10M	-$862,542	$0.00	$6.89M
Generic flat plate PV	$1.84M	$270,125	$0.00	$0.00	$0.00	$2.11M
System Converter	$72,621	$0.00	$42,390	-$9,869	$0.00	$105,142
System	$5.16M	$1.70M	$4.45M	-$1.06M	$0.00	$10.2M

3.1.2 Model 2

Results of optimization for plant 4867+5Q Gwadar, Pakistan (25' 6.6"N, 62'18.9"E). Demonstrate how the system uses each component. Following a cost study of several system configurations and their capacities, the HOMER PRO selects the model with the lowest COE and maximum percentage of renewable energy. The long-term viability of energy systems is assessed using the simulation method. The hourly simulation results in a number of configurations, using the illustrated reference case system in light blue. In this case, four alternative situations were assessed among various formed energy systems in order to identify the ideal system layout for the given configuration system of the Gwadar in order to meet the Gwadar's load demand need. Figure 11 provides information on the optimized component (the reference case is in light blue). The system with the highest level of optimization is shown in Figure 12. The system details for the optimized components are listed in Table 6.

Architecture					Cost				System	
PV (kW)	G10	Grid (kW)	Converter (kW)	Dispatch	NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)	Total Fuel (L/yr)
27,019		999,999	14,055	CC	$28.2M	$0.0347	$410,961	$21.6M	73.2	0
27,112	4	999,999	14,055	CC	$28.3M	$0.0347	$404,959	$21.8M	73.3	0
		999,999		CC	$49.8M	$0.120	$3.07M	$0.00	0	0
	9	999,999		CC	$49.9M	$0.120	$3.06M	$302,760	0.488	0

Figure 14. The proposed system's optimization results of model 2

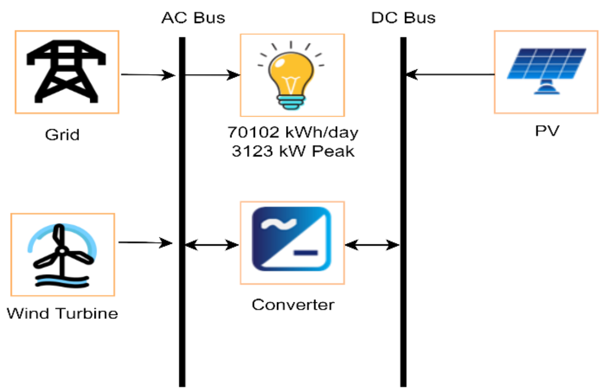


Figure 15. The optimized system architecture of model 2

Table 6. Optimized components detail of model 2

Component	Name	Size	Electricity Production (kWh/Year)
Solar	Generic flat-plate PV	27,112 kW	44,071,788
Wind Turbine	Generic 10 kW	4	55,545
System converter	System Converter	14,055 kW	-
Grid Connected	Simple Tariff	0.06 $/kW	13,423,227

The total daily electricity consumption in Gwadar is 70102 kWh, with peak loads of 3123 kW. The planned system uses the following producing sources to handle the electrical load. The findings showed that a model 2 system had the largest percentage of renewable energy (73.3%) and the lowest COE (0.0347/kWh) over the life of the project.

3.1.2.1 Electricity Generation, Consumption and Cost

Table 6 shows that the optimized system produces 76.6% renewable energy, with solar PV accounting for 43,919,754 kWh per year and wind turbines for 55,545 kWh per year. 13,452,374 kWh per year, or 23.4% of the total energy, are bought from the grid. The monthly electric output from PV and Grid is shown in Figure 16 as a summary. A solar photovoltaic system with a typical grid is shown in Figure 17 as its output. Cost analysis for model 2 is displayed in Figure 18. Tables 7 and 8 present the annualized and net present costs for Model 2 respectively.

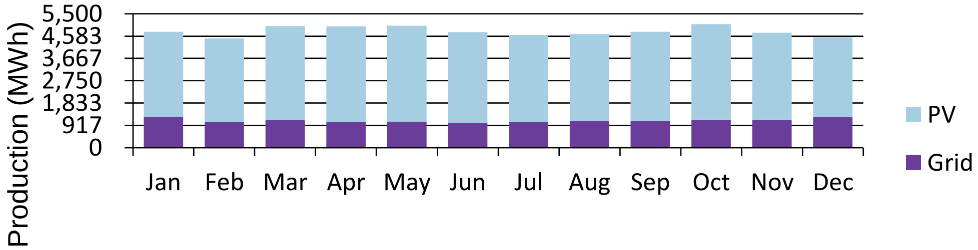


Figure 16: Monthly electric production of solar PV and Grid

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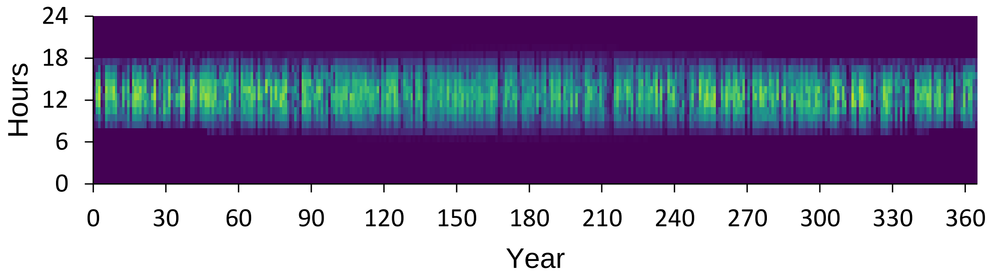
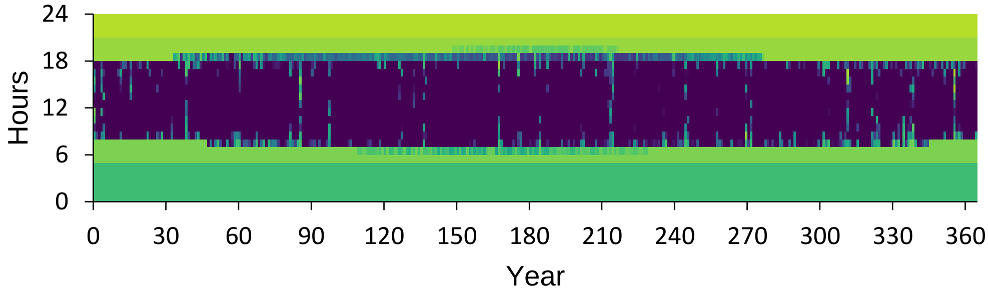


Generic flat plate PV



Electricity purchased from Grid

Figure 17: Solar PV output and Grid output.

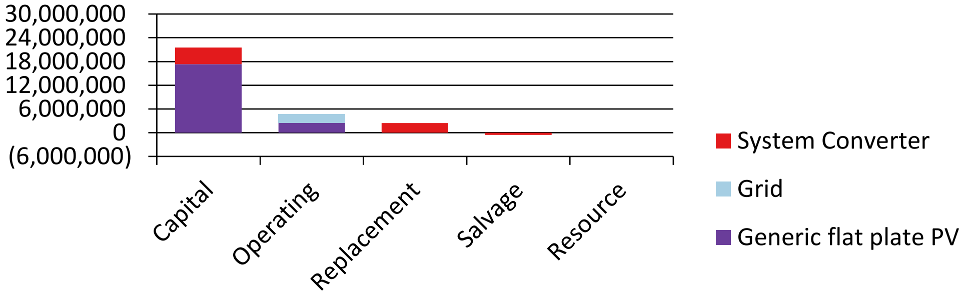


Figure 18: Cost Graph for model 1

Table 7: Net Present Costs of Model 2

Name	Capital	Operating	Replacement	Salvage	Resource	Total
Generic flat plate PV	$17.3M	$2.54M	$0.00	$0.00	$0.00	$19.9M
Grid	$0.00	$2.23M	$0.00	$0.00	$0.00	$2.23M
System Converter	$4.22M	$0.00	$2.46M	-$573,020	$0.00	$6.10M
System	$21.6M	$4.77M	$2.46M	-$573,020	$0.00	$28.2M

Table 8: Annualized Cost of Model 2

 doi:10.20944/preprints202210.0036.v1

Name	Capital	Operating	Replacement	Salvage	Resource	Total
Generic flat plate PV	$1.07M	$156,709	$0.00	$0.00	$0.00	$1.23M
Grid	$0.00	$137,761	$0.00	$0.00	$0.00	$137,761
System Converter	$260,129	$0.00	$151,842	-$35,351	$0.00	$376,619
System	$1.33M	$294,471	$151,842	-$35,351	$0.00	$1.74M

4. Conclusion

Pakistan imports electricity from Iran because of the absence of national grid in the Gwadar city. Pakistan's electricity constraints are also a hindrance for electricity transmission to Gwadar city. Therefore, Microgrid is studied in this research. Wind Turbine and PV modules are selected to fulfill the 70MW load demand. In this framework, two different models are considered. Model-1 comprises of Wind Turbine, PV, Converter and Battery system while Model-2 consists of Wind Turbine/ PV/Grid and Converter. The yearly generation of Model-1 and Model-2 is 57.37 GWh and 81.5 GWh, respectively. The LCOE for Model-1 and Model-2 is respectively $0.401/kWh and $0.0347/kWh. The simple payback of Model-1 is of 6.70 years and of Model- 2 is 7.77 years. Due to the high LCOE of Model-1, its payback years count is lesser than the Model-2. All these facts indicate that Model-2 is the most optimal approach for providing the hybrid renewable energy based electricity supply to Gwadar. This study will help the consumer of Gwadar to have cheap electricity. The government of Pakistan will not need to import electricity from Iran. Furthermore, when the electricity issue is resolved for Gwadar, new industries will open and improve the economy and lower Pakistan's unemployment. The LCOE cost can be reduced by adding another renewable energy source. This idea will be explored in future. Moreover, the feasibility of using this micro grid as a distributed generating sources in smart gird will be investigated.

Author Contributions: Conceptualization, M.S.A., S.U.A., A.W., and S.M.Q.; methodology, M.S.A., S.U.A., A.W., and S.M.Q.; implementation, M.S.A., and S.U.A. ; validation, S.U.A, S.M.Q., F.H., and A.W.; formal analysis, M.S.A., S.U.A., F.H., and A.W.; investigation, S.U.A., A.W., and F.H.; resources, A.W. and A.A.; writing—original draft preparation, M.S.A., S.U.A., and A.W.; writing—review and editing, S.M.Q., A.W., F.H., and A.A.; visualization, M.S.A., and S.U.A.; supervision, A.W., S.M.Q., and A.A.; project administration, S.M.Q., A.W., and A.A; funding acquisition, S.M.Q., and A.A. All authors have read and agreed to the published version of the manuscript.

Funding: The authors would like to thank the Deanship of Scientific Research at Najran University for funding this work under the Research Collaboration Funding program grant code (NU/RC/SERC/11/1).

Institutional Review Board Statement: Not Applicable.

Informed Consent Statement: Not Applicable.

Data Availability Statement: In this section, please provide details regarding where data supporting reported results can be found, including links to publicly archived datasets analyzed or generated during the study. Please refer to suggested Data Availability Statements in section "MDPI Research Data Policies" at https://www.mdpi.com/ethics. You might choose to exclude this statement if the study did not report any data.

Acknowledgments: The authors are grateful to Bahria School of Engineering and Applied Sciences, Bahria University Islamabad and Effat University, Jeddah, Saudi Arabia for technical support. The authors also acknowledge financial support from the Deanship of Scientific Research at Najran University for funding this work under the Research Collaboration Funding program grant code (NU/RC/SERC/11/1).

Conflicts of Interest: The authors declare no conflict of interest.

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