Journal of Autonomous Intelligence (2022) Volume 5 Issue 2.
doi: 10.32629/jai.v5i2.540

Original Research Article

Evaluating the Technical and Economic Feasibility of a Hybrid Renewable Energy System for Off-grid

Nikita Yadav[1], Yashwant Sawle[2], Baseem Khan[3,5*], Yini Miro[4,5,6]

[1] *Department of Chemical Engineering, Madhav Institute of Technology & Science, Gola ka Mandir, Gwalior 474005, Madhya Pradesh, India*

[2] *Department of Electrical Engineering, Madhav Institute of Technology & Science, Gola ka Mandir, Gwalior 474005, Madhya Pradesh, India*

[3] *Department of Electrical and Computer Engineering, Hawassa University, Hawassa, Ethiopia*

[4] *Higher Polytechnic School, Universidad Europea del Atlántico, C/Isabel Torres 21, 39011 Santander, Spain*

[5] *Department of Project Management, Universidad Internacional Iberoamericana, Campeche 24560, Mexico*

[6] *Department of Project Management, Universidad Internacional Iberoamericana, Arecibo 00613, Puerto Rico, USA*

ABSTRACT

This study describes the best hybrid energy system in terms of emissions, cost, and other factors. All the computations performed by HOMER Pro. A standalone hybrid power system model is suggested in this study. The suggested concept combines diesel generation with PV and Wind energy sources. The National Aeronautics and Space Administration (NASA) provided the data for simulation in HOMER to determine system performance. To reduce dependency on either conventional energy or renewable energy sources, a hybrid renewable energy system may be employed. Studies have shown that the suggested approach and the optimization technique for sizing standalone hybrid power systems both settle really well. The study aim is to optimize the size and expense of a renewable energy system at the chosen location in order to satisfy the electrical demand. The evaluation of the hybrid systems is based on the net present cost (NPC), levelized cost of energy (COE), initial cost, operating cost, and renewable fraction. The results support the use of RES at the chosen location, with the PV-Wind-Diesel generator system emerging as the most cost-effective RES with a COE of 0.2424 $/kWh. The outcomes are in favor of using a hybrid renewable system.

Keywords: *Renewable Energy System; PV; Wind; HOMER; Cost Analysis; Optimal Sizing*

ARTICLE INFO
Received: Dec 28, 2022
Accepted: Feb 19, 2023
Available online: Feb 27, 2023

***CORRESPONDING AUTHOR**
Baseem Khan
baseem.khan04@gmail.com

CITATION
Yadav N, Sawle Y, Khan B, Miro Y. Evaluating the Technical and Economic Feasibility of a Hybrid Renewable Energy System for Off-grid. Journal of Autonomous Intelligence 2022; 5(2): 13–23. doi: 10.32629/jai.v5i2.540

1. Introduction

This Universe is gifted by nature with numerous non-replenishable energy resources which might be sufficient to perform the energy necessities of the world, however, the time requires to discover them for green utilization. In the development of the country, energy is taken as a key factor. To solve energy and environmental issues, the global is looking for easy environmentally pleasant renewable energy sources. As we all know, renewable energy resources cannot replace fossil fuel technology, however, can satisfy the energy need to a significant level[1]. Fossil fuels were formed when dead organic matter, primarily plants and marine creatures, underwent biological decomposition. Organic matter is converted into hydrocarbons and fossil fuels through multifaceted chemical reactions in the geological cycles when it is buried and shielded from oxidation. However, the three primary fossil fuels—coal, oil, and natural gas—remain: crude oil (petroleum), oil shale, bitumen deposits, and tar sands. Oil shale, bitumen formations, and tar sands, along with other non-fossil energy resources, have the potential to become more significant when coal, oil, and natural gas supplies are exhausted.

The fact that fossil fuels take millions of years to generate and that their supplies are depleting considerably quicker than they are replenishing makes their non-renewable resources. Liquefied petroleum gas (LPG), which is mostly produced from the production of natural gas, is another prevalent fossil fuel. The stocks of both radioactive elements and fossil fuels are limited. So, these resources will ultimately run out due to human activity. There is evidence that some places are running out of specific types of fossil fuels, however, it may not be apparent how soon this will occur[2].

Fossil fuels have the ability to produce massive quantities of electricity in one place. Finding them is quite simple. Power plants are highly economical when coal is utilized in them. Gas-powered power plants have high levels of efficiency. Almost in any location fossil fuel-based power plants can be constructed. The primary drawback of fossil fuels is pollution. This is due to the greenhouse effect they produce when burned, which releases carbon dioxide and contributed to the current earth's global warming. When burnt, coal releases more carbon dioxide than burning oil or gas does. It also emits sulphur dioxide, a chemical that contributes to acid rain. Also, the use of crude oil contributes to hazards and risks, such as oil falls when oil ships, for instance, suffer leaks or perish at sea, representing a threat to the environment. Toxic compounds in crude oil are released into the air when they are burned, causing air pollution[3]. Many issues have arisen as a result of the use of fossil fuels as a primary resource in the generation of electricity. Such problems can be avoided or reduced by utilizing renewable energy such as wind, sunlight, geothermal heat, and water etc. Some issues are like global warming where the use of fossil fuels in producing electricity resulted numerous health and environmental problems. Sea level and the earth's temperature are affected by global warming. Air pollution is also affected by GHG[4]. The development of renewable energy policies plays an important role in reliable and green energy supply. There are different technologies, such as thermal and photovoltaic systems, developed to yield the benefit of solar energy[5]. Renewable energy is naturally reloaded on a human time scale and won't run out, sources such as wind, sunlight, water and geothermal heat, etc.

Solar cells are made up of thin semiconductor wafers which create an electric field. Electrons are ejected from the semiconductor material and move in reaction to the electric field when light strikes the cell. This produces electricity. While in geothermal, water boils over at the surface and turns into steam. The generator that generates power is connected to the turbine.

In a wind source, the wind blows across a wind turbine's blades, spinning them to provide mechanical power. The driving shaft that turns an electric generator to generate power is connected to the blades. And in the hydro source, a turbine attached to an electric generator that rotates when water rushes through the dam, producing mechanical energy[6]. Photovoltaic systems have a bright forthcoming in terms of commercial feasibility as well as conservational sustainability.

The two main kinds of PV systems are – grid-tied systems, which are linked to the energy grid, and stand-alone systems, which are isolated systems. Battery storage is not necessary for grid-tied PV systems because they are always linked to the electricity grid. Houses or buildings take power from solar photovoltaic systems which help in cutting down the amount of energy needed by the utility. When the electricity generated by the solar PV system exceeds the building or business demands, the extra energy is automatically sent back to the grid. Without battery backup, a solar PV system cannot function during a power loss. Stand alone systems are completely independent of the utility grid. They produce power throughout the day and store the extra for usage at night[4].

According to their configuration, installed solar

PV systems fall into one of two categories: fixed PV systems or PV tracking systems. PV tracking systems are far more effective than fixed systems because they can follow and have their face towards the sun for more time during the day, therefore tracking systems capturing more solar energy. To receive the most average solar energy, fixed PV systems are typically oriented southward in the northern hemisphere and northward in the southern hemisphere. In contrast to fixed PV systems, PV tracking systems need more area, and some of the power generated is used to track the sun. However, there is a trend toward more PV systems being installed globally. Their primary benefits are their low maintenance requirements and quiet operation. The high starting prices of PV systems are one of its weaknesses. The cost of PV systems has been steadily declining since 1970[7,8]. PV's aspect is ideal for remote places without access to the general grid. PV is a promising, clean-burning renewable energy source with a proven track record of producing reliable power. The flexible design of a PV system makes it equally easy to employ in both small and big systems. Given that PV is one of the industries with the fastest global growth, it is a proven method for converting solar irradiance into electricity to address future energy challenges[9].

India is one of the nations whose per capita energy consumption is still below the global average, and its energy demand is rising as a result of its growing population. As of June 30, 2021, India has a total installed power plant capacity of 384.11 GW, of which 96.95 GW, or 25.24%, were renewable power plants. On July 6, 2021, India's greatest peak load demand was 197.06 GW[10].

2. Software tools used for the design of a hybrid system

The reservation of fossil fuels is a global issue since their emissions affect the environment. On the other hand, renewable energy sources may generate electricity and are freely accessible in nature. We are moving toward a hybrid system since using only one renewable energy source is expensive and unreliable because they are seasonal and do not work constantly throughout the year. Due to the complexity of hybrid system solutions, software tools for design, analysis, simulation, economic planning, and optimization are required. Today's simulations are used all around the world. The software has therefore become accessible and affordable. Numerous software programs have been created to address issues with optimal layout or size, which raises installation costs. The author discussed HOMER, RETScreen, PVsyst, and iHOGA.

2.1 HOMER

Hybrid Optimization Model for Electric Renewables is referred to as HOMER. It is the most popular software. HOMER is a optimization software, that make things easy to evaluate designs of grid connected and off grid systems[11]. In 1993, Mistaya Engineering of Canada created HOMER for the National Renewable Energy Laboratory (NREL) of the United States. Simulated behavior, optimization, and sensitivity analysis are its three principles on which it works. Based on the setup of the system, the simulation conducts energy balance calculations. A list of configurations based on total net current cost is shown by an optimization procedure. The method accounts for estimates for fuel and actual interest expenses as well as costs associated with installation, replacement, operation, and maintenance. Sensitivity analysis quantifies a variety of variables, including wind speed and fuel price. HOMER assesses power system designs for grid-connected and stand-alone applications. It presents simulation results in a variety of tables and graphs that make it easier to compare setups and assess their economic viability.

2.2 RETScreen

The Canadian Ministry of Natural Resources established the Renewable Energy Technologies Screen (RETScreen) to assess the costs of the economy and the environment. It may be accessed for free. It includes more than 5,000 ground stations, energy resource maps, hydrological data, and product data in its database of the world's climate. The RETScreen Plus and RETScreen 4 versions of the software are both available. RETScreen Plus performs energy performance analyses. An energy management programme for Windows is called RETScreen Plus. Analysis of energy project is done using RETScreen 4, which is based on Microsoft Excel. It offers the following analyses for the users: financial analysis, sensitivity or risk analysis, cost analysis, emission analysis, and energy analysis.

2.3 PSyst

Pumping, stand-alone, grid-connected, and DC-grid systems all employ PVsyst. It carries out simulation, data analysis, and sizing. English, French, German, Spanish, and Italian are all supported via the software's multilingual interface. Windows 7, Windows 8, and Vista are the operating systems for this app. PVsyst offers a number of objects to demonstrate shading settings, the ability to construct numerous PV fields, and the flexibility to simulate PV systems with different orientations. This produces graphs of component behavior, electrical PV array behavior under partial shade, graph comparison with clear day model, development of hourly synthetic meteo files from monthly data, rapid meteo calculations on hourly meteo plots, and irradiation calculation as output.

2.4 iHOGA

It is a genetic algorithm-modified hybrid optimization. Spain's University of Zaragoza is the creator of iHOGA. It used to be known as HOGA. It is the iGRHYSO in a modified form. iHOGA is available in two versions: EDU and PRO. The free EDU version of iHOGA has several restrictions, but the paid PRO version has no restrictions. Only the Spanish version of iHOGA is accessible. Only Windows XP, Vista, 7 or 8 support it. This programme is utilized to study the impact of temperature on wind and solar energy output. Life cycle emissions are computed. This tool also takes into account various grid power sales and purchases. In this programme, data exports are possible. Models from iHOGA are quite accurate.

There have been several advances in software programming that allow for the unfettered analysis of hybrid systems in our day and age. All of the software tools are user-friendly. With the use of these software tools, we are able to assess the hybrid system extremely quickly[3,12].

3. Methodology

HOMER: The HOMER programme from the National Renewable Energy Laboratory (NREL) was used to select and size the hybrid power system's components. Software like HOMER is easy to use. The primary function of HOMER is to simulate the long-term performance of a micropower system[13]. Making decisions regarding the components to include in the system design, the size of each component to employ, and other configuration choices are necessary while developing a power system. These choices are challenging due to the abundance of technological possibilities, the wide range of technological prices, and the accessibility of energy supplies. Evaluation of the various system configurations is made simpler by HOMER's optimization and sensitivity analysis techniques[14].

This simulation capacity is essential to its higher-level capabilities, including optimization and sensitivity analysis. The simulation procedure determines how a certain system configuration, a combination of system elements of particular sizes, and an operating strategy that specifies how those elements interact, would behave in a specific context over an extended period of time.

A PV array, one or more wind turbines, a run-of-river hydro turbine, and up to three generators, a battery bank, an ac-dc converter, an electrolyser, and a hydrogen storage tank are just a few of the micropower system configurations that HOMER can simulate. The system can support both ac and dc electric loads as well as a thermal load and can be grid-connected or stand-alone. Photovoltaic array, wind generator, converter, load, and battery make up this system. The simulation approach accomplishes two objectives. To begin with, the system's viability is assessed. If the system can supply the electric load properly and adhere to any additional user-imposed requirements, HOMER deems it to be practical.

The system's life-cycle cost, or the entire cost of instalments and running it during its lifespan, is then calculated. Real-time weather data has been used in simulation studies to predict the system performance in various scenarios. A system must then be optimised. HOMER simulates a variety of system configurations for the optimization process, eliminates the unfeasible ones, ranks the feasible ones according to total net present cost, and then presents the feasible one with the lowest total net present cost as the ideal system configuration. A choice variable is a variable that the system designer has influence over and for which HOMER's optimization method can take into account many potential values.

The following are some potential HOMER decision variables: PV array size, WG count, the size of the DC/AC converters, and the battery capacity[13].

4. System sizing

A system implementation and the Hybrid Optimization Model for Electrical Renewable (HOMER) software are used to size the hybrid energy system. A converter is involved in the system to connect between AC and DC links. The proposed system consists of primary renewable sources (wind/PV) that are combined with standby secondary non-renewable sources (diesel generators/batteries). The best ideal system size and pre-feasibility study are calculated using the HOMER programme. During system design, sensitivity analysis is taken into account. By deciding on the best combination of solar, wind, diesel generator, battery, and converter components for renewable energy systems, the designer must determine the optimal size[15]. The designer must also input the relevant data into HOMER Pro, such as life span, quantity, capacity, efficiency, peak and average load, average energy, and cost requirement for capital etc.

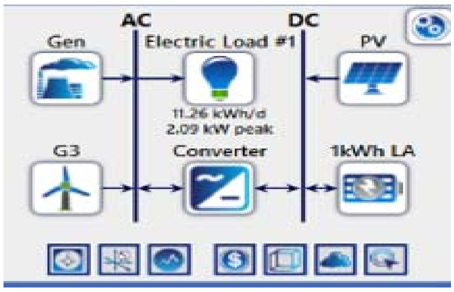

Figure 1. Schematic circuit diagram.

4.1 Resources availability

In the HOMER Pro simulation, the intended site location is situated at 21*29.5'N latitude and 73*24.4'E longitude. This site receives 5.23 kWh/m^2/day of annual average worldwide horizontal sun radiation. This location has a 5.67 m/s annual average wind speed. SRF Camp in Solapur, Maharashtra, is the location. The position here is ideal for both wind speed and sun radiation.

Table 1. Solar, wind, and temperature data

S. No.	Month	Clearness index	Solar radiation (kWh/m^2/day)	Wind average speed (m/s)	Temperature (°C)
1.	Jan	0.658	5.160	4.570	22.760
2.	Feb	0.661	5.790	4.470	25.640
3.	Mar	0.650	6.380	4.390	29.560
4.	Apr	0.612	6.460	4.340	32.510
5.	May	0.595	6.440	6.060	32.740
6.	Jun	0.470	5.090	7.350	28.200
7.	Jul	0.423	4.560	8.240	26.220
8.	Aug	0.422	4.470	7.590	25.710
9.	Sept	0.490	4.910	5.280	25.820
10.	Oct	0.560	5.060	4.720	24.890
11.	Nov	0.621	4.980	5.150	22.930
12.	Dec	0.641	4.820	5.030	21.600
Annual average			5.34	5.60	26.25

4.2 Load demand profile

The highest daily average based annual energy use is 11.26 kWh/day, while the highest peak load consumption is 2.09 kW. The load pattern was observed to remain continuous from January through December. Weekly and weekend loading patterns are based on monthly averages, the steady load trend observed from January through December. Hybrid power systems, which are standalone power plants that produce electricity using a combination of solar panels and wind turbines, are designed and improved by HOMER. The simulation makes use of an average household load. The lighting, tv, air cleaner, dryers, press, and other appliances in a normal home all require power. Using HOMER, distinct daily load profiles may be established for each month and weekday. Load profiles can be different from weekend load profiles. The user may, however, only specify one profile for the entire year if they want. A user's modifications to a daily load profile are carried over to the next year. When the user initially opens the load window, the daily load profile for a January weekday is copied to subsequent months of the year, including weekdays and weekends. Therefore, the load profile is relevant every day of the year. Changes to the month and day types in the drop-down boxes can be made to verify that the load profile graph remains the same. The user might also create a time-series plot or a map of the load data by selecting the Plot button.

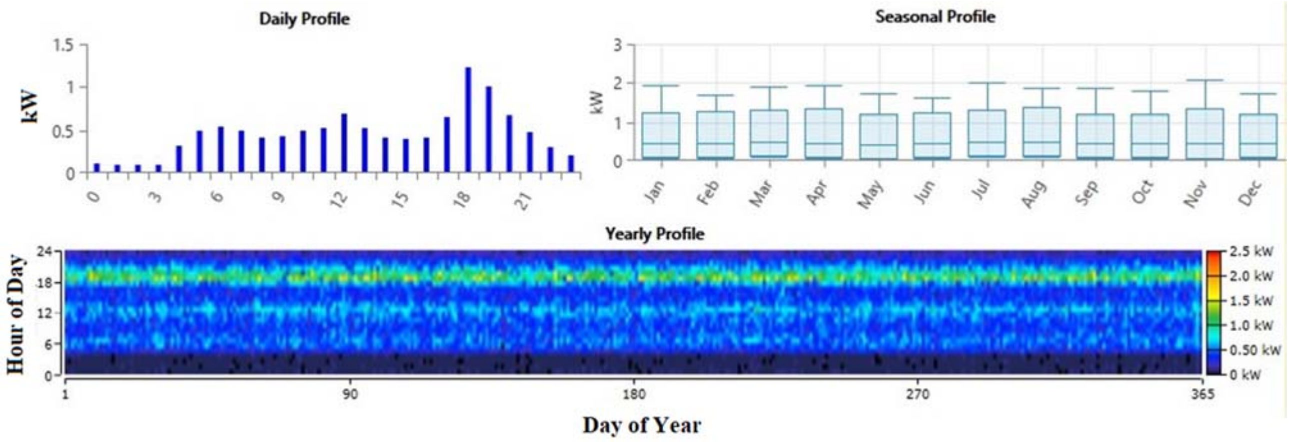

Figure 2. Load profile of the proposed system.

4.3 Solar PV

To fulfil the need for electricity, the solar-powered PV system converts sunlight-based irradiance into solar-powered energy. It basically operates while the sun is shining, and the excess energy created by the PV is used to charge the backup batteries, which may be used to satisfy the needed load in particular during the night when there is no solar-oriented vitality. This study makes use of a standard flat plate PV. The solar PV's specific expenses, which include startup costs, replacement costs, and operation and maintenance costs, are $850, $850, and $10. Solar PV has a 25-year lifespan. The PV derating factor is 80%[16].

$$P_{PV} = Y_{PV} f_{PV} \left(\frac{\overline{G}_T}{\overline{G}_{T,STC}} \right) \left[1 + \alpha_P \left(T_c - T_{c,STC} \right) \right]$$

Where, Y_{pv} is the rated capacity of the PV, f_{pv} represents the PV derating factor [%], T_c shows the PV cell temperature in the current time step and $T_{c,STC}$ shows the PV cell temperature under standard conditions(25 °C).

4.4 Wind

Since the Middle Ages, wind energy has been extensively utilized. Wind power is solar energy's inverse form. Two processes lead to the formation of wind: 1) solar energy absorption on the planet's surface and in the atmosphere, and 2) the rotation of the earth around its axis and its orbit around the sun. The kinetic energy of moving air is converted into mechanical motion by a wind turbine, which frequently takes the shape of a spinning shaft.

This mechanical process might result in the production of electricity. The advantage of using wind energy is that it doesn't pollute and has a respectable amount of potential as an energy source. In order to convert the kinetic energy of the wind into AC or DC electric energy depending on the power curve, a basic model of a wind turbine with a hub height of 17 m was chosen and developed using HOMER. According to this research, a wind turbine has a $900 initial cost and a 20-year lifespan. For modelling a building with one or more wind turbines, the HOMER user needs to have knowledge of the wind resource, which shows the range of wind speeds that will occur over a typical year[16].

4.5 Diesel generator

When renewable energy sources are not enough to meet the actual load need, the diesel engine is incorporated into hybrid systems to provide additional power. Due to delivery expenses, the price of fuel varies depending on the location. In general, the cost of fuel is higher in regional locations since there are additional freight costs associated with delivering gasoline to certain communities. The diesel generator used for this investigation is an auto-size genset. The three costs are $500, $500, and $0.30 respectively for capital, replacement, and operation and maintenance. A diesel generator lasts 15,000 operational hours. The generator's minimum load ratio is 25%[16].

Generators have two types of dispatch method, the first is load following and the second is cycle-charging. The load following strategy is a dispatch strategy which produces only enough power to meet the primary load while the cycle-charge strategy operates at full output power. Results were obtained by load following dispatch strategy.

4.6 Battery

For this feature, a standard lead-acid rechargeable battery with a nominal capacity of 1 kWh and a nominal voltage of 12 V is used. Additionally, it has an 80% roundtrip efficiency, and the battery may last up to 10 years. When the load cannot be met by RES and when the battery capacity is fully depleted, a backup diesel generator supplies the electricity. Battery and controller were also created as major components of the system since it was thought that it would operate continuously. HOMER assumes that the qualities will not change throughout the course of the battery's life due to environmental conditions like temperature. The selected battery has a capacity of 12 V, 83.4 AH. The approximate cost of the battery is $150 and the replacement cost is $120. It is estimated that each battery will provide 800 kWh of output during its lifetime[16].

4.7 Converter

A generic converter with a 95% efficiency and 100% rectifier relative capacity is employed in this paper. A circuit known as a converter changes DC power into AC power. For all sizes taken into account, it is expected to have a 95% efficiency. A typical inverter costs 150 dollars, costs 130 dollars to replace, and lasts up to 15 years[16].

8. HOMER simulations results

HOMER runs simulations frequently while taking into account all inputs to determine the most appropriate result. A classified and overall display of the optimization results is given, highlighting the absolutely best architecture that satisfies all inputs and design constraints. All feasible configurations were simulated, and the final results are displayed in **Figure 3**.

Architecture						Cost				System		Gen			
PV (kW)	G3	Gen (kW)	1kWh LA	Converter (kW)	Dispatch	NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)	Total Fuel (L/yr)	Hours	Production (kWh)	Fuel (L)	C
2.10	1	2.30	12	1.69	LF	$12,770	$0.240	$540.72	$5,780	97.1	55.1	207	121	55.1	1
4.40		2.30	15	1.78	LF	$15,392	$0.290	$634.74	$7,187	93.0	130	481	288	130	3
	2	2.30	11	1.30	CC	$17,753	$0.334	$1,002	$4,794	75.4	313	580	1,011	313	4
9.87			28	2.21	CC	$20,240	$0.381	$604.01	$12,431	100	0				
9.95	1		24	2.35	CC	$21,958	$0.413	$707.45	$12,813	100	0				

Figure 3. Optimized input for OFF grid system.

According to the NCP, the outcomes are rated from the maximum lucrative to the least profitable (top to bottom). It should be well-known that the hybrid system has a CEO of $0.242/kWh and is the least costly version. With a $12,877 investment, this system comprises of a 2.10 kW PV, a 2.30 kW diesel generator, a 12 kWh battery, and a 1.69 kW converter. Numerous technical and financial information on each system configuration that HOMER models is shown in the simulation results window. The best setup, whose technical and financial information are then displayed, is what the initial double click is interested in.

Total NPC:	$12,877.11
Levelized COE:	$0.2424
Operating Cost:	$540.85

Figure 4. Economic output of proposed system.

Using all renewable energy sources (solar PV, wind turbine, diesel generator) and components (battery, converter), the system was optimized, and the results are displayed in **Figure 5**. In addition to information on the potential annual energy output from renewable energy sources, these cost statistics also contain information on the cost of energy (COE), net present cost (NPC), operational cost, and capital cost.

To calculate the COE, HOMER software divides the annualized cost of producing electricity by the total electric load served, using the following equation:

$$COE = \frac{C_{ann,tot} - c_{boiler} H_{served}}{E_{served}}$$

Where, $C_{ann,tot}$ represents the total annualized cost of the system ($/yr), C_{boiler} shows the boiler marginal cost ($/kWh), H_{served} shows total thermal load served (kWh/yr), E_{served} shows the total electric load which will served by the system (kWh/yr).

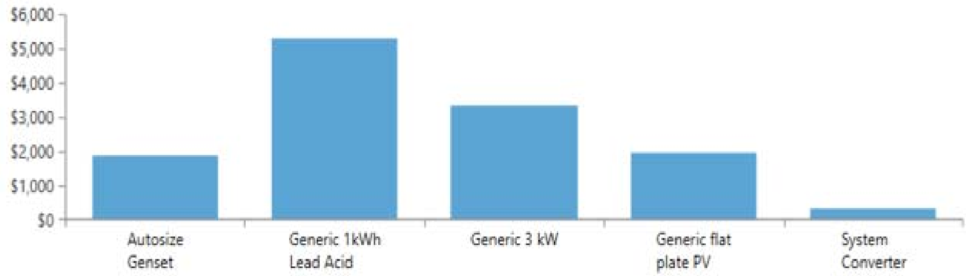

Figure 5. Cost summary of all the components.

In the **Figure 5**, energy production from system converter is very less around $400 and from battery energy production was very high around $5,300. And others will be shown in **Figure 5**.

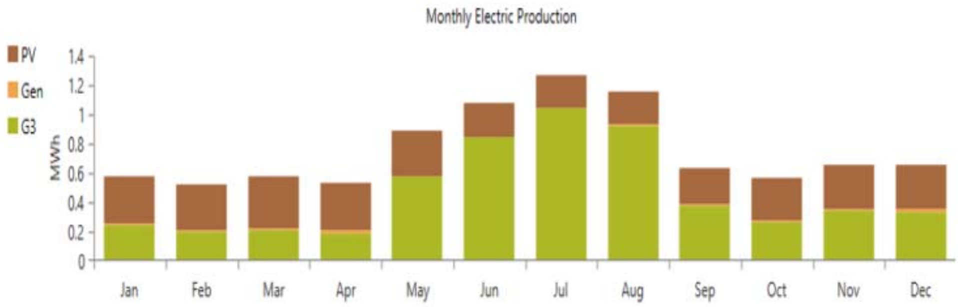

Figure 6. Monthly electric production.

Figure 6 shows the data of monthly electric production of the system. This figure shows that electricity generation from the wind turbine had a large portion of the electricity production in this system. It is clear that wind produces more electricity than PV and generator produce. Monthly electric production varies seasonal-wise. In the month summer season, production of electricity through wind is high and low between winter and spring. In the winter and spring seasons, electricity the production through PV is high.

The suggested technique can potentially meet the community's load requirements while also being environmentally gentle. Due to the Indian government's efforts, these kinds of projects are often easy to build in rural locations. The Indian government is implementing helpful policies to enable consumers to use green energy for their daily load requirements, therefore reducing their reliance on coal-fired power plants. The above-proposed solution is determined to be the best one from a low energy cost and efficiency point of view in the areas that experience an energy crisis or have grid electricity availability for a certain duration.

Additionally, there is a large amount of greenhouse gas emission from the fuel of a comparable traditional system. The emission of all these hazardous gases may be significantly decreased by implementing PV technology. Greenhouse Gases (GHG) reduction is one of the crucial factors for verifying the best-case study site. Therefore, if the suggested example were to be followed, the model calculates the overall percentage and yearly decrease in the quantity of greenhouse gas emissions that would result.

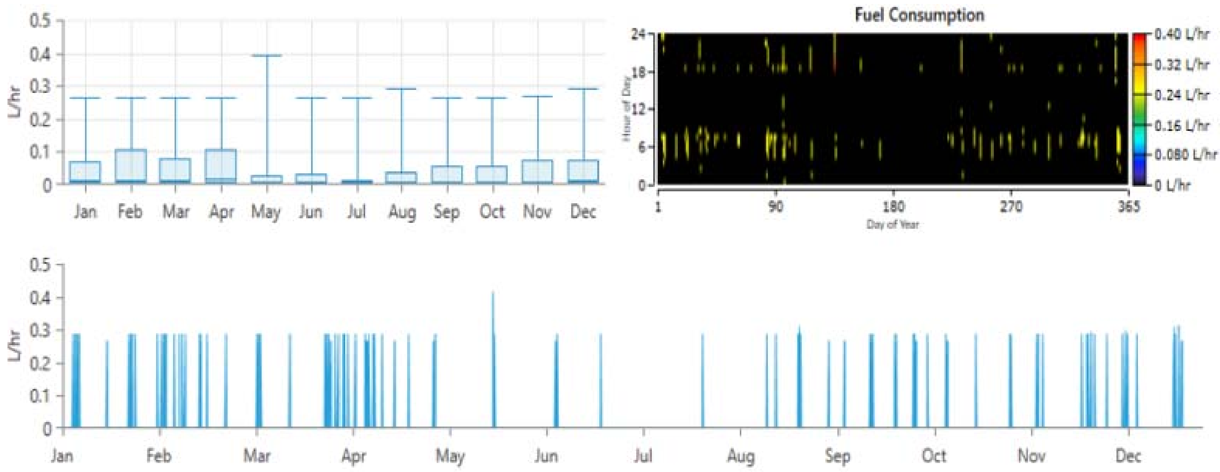

Figure 7. Fuel summary of the proposed system.

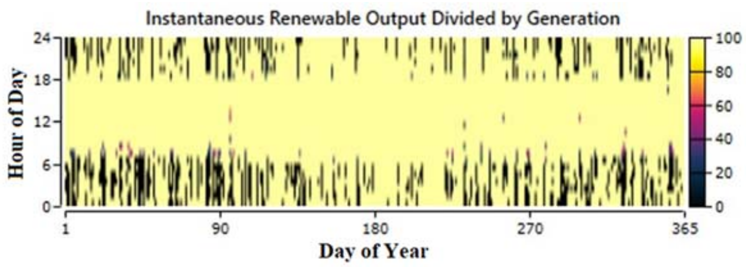

Figure 8. Renewable penetration of the system.

Quantity	Value	Units
Carbon Dioxide	144	kg/yr
Carbon Monoxide	0.909	kg/yr
Unburned Hydrocarbons	0.0397	kg/yr
Particulate Matter	0.00551	kg/yr
Sulfur Dioxide	0.353	kg/yr
Nitrogen Oxides	0.854	kg/yr

Figure 9. Emissions profile.

It is advised that solar photovoltaic power plants be built in the study area in order to gain new knowledge and promote PV technology in the local environment.

9. Outcomes and discussion

The proposed methodology would perform efficiently in the Solapur area because of improvements in performance and lower mechanism costs. The solar radiation at this site is 5.34 kWh/m^2/day, which is more than adequate to generate electricity using the proposed system method. The system's NPC acquisition cost is $12,877 for 25 years of operation. This study focuses on the investigation of the proposed methodology's performance and economic viability for the region of Maharashtra, India.

According to the literature review, several renewable energy sources, including solar, wind, and diesel generators, should be combined to fulfil the rising need for energy. Therefore, the focus of this article is on calculating the installation capacity of a renewable energy source by design. Analysis using HOMER Pro in a manner that ensures the generated power matches the same load request from users. It is evident that identical HRES ratings will not be acceptable for all sites, thus it is necessary to identify workable combinations, calculate the ideal size, and conduct the cost analysis[15].

10. Conclusion

The HOMER simulation has shown the cost-effectiveness of the hybrid PV/Wind/Diesel system. Utilizing wind turbines and solar panels in the research area was found to be economically sustainable, and because of the area's geographic location, the wind speed was suitable for the turbine, and sunlight was pleasant for the radiation. The method for modelling and optimizing hybrid renewable energy systems is presented in this study. The simulation results show that the PV/Wind/ Diesel Generator system with a COE of 0.2424 $/kWh is the most economically feasible system configuration for the selected location. This approach takes into account all economic expenses, including capital costs, replacement costs, operating costs, and maintenance costs.

We may conclude that this technology is essential in the future to prevent an energy crisis based on what we have seen so far. For data of solar irradiance and wind speed at Srf camp, Solapur, the suggested model is created and examined in HOMER. HOMER presents a list of configurations that are ranked by net present cost, also known as lifespan cost, after simulating all possible system configurations. To evaluate different system design solutions, this net present cost is utilized. The results given in this research provide strong evidence that the comparative economic analysis conducted with each configuration evaluated the optimal system design. Therefore, HOMER is useful in choosing a feasible design by performing an energy balance configuration for each hour.

Conflict of interest

The authors declare that there is no conflict of interest.

References

1. Mehmood A, Shaikh FA, Waqas A. Modeling of the solar photovoltaic systems to fulfill the energy demand of the domestic sector of Pakistan using RETSCREEN software. 2014 International Conference and Utility Exhibition on Green Energy for Sustainable Development (ICUE); 2014 Mar 19-21; Pattaya. New York: IEEE; 2014. p. 1-7.
2. Deswal S. Energy, environment ecology & society. New Delhi: Dhanpat Rai & Co. (P) LTD.; 2020.
3. Boyle G. Renewable energy: Power for a sustainable future. 2nd ed. Oxford: Oxford University Press; 1996.
4. Albadi MH, Al Abri RS, Masoud MI, *et al*. Design of a 50 kW solar PV rooftop system. International Journal of Smart Grid and Clean Energy 2014; 3(4): 402-409. doi: 10.12720/sgce.3.4.401-409.
5. Zandi M, Bahrami M, Eslami S, *et al*. Evaluation and comparison of economic policies to increase distributed generation capacity in the Iranian household consumption sector using photovoltaic systems and RETScreen software. Renewable Energy 2017; 107: 215-222. doi: 10.1016/J.RENENE.2017.01.051.
6. Bhutada G. What are the five major types of renewable energy? [Internet]. Vancouver: Visual Capitalist; 2022 [updated 2022 Jun 9]. Available from: https://www.visualcapitalist.com/what-are-the-five-major-types-of-renewable-energy/.
7. Lee-Jones D. Feasibility study of building integrated hybrid solar PV and wind power systems: A case-study on the Swedish Island of Gotland. Uppsala: Uppsala University; 2016.
8. Mirzahosseini AH, Taheri T. Environmental, technical and financial feasibility study of solar power plants by RETScreen, according to the targeting of energy subsidies in Iran. Renewable and Sustainable Energy Reviews 2012; 16(5): 2806-2811. doi: 10.1016/J.RSER.2012.01.066.
9. Khalid A, Junaidi H. Study of economic viability of photovoltaic electric power for Quetta–Pakistan. Renewable Energy 2013; 50: 253-258. doi: 10.1016/J.RENENE.2012.06.040.
10. Kumar S, Sethuraman C, Gopi C. Design of optimum sizing for hybrid renewable energy system using HOMER Pro to meet the identical load demand at selected Indian cities. International Journal of Grid and Distributed Computing 2021; 14(1): 1589-1607.
11. Okedu KE, Roland U. Optimization of renewable energy efficiency using HOMER. International Journal of Renewable Energy Research 2014; 4(2): 421-427. doi: 10.1234/IJRER.V4I2.1231.G6294.
12. Prashant Kumar A. Analysis of hybrid systems: Software tools. 2016 2nd International Conference on Advances in Electrical, Electronics, Information, Communication and Bio-Informatics (AEEICB); 2016 Feb 27-28; Chennai. New York: IEEE; 2016.
13. Sureshkumar U, Manoharan PS, Ramalakshmi APS. Economic cost analysis of hybrid renewable energy system using HOMER. IEEE-International Conference On Advances In Engineering, Science And Management (ICAESM-2012); 2012 Mar 30-31; Nagapattinam. New York: IEEE; 2012.

14. Salam MA, Aziz A, Alwaeli AHA, Kazem HA. Optimal sizing of photovoltaic systems using HOMER for Sohar, Oman. International Journal of Renewable Energy Research 2013; 3(3): 470-475. doi: 10.20508/IJRER.84833.
15. Thirunavukkarasu M, Sawle Y. An examination of the techno-economic viability of hybrid grid integrated and stand-alone generation systems for an Indian tea plant. Frontiers in Energy Research 2022; 10: 8. doi: 10.3389/fenrg.2022.806870.
16. Thirunavukkarasu M, Sawle Y. Design, analysis and optimal sizing of standalone PV/diesel/battery hybrid energy system using HOMER. IOP Conference Series: Materials Science and Engineering 2020; 937(1): 1-10. doi: 10.1088/1757-899X/937/1/012034.