Techno-economic assessment of Biomass energy to mitigate power shortage of Hyderabad Sindh

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Abstract
Pakistan possesses abundant renewable resources to support the power sector. The goal of this research is to close gaps and create technically sound and economically viable sustainable energy systems. This study uses HOMER software to do a techno-economic analysis of an hybrid system in Hyderabad, Sindh, Pakistan. In order to meet Hyderabad, Sindh, Pakistan's power needs, this paper suggests an energy model that consists of multiple case studies with varying powers (PV of 0, 292, 250, and 500 kW, BG of 1000, 1000, 750, and 500 kW) and incorporates photovoltaic, biomass generator, battery, and converter. These systems have been designed, modelled, and refined for techno-economic viability while accounting for climate data, geographic locations, and the profile of electricity demand. In order to identify the best cost-effective solutions for generating 0.90079 Megawatt hours of energy daily, a sensitivity analysis has been performed. The hybrid system's net present cost (NPC) ranges from 285.211 million to 743.182 million rupees, according to simulation results, while its cost of energy (COE) ranges from 52.51 to 136.78 rupees per kilowatt hour. To do a techno-economic assessment, a comparison study is conducted using varying power outputs from photovoltaic and biomass generators. The lowest net present cost and energy cost, at 285.211 million rupees and 52.51 rupees per kilowatt hour, respectively, are provided by the 500 kW PV and 500 kW biomass generator. Because of the benefits to the system, the research findings indicate that using biomass and photovoltaic together is a more practical and cost-effective approach. The study also demonstrated the efficiency of combining solar and biomass energy to generate surplus electricity.

Keywords: Net present cost (NPC), Cost of energy (COE), PV, biomass, hybrid system, HOMER software, and techno-economic assessment.

1. Introduction

Every nation's economy revolves around the electricity sector, which is also essential in directing the nation's advancement along the long-term sustainable development path. Ensuring that all economic sectors have access to affordable, sustainable, and dependable electric power services are essential to achieving and sustaining the nation's desired economic growth. In order to maintain energy security, self-sufficiency, affordability, sustainability, and a decrease in reliance on imported fuel-based generation, it is imperative to increase the percentage of power generated by indigenous energy sources. Pakistan is a fast-growing nation with strong industrial and economic expansion as well as an 11–13% yearly increase in energy consumption. Due to this tendency, load shedding—this can endure up to 6–8 hours in urban regions and 10–12 hours in rural ones—has resulted in energy shortages (Hayat et al, 2023). The primary cause of the shortages is the nations over reliance on non-renewable conventional energy sources including coal, natural gas, and oil. Pakistan has a total installed power generation capacity of 39772 MW, of which 63% originates from thermal energy (fossil fuels), 25% from hydropower, 5.4% from renewable energy sources (wind, solar, and biomass), and 6.5% from nuclear power, according to the National Electric Power Regulatory Authority's (NEPRA) 2021 annual report. To enhance the capacity of generation, RE system is used. (AM Soomro, et al, 2020) Under the current circumstances, resources for renewable energy (RE) can play an important role in closing the deficit. The MOE recently updated the Renewable Energy (RE) Policy 2019 in light of the current government's preference for non-conventional energy. Pakistan's government has amended its RE strategy with the goal of obtaining 60% of its energy from renewable sources, including hydropower, by 2030. This move is intended to reduce Pakistan's reliance on petroleum imports. Figure 1 shows the distribution of energy sources; however, Pakistan's per capita energy consumption is five times lower than that of China and twenty times lower than that of the USA, at 0.53 tons of oil equivalent (World Bank, 2022). It is difficult for policymakers and planners to find new and more environmentally friendly energy sources to meet energy needs without the associated drawbacks because of factors like depleting resources, increasing demand, sustainability issues, and environmental damage from burning fossil fuels. Non-renewable fuels are also more expensive. The techno-economic evaluation of biomass energy for Pakistani sustainable energy was the main emphasis of this study. To determine the optimum economic outcomes for this study, a comparative analysis between solar and biomass is conducted.

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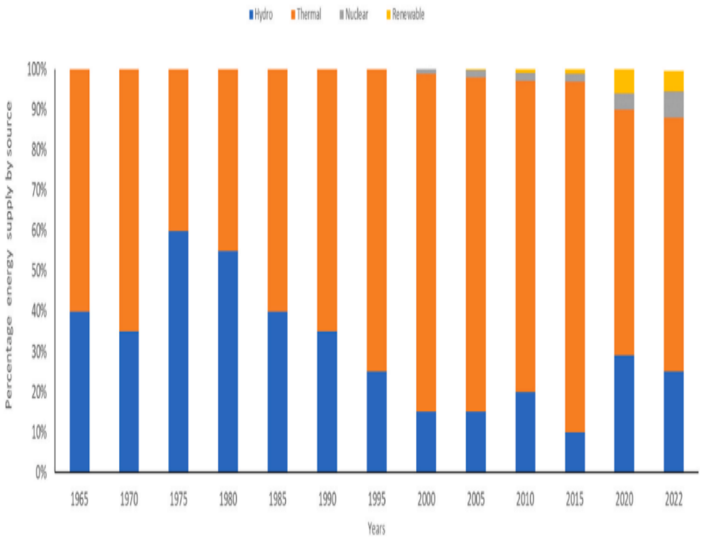
Fig 1: Share of different energy resources in Pakistan with percentage.

2. Related Work



Ali Q. Al-Shetwi (2023) gives a techno-economic analysis, using HOMER Software, of five distinct hybrid energy systems (HES)-based renewable energy sources (RES) in the northern region of Saudi Arabia. The goal of this analysis is to offer important insights into the technical compatibility, environmental implications, and economic viability of these systems. Decision-makers, researchers, and other interested parties can choose the best hybrid energy systems by using the information this research offers,which takes economic, technological, and environmental factors into account. **Amir Rashid (2023)** The aim is to model a hybrid power system that is economically and technically viable, contributes significantly to the production of clean energy, and protects the environment from harmful emissions for COMSATS University in Islamabad. A case study of COMSATS University Islamabad is presented in this essay.

The optimal choice, according to the data, was a hybrid system that included a grid and a wind turbine producing one megawatt-hour annually. **K.T. Akindeji (2023)** attempts to provide a low-cost, continuous supply to vital loads, such a university library, by utilizing a hybrid system that combines solar PV, battery storage, and a diesel generator. According to the statistics, the hybrid system outperforms the DG only when it comes to fuel savings, which are 31% and 22.3% for summer weekdays and weekends, and 29.3% and 40.7% for winter weekdays and weekends. **Amina Shahab (2022)** comprises suitably maximizing the solar potential and capacity in a specific area for a possible hybrid model in consideration of variable renewable energy and optimized software-based outcomes, like the NPC and the Cos Energy cost (COE) that have been assessed in HOMER simulations in consideration of the system's reliability, durability, income, and efficiency. According to our research, the system with a 200 MW total power generation capacity will be the most workable and cost-effective system if we use a hybrid model design that is examined for various plant capacities of 50 MW, 100 MW, 150 MW, and 200 MW and create a comparison analysis with a 25-year lifespan. It generates a four-fold profit. **Haseeb Yaqoob (2021)** Examines the potential of different wastes utilize for the production of biogas also called waste to energy (WTE) to overwhelm the crises of Pakistan and this generation of power is determined for Bahawalpur as well as for Pakistan. Total generation is 49.4 percent which is enough to mitigate the shortfall of power. It summarizes that for sustainable development, biomass is used as an environmental and eco-friendly source that could solve the issues of power in Pakistan. **David Ribo-Perez (2021)** simulation of electric generator fueling by using syngas that generates in biogas plant from some steps that include economic and technical parameters. In this research, two rural areas in Zambia and Honduras show the feasibility of the system and this system proves the feasibility of hybrid system micro grids. The demand for energy supply and distribution is LCOE (Levelized Cost of energy) by micro grid which is lower than the increasing alternative in the grid. **Krishan Lal Khatri (2021) (2021)** analyzes the gap between supply and demand in the power division of Pakistan and investigates the production of electricity from the solid waste by using a technique of distributed generation (DG) in Karachi city. The research results show that 1263.3 megawatts (MW) of power can be produced from 16000 tons of waste that are produces in Karachi city.

This research concludes that Pakistan has an immense potential to generate sustainable energy than non-renewable energy. **Milad Izanloo (2021)** Capacity utilization of renewable sources such as wind, biomass, solar, and enrichment of capacity factor and efficient power plants in Mazandaran South state in Caspian sea. The system of energy is analyzed and modeled by 6 (six) plots and shows the production of electricity from the share of non-conventional is reached from 5.4 percent to 47.7 percent. The 6th scenario shows the analysis of cost which is an integrated policy of rising share of renewable energy resource and enhances the efficiency and CF (capacity factor)and mitigate the total yearly cost, emission of CO2, and consumption of fossil fuel. **K. Kumar (2021)** An off-grid solar PV system is being installed in Pakistan, where the desert landscape is nearly entirely deprived of electricity. Solar energy will cost approximately 63 percent less in energy than utility or grid electricity, therefore installing an off-grid PV system will save a significant sum of money annually—roughly 674 million Pakistani rupees. **M. M. Samy (2020)** proposed a (MOPSO) technique to determine the optimized sizing of fuel-cell and biomass micro grid where the primary source is biomass and the backup source is fuel-cell which is used to resolve the problem of sizing for micro grid through economic aspect.

This technique tries to reduce the cost of energy to a more economical value by following the LPSP (loss of power supply probability) as little as possible. It concludes that this algorithm is stable, precise and statistical control. **M. Kumar (2020)** Non-renewable energy are helpful for the enhancement in the country economy. Though some negative environmental effects of traditional sources of energy have forced us to use them within certain bounds and have shifted our focus to renewable energy sources, traditional energy sources are still highly beneficial for boosted national economies. Utilizing renewable energy sources can avoid social, environmental, and financial issues because these resources are thought to be environmentally beneficial. In the near future, renewable energy sources will play a significant role in power generation since they can be repeatedly used to provide energy that is useful. **Muhammad Safar Korai (2019)** investigates the state of MSW management in Pakistan and China. The accumulation and disposal of MSW are continuously improved which results in the overall development of MSW management and land-filling is an effective and cost-efficient way in china. Whereas Pakistan has less effective collection and disposal arrangements. The collection rate of MSW is 60 percent and the remaining 40 percent is leftover at vacant poles or streets. So, Pakistan needs sustainable and economic technology to obtain a prompt resolution for this problem. **K.M.Ahsan-uz-Zaman (2018)** describes an analysis of feasibility for Solar-Biomass system using Hybrid Optimization Model for Electric Renewables (HOMER) software for a village in Mymensingh, Bangladesh, and compares it with a non-renewable diesel-based system of generation.

This model is determined more efficient to mitigate the deficiency of energy and provide electricity for rural areas in terms of analysis of the economy and environment features. **Rumi Rajbongshi (2017)** focuses on optimizing the configuration of system for various load profiles through the design of hybrid systems based on PV, biomass gasifier, diesel, and grid. Energy costs are computed for varying peak loads, profiles of energy use, and grid availability. The study found that, for comparable load profiles, the energy cost of an off-grid hybrid system is higher than that of a grid-connected hybrid system. The economic distance limit has been established after a comparison between grid expansion and the off-grid hybrid system has been completed. The results of the simulation indicate that a biomass gasification system is a better option than a photovoltaic system in every scenario. **Rasool Bux Mahar (2016)** by using nice (9) empirical models, assessing the potential of energy from the OFMSW(organic fraction of municipal solid waste) .

The results show that the model of empirical numbers 3 and 4 has the highest potential of energy restoration that is based on proximate analysis. **S. Mekhilef (2011)** proposes the recent state and prospects of the utilization of biomass and future strategies to promote the development in Malaysia. As power crises are increasing day by day and it has become a serious issue for sustainable development. The quantity of fossil fuel is depleting day by day and Malaysia is facing extreme growth in economy and population that require alternative sources to meet the demand. Biomass is available in large quantities and it is a sustainable source of energy. **Hongbo Ren (2010)** proposes a model of linear programming to evaluate and design of biomass system while considering the demand side. It minimizes the total cost annually with biomass CCHP (combined cooling, heating, and power) plant as well as fueled boiler as backup. The researcher assesses the biomass optimal CCHP way for a household area situated in the park of Kitakyushu Research and science, Japan, and analysis of sensitivity has been taken to determine the optimized solution would alter from some parameters that include price of biogas city gas, and electricity tariffs etc.

3. METHODOLOGY

Four systems total—photovoltaic (PV), biomass generator, battery, and converter—with varying power levels are constructed, modeled, and examined in this study using HOMER software, which uses a load-flowing dispatch technique. The methodological framework aids in the implementation of biomass projects in developing nations, and it is used as input for short- and long-term planning for Hyderabad, Sindh, Pakistan, by comparing the methodological approaches adopted for biomass and solar energy.

Study Area

Hyderabad, Pakistan was selected as the study area in this study in order to conduct a comparative analysis and techno-economic evaluation of solar and biomass energy in order to address the electricity constraint. Based on the population, it ranks as the third largest city in Pakistan and the second largest in the Sindh province. Its location on the globe is between 25°25.8 ′North and 68°16.9 ′East, and its population is roughly two million. The district of Hyderabad, Pakistan's Sindh Province, is seen in the figure.

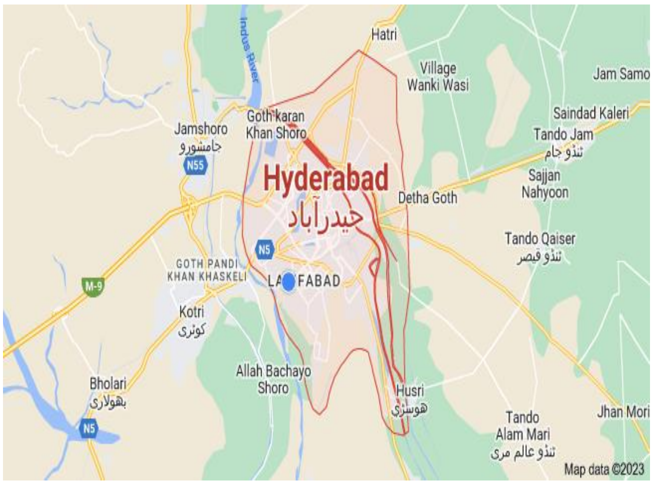


Fig 2 Map of Hyderabad Sindh

Load Demand

Determining the ideal sizes of system components and planning and implementing electrical sources both depend on the evaluation of electric load demand. The load profile is a crucial tool for the design and optimization of the energy system's component parts as it offers a thorough understanding of the features of the energy demand of the system. Modeling the demand curve is required in order to develop power sources and individual system components. The people who live in Hyderabad, Sindh, make use of a variety of standard appliances, including computers, refrigerators, air conditioners, fans, and lighting. As a result, Hyderabad's consumption schedule is taken into account while calculating the power demand. Fig. 3 shows the daily average load demand of Hyderabad, which is computed based on electricity usage. In Hyderabad, Sindh, the average daily electricity consumption is predicted to be 900.79 kWh with a peak demand of 136.2 kW. The average monthly load needs for all loads of Hyderabad are shown in Fig. 4 (Manoo et al, 2023). The predicted daily lowest and greatest load demands throughout the course of the year are determined to be between 15.56 kW and 19.14 kW and 54.86 kW and 83.08

kW, respectively. Furthermore, the annual minimum and maximum needs for daily load are 1.35 kW, 43 kW, and 79.17 kW to 133.97 kW, respectively.

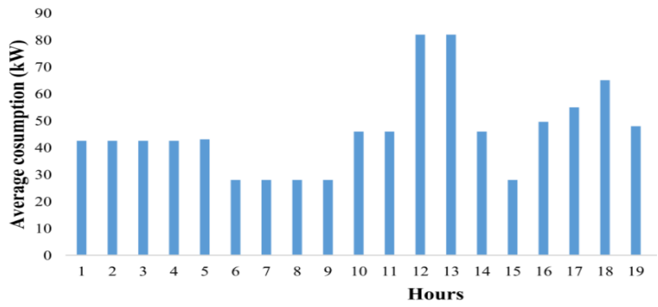


Fig 3 Curve of daily load of Hyderabad Sindh

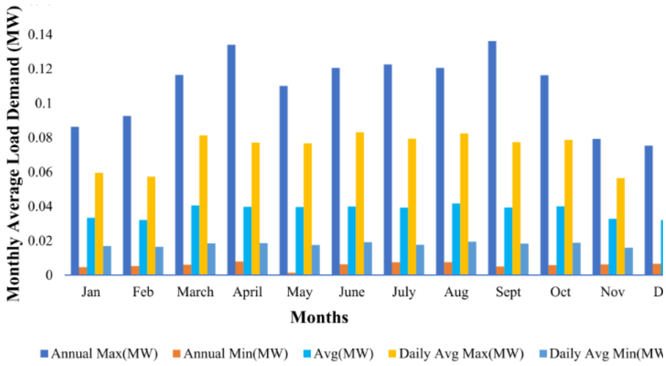


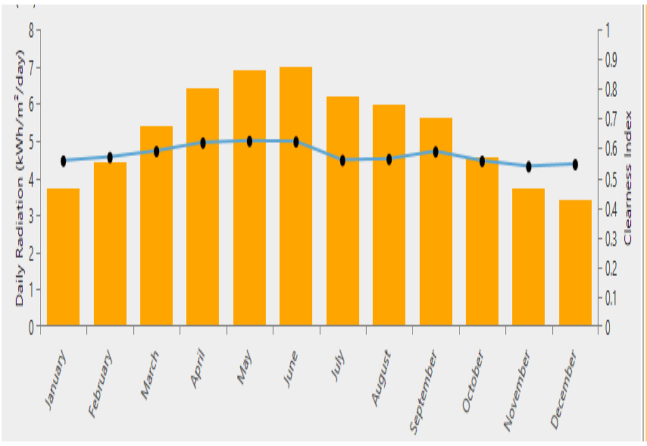
Fig 4: Monthly average demand of load

Available resources assessment

It is advised to use an energy system including photovoltaic, biomass, battery, and converter to power the study area. As a result, we examine four scenarios with varying power sources to satisfy the demand for energy. A hybrid solar/biomass electric system was taken into consideration for this instance. Thus, the comprehensive evaluation of the biomass and resources accessible is shown below:

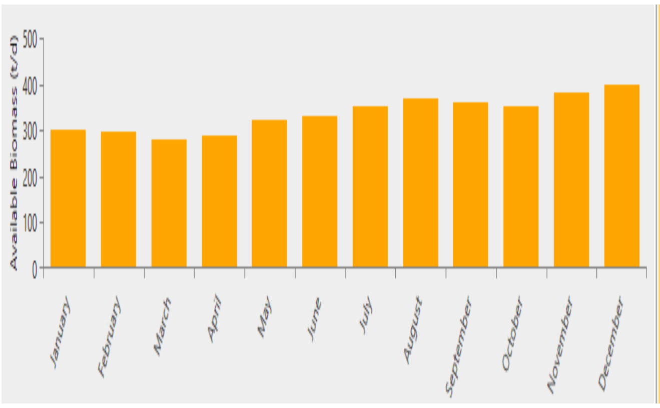
Available solar radiation

In this work, solar radiation and ambient temperature data from NASA satellites are used to simulate the system. As such, this data will be used as input by the HOMER. NASA satellite data on solar radiation was used by several researchers (Islam MD, et al 2010, Aliana A, et al. 2022, Mondal M, et al, 2011) for multiple experiments, with adequate precision. The annual average solar radiation was determined to be 5.27 kwh/m2 /day.. According to data, the area can generate significant solar potential and can generate electricity using photovoltaic (PV) panels in an effective manner. Figure 4 displays a profile that the HOMER generated for the site, showing the solar radiation and clearance index.



Available biomass resources

Another renewable energy source is biomass, which is produced from the waste products of various human and natural activities. The sources of biomass are diverse and include domestic garbage, agriculture and crop leftovers, byproducts of industry, raw materials from forests, and large chunks of wood. The biomass resources in Pakistan are abundant. 3973 tons of garbage are produced everyday by biomass. The annual biomass was calculated to be 1.4 million tons per year, with an average of 334.50 tons per day. The monthly biomass resource available at the research location is shown in Fig.



4. System architecture

It is advised to use an energy system including photovoltaic, biomass, battery, and converter to power the study area. As a result, in order to fulfill Hyderabad, Sindh, Pakistan's need for energy, we examine four scenarios, each with varying powers. The diagram displays the system.

In instance I, a 300 kW converter, 1000 kW of biomass, 10 strings of batteries, and 0 kW of photovoltaic are employed. In Case II, there is a utilization of 292 kW of photovoltaic, 1000 kW of biomass, 10 strings of batteries, and 179 kW of converter. Case III uses a 250kW photovoltaic system, 750kW of biomass, ten strings of batteries, and a 300kW converter. Case IV uses a 500kW photovoltaic system, a 500kW biomass system, ten strings of batteries, and a

300kW converter.

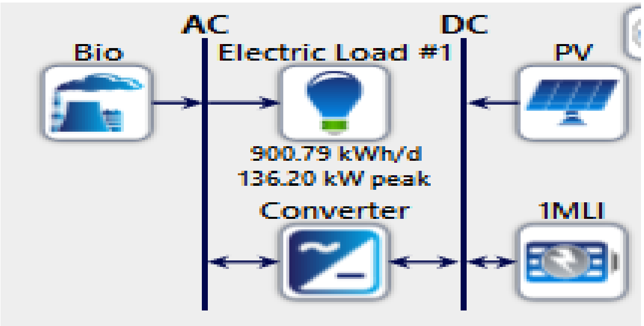


Fig 7

Cases	PV	Biomass	Converter	Battery
Case I	0 kW	1000 kW	300 kW	10
Case II	292 kW	1000 kW	179 kW	10
Case III	250 kW	750 kW	300 kW	10
Case IV	500 kW	500 kW	300 kW	10

Pre-HOMER evaluation

The HOMER program is used in this study to carry out optimal scaling and techno-economic analysis. It can do financial and technical studies for HES intended for different kinds of loads. In order to satisfy the demand of energy Pre-evaluation of the region is required and reach the desired goals (Kumar, et al.2017). In order to do this, a thorough examination of the available resources, the sociocultural context of Hyderabad, Sindh, and the requirements of Hyderabad are carried out while taking its energy consumption habits into account.

HOMER Optimization

Three primary phases comprise the HOMER modeling process: Modelling of system, simulation & optimization, and sensitivity analysis. The first stage is to design the renewable energy system (RES), taking into account the power requirements, activities, and processes, as well as the technical and economic aspects. Mean hourly data on solar irradiation and connected load are also required. The system is optimized in the second stage, and several RES setup settings are simulated in the third step. This procedure determines the optimal configuration based on net present cost (NPC). In the latter phases, based on the data of input of crucial parameters, the procedure of optimization is repeated for every input value for each parameter to evaluate the effect of the results. The procedures for HOMER optimization, pre-evaluation, and simulation are illustrated in Figure 8.

Assessment of individual components of the HRES
Photovoltaic Panel

Renewable solar energy is capable of being immediately transformed into electrical power. For the HRES in this work, we have chosen solar panels composed of mono-crystalline silicon cells. The NASA base has provided hourly solar radiation data, which has been fed into HOMER to calculate the output of electrical power. The PV power output may be estimated using the formula.

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

whereas the temperature of solar cell is calculated using Equation

$$T_C = T_A + S_T\left(\frac{T_{C,NOCT} - T_{A,NOCT}}{S_{T,NOCT}}\right)\left(1 - \frac{\eta_C}{\tau_\alpha}\right)$$

Where,
P_{PV} = PV array's power output (in kW),
$\overline{G_T}$ = Solar radiation incident on PV array (in kW/m^2).
α_P = Temperature coefficient of power (in %/°C).
$G_{T,STC}$ = Incident radiation at standard test conditions (in 1 kW/m^2).
$T_{C,STC}$ = PV cell temperature under standard test conditions (at 25°C).
Y_{PV} = Rated capacity of PV array (in kW)
F_{PV} = PV derating factor (in %)
T_C = PV cell temperature (in °C).
$T_{C,NOCT}$ = the nominal operating cell temperature [°C]
G_T = the solar radiation striking the PV array [kW/m^2]
$T_{a,NOCT}$ = the ambient temperature at which the NOCT is defined [20°C]

$S_{T,NOCT}$ = the solar radiation at which the NOCT is defined [0.8 kW/m^2]
Ʈ = the solar transmittance of any cover over the PV array [%]
α = the solar absorptance of the PV array [%]
η_c = the electrical conversion efficiency of the PV array [%]

Biomass

To produce biogas, the biomass feedstock is put into a gasifier. The biogas is then used by one or more generators to create energy. Using the equation, the hourly energy produced by the biomass generator was calculated.

$$E_{BMG} = \frac{\text{Biomass availability (kg/year)} \times CVBMG \times \eta BMG \times \Delta t}{365 \times 860 \times h_{BGG}}$$

Whereas,
EBMG = output energy generated from biomass generator
ηBMG = the efficiency of system conversion
CVBMG = Calorific value of biomass gasifier (4015 kcal/kg).

Battery

The primary function of the batteries is to store photovoltaic output throughout the day for usage when there is no solar radiation. 32 Li-ion, 6.0 V, 167Ah batteries were utilized in this hybrid setup. Two distinct components of the HOMER software that might impair performance of battery are the lifetime the reserve floating duration and output. The lithium ion (Li-ion) battery employed in this investigation has a string size of 40 V. The steps that HOMER performs to calculate performance of battery in years (Rbatt) are listed below: Equation

$$R_{batt} = \begin{cases} \dfrac{N_{batt} \times Q_{lifetime}}{Q_{thrpt}} \\ R_{batt,f} \\ MIM\left(\dfrac{N_{batt} \times Q_{lifetime}}{Q_{thrpt}} \times R_{batt,f}\right) \end{cases}$$

where
Nbatt = number of batteries within storage bank,
Qlifetime = lifetime output of a unit stored in kWh,
Qthrpt = yearly throughput of stored in kWh/year,
Rbatt = reserve floating life in years with in relationship above

Converter

In an HRES, the energy flow between alternating current (AC) and direct current (DC) must be retained and transformed by a converter. Although the load used in this research is AC, DC power is produced by the PV panel and battery. Equation may be used to determine the converter's efficiency. 90% converter efficiency has been taken into consideration in this investigation.

$$\eta_{con} = \frac{P_{ocon}}{P_{icon}}$$

Techno-economic analysis

Net Present Cost (NPC)

During the simulation process, HOMER considers the net present cost in order to rate the prospective renewable energy system. The overall budget of an energy system throughout its whole life cycle is referred to as net present cost, or NPC. As part of the modeling process, HOMER weighs the net present value while assessing the different configurations for RE systems. HOMER calculates an energy system's NPC using the following formula.

$$NPC = \frac{C_{total}}{CRF(i, T_P)}$$

Equations are utilized to compute the annual cost of the systems (Ct) and the capitals recovering factors (CRF).

$$C_t = C_{cap} + C_{rap} + C_{O\&M} + C_{opr} + C_f$$

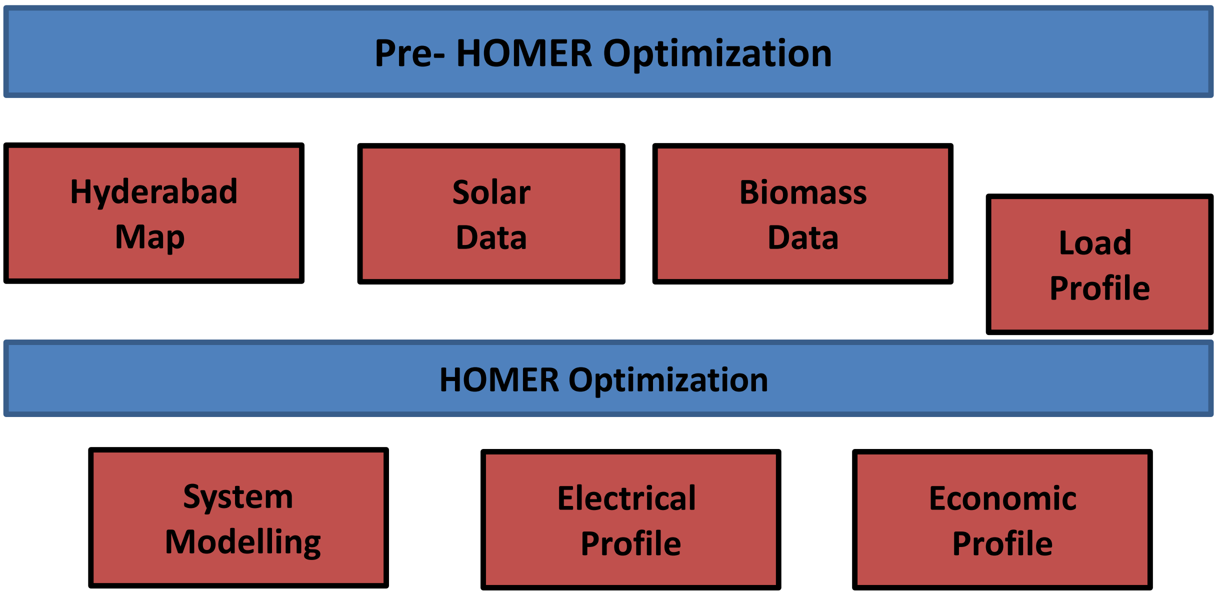


Fig 8

$$CRF(i,n)=\frac{i(1+I)^{n}}{i(1+I)^{n}-1}$$

Whereas,

NPC = Net Present Cost of the system

C_{total} = Total cost of energy annually

T_P = Project life span.

CRF = Capital Recovery Factor.

i = Annual interest rate (in %).

Cost of Energy (COE)

The average cost per kilowatt-hour (kWh) of useful electricity produced by a system is referred to as the cost of energy (COE). The lowest price at which energy must be sold in order to pay for all continuous operating expenses is determined by this value. In order to assess and contrast various power systems according to how cost-effective they are, COE is an essential indicator that offers important information about their viability from an economic standpoint. COE is calculated as total cost of power generation to the total served load. as stated in Equation, HOMER determines COE.

$$COE=\frac{C_{total}}{E_{served}}$$

Whereas

COE = Cost of Energy

C_{total} = Total cost of the energy system annually

E_{served} = Total system load served.

5. Results and Discussions

In order to satisfy Hyderabad, Sindh, Pakistan's electricity requirements, four HRES (hybrid renewable energy systems) with varying powers were created, optimized, and assessed using the HOMER program. HOMER produced several possible system configurations throughout the optimization process, but only the best option was chosen for each system. The lowest Total Net Present Cost (TNPC) and Cost of Energy (COE) were among the selection criteria. In the sections that follow, the economic characteristics of the four models' optimum solutions will be covered.

In Case I, solar energy produces 0 MWh/year with a percentage of 0% and biomass produces 542.5 MWh/year with a percentage of 100%. The excess electricity produced is 150.048 MWh/year with a percentage of 27.3%. The energy cost is 98.15 rupees per kWh and 533.206 MRs, respectively, net present cost.

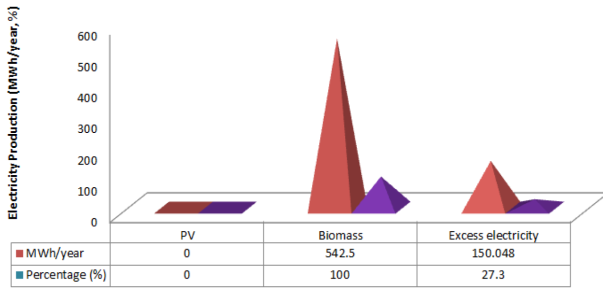
In Case II, the annual electricity output from solar power is 484.91 MWh with a percentage of 90.63% and biomass is 50 MWh with a proportion of 9.73%. The annual excess electricity production is 167.766 MWh with a percentage of 31.4%. The energy cost, or net present value, is 61.62 rupees per kWh and 334.73 MRs.

In Case III, the annual electricity output from solar power is 414.942 MWh with a percentage of 90.58% and biomass is 43.125 MWh with a percentage of 9.42%. The annual excess electricity production is 90.184 MWh with a percentage of 19.8%. The cost of energy is 136.78 rupees per kWh and the net present cost is 743.182 rupees.

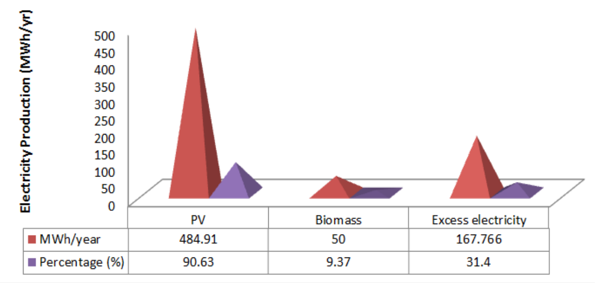
In Case IV, solar energy produces 829.883 MWh/year with a percentage of 96.6%, biomass produces 8.25 MWh/year with a percentage of 2.50%, and extra electricity is produced at a rate of 473.075 MWh/year with a percentage of 56.4%. The cost of energy is 52.51 rupees per kWh and the net present cost is 285.211 rupees.

Figure displays the amount of electricity produced, surplus electricity, net present cost, and energy cost of biomass and solar power.

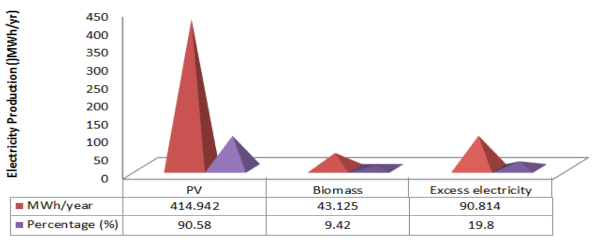
Case I

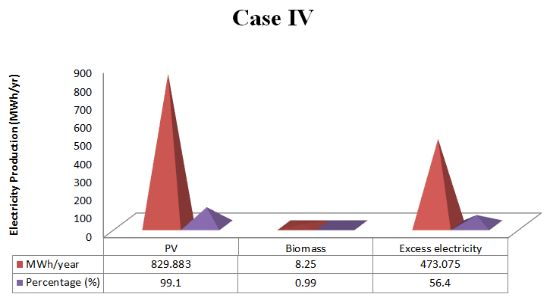


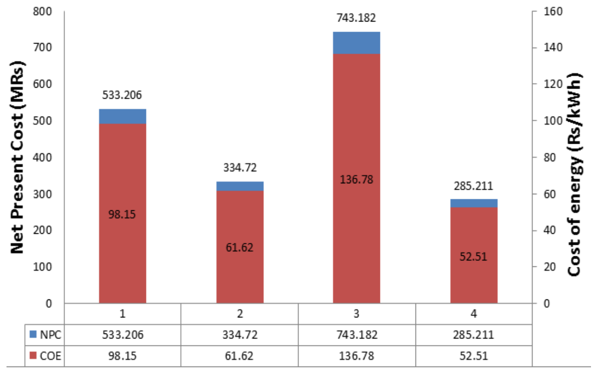
Case II

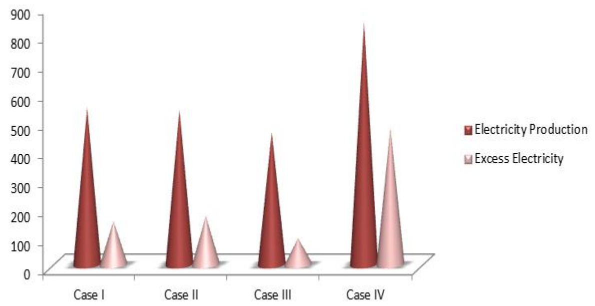


Case III









6. Conclusion

Using HOMER software, this study proposed four off-grid renewable energy systems to guarantee Hyderabad, Sindh, Pakistan, could meet its electricity demand. An assessment of the techno-economic feasibility of different off-grid setups for Hyderabad, Sindh, Pakistan, is presented in this report. HOMER was used to simulate a dynamic hybrid model in order to examine four system configurations of hybrid PV-biomass units with varying powers. A cost analysis was used to determine the best course of action after these hybrid designs were evaluated using sensitivity analysis utilizing variables including solar radiation, biomass resource availability, and system size. With a net present cost (NPC) of 285.211MRs and a cost of energy (COE) of 52.51 Rs/kWh, the combination of 500 kW PV modules, a 500 kW biogas-fueled generator, 10 storage batteries, and a 300 kW convertor was found to be the optimal option for this case study based on the findings of the cost analysis. With an annual production of 838.133 MWh and an excess of 473.075 MWh from this hybrid renewable system, the examined region is grid-independent. In addition, the system's predicted payback period of 9.5 years and realistic net present cost for the 25-year forecast period are also evident. With the help of these hybrid renewable energy systems, which are a more dependable and efficient source of energy, the Pakistani government may significantly contribute to the resolution of energy challenges. The government may establish a national electrification initiative, alter its enabling policies, and offer incentives for system employment. Hyderabad may become grid-free by using the hybrid renewable source configuration that this study suggests.

7. References

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