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Performance Analysis of Hybrid Renewable Energy Using Homer Software

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Abstract: Renewable energy resources are distributed globally and have the potential to play a critical role in guaranteeing global energy development. The purpose of this research was to conduct a performance analysis of Hybrid Renewable Energy Using Homer Software in the Bihar-Araria and Bihar-Banka regions. The process started with the site specification, average electric load demand, daily radiation, clearness index, daily temperature at the place, and system architecture. The findings show the performance of solar radiation speeds, biomass radiation speeds, wind radiation speeds, and so on, as well as a cost analysis. One of the key reasons Bihar has failed to properly integrate renewable energy is a lack of critical mass among society and government about commercially generated power from renewable energy. Renewable energy as a replacement for fossil fuels and addressing global warming have been successfully implemented in developed countries, from which developing countries can learn, and future generations and society can learn to create critical mass at the lower level of society.

Keywords: Hybrid Renewable Energy, Renewable Energy Resources, Development, Sustainable Energy, Performance Analysis, Homer Software, Bihar-Araria and Bihar-Banka Region.

1. Introduction

Scientists first raised the issue of global warming decades ago, after the industrial revolution, which used a massive quantity of fossil fuel. The effect of global warming may be seen now via climatic changes throughout the world caused by human activities on energy provision[1]. Electricity production, which mostly consumes coal, gas, and oil, is a substantial contribution to global warming. These fossil fuels contribute significantly to greenhouse gas emissions[2].

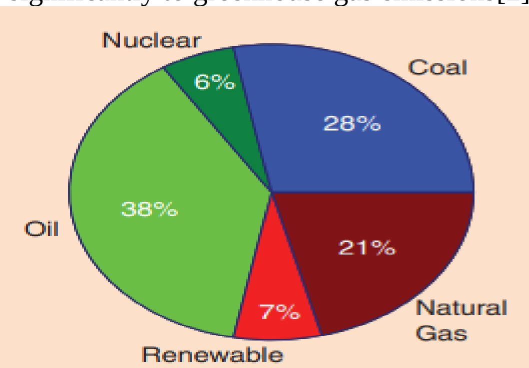


Fig.1. 1 Global and energy generation scenario.
[Source: Bimal K. Bose, 2010]

Energy is widely acknowledged to be inextricably tied to the environmental, social, and economic components of sustainable development. Providing stable and secure energy supplies, decreasing environmental consequences, and ensuring universal access to electricity have been identified as critical challenges for all electrical sectors worldwide[3]. Thus, energy management is one of the most critical issues that every administration must address. Individually, rural sectors or hamlets may not be significant energy markets with significant critical mass, but when combined, they constitute the world's biggest niche market for renewable energies[4]. In reality, the majority of the RE in the energy balance is now found in villages and rural regions[5].

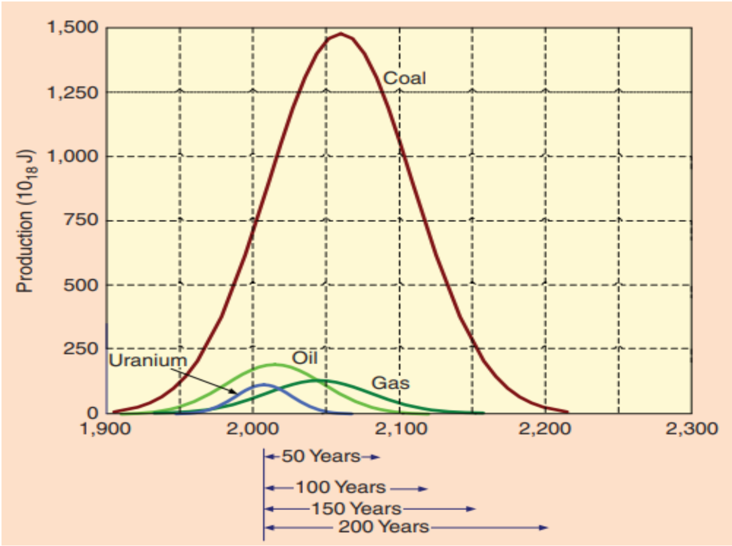


Fig.1. 2 Idealized energy-depletion curves of the world
[Source: Bimal K. Bose, 2010]

Access to inexpensive energy is now one of the most basic human requirements in our everyday lives, and has been for many decades, if not centuries. With current technological breakthroughs, expanding global population, and resurging requirements to cut CO2 emissions, the worldwide drive for clean and sustainable energy is accelerating[6]. According to the International Renewable Energy Agency (IEA), about one billion people still do not have access to electricity. Access to inexpensive energy for the people is a critical component that helps to local development and consequently decreases poverty rates in rural regions[7]. Adopting renewable energy sources to meet such objectives not only ensures a country's long-term economic prosperity, but also cuts CO2 emissions, which contribute directly to global warming. To overcome these issues, regulations and methods for electrical energy generation, consumption, and distribution must be implemented as part of the renewable energy development process[8].

Solar and wind resources are frequently utilised as critical components of renewable energy systems. As a result, a PV-wind hybrid design is one of the finest solutions for decentralized power production in distant rural, urban, grid-connected, or off-grid regions[9]. The construction industry is one of the greatest consumers of energy, accounting for more than 30% of total consumption, and it is also predicted to increase at a higher rate[10]. Given that India's construction industry is expected to grow fivefold by 2030, energy-saving measures in the building sector seem potential. The rooftop of a building is one of the potential locations for PV-wind hybrid systems to be placed efficiently. Though solar photovoltaic rooftop generating is becoming more popular across the globe, using a wind turbine will improve hybrid system dependability even further[8].

On the other hand, rural sector growth in developing nations is often found to be wasteful and unsuitable, since they frequently become non-functional after a few years after installation owing to a number of factors[11]. There are also political, financial, legal, and information constraints to the optimal use of renewable energy technologies (RETs), which must be solved in order to establish a favorable socioeconomic and technological environment for rural electrification. In this context, an in-depth examination of the techno-economic elements of RETs for rural electrification in order to provide clean, dependable electricity is critical[12].

According to the Government of India's rural electrification program of 2006, a village is considered "electrified" if essential infrastructure such as distribution transformers and distribution lines have been installed in the populated neighborhood, including a "Dalit Basti."[13]. According to official statistics, practically all villages in the nation, or 98.7 percent of them, have been electrified[5]. However, a deeper examination of statistics from the hinterland, particularly from states like as Bihar, Uttar Pradesh, Assam, Jharkhand, and Odisha, reveals that a sizable number of families in villages across most states remain in the dark, without access to electricity. Approximately one-third of India's population does not presently have access to electricity, and the majority of these people live in rural regions[14].

Current Status of Renewable Energy in India:
The Indian government has said that providing power to every family in India is one of their top goals. While progress in expanding the central electrical grid has been achieved, serving all rural homes via such initiatives is not a sustainable alternative[15]. Increased deployment of decentralized energy production via the use of microgrids, which refers to a smaller-scale electric grid linked with a local generating source, is a potential response to the problem of rural electrification[16].
The Ministry of New and Renewable Energy (MNRE), Government of India, developed a "National Wind-Solar Hybrid Policy" in 2018 to optimize and enhance the utilization of renewable resources, to expedite technological breakthroughs, and to strengthen the nation's commitment to the Paris Climate Change Agreement[17]. Under the Jawahar Lal Nehru National Solar Mission, which was initiated in 2010v, India has set a goal of 175 GW installed renewable power capacity, of which 100 GW is solar and 60 GW is wind. The nation contains huge wasteland regions with moderate to high wind and solar resource potential, which may also be used for modest hybrid power production since both resources complement one other[18].

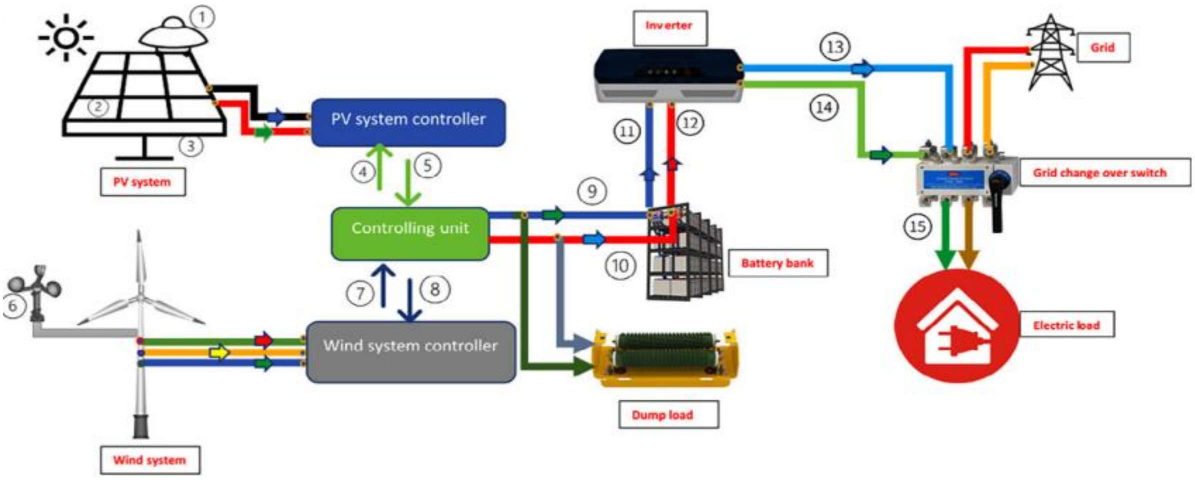


Fig.1. 3 Monitoring system of the solar-wind hybrid system
[Source: Sunanda Sinha, 2021]

The construction industry is one of the possible applications for micro wind turbine-based systems to minimize traditional power usage and increase the dependability of solar-based hybrid systems. Roof-mounted wind turbines are higher in elevation and hence subject to stronger winds than ground-based turbines[19]. As a result, wind-based hybrid systems have the potential to have a substantial influence on rooftop power production, which should be investigated. The use of many renewable energy sources in a hybrid system not only enhances dependability and efficiency, but also reduces the need for energy storage[20].
India has a vast need for energy to drive its fast-rising economy, with a population of 1.3 billion people. From a power-deficit country at the time of independence, India's attempts to become energy-independent have lasted more than seven decades[21]. We are now a power surplus country, with a total installed capacity of nearly 4 lakh MW. With the objective of achieving sustainable development, India's power generating mix is fast transitioning towards a greater proportion of renewable

energy[22]. Today, India is the world's third biggest generator of renewable energy, with non-fossil fuel sources accounting for 40% of installed capacity[23].

Table.1. 1 Installed capacity of renewable sources of energy in India
[Source: Ministry of New and Renewable Energy, 2022]

Solar	Wind	Small hydro	Large hydro	Bio power	Nuclear
48.55 GW	40.03 GW	4.83 GW	46.51 GW	10.62 GW	6.78 GW

At the time of its independence, India was a developing country that depended significantly on coal to supply its energy needs. However, India has always been devoted to exploring new alternative energy sources for long-term growth. The first step was taken with hydropower, with significant hydroelectric power projects emerging on the Indian energy landscape[24]. Many governmental and regulatory actions have aided hydropower growth and investment throughout the years. We now rank fifth in the world in terms of exploitable hydropower potential. In the 1950s, the Bhabha Atomic Research Centre (BARC) was established to ensure the country's long-term energy independence[25]. We are the only developing country that has designed, proven, and deployed nuclear reactors for power production. This has been made feasible by decades of considerable scientific investigation and technological advancement[26].

Wind energy research began in India in the 1960s, when the National Aeronautical Laboratory (NAL) constructed windmills largely for agricultural water delivery. Today, we have the world's fourth greatest wind power capacity, thanks to the steady flow of wind, particularly in the southern, western, and northwestern areas[27].

Millions of Indians have profited from solar energy-based applications that satisfy their cooking, lighting, and other energy demands in an environmentally benign way[28]. With large-scale success in solar energy solutions, India has launched the International Solar Alliance (ISA), which is an action-oriented, member-driven, collaborative platform for enhanced solar energy technology deployment[29]. Membership in the ISA is accessible to all United Nations member nations, and the ISA Framework Agreement currently has 107 signatories. The Alliance's goal is to effectively use solar energy to lessen reliance on fossil fuels, resulting in a cleaner world[30].

In addition, biomass has been an important source of energy for India. It is renewable, widely accessible, carbon-neutral, and has the potential to generate large rural employment[31]. Rapidly improving technology has allowed thermal power plants to operate in a more cost-effective and energy-efficient manner[32]. To lower its CO_2 footprint in thermal power production, India has co-fired biomass in thermal plants around the nation. Since the mid-1990s, there has been a biomass power/cogeneration programmer. In the nation, around 800 biomass power and bagasse/non-bagasse cogeneration plants have been erected to provide electricity to the grid[33].

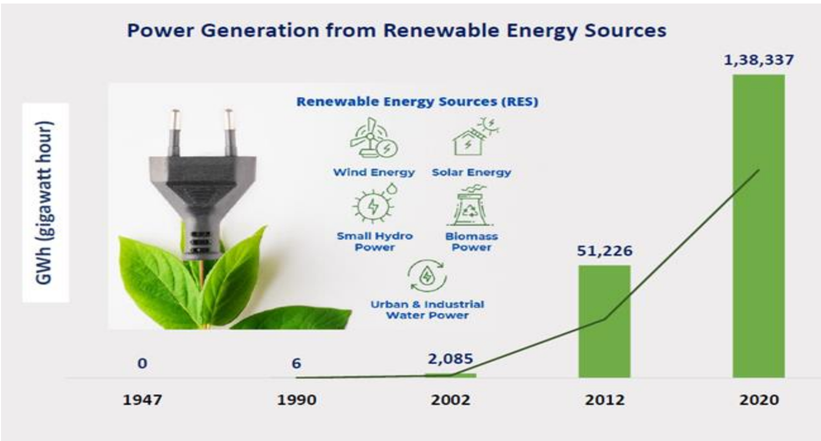


Fig.1. 4 The Journey towards Renewable Energy in India
[Source: Ministry of New and Renewable Energy, 2022]

India has always shown its determination to take the lead in combating climate change. The country's ambition is to reach Net Zero Emissions by 2070, in addition to meeting short-term goals such as: Expanding renewable energy capacity to 500 GW by 2030[34], Meeting 50% of energy needs with renewables, cutting cumulative emissions by one billion tonnes by 2030, and lowering the carbon intensity of India's GDP by 45% by 2030[35].
India's experience will be useful to other developing countries as they implement their climate promises and move to a more sustainable energy future.

Hybrid Renewable Energy Systems (HRES):
The most important commodity in today's world is electricity. Electricity has been acknowledged as a critical role in initiating and maintaining a process of growth from a small town to a nation[36]. With increased industrialization, renewable energy is replacing fossil fuels as a source of electricity. All renewable energy sources, however, have downsides. These resources do not provide useful energy constantly throughout the year because to their reliance on changeable sunlight hours and shifting wind speeds. However, implementing two or more energy resources may avoid these issues[37]. Hybrid renewable energy systems (HRES) may be deployed to generate significant amounts of energy in locations that are experiencing massive power outages or in distant areas that are still electrified. Solar and wind energy have been designated as pure, inexhaustible, limitless, and environmentally benign. Such attributes have enticed the energy industry to make more use of renewable energy sources[38]. The environmental value of renewable systems is well recognized, and if shown to be economically beneficial as well, it will provide an incentive for the government and organizations to install such systems in appropriate areas. However, our current administration, led by Prime Minister Narendra Modi, is placing a strong emphasis on renewable energy sources for electricity production[39].

A. Wind Power:
Wind energy systems use wind energy for practical applications such as power generation, battery charging, water pumping, and grain milling. Wind is a natural phenomenon that is created by the movement of air masses induced principally by differential solar heating of the earth's surface. The intensity and direction of the wind are affected by seasonal fluctuations in the energy received from the sun. The wind turbine harnesses the kinetic energy of the wind in a rotor that is mechanically connected to an electrical generator. To improve energy collection, the turbine is installed on a tall tower[40].

B. Solar Power:
India is heavily inhabited and has significant sun insolation, making it a good location for solar power. When sunlight shines on solar modules (photovoltaic cells), DC power is generated. The solar modules should be oriented at an optimal angle for that specific site, facing straight south, and not shadowed at any time of day[41].

C. Hybrid Solar Wind System:
A stand-alone wind system combined with a solar photovoltaic system is the best hybrid combination of all renewable energy systems and is suited for the majority of applications while accounting for seasonal variations. During lean seasons, they also complement each other; for example, higher energy production from wind during monsoon months compensates for the lower output provided by solar. Similarly, when the wind is calm in the winter, solar photovoltaic takes over[42]. The hybrid solar wind power system is as shown in fig.1.

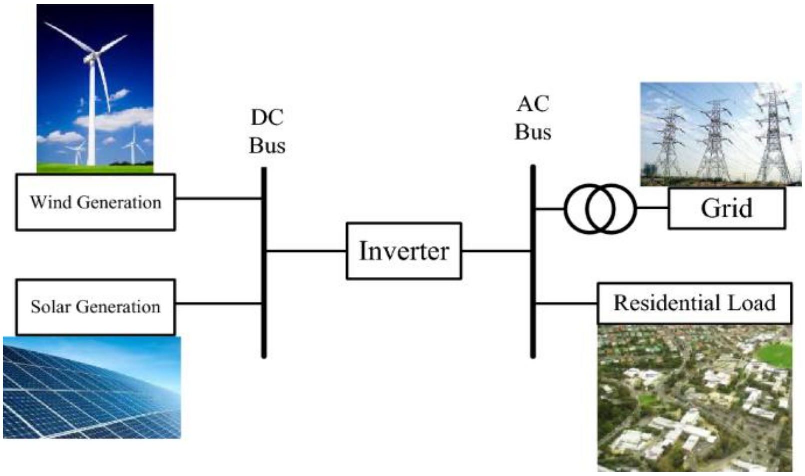


Fig.1. 5 Hybrid Solar Wind Power System
[Source: Esmaeil Eslami, 2019]

The goal of designing a solar hybrid winding system for the investigated network is to identify the quantity of solar panels and wind turbines with the goal of lowering energy prices and minimizing energy expenses due to energy not given in the network. The proposed system's total cost comprises the entire initial investment expenses, the unprotected energy cost, and the net present value of all running and maintenance costs[43]. This comprises the replacement cost, energy not supply cost (SCOC), and residual value of each system component, as well as the difference between the present value of the cost and income from power distribution to the network, which is the cost function in the form of Eq. (1):

$$\min \mathbf{C_T} = \sum_{i \in PV,W} (I_i + R_{NPV\_i} + OM_{NPV\_i} - S_{NPV\_i}) + P_e * C_e + P_b * C_a - P_s * I_a + SCOC \quad (1)$$

The Apv and AW variables per square metres indicate the total area of the solar panels and the swept surface of the wind turbine blades, respectively. As a result, the total setup cost is:

$$I_{PV} = \alpha_{PV} * A_{PV} = c_1 * A_{PV} \quad (2)$$

It is worth mentioning that the project's N-year assessment horizon is comparable to the useful life of a solar panel (LPV), therefore removing this component from the system is free. (RNPV_PV equals 0). Wind turbines often have a shorter useful life (LW) than solar panels (here, N). As a result, extra investment in wind turbines will be necessary before the project is finished. The number of times the wind turbine project's N-year horizon to be updated is equal to XW =N/LW. If W is the initial investment in dollars per square metres in the current year, then the investment in year y is equal to:

$$\alpha_W * \left(\frac{1+\varepsilon_W}{1+r}\right)^y \quad (3)$$

$$I_W + R_{NPV\_W} = \alpha_W * A_W * \sum_{X=1}^{X_W} \left(\frac{1+\varepsilon_W}{1+r}\right)^{(X-1)L_W} = c_4 * A_W \quad (4)$$

Total Net Value Total O&M costs are:

$$OM_{NPV_{PV}} = \alpha_{OMPV} * A_{PV} * \sum_{k=1}^{N} \left(\frac{1+\varepsilon_{PV}}{1+r}\right)^k = c_2 * A_{PV} \quad (5)$$

$$OM_w = \alpha_{OMw} * A_W OM_{NPV_W} = \alpha_{OMw} * A_W * \sum_{k=1}^{N} \left(\frac{1+\varepsilon_W}{1+r}\right)^k = c_5 * A_W \quad (6)$$

Total revenue from resale and total net worth total revenues from resale are equal to:

$$S_{NPV\_PV} = S_{PV} * A_{PV} * \left(\frac{1+\delta}{1+r}\right)^N = c_3 * A_{PV} \quad (7)$$

The resale price of the Sd wind turbine in dollars per square meter during its useful life is linearly reduced from αW to SW.

$$S_d = \left(\frac{S_W - \alpha_W}{L_W}\right) * y_d + \alpha_W \quad (8)$$

$$S_{NPV\_W} = S_W * A_W * \sum_{x=1}^{X_w - 1} \left(\frac{1+\delta}{1+r}\right)^{x*L_W} + S_d * A_W * \left(\frac{1+\delta}{1+r}\right)^N = c_6 * A_W \quad (9)$$

Assuming a constant consumption of energy per year, the total net value of purchasing energy from the network will be as follows:

$$\boldsymbol{P}_{NPVb} * C_a = C_A \sum_{k=1}^{N} \left(\frac{1+\delta}{1+r}\right)^k = C_7 * C_a \quad (10)$$

If the amount of energy sold to the network is equal to Es and the annual energy sales to the Ps network are in $/kWh, then the annual energy sales to the network are equal to Ia = Ps.Es, so the total net sales value of energy sales to the network is equal to with:

$$\boldsymbol{P}_{NPVs} * I_a = I_A \sum_{k=1}^{N} \left(\frac{1+\delta}{1+r}\right)^k = C_8 * I_a \quad (11)$$

The LPSP limitation for a solar-hybrid hybrid system in the time period T is calculated from the following equation. The amount of LPSP should not be less than the amount considered in this article is 2%[43].

$$LPSP = \frac{\sum_{t=1}^{T} P_{deficit}(t) \cdot \Delta t}{\sum_{t=1}^{T} P_{demand}(t) \cdot \Delta t} \leq \overline{LPSP} \quad (12)$$

In this paper a new objective function is proposed for designing solar–wind hybrid system in an area in the Bihar. The proposed objective function is a combination of cost analysis, and solar, biomass, wind radiation. Also, sensitivity parameters are considered in the design process.

2. Related Work:

In this research, we analyzed publications from the last 10 years as well as worldwide studies on renewable energy system components, performance, and global energy development. The majority of studies on the technical economic feasibility assessment of hybrid mini-grids and renewable energy have relied on evaluating two criteria, the NPC or the LCOE, or both at the same time. Given the significance of lowering CO2 emissions in the energy balance during energy production and consumption, we thought it would be useful to calculate the amount of CO2 averted by replacing fossil fuels with renewable energy.

T. M. I. Riayatsyah et al. [2022] investigated the Techno-Economic Analysis and Optimization of a Campus Grid-Connected Hybrid Renewable Energy System Using HOMER Grid.

The purpose of this research was to undertake a techno-economic performance and optimization analysis of grid-connected PV, wind turbines, and battery packs for Syiah Kuala University, which is located at the tip of Sumatra Island in a tsunami-affected zone. The simulation programme Hybrid Optimization Model for Electric Renewables (HOMER) was used to examine and optimize the institution's renewable energy requirements. According to the research, by connecting solar PV and wind turbines to the local grid, this renewable energy system may produce up to 82% of the necessary power. However, one barrier to integrating renewable energy in Indonesia is the low cost of power, which is mostly produced using inexpensive coal, which is plentiful in the nation.

Abdelhamid Issa Hassane et al. [2022] investigated Comparative study of hybrid renewable energy systems for off-grid applications. The multi-criteria assessment approach was used to conduct a techno-economic feasibility analysis of hybrid renewable energy systems for four family groups in rural Chad. The project's goal is to determine the most optimum solution in the technical and economic feasibility analysis of decentralized mini-grids for rural electrification of distant communities in Chad. In terms of energy prices, the lowest Levelized Cost of Energy (LCOE) was predicted to be US $ 0.236/kWh in a photovoltaic/Wind/Battery configuration at the Koundoul site, while the highest costs were assessed to be US $ 0.363/kWh in a photovoltaic/Battery configuration at the Linia site.

Sunanda Sinha et al. [2021] investigated a building-integrated solar photovoltaic-wind-battery hybrid energy system. For the first time, the performance of an off-grid roof-mounted Photovoltaic (PV)-micro wind-battery hybrid system is experimentally evaluated in the Indian Western Himalayan area for 1.5 years under actual fluctuating outside weather circumstances. The system's performance in several seasons and weather types (cloudy, partly cloudy, and sunny) indicates a maximum monthly production of 91% by PV with a wind system participation of 9%. Following study fields are also indicated for the sustainable use of existing resources, which may greatly contribute to the achievement of the sustainability objective. A review of municipal solid waste as a renewable source for waste-to-energy projects in India: present practices, problems, and future potential was undertaken by **Lal**

Chand Malav et al. [2020]. The purpose of this review is to (1) describe the challenges of MSW management, (2) summaries the health significance of MSW management, (3) explain the opportunities and requirements of energy recovery from MSW through WtE technologies, (4) explain several WtE technologies in detail, and (5) discuss the current status of WtE technologies in India. The study also covers the difficulties that WtE initiatives face in India. Furthermore, a number of suggestions are made to improve the existing implementation of solid waste management (SWM) in the Indian context. This evaluation has the ability to assist academics, researchers, authorities, and stakeholders involved in MSW management in making informed judgements**.**

Desh Bandhu Singh et al. [2020] investigated a solar energy-based irrigation pumping system. This paper presents a review of solar energy-based pumping systems. Conclusions have been formed based on the research. All rights reserved, 2020 Elsevier Ltd. If employed appropriately, solar energy has the ability to provide the energy requirements for human subsistence on Earth. Some of the uses include electric power production using solar panels/thermoelectric generators/Racine cycle technology, water purification, agricultural product dryers, and refrigeration. Solar energy is pollution-free, and it may be used for irrigation with the assistance of a solar-powered pump and a water-distribution system. Many solar-powered pumping devices have been reported by researchers all around the world.

Jompob Waewsak et al. [2020] investigated the assessment of hybrid, firm renewable energy-based power plants: application in Thailand's southernmost area. The goal of this research is to examine suitable locations for Small Power Producers (SPP) hybrid, firm renewable energy-based power plants and their scenario applicability, with an emphasis on Thailand's southernmost regions. According to the findings, the best scenario is a 40 MW solar PV power plant supplemented by a 10 MW biomass power plant and a significant energy storage system (ESS). This design offers the maximum generating capacity (almost 1,200 PWh/yr), the lowest LCOE (11.2 US cents/kWh), and avoids over 38 ktonnes of CO2eq emissions per year. The technique established, which is based on a cost-benefit analysis, levelized cost of energy, and greenhouse gas emission reductions, may also be utilized in other jurisdictions where biomass, solar, and wind resources are available for power production.

Esmaeil Eslami et al. [2019] investigated the optimal design of a solar-wind hybrid system linked to a network using a cost-saving method and an enhanced network reliability index. The best design of a grid-connected hybrid energy system for a sample region in north Iran is investigated in this article. Furthermore, the loss of power supply probability (LPSP) requirement is regarded as a limitation for assuring a specific degree of system dependability. The design process is carried out in such a manner that the overall cost of the system is kept to a minimum. A modified version of the Bee algorithm has been presented to accomplish this aim. The real sample system, whose data was accessible, was investigated in order to conduct investigations. The findings show that the suggested hybrid system performs well in terms of lowering system costs.

Sunil Kumar et al. [2019] carried a study on the present state of renewable energy sources in India. This report assesses the possibilities of several renewable energy sources in India. It also emphasizes the patterns in the expansion of the renewable energy industry, while also demonstrating the necessity for a hybrid renewable energy model for rural electrification in India. The paper's major goal is to evaluate all available solutions in the renewable energy industry so that a substantial part of the rural population may have access to power and satisfy their basic energy demands. **Om Krishan et al. [2019]** conducted a techno-economic study of a hybrid renewable energy system for an energy-insecure rural community. This study describes the techno-economic analysis and optimal design of an HRES intended to fulfil the residential and agricultural electric load needs of an energy-poor community in the Yamunanagar area of the Indian state of Haryana. Based on the simulation findings, it is determined that wind/PV/battery-based HRES is the most cost-effective design for the particular area under examination, as well as the optimal sizes of the various components. The originality of this study consists in the sequential use of both HOMER and MATLAB simulation tools to perform techno-economic analysis of the proposed HRES and verify the concept.

Abhi Chatterjee et al. [2018] investigated the techno-economic analysis of hybrid renewable energy systems for rural electrification in India. This article covers a Hybrid Renewable Energy System (HRES) based on the available energy resources in the site. The technical reliability and economic feasibility of HRES for a single off-grid home are investigated. This is the first of its sort in the Indian state of Jharkhand, and it may be used as a framework to enhance energy infrastructure in underserved areas. **Yahya Z. Alharthi et al. [2018]** investigated the resource assessment and techno-economic analysis of a grid-connected solar PV-wind hybrid system for several Saudi Arabian sites. A grid-connected solar PV-wind hybrid energy system was constructed in this research with an average community load demand of 15,000 kWh/day and a peak load of 2395 kW in mind. HOMER software is used to evaluate the potential of renewable energy resources and to conduct technical and economic evaluations of grid-connected hybrid systems. Because of its high renewable energy penetration, this city's system has the lowest net present cost (NPC) and levelized cost of energy (LCOE), the greatest total energy that can be sold to the grid, and the lowest CO2 emissions. **Tick Hui Oh et al. [2018]** investigated Malaysian energy policy and alternative energy: Issues and challenges for sustainable development. This article is an update to a paper with the same title that was published in 2010. Malaysia's energy and power generating landscape has changed dramatically since then. This article will provide an update on current and new key energy-related events that have occurred, as well as how they have influenced the country's energy landscape. Finally, the newest developments and concerns concerning the government's present nuclear fantasy will be examined.

Sunanda Sinha et al. [2017] investigated the dependability of a photovoltaic-based hybrid power system with battery storage in low wind areas. The goal is to use available wind resources to augment solar resources in order to improve dependability and reduce energy storage needs in hybrid systems. The feasibility study is carried out for 12 sites, with one location utilizing measured data and the other 11 locations using NASA satellite data. For these sites and a typical demand, a 1 kWp micro-wind turbine with a reduction in speed of 2 m/s is determined to yield the most energy yearly. The methodology may be used to find the best micro-wind PV hybrid systems for low-wind regions all around the globe. **S. Manju et al. [2017]** investigated Progressing towards the Development of Sustainable Energy: A Critical Review of the Current Status, Applications, Developmental Barriers, and Prospects of Solar Photovoltaic Systems in India. The paper also discusses present renewable energy legislation, hurdles to the growth of solar manufacturing units, and some potential future proposals that might accelerate renewable energy development in India. Water heaters, desalination units, pasteurizers, food drying machines, water purifiers, space heating systems, air-conditioning units, cookers, water pumps, aerators, solar-wind hybrid systems, and grid-connected photovoltaic systems are examples of solar energy uses.

Pranav M.S. et al. [2017] conducted a review on hybrid renewable energy sources (HRES). This article concludes with a summary of the use of hybrid renewable energy sources (HRES) and a comparative assessment of optimization methodologies. The use of renewable resources as a source of electrical energy contributes to the creation of a sustainable environment. In the current context, hybridizing (combining more than two renewable energy sources) these resources for efficient energy production in power systems is quickly rising.

Yashwant Sawle et al. [2016] investigated the PV-wind hybrid system: A review with case study. The purpose of this study is to provide an overview of hybrid system architecture, modelling, renewable energy sources, hybrid system optimization and control methodologies, and software utilized for optimum sizing. India also discussed and discovered that the PV-Wind-Battery-DG hybrid system is the best cost-effective and emission-free option among all hybrid system combinations. This study also includes several near-term changes that have the potential to increase the real monetary appeal associated with these types of strategies and their customer acceptance. **Mukesh Kumar Mishra et al. [2015]** investigated small hydro power in India: current status and future prospects. The goal of this research is to thoroughly examine the present state of small hydropower development in India and to predict growth prospects. Potential and installed capacity, technical state, policy and regulatory support for small hydro power, and the whole development process for a small hydro power plant have all been thoroughly studied. The Vensim DSS suite was used to create future growth scenarios for small hydro power up to 2050. According to model simulation, even by 2050, the nation would not be able to completely use tiny hydropower potential at the present pace of capacity construction.

3. Research Gap:

While many studies have been conducted to investigate the optimization and performance analysis of standalone renewable energy systems or conventional energy systems, there appears to be a significant research gap in the comprehensive analysis of hybrid renewable energy systems using advanced simulation tools such as HOMER (Hybrid Optimization Model for Electric Renewable). Although the concept of combining multiple renewable energy sources to improve overall system efficiency and reliability is gaining traction, the literature lacks in-depth investigations using sophisticated modelling techniques into the intricate interactions between different renewable energy sources, energy storage technologies, and load demands. Furthermore, the use of simulation tools such as HOMER offers a strong platform for doing system-level optimization; yet, there is a research gap in fully exploiting the potential of these tools. Many research concentrates on isolated case studies or simplified models, possibly ignoring real-world issues and different geographical, meteorological, and operational situations that hybrid renewable energy systems may face. Addressing these difficulties via sophisticated modelling approaches and scenario analysis will lead to a better knowledge of system performance and improve decision-making for developing and running such systems.

4. System Description and Methodology:

The simulation program Hybrid Optimization Model for Electric Renewables (HOMER) was used to assess the performance of the institution's necessary renewable energy. The HOMER grid, which was created in 2018 as a more effective method for simulating hybrid energy systems and researching alternatives for cutting power prices for a grid-connected system, was employed. It is a useful tool for swiftly assessing self-consumption value, demand charge reduction, and energy arbitrage by combining technical and economic data into a single model. Users may study various components and design outputs, determine cost-competitive points for different technologies, investigate risk-reduction measures, and determine the most cost-effective design. It also simulates real-world performance to assist system designers and optimizers in making more informed judgements. The purpose of this research was to conduct a performance analysis of Hybrid Renewable Energy Using Homer Software in the Bihar-Araria and Bihar-Banka regions.

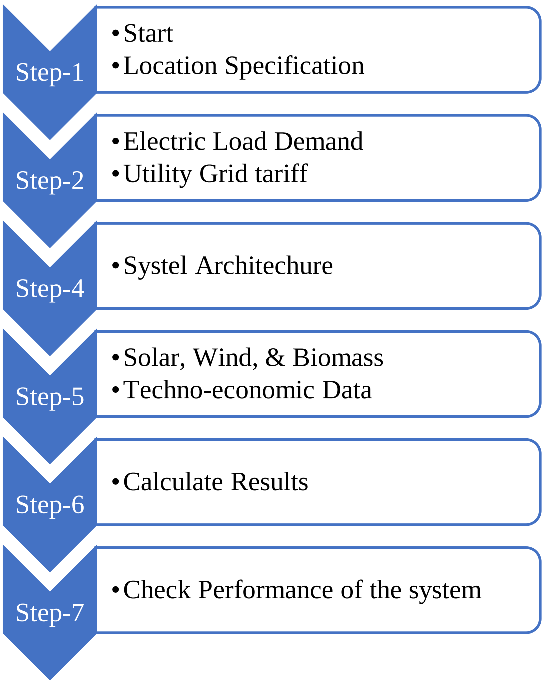


Fig.4. 1 Methodology Flowchart

HOMER Software:
The current effort used the NREL's HOMER program to select and size components of a hybrid power system. HOMER is simple to use program. The core capacity of HOMER is to simulate the long-term functioning of a micro power system. This simulation capacity is used by its higher-level features, such as optimization and sensitivity analysis. The simulation method examines how a certain system configuration, a mix of precise-size system components, and an operational strategy that governs how those components function together, would behave in a given context over a lengthy period of time. HOMER can simulate a broad range of micro power system configurations, including a PV array, one or more wind turbines, a run-of-river hydro turbine with up to three generators, a battery bank, an ac-dc converter, an electrolyze, and a hydrogen storage tank. The system may be grid-connected or self-contained, and it can supply alternating current and direct current electric loads as well as a thermal load.

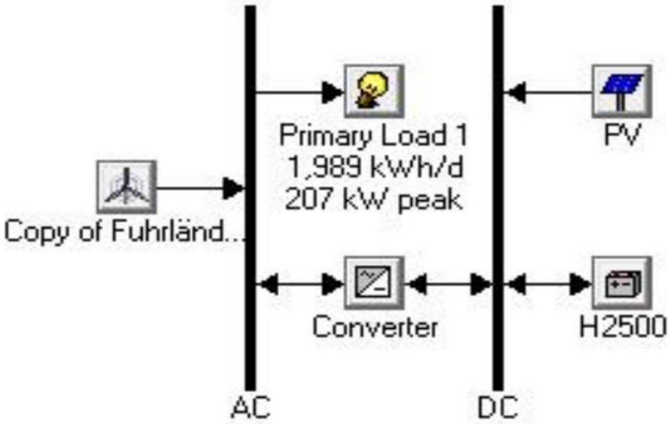


Fig.4. 2 Hybrid power system design using HOMER

The Figure 4 depicts the design of a hybrid power system using Homer. It is made up of a photovoltaic array, a wind generator, a converter, a load, and a battery. The simulation procedure provides two functions. First and foremost, the system's practicality is assessed. HOMER deems the system viable if it can sufficiently supply the electric load and meet any other user requirements. Second, the system's life-cycle cost is calculated, which is the entire cost of installing and running the system during its lifespan. Simulation studies were conducted using actual meteorological data (solar insolation and wind speed) to evaluate system performance under various conditions. The system must then be optimized. HOMER simulates many different system configurations for the optimization process, discards the infeasible ones (those that do not satisfy the user-specified constraints), ranks the feasible ones by total net present cost, and presents the feasible one with the lowest total net present cost as the optimal system configuration. The optimization process's purpose is to find the best value for each decision variable that interests the modeler. A choice variable is one that the system designer has influence over and for which HOMER may examine numerous alternative values throughout the optimization process.

Possible decision variables in HOMER include:

The size of the PV array, The number of WG, The Capacity of batteries, and the size of the DC/AC converters.

Table.4. 1 Global Hirizontal Irradiation (kWh/m2 per DAY) - Globas Atlas

SR. NO	State	District	Taluka	BLOCK	CO-ORDINATES	GLOBAL HIRIZONTAL IRRADIATION (kWh/m2 per DAY) - Globas Atlas
1	BIHAR	ARARIA	Bhargama	Bhargama	25°19'24.86"N 84°54'41.39"E	4.827

Table.4. 2 Population

SR. NO	State	District	No of Households	Population	Male Population	Female Population	Children Population	Area of Village (hectares)	Area of Village (Acers)	Biomass Production ton / acers	Biomass Production In village in Ton / yr
1	BIHAR	ARARIA	424	2501	1286	1215	572	82	202.626	2.34292	474.737

5. Results and Findings:

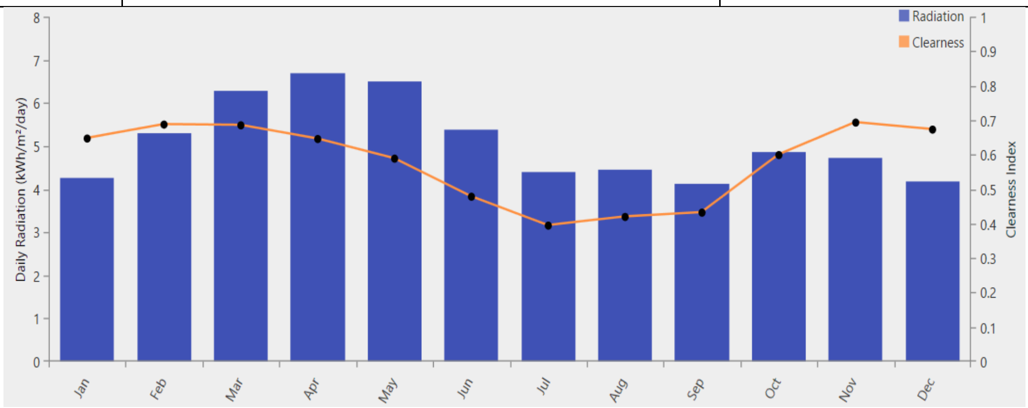
HOMER stands for Hybrid Optimization Model for Electric Renewables. Midwest Research Institute has the copyrights of this software. It was developed by National Renewable Energy Laboratory (NREL) of United States. It is used to help the designing of various power plant configurations. It has different built-in components in it such as PV panels, Wind turbines, Utility loads of various kinds, Generators, Converters and Battery Backup etc. In this study find out the results for Solar GHI, Wind resource, Electric load, and Biomass.

Solar GHI:

The total solar radiation incident on a horizontal surface is referred to as global horizontal irradiance (GHI). It is calculated as the sum of Direct Normal Irradiance (DNI), Diffuse Horizontal Irradiance (DHI), and ground-reflected radiation. HOMER computes flat-panel PV output using Solar GHI.
The quantity of solar energy that touches the earth's surface in a normal year is represented by solar resource data. This is the Solar GHI Resource input parameter in HOMER Pro. This information is sent into the HOMER Pro. Graph shows a HOMER Pro view for solar radiation intensity (KWh/m2 /Day) table for the whole year.

Table.5. 1 Avaerage Solar GHI

Month	Clearness Index	Daily Radiation (KWh/m2 /Day)
Jan	0.647	4.250
Feb	0.687	5.300
Mar	0.685	6.270
Apr	0.646	6.700
May	0.589	6.510
Jun	0.478	5.390
Jul	0.394	4.390
Aug	0.419	4.440
Sep	0.432	4.120
Oct	0.599	4.860
Nov	0.693	4.720
Dec	0.673	4.170



Graph.5. 1 Avaerage Solar GHI

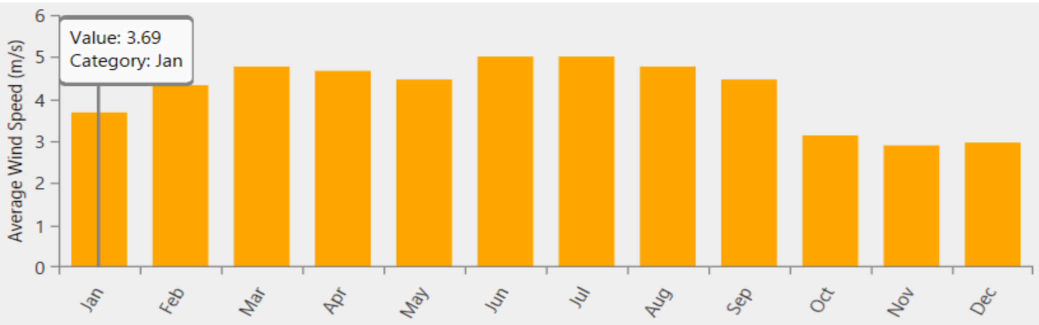
The provided data table shows two sets of information for each month: the Clearness Index and the Daily Radiation in KWh/m2/Day.This column shows the months of the year, beginning with January (Jan) and ending with December (Dec). January has a Clearness Index of 0.647, suggesting that the skies are partly overcast to fairly clear. The Clearness Index is 0.687, indicating that February is sunnier than January. Clearness Index of 0.685, reflecting comparable clarity to February. Clearness Index of 0.646, indicating somewhat less clear sky than in March. A clearness index of 0.589 indicates that May is generally cloudier than prior months. In June, the Clearness Index was 0.478, suggesting a considerable decline in clarity, most likely predicting cloudier weather. July has a Clearness Index of 0.394, indicating that it is one of the cloudiest months of the year. In August, the Clearness Index was 0.419, suggesting continuously overcast weather. Sep Clearness Index of 0.432 indicates that it is still foggy but somewhat clearer than in July and August. Oct Clearness Index of 0.599, indicating an increase in clarity during the summer months. November has a clearness index of 0.693, suggesting that it is moderately clear and sunny. With a Clearness Index of 0.673, December provides clear skies but not as clear as November.

Wind turbine:

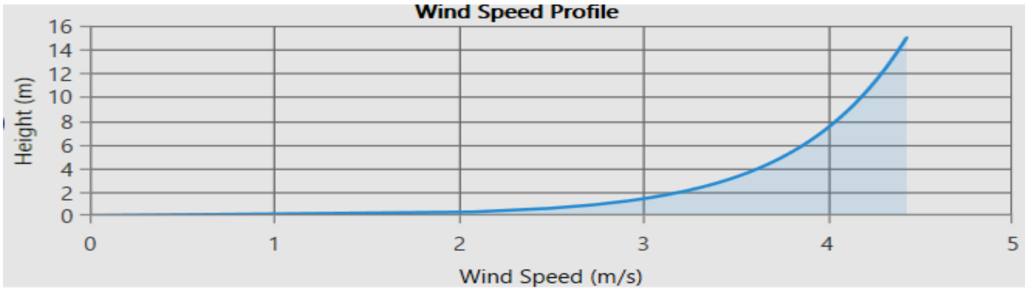
In the schematic viewpoint, we can see a wind turbine component. This wind turbine depicts a full wind power plant with an alternating current output. A full wind power station is shown in schematic wind turbine symbol G3. This is the most appropriate size turbine for the planned power plant. Wind turbines account for around 70% of the total cost of the project. As a result, they are critical for producing power at the optimal level for the specific location. The power curve of a wind turbine is seen in graph.

Table.5. 2 Avaerage Wind turbine

Month	Average (m/s)
Jan	3.690
Feb	4.320
Mar	4.770
Apr	4.680
May	4.470
Jun	5.010
Jul	5.020
Aug	4.760
Sep	4.470
Oct	3.120
Nov	2.900
Dec	2.970



Graph.5. 2 Avaerage Wind turbine



Graph.5. 3 Wind Speed vs Height

The provided data table shows the average wind speed in meters per second (m/s) for each month of the year. This column shows the months of the year, beginning with January (Jan) and ending with December (Dec). In January, the average wind speed was 3.690 m/s. This suggests that modest wind speeds are common in January. Wind speed of 4.320 m/s on average. Winds are marginally stronger in February than in January. Wind speed of 4.770 m/s on average. Wind speed increases further in March, suggesting possibly windier weather. Wind speed of 4.680 m/s on average. The wind speed remains quite high in April. Wind speed of 4.470 m/s on average. Winds are still fairly strong in May. Wind speed of 5.010 m/s on average. The wind speed increases significantly in June, indicating that it is one of the windiest months. Wind speed of 5.020 m/s on average. The wind speed in July stays high, as it was in June. Wind speed of 4.760 m/s on average. Winds are strong in August, although significantly lower than in June and July. Wind speed of 4.470 m/s on average. Wind speeds are moderate in September. Wind speed of 3.120 m/s on average. Wind speeds drop significantly in October. Wind speed of 2.900 m/s on average. Wind speeds continue to remain modest throughout November. Wind speed of 2.970 m/s on average. Wind speeds in December remain moderate in comparison to the rest of the year.

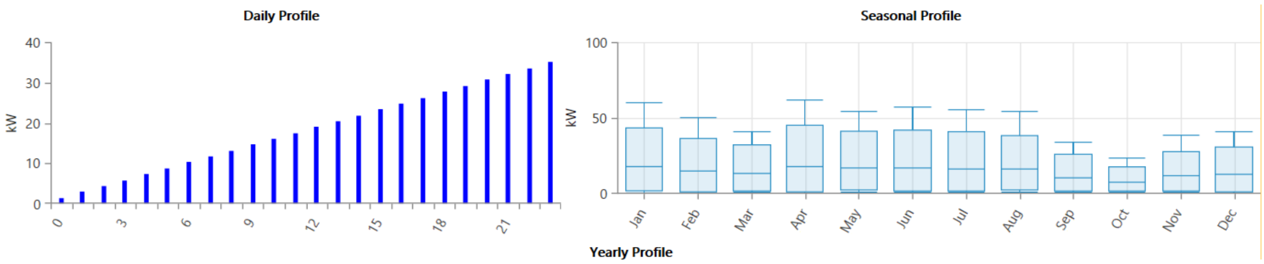
Load demand:

Load is shown as projected load in the hybrid power plant diagram. A typical feeder is used to estimate load demand since it has a high average load demand. This information is supplied into HOMER Pro as principal load demand.

Table.5. 3 Avaerage Load demand

Hour	Jan	Feb	March	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
0	1.458	1.250	1.042	1.458	1.354	1.354	1.354	1.250	0.833	0.625	0.937	1.041
1	2.916	2.500	2.083	2.916	2.708	2.708	2.708	2.500	1.666	1.250	1.875	2.083
2	4.374	3.750	3.125	4.374	4.062	4.062	4.062	3.750	2.499	1.875	2.813	3.125
3	5.832	5.000	4.166	5.832	5.416	5.416	5.416	5.000	3.332	2.500	3.751	4.167
4	7.290	6.250	5.208	7.290	6.770	6.770	6.770	6.250	4.165	3.125	4.689	5.209
5	8.748	7.500	6.249	8.748	8.124	8.124	8.124	7.500	4.998	3.750	5.627	6.251
6	10.206	8.750	7.291	10.206	9.478	9.478	9.478	8.750	5.831	4.375	6.565	7.293
7	11.664	10.000	8.332	11.664	10.832	10.832	10.832	10.000	6.664	5.000	7.503	8.335
8	13.122	11.250	9.374	13.122	12.186	12.186	12.186	11.250	7.497	5.625	8.441	9.377
9	14.580	12.500	10.415	14.580	13.540	13.540	13.540	12.500	8.330	6.250	9.379	10.419
10	16.038	13.750	11.457	16.038	14.894	14.894	14.894	13.750	9.163	6.875	10.317	11.461
11	17.496	15.000	12.498	17.496	16.248	16.248	16.248	15.000	9.996	7.500	11.255	12.503
12	18.954	16.250	13.540	18.954	17.602	17.602	17.602	16.250	10.829	8.125	12.193	13.545
13	20.412	17.500	14.581	20.412	18.956	18.956	18.956	17.500	11.662	8.750	13.131	14.587
14	21.870	18.750	15.623	21.870	20.310	20.310	20.310	18.750	12.495	9.375	14.069	15.629
15	23.328	20.000	16.664	23.328	21.664	21.664	21.664	20.000	13.328	10.000	15.007	16.671
16	24.786	21.250	17.706	24.786	23.018	23.018	23.018	21.250	14.161	10.625	15.945	17.713
17	26.244	22.500	18.747	26.244	24.372	24.372	24.372	22.500	14.994	11.250	16.883	18.755

18	27.702	23.750	19.789	27.702	25.726	25.726	25.726	23.750	15.827	11.875	17.821	19.797
19	29.160	25.000	20.830	29.160	27.080	27.080	27.080	25.000	16.660	12.500	18.759	20.839
20	30.618	26.250	21.872	30.618	28.434	28.434	28.434	26.250	17.493	13.125	19.697	21.881
21	32.076	27.500	22.913	32.076	29.788	29.788	29.788	27.500	18.326	13.750	20.635	22.923
22	33.534	28.750	23.955	33.534	31.142	31.142	31.142	28.750	19.159	14.375	21.573	23.965
23	34.992	30.000	24.996	34.992	32.496	32.496	32.496	30.000	19.992	15.000	22.511	25.007



Graph.5. 4 Avaerage Load demand

Biomass:

Biomass is one of the most important energy resources. Biomass is the most important non-conventional energy sources. Cow dung, rice straw, and other wastes are among the several types of bio garbage available.

Table.5. 4 Basic Information of the Bihar

Fetch Area (in Sq. Km.)	2795.71
Coordinate of Site Location	Latitude: 25.96859, Longtitude : 87.18909
State of Site Location	Bihar
District of Site Location	Araria
City of Site Location	Araria
Nearest Railway Station	Banmankhi Jn Railway Station, 9.306 Kms away
Nearest Petrol/Gas Station	Indian Oil Petrol Pump, 7.131 Kms away

Table.5. 5 Available Biomass/Bioenergy Resources

	Kharif Rice	Rabi Rice	Wheat	Cotton	Sugarcane	Total
Gross Biomass over fetch area (Kilo tons)	NS	NS	NS	NS	NS	NS
Surplus biomass over fetch area (Kilo tons)	12.97	0.00	16.57	0.00	0.00	-

Bioenergy potential over fetch area (Giga Joule)	201.01	0.00	288.35	0.00	0.00	489.35

Table.5. 6 LULC Statistical Details of Bihar

LULC Class	Area (Sq. Km.)
Built-up	153.13
Kharif Crop	167.72
Rabi Crop	179.9
Zaid Crop	63.61
Double/Triple Crop	1534.63
Current Fallow	96.9
Plantation	44.06
Deciduous Forest	127.14
Degraded/Scrub Forest	1.68
Wasteland	20.3
Waterbodies max	91.79
Waterbodies min	0.83

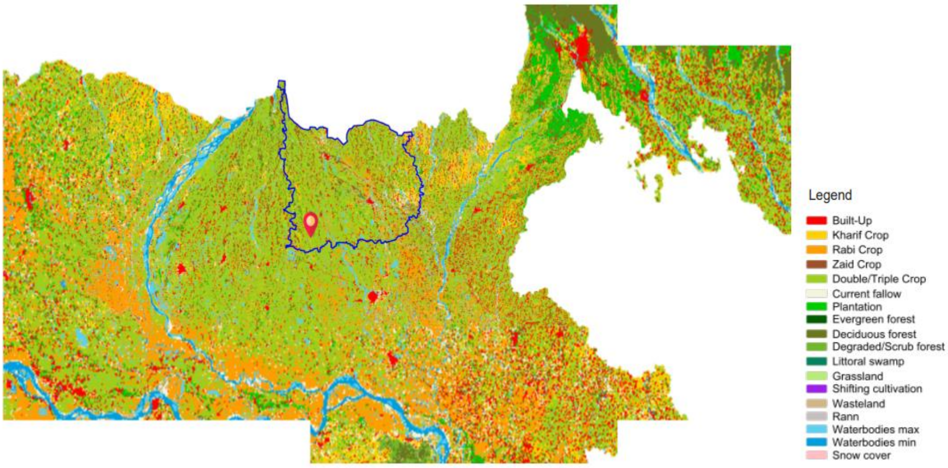
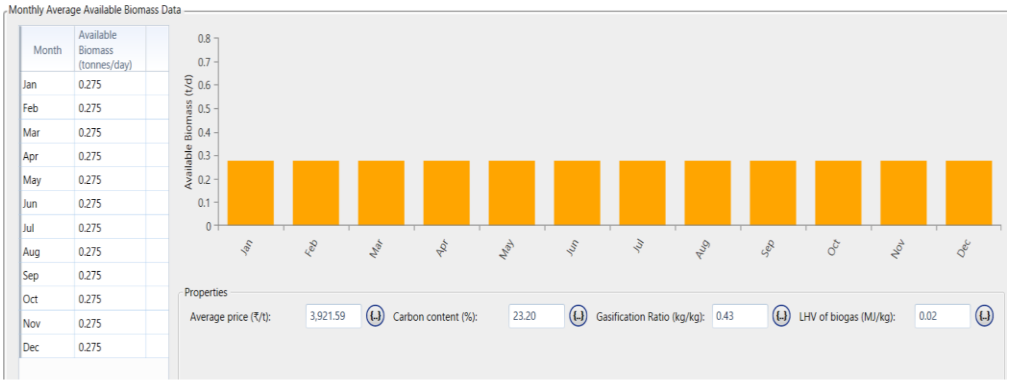


Fig.5. 1 Land Use Land Cover Map of the Fetch Area

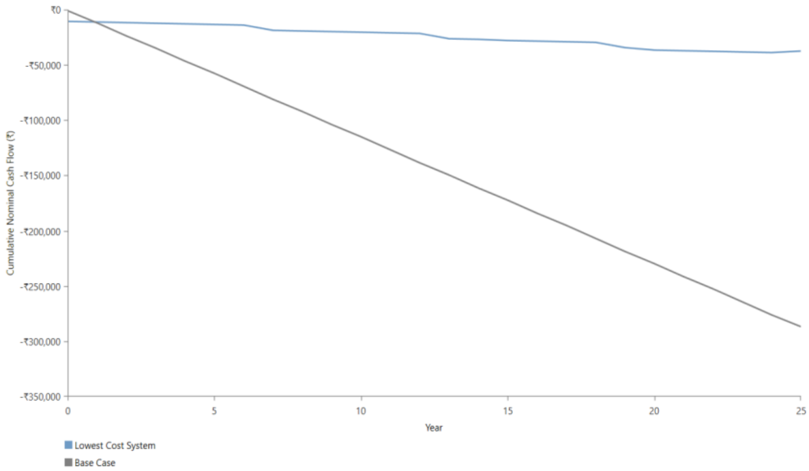


Graph.5. 5 Average Biomass

With Battery: Cost analysis:

Table.5. 7 With Battery: Cost analysis

Cost/NPC	Cost/COE	Cost/Operating cost	Cost/Initial capital
24642.07	0.4638881	1086.252	10599.52
27010.77	0.508479	1261.901	10697.52
31481.81	0.5927835	1001.753	18531.63
33136.49	0.623796	1693.982	11237.52
34900.73	0.6575242	1035.638	21512.5
54131.98	1.019037	3855.286	4292.708
69306.07	1.305691	2790.161	33236.21
92143.19	1.7346	5477.16	21337.12
105625.4	1.988403	6793.678	17800
113225.8	2.131482	7482.168	16500
148895.1	2.802957	11440.33	1000



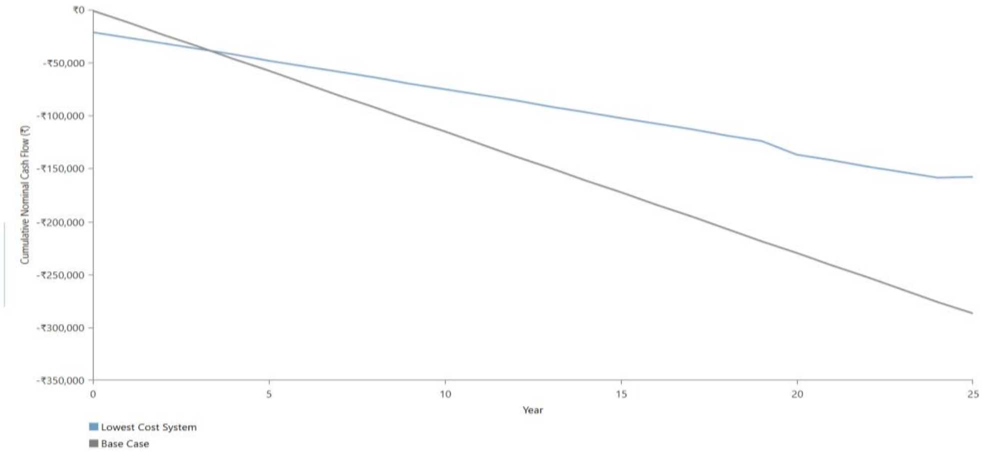
Graph.5. 6 With Battery: Average Cost analysis

This column shows the Net Present Cost, Energy Cost, Cost/Operating Cost, and Cost/Initial Capital. The results vary between 24,642.07 to 148,895.1. As we travel down the table, the expenses rise, showing that the project gets costlier over time or for various situations. Energy costs vary from roughly 0.464 to 2.803. The Cost of Energy, like the Net Present Cost, rises as we proceed down the table, implying that energy production gets costlier. The Cost/Operating Cost values range from 1,001.753 to 3,855.286 and 11,440.33. The running costs tend to vary dramatically, showing changes in expenditures associated with the project's continued operation. The cost/initial capital numbers vary between 4,292.708 and 21,512.5. The Cost/beginning Capital statistic, like other metrics, displays changes, indicating variances in the beginning capital needs for various situations or time periods.

Without Battery: Cost analysis

Table.5. 8 Without Battery: Cost analysis

Cost/NPC	Cost/COE	Cost/Operating cost	Cost/Initial capital
92143.19	1.7346	5477.16	21337.12
105625.4	1.988403	6793.678	17800
113225.8	2.131482	7482.168	16500
148895.1	2.802957	11440.33	1000



Graph.5. 7 Without Battery: Average Cost analysis

The Cost/NPC, Cost/COE, Cost/Operating Cost, and Cost/Initial Capital tables indicate the present value of all project costs throughout their lifespan, adjusted for the time value of money. This subset's Cost/NPC values vary from around 92,143.19 to 148,895.1. These figures represent the total cost of the project during its lifespan for various scenarios or time periods. This subset's Cost/COE values vary from about 1.7346 to 2.802957. These figures represent the cost of creating energy and imply that as we travel down the table, it gets costlier per unit of energy. The Cost/Operating Cost numbers in this subgroup range from 5,477.16 to 6,793.678 and 11,440.33. These figures represent the operating costs incurred throughout the project's operation. This subset's Cost/Initial Capital values vary from around 1,000 to 21,337.12. These figures represent the cost-to-capital-investment ratio, which provides information about the project's financial efficiency.

6. Conclusion and Future Scope:

Conclusion:

Finally, the performance analysis of hybrid renewable energy systems performed in this work utilising Homer Software gave useful insights into the practicality and potential of incorporating different renewable energy sources into the energy mix. The study focused on critical parameters such as solar radiation, wind turbine utilisation, load demand, biomass utilisation, and other relevant factors. The examination of solar radiation data indicated significant solar energy resources in the researched region. This resource has great potential for renewable energy production, particularly via photovoltaic technology. Wind turbine performance evaluations have proved the ability to successfully capture wind energy. Wind turbines have the ability to considerably add to the region's total energy generating mix. Understanding load demand patterns is critical when developing a hybrid renewable energy system. We may improve system efficiency and reduce dependency on non-renewable sources during peak demand times by aligning renewable energy output with the demand curve. Biomass resources have been acknowledged as an important part of the energy mix. Biomass may be used to generate electricity, heat, and ethanol, making it a flexible and sustainable energy source. A cost study has revealed critical information on the economic feasibility of adopting a hybrid renewable energy system. This data is critical for decision-makers since it aids in analysing the financial elements of such initiatives.

Overall, this study demonstrated the enormous potential of hybrid renewable energy systems to cover the energy demands of the examined region while lowering dependency on fossil fuels and minimising environmental concerns. When combined with powerful modelling tools like Homer, the combination of solar, wind, and biomass resources provides a sustainable route to energy security and decreased carbon emissions. Finally, the results of this performance study of hybrid renewable energy systems highlight the need of a multifaceted approach to sustainable energy production. We may prepare the road for a greener, more resilient, and more sustainable energy future by harnessing the advantages of various renewable sources and optimising their integration.

Future Scope:

Future research should examine more broad and accurate data gathering approaches, such as sophisticated monitoring systems and remote sensing. This would allow for more precise estimates of solar radiation, wind patterns, and biomass availability, resulting in more sophisticated energy system models. As energy storage technologies evolve, it will become more important to investigate how adding energy storage options, such as batteries or thermal storage, might increase the dependability and flexibility of hybrid renewable energy systems. This would allow for more effective control of intermittent energy sources such as solar and wind. Look at combining hybrid renewable energy systems with smart grid technology. This has the potential to improve grid stability, demand response capabilities, and the efficient delivery of renewable energy to end consumers. Future research might concentrate on creating sophisticated algorithms and optimisation approaches to improve the design of hybrid renewable energy systems. This involves establishing the appropriate combination of renewable energy sources, scaling components, and more precisely anticipating energy output patterns. Finally, the future offers considerable potential for the advancement of hybrid renewable energy systems. As technology advances and society puts a greater focus on sustainability, further research and innovation will be required to fully realise the promise of renewable energy sources and to build a more sustainable and resilient energy future.

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