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EMBRACING A SUSTAINABLE FUTURE: THE SYNERGY OF SOLAR-WIND INTEGRATED SYSTEMS IN AN EDUCATIONAL INSTITUTIONS-A CASE STUDY OF SOM, PDEU

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ABSTRACT: The urgent need to combat climate change and maintain energy security is causing a significant shift in the current global energy landscape. Leading the way in this shift to a sustainable future are solar and wind energy. However, maintaining a steady and dependable power supply is made more difficult by the intermittent nature of these renewable energy sources. Solar-Wind Integrated Systems have emerged as a viable approach to address this problem by fusing the advantages of photovoltaic (PV) and wind turbine (WT) technologies synergistically. One particularly noteworthy strategic strategy for addressing climate change and improving energy security is the integration of solar and wind energy. Compared to standalone solar or wind systems, PVWT systems have many benefits, such as better dispatchability, less output variability, and better use of the infrastructure already in place. The technical performance, viability, economic viability, environmental benefits, and the potential to lower operating costs, return on investment (ROI), and internal rate of return (IRR) are all highlighted in this paper's comprehensive techno-economic analysis of PVWT. PVWT technology development has accelerated significantly, as seen by several research projects and continuing pilot programs. PVWT systems are positioned to play a key role in accelerating the global shift of technological energy future as the technology advances and costs keep falling. In addition to addressing the issues brought on by climate change, this integrated approach strengthens the energy grid's general resilience and dependability.

KEYWORDS

PVWT (Photovoltaic and Wind Turbine) Integration, Technoeconomic Analysis, Solar-Wind Systems, Renewable Energy, Synergy

Introduction

The urgent need to switch from fossil fuel-based systems to cleaner, more sustainable alternatives is causing a significant transformation in the global energy landscape. (Wang, et al 2023) Because of their abundance, sustainability, and low environmental impact, solar and wind energy are among the renewable energy sources that are essential to this transition. However, there are inherent drawbacks to both solar and wind energy that may prevent their widespread use. (Ahmed, et al 2008). While wind energy is variable and dependent on wind direction and speed, solar energy is sporadic and dependent on daylight hours. These elements may cause variations in energy output, which makes it difficult to offer a steady and dependable power source. India is ideally situated to take advantage of both solar and wind energy due to its large land area and varied climate. The estimated unrealized potential for wind and solar energy in the nation is 100 GW and 5,000 GW, respectively. (Maouedj, et al 2014). With 175 GW of installed solar power and 41 GW of installed wind power, India currently ranks fourth in the world for solar power production and has made significant progress in this area. Wind energy in India is also growing at a rapid rate with an installed capacity of 38GW. The National Wind Energy Mission aims to achieve the target of an installed capacity of 60GW. Wind power is spread across the states like Gujarat, Rajasthan, Tamil Nadu, Karnataka, and Maharashtra.

A potential remedy for the problems caused by the erratic nature of solar and wind power is Solar-Wind Integrated Systems (SWIS). The goal of SWIS is to lessen each other's disadvantages by utilizing the complementary qualities of solar and wind energy generation. The main idea is to integrate the benefits of both technologies to offer a more dependable and consistent supply of electricity. By 2030, the Indian government hopes to generate 500

GW of electricity without the use of fossil fuels, and it has set ambitious targets to increase the use of renewable energy sources. (Komrit, & Zabihian, F.,2023). A strategic method for accomplishing these objectives through optimizing the advantages of solar and wind energy is represented by SWIS. SWIS may play a key role in the global shift towards a more dependable and sustainable energy future as infrastructure and technology develop further. The advantages and financial challenges of the photovoltaic wind turbine (PV-WT) integrated system are shown below:-

Advantage	**Financial Challenges**
Enhanced Reliability	Technological Advancement
Improved Efficiency	Regulatory Framework
Reduce Infrastructure Cost	Financial Incentives
Environmental Benefits	Capacity Building
Sustainable Development	Community Engagement

Literature review

Academic curiosity has been piqued by Narendra Modi's 2021 commitment to India becoming net-zero carbon emissions by 2070, which was made public at COP26. (Gupta 2023) examines the viability of India's roadmap, (Kumar 2023) investigates the political aspects, and (Smith 2022) assesses the worldwide influence. (Patel 2022) investigates public opinion, and (Johnson 2023) provides a comparative evaluation of the climate pledges made by world leaders. Together, these pieces aid in our comprehension of the political dynamics, ramifications, and difficulties associated with Modi's audacious environmental objectives. India's pursuit of renewable energy (RE) aligns with its goal of achieving 175GW by 2022, as outlined in government initiatives allowing up to 100% FDI. Diversifying into solar, geothermal, biomass, and fuel cell technologies, India anticipates substantial investments, addressing energy shortages and environmental concerns. The economic impact is evident, with reduced imports of petrol and coal, fostering sustainable development. RE's potential for job creation, exemplified by 2.3 million global jobs, contributes to improved health and education. Green energy emerges as a crucial driver for India's future progress, ensuring economic growth, environmental sustainability, and social well-being (Edenhofer et al., 2011; Twidell & Weir, 2015; Panwar, Kaushik, & Kothari, 2011). The integration of solar and wind turbine systems, known as PVWT, is a promising approach to achieving sustainable energy (Deymi *et al*, 2022) highlights the benefits of PVWT, including increased energy output, reduced grid costs, and enhanced resilience. Similarly, Hybrid Renewable Energy Systems (HRES) have been considered as a potential solution to the intermittent nature of individual renewable energy sources (Roy *et al*. 2022). HRES combines complementary renewable energy sources with energy storage to provide reliable electricity. Both PVWT and HRES represent advancements towards resilient, dependable, and cost-effective renewable energy options, which are crucial for developing modern power grids and achieving sustainability goals. There is research that has focused on medium-scale solar installations in green campuses, and ways to employ Renewable Energy Systems (RES) to address the fuel-based energy demand, especially in Indonesia (Kristiawan *et al*, 2018). The research evaluated the technical viability and economic parameters using HOMER software, examined conventional power grid architectures, and emphasized the need for equilibrium in the face of challenges posed by renewable energy sources (Kristiawan *et al*, 2018). Extant literature provides insights into the technical and financial considerations for integrating solar and wind power, underscoring the importance of local conditions and careful planning. The eco-financial impact of PV systems was examined in a study in Romania using BlueSol Design and Open LCA software and it was found valuable insights into the environmental and economic aspects of PV system implementation (Orboiu & Andrei, 2019). Meanwhile, a global review study also highlights initiatives and challenges faced featuring case studies from the US and India (Lottu *et al*. 2023). A solar farm in the United States exemplifies a large-scale installation, and the Solar Schools program combines education with solar initiatives. The design of solar panel PV systems can be performed using various software tools, including RET screen analysis, SAM, and PVGIS (Kumi et al. 2018; CS Psomopoulos 2015, Abbood et al.; Malvoni 2014; Akash Kumar Shukla et al. 2020; Huld 2006). To ensure the economic viability and technical feasibility, appropriate design, performance analysis should be conducted using suitable software (Manoj Kumar, 2019; Psomopoulos, 2015; Sharma & Goel, 2017).

Research Gap

To get the most output out of this industry, even though the photovoltaic wind turbine sector has conducted a significant amount of research, many problems and questions remain to be answered. The following lists the key gaps that we found: -

Integration of PV and Wind Systems: To improve overall efficiency and dependability, research the best practices for combining photovoltaic and wind power systems.

Energy Storage Technologies: Examine cutting-edge energy storage options to deal with sporadic problems in wind and photovoltaic power generation.

Grid Integration Issues: Analyze issues pertaining to the grid integration of wind and photovoltaic power and suggest fixes for a smooth transition into the current power infrastructure.

Techno-economic Analysis: To determine the most economical PV and wind power system configurations for various locations and scales, conduct thorough techno-economic analyses.

Environmental Impact Assessment: Examine how large-scale photovoltaic wind turbine installations will affect the environment, considering things like wildlife, land use, and ecological balance.

Impact of Climate Variability: Examine how the performance of wind and photovoltaic systems is affected by climate variability and create strategies for adaptation. Evaluate the contribution of smart grid technologies to improving photovoltaic wind turbine integrated system integration and management in the context of the larger energy infrastructure.

Research Objectives

The examination of alternative energy sources is required due to the increasing demand for sustainable and clean energy sources. Wind turbine (WT) and solar photovoltaic (PV) systems present viable means of accomplishing this objective. Nevertheless, the intermittent and variable power outputs of both sources restrict their respective efficacy. The main objective of research is given below:

- Assessing the PVWT system's viability
- Investigating into integrated system optimization
- Searching into grid integration issues
- Evaluating community involvement with renewable energy
- To investigate the system's operational and economic challenges

The research objective is accomplished by looking at optimal system configurations, resolving grid integration problems, and offering strategies for community engagement. This study provides organizations searching for sustainable energy solutions with a helpful road map. The study looked at the advantages and financial effects of putting photovoltaic wind turbine into practice, accounting for the significance of technological advancements, legal frameworks, financial incentives, and capacity building. By bridging the gap between theoretical potential and practical implementation, this research ultimately aims to provide insightful information that will assist educational institutions in starting down the path towards energy sustainability.

Research Methodology

With its ability to facilitate environmental and economic analysis, validate models, and pinpoint potential drawbacks, HOMER is a flexible instrument for developing and accessing renewable energy systems. A case study will demonstrate how HOMER can be used in practice to design a renewable energy system for a particular site, considering site-specific data, system design limitations, and environmental and economic performance standards. The technical feasibility, economic viability, and environmental impact of the renewable energy system will all be thoroughly assessed using HOMER software. The study will assess HOMER's efficiency in developing renewable energy systems and offer learnings from the examination of the case studies. It will also make recommendations for future studies to overcome HOMER's shortcomings and increase its capabilities.

HOMER Simulation Model

The Homer Energy website includes several case studies that illustrate how HOMER has been used in real-world projects. For example, one case study describes how HOMER was used to design a microgrid system for a remote village in Alaska. The system is powered by a combination of solar panels, wind turbines, and a diesel generator. HOMER was used to optimize the system design and to ensure that it could meet the village's electricity needs reliably and affordably. (HOMER Energy,2023). A 2019 paper published in the journal "Renewable and Sustainable Energy Reviews" reviews the use of HOMER for microgrid design and optimization. The paper concludes that HOMER is a valuable tool for microgrid planning and that it can help to reduce the cost and complexity of microgrid projects. (Lalit, P., & Bahar, R. 2019).

The hybrid optimization model for electric renewables (HOMER) computer model was developed by the National Renewable Energy Laboratory (NREL) in the United States to help designers create renewable energy systems for both on-grid and off-grid projects. It also facilitates the evaluation of various combinations of power generation technologies. A detailed flowchart in figure 1 shows the HOMERS simulation process is provided below, covering each step-in detail.

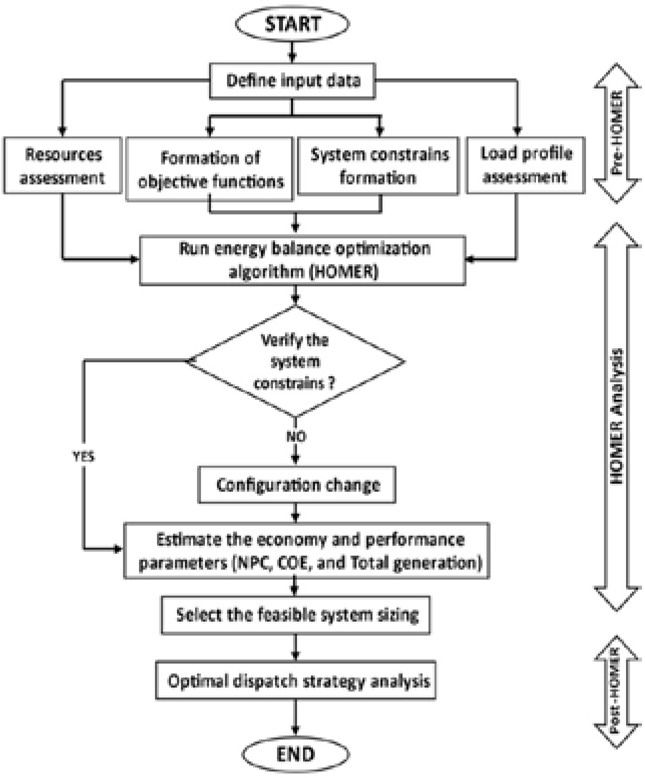

Figure 1: HOMER simulation process

HOMER helps with optimization for different load scenarios and supply systems. The supply system includes PV, wind, biogas, generators, converters, batteries, hydro power, hydrokinetic, and grid supply. It is also simple to calculate net energy costs. HOMER generates the best outcome after analyzing various combinations for the input that was supplied. HOMER makes it easier to compare the various results. This allows us to select the design that best suits our needs in terms of available funds, available space, figure 2 shows how the cost analysis takes place in HOMER software.

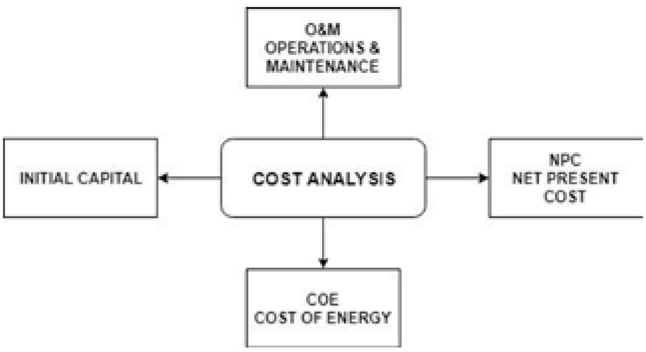

Figure 2: Cost analysis

System Cost Comparison

Systems	Technical			
	PV (kW)	G10	Converter (kW)	1000KWh Li
PVWT	992	9	456	13
Only solar (PV)	1217	0	435	16
Only wind (WT)	0	141	768	50

Systems	Economical			
	NPC (M)	Initial Capital (M)	O&M (per year)	LCOE (/kWh)
PVWT	₹ 4.90	₹ 4.00	₹ 62,932.00	₹ 0.39
Only solar (PV)	₹ 5.24	₹ 4.31	₹ 64,255.00	₹ 0.42
Only wind (WT)	₹ 15.20	₹ 10.80	₹ 3,02,305.00	₹ 1.23

Table 1: System comparison

The Table 1 above shows the comparison of the 3 systems which is taken for simulation to find the levelized cost of economics.

Only Solar (PV)

With a 1217 kW capacity, a 435-kW converter, and a 16-kWh lithium-ion battery, the Only Solar (PV) System is exclusively focused on photovoltaic energy. Economically speaking, it has an LCOE of ₹0.42 per kWh **($0.0050 per kWh)**, an annual O&M cost of ₹64,255.00 **($770.59)**, an initial capital of ₹43.1 Lakhs (**$51,688.49)**, and an NPC of ₹52.4 Lakhs (**$62,841.70)**.

Only Wind (WT)

With a 50-kWh lithium-ion battery, a 768-kW converter, and a 141-kW wind turbine, the Only Wind (WT) System runs solely on wind energy. In terms of economics, this system has a higher LCOE of ₹1.23 per kWh **($0.015 per kWh)**, a higher annual O&M cost of ₹3,02,305.00 (**$3,625.45)**, a larger initial capital of ₹1.08 crore **($129,521.05)**, and a higher NPC of ₹1.520 crore **($182,288.89).**

Photovoltaic Wind System (PVWT)

In contrast, Solar and wind energy are combined in the PVWT (Photovoltaic and Wind Turbine) system. It attempts to integrate various renewable sources for effective power generation with a solar capacity of 992 kW, a wind turbine capacity of 9 kW, a converter capacity of 456 kW, and a 13-kWh lithium-ion battery. The system is economically valued at ₹4.90 million for Net Present Cost (NPC), ₹40.0 Lakhs **($47,970.76)** for Initial Capital, ₹62,932.00 **($754.72)** for Annual Operations and Maintenance (O&M), and ₹0.39 per kWh **($0.0047 per kWh)** for Levelized Cost of Electricity (LCOE). Figure 3 below shows the LCOE of 3 simulated systems. So, we can conclude that PVWT has the lowest cost of economics.

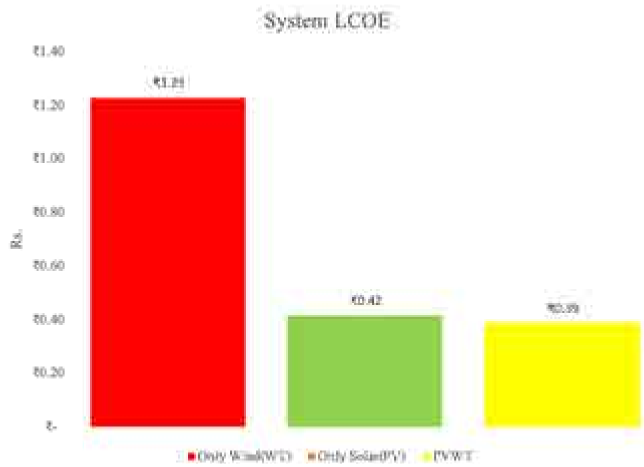

Figure 3: LCOE of systems

System Description

Electricity is produced by the hybrid solar-wind power system by combining off-grid components. The solar Global Horizontal Irradiance (GHI) or the Direct Normal Irradiance (DNI) are used to calculate the available solar radiation, while the wind resource comes from the wind energy forecast by NASA. Figure 4 provides the location of the case study.

Figure 4: SoM Campus, PDEU

Wind turbine

These are the systems that convert the mechanical energy of wind to electrical energy. Wind turbines start generating electricity at the cut in speed which is usually 3-5 m/s. The wind output power is specified by the relation given below: -

$P_w = 0.5 * pa * C_p * A * n_t * n_g$ where,

Pa = air density (1.22kg/m3)

A = area swept by rotor in m2

C_p = wind turbine power coefficient

n_t = efficiency of wind turbine

n_g = efficiency of generator

Photovoltaic System

Solar panels convert the radiation of sun rays into electrical energy using photovoltaic cells which are made up of semiconducting material like Silicon, Germanium, Gallium, and arsenide. The equation below can help to calculate the total annual power (SE) results from Photovoltaic system in (kWh). Where (N_h) is the number of data hour in the year, (t) is the hour of the year, (A_{solar}) is the fixed area of the solar field in (m2), (G_t) is the hourly insulation in (Wm-2), ($n_{solar,\,t}$) is the solar system efficiency for a specified hour of day through a given month.

$$S_E = \sum_{t=1}^{N_h} n_{solar,t} \, A_{solar} \, G_t$$

The output power of the photovoltaic system (ppv) in (kW) is expressed below. Where (fPV) is the derating factor percentage for the photovoltaic array, (YPV) is the photovoltaic array rated capacity in (kW), which is the power production under STC. (GT, STC) is the incident solar insolation at STC (1 kW/m2), (GT) is the solar insolation incident on the PV array at the current time step in (kW/m2), (Tc,STC) is the temperature of the photovoltaic cell under STC which is 25°C, (Tc) is the temperature of the photovoltaic cell at the current time step in (°C), and (αP) is the power temperature coefficient in (%/°C).

$$P_{pv} = Y_{pv} \cdot f_{pv} \left[\frac{G_T}{G_{T,STC}}\right] [1 + \alpha_P (T_C - T_{C,STC})]$$

Off-grid model

Off grid systems are systems that are not connected to the grid and work independently as its own grid. Batteries are used in the storage of energy generated by the system. The model shown in figure 5 consists of a wind turbine of 10KW, generic PV plate of 1KW, 100KWHh Li battery storage system converter and 2 loads, one being residential PDEU HRH and other being SoM, PDEU campus.

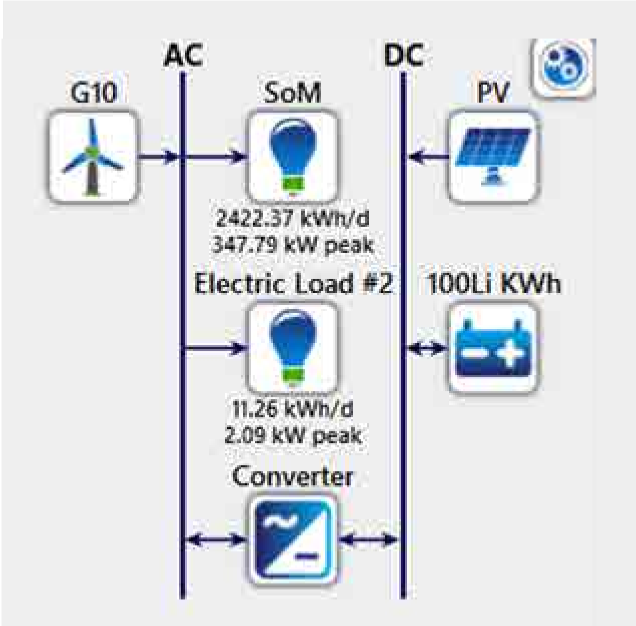

Figure 5: Off grid Model

Analysis & Results

The analysis of the simulation of our proposal system is shown below with the component description and the cost summary. The description includes the main information like the rated capacity, quantity of the component required, total production, losses etc. The electricity needs of School of Management (SoM), Raysan, Gujarat 382421, India is met with 992 kW of PV, 1,300 kWh of battery capacity and 90 kW of wind generation capacity. The operating costs for energy are currently ₹62,932 **($754.78)** per year. Figure 6 below shows the description of the wind turbine, system converter, and PV system. This microgrid requires 2385 kWh/day and has a peak of 349 kW. Table 2 shows the summary and specification of the components used in the model.

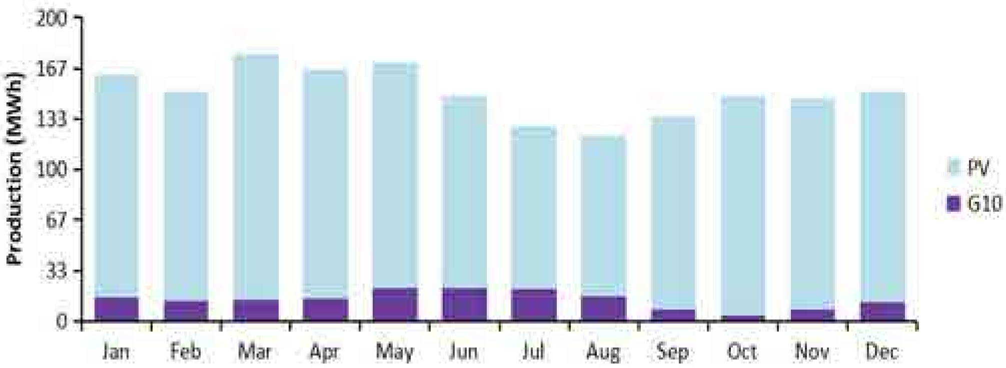

Figure 6: Total production of G10 and PV

Generic flat plate PV			System Converter				G10		
Quantity	Value	Units	Quantity	Inverter	Rectifier	Units	Quantity	Value	Units
Rated Capacity	992	kWh	Capacity	456	456	kW	Total Rated Capacity	90	kWh
Mean output	186	kW	Mean output	81.6	1.14	kW	Mean output	19.8	kW
Mean output	4472	kWh/d	Maximum output	346	70.4	kW	Capacity Factor	22	%
Capacity Factor	18.8	%	Hour of operation	7924	456	hr/yr	Maximum output	90	kW
Maximum output	989	kW	Energy out	714121	9968	kWh/yr	Wind Penetration	19.5	%
Hour of operation	4393	hr/yr	Energy in	751707	10493	kWh/yr	Hour of operation	7,216	hr/yr
Total Production	16,32,399.00	kWh/yr	Loss	37585	525	kWh/yr	Total Production	1,73,165	kWh/yr

Generic 100kWh Li-ion		
Quantity	Value	Units
Batteries	13	nos.
String size	1	batteries
String in parallel	13	strings
Bus voltage	600	V
Autonomy	10.3	hr
Storage Wear cost	0.246	Rs./kWh
Nominal Capacity	1300	kWh
Usual nominal Capacity	1040	kWh
Lifetime output	27,07,900.00	kWh
Expected Life	15	yr
Losses	19,015	kWh/yr
Annual Throughput	180527	kWh/yr

Table 2: Specification of components

Table 3 shows the cost summary of the system with various factors like capital cost, replacement cost, O & M cost etc. The total cost of the system is 40Lakhs **($47,972.64)** and after 25 years the value of the system is 49Lakhs **($58,766.48)** with 9 Lakhs **($10,793.84)** profit every year.

Cost Summary					
Component	Capital (Rs.)	Replacement (Rs.)	O& M (Rs.)	Salvage (Rs.)	Total (Rs.)
Generic 10kW	4,50,000.00	1,77,478.00	64,964.00	-1,05,484.00	5,86,958.00
Generic PV	24,79,076.00	-	1,43,156.00	-	26,22,232.00
100KwH Li ion	9,10,000.00	4,52,887.00	1,87,674.00	-94,805.00	14,55,756.00
Other	20,000.00	-	28,873.00	-	48,873.00
System converter	1,36,675.00	68,020.00	-	-14,239.00	1,90,456.00
System	39,95,751.00	6,98,385.00	4,24,667.00	-2,14,528.00	49,04,275.00

Table 3: Cost Summary of the system

Here the total capital cost is 40 lakhs **($47,974.56)** and after 25 years the value of the system will be 49 lakhs **($58,768.84)**, which is a profit of 9 lakhs **($10,794.28)**. Figure 7 below shows the cumulative cash flow over the lifetime of the project. The economics of off grid system is given in Table 4 below which consists of NPV, LCOE, operating cost and other rates of the system.

Economics	Value
Net Present Value	₹ 49,04,278.00
LCOE	₹ 0.390
Operating Cost	₹ 62,932.00
ROI	4.90%
IRR	7.10%
Simple Payback	14.28yr
Discounted Payback	14.62 yr
Project Lifetime	25yr
Discount Rate	10.0%
Expected inflation rate	5.0%
Real Intrest Rate	4.80%

Table 4: Economics of the system

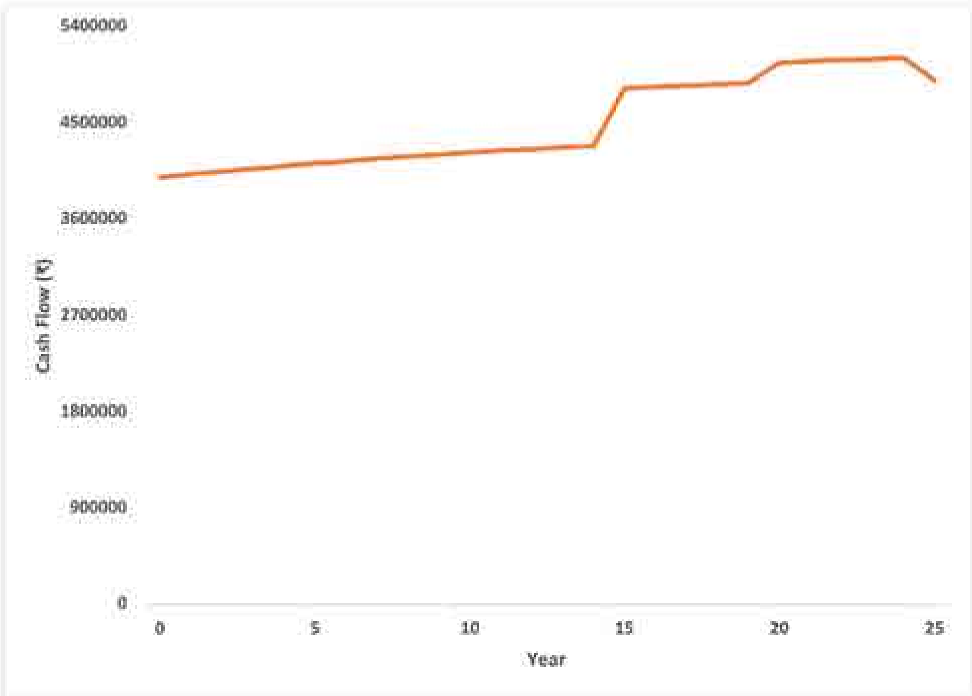

Figure 7: Cumulative cash flow

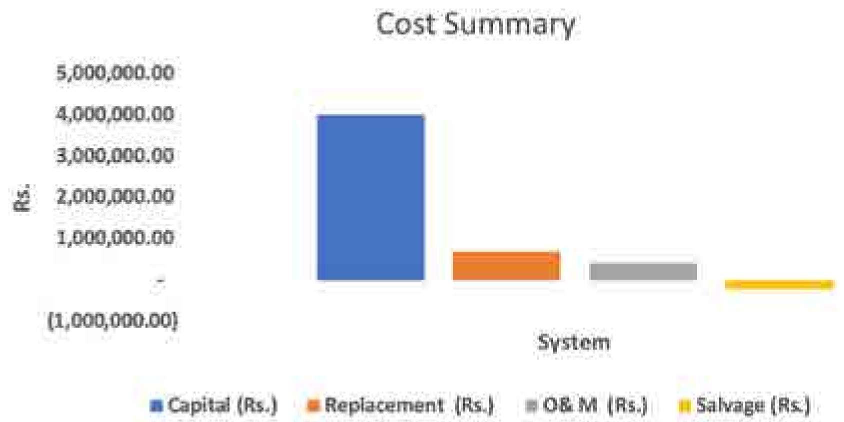

Figure 8: Cost summary

The cost summary provides a comprehensive overview of the financial aspects associated with the implementation and maintenance of various components in a renewable energy system is shown in figure 8. The system in question involves a Generic 10kW, Generic PV, 100KwH Li ion, other components, and a System converter. The Generic 10kW component incurs a capital cost of Rs. 450,000.00 **($5,397.24)**, with additional expenses for replacement, operation, and maintenance (O&M), and a negative salvage value, resulting in a total cost of Rs.586,958.00 **($7,039.89)**. The Generic PV, with a capital cost of Rs.2,479,076.00 **($29,733.69)** and O&M costs of Rs. 143,156.00 **($17,16.99)**, presents a total investment of Rs.2,622,232.00 **($31,447.27)**. The 100KwH Li ion component involves a capital investment of Rs.910,000.00 **($10,913.23)**, replacement costs of Rs.452,887.00(**$5,107.47)**, and O&M expenses of Rs.187,674.00 **($2,250.69)**. The negative salvage value contributes to a total cost of Rs.1,455,756.00 **($17,458.24)**. Other components have a capital cost of Rs.20,000.00 **($239.85)** and O&M costs of Rs.28,873.00 **($346.26)**, totaling Rs. 48,873.00 **($586.11)**. The System converter, with a capital investment of Rs. 136,675.00 **($1,639.08)**, replacement costs of Rs. 68,020.00 **($815.73)**, and a negative salvage value, results in a total cost of Rs. 190,456.00 **($2,284.05)**.

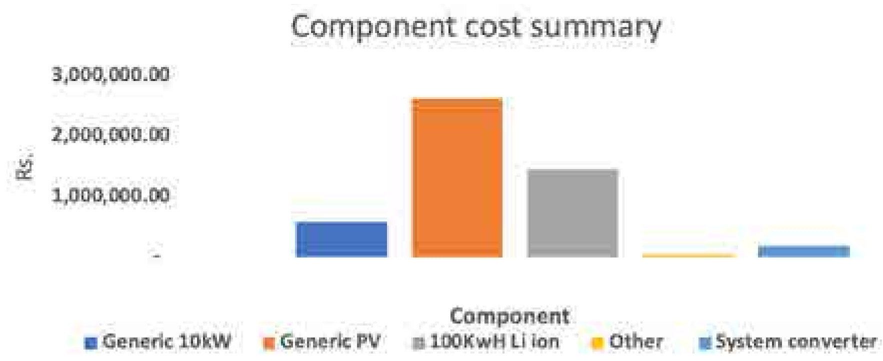

Figure 9: Component cost summary

In summary, the overall cost of the entire system, including all components, is figure 9 outlined at the bottom. The total capital investment stands at Rs. 3,995,751.00 **($47,919.80)**, with replacement costs amounting to Rs. 698,385.00 **($8,375.51)** and O&M expenses at Rs. 424,667.00 **($5,092.90)**. The negative salvage value is factored in, resulting in a net total cost of Rs. 4,904,275.00 **($58,815.45)**. This cost summary provides a clear breakdown of the financial implications associated with each component, aiding in decision-making and budgetary considerations for the renewable energy system.

Limitations

- Initial Investment Costs: Installing wind turbines and solar panels can come with high upfront costs, which means the institution will need to make a sizable initial investment.
- Site Restrictions: The SoM, PDEU campus may not have enough suitable land for the installation of solar panels and wind turbines, which could limit the system's capacity.
- Renewable Energy Source Variability: The output of intermittent sources like solar and wind energy can vary based on the weather. Energy storage options might be necessary because of this unpredictability to guarantee a steady supply.
- Maintenance and Expertise: To guarantee optimal performance, solar wind integrated systems need to have regular maintenance. It might be necessary for the organization to outsource maintenance services or acquire expertise in maintaining these systems.
- The research can also be done at the places above the Tropic of Cancer where there is less potential for solar energy and greater potential for wind energy.

Managerial Implications

The practical consequences of study findings or conclusions for managers and decision-makers are known as managerial implications. They offer perspectives on how the results can be used to strengthen organizational performance, make better decisions, and take advantage of opportunities or challenges.

Technical Understanding: Staff and students at the PDEU School of Management (SoM) will gain technical knowledge of the integration of solar and wind systems into the energy infrastructure, as well as interdisciplinary skills. Participants can apply their interpretation of site-specific data to the renewable energy system design decision-making process through the case study.

Holistic Analysis: Understanding of the environmental and economic analysis of renewable energy systems will be imparted to participants from SoM and PDEU, with an emphasis on the need for a long-term balance between ecological and financial factors. Users can verify that the models accurately forecast system performance and align with the institution's social and environmental commitment by establishing the models.

Practical Applications: Through case studies, instructors and students can apply theoretical knowledge to real-world scenarios, which aids in the development of practical problem-solving skills relevant to the educational setting. Participants can acquire practical knowledge with the HOMER application for renewable energy system design through the case study.

Sustainable Campus planning: The management can utilize the case study's insights to guide decisions about sustainable campus planning, considering the possible risks, disadvantages, and advantages of combining solar and wind systems.

Optimizing Campus Energy Usage: The institution's energy systems can be optimized with the management's assistance to meet both environmental and economic performance requirements. The environmental benefit includes reducing GHG emissions, reducing load on grid system while the economic performance includes the ROI, payback period, inflation rate etc.

Monitoring and Reducing Risks: The School of Management, PDEU's case study enables students to acquire practical risk management skills for wise decision-making in solar wind integrated systems. Interdisciplinary collaboration fosters effective risk identification and mitigation by integrating technical and managerial knowledge. Emphasis on balanced risk assessment, considering environmental and economic effects, contributes to a sophisticated strategy for handling uncertainty in the institution's renewable energy projects.

Future Scope

- Improve solar and wind technology with energy-storage, smart grids, next-generation turbines, and efficient panels. Investigate hybrid systems for maximum dependability.
- Examine how to maximize the efficiency of solar-wind systems in learning environments while taking demand, location, and weather into account. Boost dependability with cutting-edge control systems.
- Ensuring integrated solar-wind systems operate sustainably and effectively requires teamwork, hands-on learning, and ongoing upkeep, upgrades, and monitoring.

Conclusion

Lastly, by combining solar and wind energy, photovoltaic wind Integrated Systems (PVWT) present an alluring solution to the issues brought on by climate change and the need for sustainable energy sources. The state of the global energy system makes it abundantly evident how urgently cleaner alternatives must replace fossil fuel-based ones. The project will require 40 lakhs in capital, with a 9-lakh profit margin anticipated after 25 years, according to the cost summary. The cumulative cash flow graph is trending in the right direction. The system breaks even and begins to turn a profit after 14.68 years. This illustrates the long-term economic viability of PVWT systems, making them investments that are wise for the environment and the economy.

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