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Techno-Economic Assessment of Grid Connected Solar PV/Wind hybrid System

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Abstract. Wind and Solar PV energy as alternative energy supplies to the traditional fossil fuel have been a subject of study for researchers at various fora including climate change summits. However, the technical and economic feasibility of wind and solar projects involve a lot of complexity and depends mostly on geographical location and availability of resources. To address the constraints and factors affecting wind and solar PV systems, this paper aims to undertake a techno-economic feasibility assessment of a grid connected solar PV/Wind hybrid system capable of meeting a typical commercial load, located in Kumasi, Ghana. To achieve the purpose of this study an energy audit has been undertaken to establish the load demand of the facility. Again, RETSCREEN software was used to design and simulate the proposed hybrid system in order to analyse the technical, economic and environmental implications of the system. Findings show that, there is a high potential for providing commercial scale energy consumption in most months in the year, and there is extra energy available to be sold to the grid, generating considerable income. Though the system has a high levelized cost of energy (LCOE) as compared to the existing grid tariff, the study adds significantly to the national objective to reduce its dependency on fossil fuels while meeting local energy requirement.

1. Introduction

Important, worldwide debates have concentrated on problems such as sustainable energy development and greenhouse gas (GHG) emissions in recent years. The International Energy Agency (IEA) has stated that, assuming current government policies remain unchanged, the world's primary energy demand is predicted to rise by 1.5 percent each year from 2007 to 2030, for a total increase of roughly 40 percent [1]. Global electricity demand, on the other hand, is predicted to rise by 2.5 percent every year over the same time period [2] However, fossil fuels continue to dominate the world's fuel mix, resulting in continuous increases in carbon dioxide in the atmosphere, exacerbating the negative effects of global warming.

Conventional energy sources, such as fossil fuels, are rapidly decreasing, requiring international leaders to implement more sustainable energy policies to control this trend [3]. Renewable energy has been considered as one of the primary solutions to the world's energy crisis [4]. Renewable energy sources are often carbon-free or carbon-neutral, making them one of the most effective ways to help alleviate the consequences of climate change. The biggest disadvantage of renewable energy technology is the expensive initial cash required [5]. The costs of these renewable energy sources, on the other hand, have been declining in recent years as a result of technological advancement and market maturity [5].

Most economies benefited greatly from this cost decrease from the use of those technologies were encouraged. This eventually led to sustainable energy development and the mitigation of the effects of climate change. Global renewable energy capacity rose at rates ranging from 10% to 60% per year for many technologies throughout the five-year period spanning from the end of 2004 to the close of 2009 [6]. However, grid-connected solar photovoltaic (PV) and wind systems continue to be the world's fastest growing energy technologies, with cumulative installed capacity increasing by 60% per year from the end of 2004 to the end of 2009 [7].

In the past few years, the people of Ghana had to endure some intermittent power outages and this was partially due to over dependence on hydropower which suffers from low water volume during the dry season. Again, the insufficient supply of fuel to thermal power plants and foreign exchange challenges are partially responsible for these intermittent power outages. Grid power demand is expected to increase beyond 24,000GWh by 2023, from around 6,900GWh in 2000 [8]. To ensure reliable, uninterrupted energy supply by 2030, Ghana's present capacity, which was 1760 MW in 2006 must be increased to meet growing energy demand by 2030 [8]. Ghana aims towards increasing the percentage of alternative clean and renewables in it energy mix to 10% by 2030 [8].

A glance at the global mean solar radiation reveals that, the continent of Africa experiences the most intense sun radiation, which ranges from 300 to 350 W/m2 annually, and moderation to commercial scale wind speeds, making a combination of solar PV and wind power system a great option for hybrid energy supply [9,10]. Ghana has great potentials for solar energy such as standalone and grid connected solar PV system. Despite these enormous potentials, Ghana has not made enough use of its renewable energy potentials and still suffer from intermittent power outages while many communities do not still have access to grid electricity.

A plethora of studies has been conducted in the field of grid connected hybrid renewable energy systems all around the world as elaborated in the paragraphs below.

At Hashemite University, [11] examined the economic and technical performance of an open-loop and double axis fixed solar PV system in Jordan. The grid connected solar PV system was technically evaluated based on the final energy yield and conversion efficiency. The economic evaluation considered for the grid connected solar PV system were internal rate return, payback period and cost of electricity per kilowatt hour. The result of the study revealed that the solar PV with the tracker performed better in energy yield than the fixed axis solar PV system.

Pradhan et al. (2015) evaluated a grid connected solar PV system for a Hostel and an engineering college in India [12]. The authors used RETScreen computational software to simulate the design. The study objective was to examine the amount of reduction in energy consumption from the grid system with the introduction of solar PV power into the energy mix. According to the study, 772 gallons of crude oil was saved from the adoption of the grid connected solar PV system. However, the study could not establish the base emission of the study area.

Another study was conducted by [13] to see how much electricity may be saved in Jordan's water industry by using grid-connected PV systems. The study was held in five different locations, and it proved that grid connected PV power system is a feasible and cost-effective alternative.

Kumi (2012) assessed the economic and technical impact of a grid connected solar PV system for Kwame Nkrumah University of Science and Technology (KNUST) in Kumasi, Ghana [14]. The proposed system is only viable if the LCOE is more than 0.43$/kWh according to the findings of the study. The study also discovered that the most expensive solar PV module was the amorphous silicon panels, but performed better in energy yield as compared with monocrystalline and polycrystalline modules.

Al-Masri et al. (2019) conducted a technical and economic investigation of a grid-tied wind power system in the desert of Jordan [15]. The study performed a mathematical modelling in MATLAB using hourly wind speed data and load demand of the case study area. Simulated annealing and genetic algorithm were used by the authors to find the lowest LCOE of the proposed system. The study resulted in the reduction of CO2 emission and LCOE by 18.74% and 58.39% respectively.

Similarly, Dalabee (2017) picked five Jordanian locations to assess the economic potential of wind energy plants [16]. Their best site's LCOE was 0.0259 to 0.0498 $/kWh, while the LCOEs of other sites were 0.2220 to 0.2220 $/kWh. The cost range was considered appropriate within the limitations of the MENA region's needs.

Ammari (2015) used recorded averages and the Weibull function in similar research for five locations in Jordan to measure wind power [17]. According to the authors, the greatest wind speed at Aqaba airport was 7.05 m/s, while the minimum wind speed at Azraq was 1.15 m/s. The Aqaba airport produced the most energy, with the Weibull function having shape parameter within the range of 1.65 to 2.78.

Other literatures were conducted in a combination of renewable energy systems mainly on hybrid systems which focus on combinations that include solar and wind in the energy mix.

Acakpovi et al.(2020) designed and compared two hybrid systems using HOMER software based on the same load profiles [18]. The wind energy system using hydrogen fuel cell storage had the lowest NPC compared with the simple wind system using battery as a means of storage. Again, the wind energy and hydrogen fuel cell system had the lowest LCOE compared with the wind energy system with battery energy storage system. Technically, the wind energy system with battery had more energy reserves than the wind energy system with hydrogen fuel cell.

Al-Ghussain (2018) conducted an economic and technical assessment of different mixtures of Solar PV, pumped hydro-storage, and hydrogen fuel-cell system for a university in Northern Cyprus [19]. The objective function of the optimization model for the proposed system was to have an LCOE equal the national electricity price whiles maximizing the renewable fraction of the system. The optimal system consisted of a combination of pumped hydro system of 4.14 MWh, 1.16 MWh hydrogen fuel-cell, and 2.57 MW solar PV system with an LCOE of 0.181$/kWh.

Again, Acakpovi et al. (2021) in [20], used the Anloga wind regime in Ghana to conduct an economic and technical assessment of wind and hydrogen fuel cell system. The study adopted HOMER software to design, analyze and optimize the proposed system. Technically, the proposed system was unable to meet the load during the whole by 10%. However, the system generated an annual electricity of 25,999kW for the first year of the project with an LCOE of 0.602$/kWh. The proposed system had a reduced emission compared with a diesel generator used as back-up.

Alternatively, Halawani et al. (2015) in [21], explored the viability of hybrid renewable energy systems in off-grid and remote areas with a smart microgrid capability. The developed hybrid system consisted of solar PV, diesel generator, Wind, hydrogen fuel cell, and battery. The proposed system was designed and simulated in HOMER and MATLAB. The system incorporated a control and synchronization strategy for the various configurations.

Okonkwo et al. (2017) designed and simulated an off-grid HES made of Solar PV/Wind battery storage system to satisfy the energy demand of a hotel in Jordan [22]. The proposed system was technically and economically assesses based on ability to serve the load requirement, NPC, payback period and savings-to-investment ratio. The off-grid hybrid system was technically and economically feasible as compared to the on-grid system.

Again, Vick and Neal (2012) evaluated a grid connected solar PV and wind system for water pumping system [23]. The authors simulated and analysed each RET that has the capacity to serve the load requirement. The study concluded that a standalone single RET was not as efficient in pumping water as compared to hybridized system of multiple RET. The hybridized RET of Wind and Solar PV power generation pumped about 28% more water than the single RETs.

Alharthi et al. (2018) performed a technical and economic assessment of a grid connected hybrid solar PV/wind system using HOMER software in Saudi Arabia [24]. The proposed system was designed in HOMER to meet a peak load of 239kWp and an energy demand of 15000 kWh/day. The technical parameters used to evaluate the proposed system were annual electricity production (AEP). The economic parameters of the proposed grid connected RET were the net present cost and the levelized cost of electricity. The proposed system was technically and economically feasible according to the study.

Budes et al. (2020) used HOMER Pro to conduct smilar assessments of the impact of an ON grid wind and solar PV system [25]. The HOMER software was used by the authors to access the weather data of the study area (Puerto Bolivar in Colombia) and to comprehensively design a HES system that can supply a fraction of the energy requirement of the study area. The optimal hybrid renewable configuration to combine with the thermoelectric grid power generation was a 441 Solar PV panels and 3 wind turbines (2.5kW capacity each). The economic parameters used to evaluate the proposed system was NPC with a cost of $11.8 million and a reduction in CO2 emission of 244.1tons annually.

Mahesh and Sandhu. (2020) used genetic algorithm and developed an energy filter method to optimize a hybrid power supply with battery storage system using solar PV and Wind [26]. The study aimed at reducing the total cost of the proposed system whiles ensuring a reliable power supply from the hybrid RET. The reliability index used to assess the proposed algorithm and energy filter were battery state of charge (SOC), full use of energy resources and quality of power injected into the grid. These were modelled as reliability constraints and used to size each component of the proposed system. The authors validated the proposed energy filter method to evaluate it effectiveness in sizing a hybrid RET.

Hybrid energy systems have also grown in popularity as a result of their ability to regulate resource consumption while allowing for the optimal mix of technologies to accomplish the desired outcomes [27].

The reviewed literature demonstrates the numerous researches into finding the best configuration and sizing of hybrid RETs. The economic and technical evaluation of these hybrid RETs are a major objective in analyzing the feasibility of hybrid renewable energy systems. In this regard, this paper aims at evaluating the economic and technical feasibility of a grid connected solar PV/Wind energy supply for a commercial office in Kumasi, Ghana. Though many studies have used HOMER software for these assessments, few literatures used the RETScreen that presents several and proven benefits in terms of technical, economic and emission estimation.

To the authors' best of knowledge, no similar study on hybrid solar/wind supply has been undertaken in the proposed location in Ghana before and especially with the use of RETScreen software. Indeed, an economic and technical study of a grid connected hybrid renewable energy system at Kumasi Metropolitan Assembly (KMA) will set a precedence for the development and integration of Hybrid RE system into the national grid. Again, the study will set the pace for other investors to emulate and, provide support to the national agenda of increasing the renewable energy integration to the national energy mix by 10%.

In this paper, a grid connected solar PV/wind system is designed to serve the power requirement of KMA; the design has been assessed using established techno-economic metrics. Mainly, the significance of this study relates to the location specific renewable energy resource; the specific hybrid configuration suitable for the selected area and the unique approach by using RETScreen software.

2. Materials and Methods

The renewable power capacity in the targeted city of Kumasi is shown in the following subsections, with specifications for PV modules and wind turbines, as well as system economic metrics and corresponding national grid statistics.

2.1. Electricity Requirement of KMA Office

The seasonal electricity consumption for KMA office is depicted in Figure 1. This was determined through walk-through energy audit and energy consumptions pattern from their utility bills. The highest peak demand in February and March were 439 kW and 455 kW, respectively. With a high

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demand of 330 kW, November was the month with the lowest demand. These values, on the other hand, show the maximum and minimum demands reported on a given month's day. As a result, the study considered the average annual energy use, which was roughly comparable throughout all months. Following that, a monthly average of 3,850.00 kWh was given as the daily mean energy use.

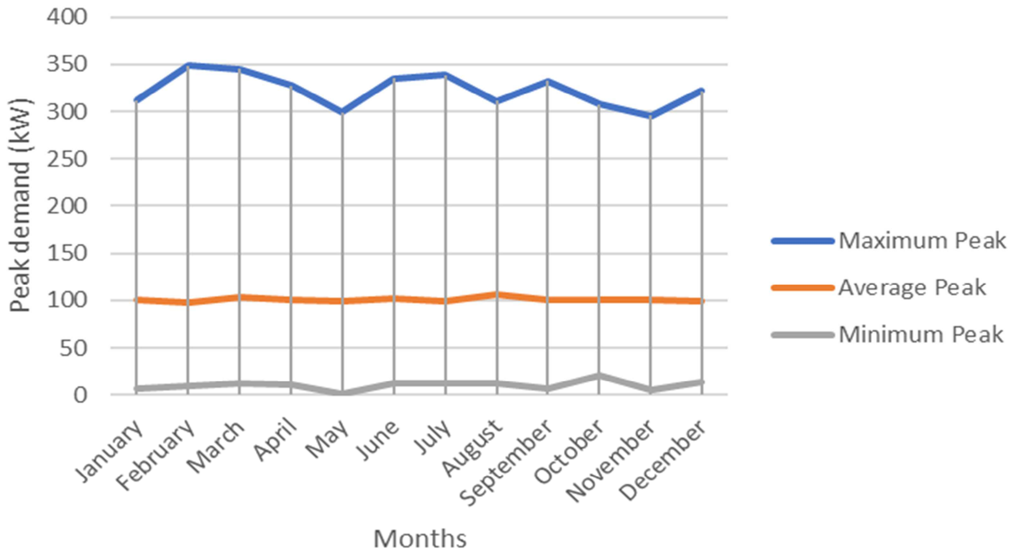

Figure 1. Scaled monthly energy demand of KMA office

2.2. *Solar and Wind Potential of Kumasi*

Kumasi's geographical position provides a tremendous chance for plentiful renewable energy resources. Kumasi central in particular, receives an average of 4.96 kWh/m^2/day of solar irradiation, with July and August are receiving the least (4.225 kWh/m^2/day) and February receives the most (5.582 kWh/m^2/day). The average wind speed and irradiance for the Kumasi central where KMA office is located are shown in Figure 2 and 3 respectively from the National Renewable energy laboratory (NREL) weather database. The average wind speeds in the Kumasi central area is 4.15m/s at 10m anemometer height with July and August recording highest wind speeds of 4.95 and 5.01m/s respectively. The lowest wind speeds were recorded in November and December with 3.4 and 3.36m/s respectively.

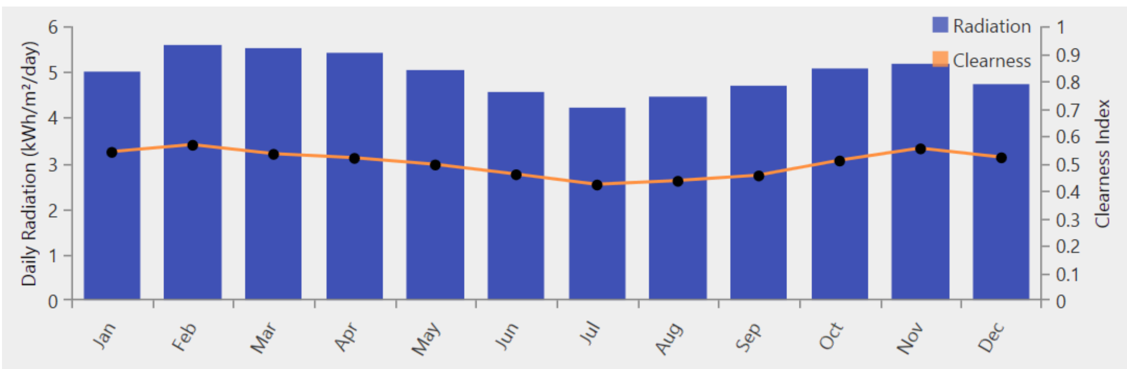

Figure 2. Solar radiation and clearness index of Kumasi central

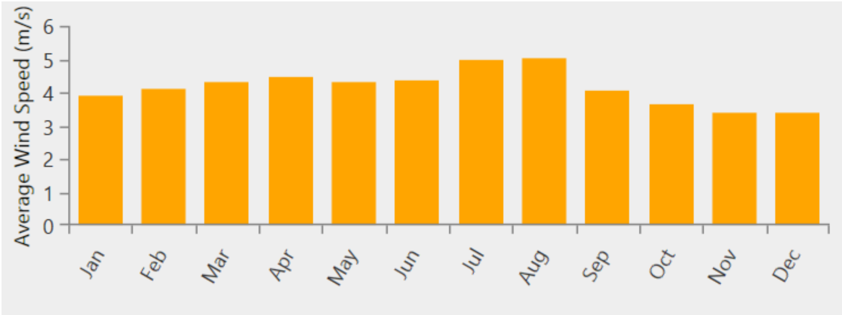

Figure 3. Wind speed of Kumasi central

2.3. Solar PV Module and Wind Turbine Details

For the PV farm, the study adopted 1000 units of polycrystalline silicon Canadian Solar, poly-Si - CS6X-300Wp module from RETSCREEN library. Each unit is rated at 300 Wp, with a total installed capacity of roughly 300 kW. Under typical test circumstances, the module efficiency is 15.63%, and it is installed in a rack-mount configuration. In this paper, the selected winf turbine has 500 kW power rating and a height of 70m. The technical specifications of the solar PV and wind turbine used in this study are provided in Figure 4 and 5. The overall configuration of the hybrid system is also shown in Figure 6.

Wind turbine		
Power capacity per turbine	kW	500
Manufacturer		DeWind
Model		DEWIND 41 - 70m
Number of turbines		1
Power capacity	kW	500
Hub height	m	70
Rotor diameter per turbine	m	41
Swept area per turbine	m^2	1,320.25
Energy curve data		Standard
Shape factor		2

Figure 4. Wind turbine specifications

Photovoltaic		
Type		poly-Si
Power capacity	kW	300
Manufacturer		Canadian Solar
Model		poly-Si - CS6X-300P - MaxPower
Number of units		1,000
Efficiency	%	15.63%
Nominal operating cell temperature	°C	45
Temperature coefficient	% / °C	0.4%
Solar collector area	m^2	1,919

Figure 5. Solar PV specifications

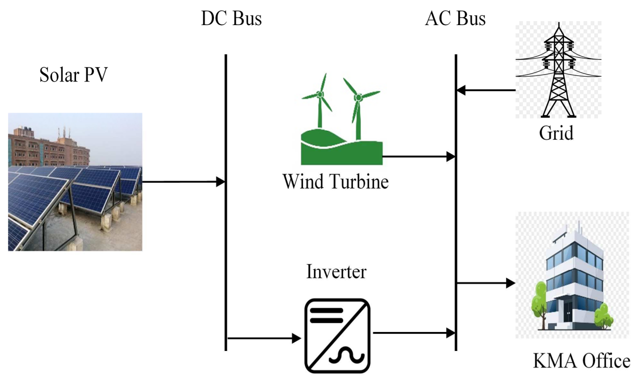

Figure 6. Schematic diagram of the proposed system

2.4. *Proposed Hybrid System Economic and Electric Grid Input Parameters*

The cost of the proposed grid connected hybrid solar PV and wind system is made of feasibility studies, development cost, engineering cost, balance of system cost which make up the total initial cost of the project. The annual cost which comprises the operation and maintenance cost is also presented in the summary (see Figure 7 and 8). The project is assumed to receive a government grant of US$30,000.00 according to the energy commission of Ghana. This grant is factored into the study as annual savings.

Annual costs (credits)	Unit	Quantity	Unit cost	Amount
O&M				
Show data				$ 62,600
Land lease & resource rental	project	12	$ 200	$ 2,400
Property taxes	project	1	$ 5,000	$ 5,000
Insurance premium	project	1	$ 7,000	$ 7,000
Parts & labour	project	1	$ 12,500	$ 12,500
GHG monitoring & verification	project	1	$ 2,300	$ 2,300
Community benefits	project	1	$ 3,000	$ 3,000
General & administrative	%	5.0%	$ 94,800	$ 4,740
User-defined	cost			$ -
Contingencies	%		$ 99,540	$ -
Subtotal:				**$ 99,540**
Annual savings	**Unit**	**Quantity**	**Unit cost**	**Amount**
User-defined-Subsidy	cost			$ -
Government subsidy	cost	1	$ 30,000	$ 30,000
Subtotal:				**$ 30,000**

Figure 7. Annual cost of the system

RETScreen - Cost Analysis

Initial costs (credits)	Unit	Quantity	Unit cost	Amount	Relative costs
Feasibility study					
Site investigation	p-d	1	$ 3,000	$ 3,000	
Resource assessment	project	1	$ 2,500	$ 2,500	
Environmental assessment	p-d	1	$ 3,000	$ 3,000	
Preliminary design	p-d	1	$ 4,500	$ 4,500	
Detailed cost estimate	p-d	1	$ 3,000	$ 3,000	
GHG baseline study & MP	project	1	$ 1,500	$ 1,500	
Report preparation	p-d	1	$ 2,000	$ 2,000	
Project management	p-d	1	$ 6,000	$ 6,000	
Travel & accommodation	p-trip	5	$ 2,500	$ 12,500	
User-defined	cost			$ -	
Subtotal:				**$ 38,000**	0.8%
Development					
Contract negotiations	project	1	$ 1,500	$ 1,500	
Permits & approvals	project	1	$ 5,500	$ 5,500	
Site survey & land rights	project	1	$ 4,300	$ 4,300	
GHG validation & registration	project	1	$ 1,500	$ 1,500	
Project financing	project	1	$ 3,800	$ 3,800	
Legal & accounting	project	1	$ 4,500	$ 4,500	
Project management	project	1	$ 2,100	$ 2,100	
Travel & accommodation	p-trip	5	$ 2,500	$ 12,500	
Engineering					
Site & building design	project	1	$ 3,000	$ 3,000	
Mechanical design	project	1	$ 3,500	$ 3,500	
Electrical design	project	1	$ 1,500	$ 1,500	
Civil design	project	1	$ 2,500	$ 2,500	
Tenders & contracting	project	1	$ 3,000	$ 3,000	
Construction supervision	project	10	$ 500	$ 5,000	
User-defined	cost			$ -	
Subtotal:				**$ 18,500**	0.4%
Power system					
Photovoltaic	kW	300	$ 3,300	$ 990,000	
Wind turbine	kW	500	$ 7,500	$ 3,750,000	
Road construction	km	3	$ 5,000	$ 15,000	
Transmission line	km	3	$ 2,000	$ 6,000	
Substation	project	1	$ 7,000	$ 7,000	
Energy efficiency measures	project	1	$ 25,000	$ 25,000	
User-defined	cost			$ -	
Subtotal:				**$ 4,793,000**	98.1%
Balance of system & miscellaneous		Specific project costs			
Building & yard construction	m²			$ -	
Spare parts	%			$ -	
Transportation	project			$ -	
Training & commissioning	p-d			$ -	
Total initial costs				**$ 4,885,200**	100.0%

Figure 8. Initial cost of the system

In addition, the economic parameters of the national grid are essential for evaluating and comparing the efficacy of the proposed hybrid system. According to the Ghana Electricity Company, the average energy price for power purchased from the national grid is about 0.50 $/kWh.

2.5. Economic Assessment of the HES

The economic feasibility of any renewable project is dependent of Internal Rate of Return (IRR), Net Present Value (NPV), Payback period (PBP) and the cost of energy per kilowatt hour. These economic parameters have also been used by researchers to evaluate the economic performance of projects especially renewable energy projects. As a result, the study presents the important theoretical formulations of the criteria mentioned in the following subsections in order to conduct the economic evaluation.

2.5.1 *Levelized Cost of Electricity (LCOE).* Cost of energy per kilowatt-hour as stated in the above subsection is employed to assess the economic performance of the renewable energy system proposed in this study. The cost of electricity is estimated using equation (1)

$$LCOE(\$/_{kWh}) = \frac{Total\ life\ cycle\ \cos t(\$/_{W_p})}{Total\ Lifetime\ yield(kWh/_{W_p})} \tag{1}$$

Where $LCOE(\$/_{kWh})$ represent the cost of electricity per kWh

kWh is Kilowatt-hour of electricity

W_p is watt-peak of solar radiation

2.5.2 *Estimation of NPV and IRR.* The NPV is an important metric in assessing HES. It refers to the current net value fo the project while considering all future earnings. The NPV is calculated as shown in equation (2)

$$NPV = \sum_{t=0}^{N} \frac{c_n}{(1+r)^n} \tag{2}$$

C represents the capital cost

n is the project lifespan

r is the interest rate

On the other hand, IRR is a frequently used metric for assessing the competitiveness of energy generation projects. Technically it is considered as the discount rate when the NPV is null and can be calculated with equation (3) as follows.

$$IRR = \sum_{t=1}^{1} \frac{R_t}{(1+r)^t} - c \tag{3}$$

Where R_t is the Net cash inflow during period t

r is discounted rate

2.5.3 *Payback Period (PBP).* The PBP is an economic parameter used to determine the payment period of the any project. In this study it is adopted to evaluate the economic viability of the project, a shorter PBP is preferred. Equation (4) is adopted to estimate the PBP of the RE project under study.

$$PBP = \frac{C}{R_1} \tag{4}$$

Where the PBP denotes payback period for the investment and $R_1$is the returns from the proposed hybrid system project in terms of \$/kWh in the first year.

3. Results and Interpretations

The results illustrate the efficacy of the proposed system with regard to the fulfillment of the monthly energy requirement of the KMA office while also delivering a large economic benefit when compared to the price of electricity delivered by the national grid.

3.1. Electricity Production from the Proposed Syste

The annual energy output of the PV generator and wind turbine is 388MWh and 374 MWh, respectively. Figure 9 depicts the daily energy production of PV, wind systems and grid purchase. Figure 10 presents a summary of electricity production from each of the systems in a year.

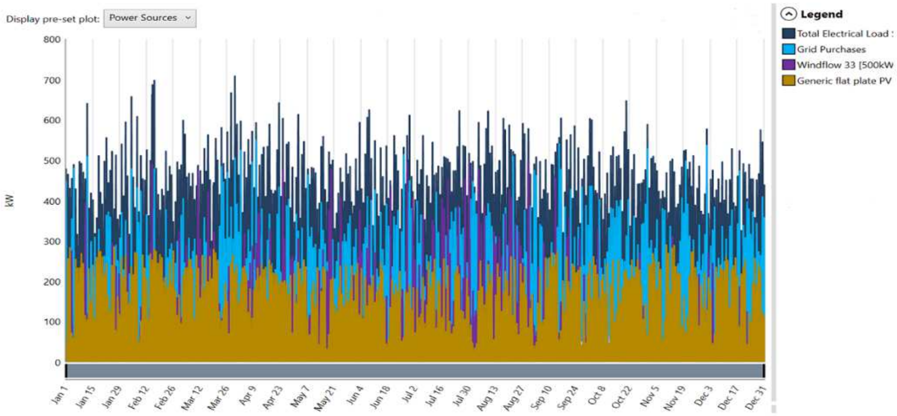

Figure 9. daily electricity production from the grid connected hybrid system

Power system - Total		
Capacity	800	kW
Electricity	762	MWh
Photovoltaic		
Capacity	300	kW
Electricity	388	MWh
Wind turbine		
Capacity	500	kW
Electricity	374	MWh

Figure 10. Electricity production and capacity of the hybrid system

3.2. System Economics

Figure 11 illustrates the proposed hybrid system's yearly cash flow. As can be seen from the graph, the simple payback for this proposed system before tax is 15 years and 6 months. Considerung the payback period, the cash flow of the proposed system is positive, with an indicated positive revenue. Figure 12 presents the cumulative cash flow of hybrid supply. The equity payback period of the project happens in the 26th year on the 8th month. The financial viability of the proposed system is presented in Figure 13. The Figure presents the IRR and PBP.

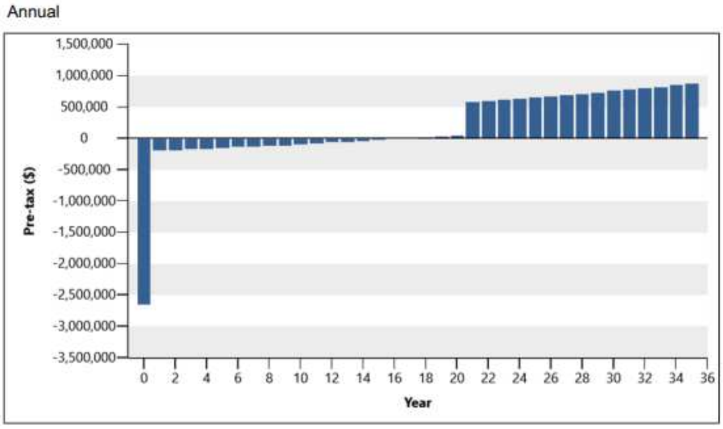

Figure 11. Annual cash flow

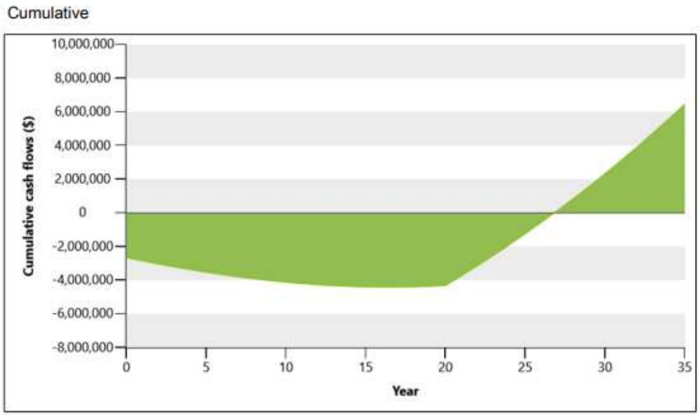

Figure 12. Cumulative cash flow

Financial viability		
Pre-tax IRR - equity	%	7.7%
Pre-tax IRR - assets	%	2.9%
Simple payback	yr	15.7
Equity payback	yr	18.6
Net Present Value (NPV)	$	-397,403
Annual life cycle savings	$/yr	-37,609
Benefit-Cost (B-C) ratio		0.73
Debt service coverage		0.85
GHG reduction cost	$/tCO$_2$	51.69
Energy production cost	$/kWh	0.671

Figure 13. Financial viability of the proposed system.

3.3. Emission Reductions

Figure 14 shows the total emission reduction of the hybrid system. The Figure show the initial base GHG emission and proposed case emission. Again, the Figure presents the GHG reduction revenue if the GHG reduction is converted into emission credit. The base case GHG emission is 176.5 tCO_2 whiles the proposed hybrid system is 12.4 tCO_2. The total reduction in GHG emission if the proposed hybrid system is implemented is 164.2 tCO_2. In simple terms, this equivalent to 381.8 barrels of crude oil not consumed.

GHG reduction revenue		
GHG reduction credit rate	$/tCO₂	25.00
GHG reduction credit duration	yr	25
GHG reduction credit escalation rate	%	0.1%
GHG credits transaction fee	%	0.2%
Net annual GHG emission reduction	tCO₂	163.9
GHG reduction revenue	$	4,096

Figure 14. Emission savings

4. Discussion

The total electricity production from the proposed system shows that a single renewable energy technology could not meet the electricity demand of the KMA office effectively and throughout the year. Technically, the proposed system is more effective to supply the load as compared to a single renewable energy technology. Abujubbeh et al.(2019) performed an economic and technical analysis of a grid connected solar PV and wind system for a town in Jordan [28]. It was observed that a single renewable energy technology was not capable of suppling the load conveniently due to intermittency challenges.

Renewable energy systems in general are technically not too complex to implement, however, their economic feasibility is challenged with numerous primary roadblocks. For instance, the price of solar PVs has been considerably higher over the year, even though it has known recently a significant decrease. The technology of wind energy conversion has been limited to well developed countries, making them quite expensive in developing countries with these resources available. The technology to convert heat of the sun (CSP) for power generation is not well established in Ghana just as tidal and wave energy technologies. These economic roadblocks make RET projects, excessively expensive in terms of profitability and shorter project life. In countries where feed-in-tariff exists, the feed-in-tariff per kWh of electricity are not investment friendly.

In this paper, a PV and wind hybrid system with PBP of 15.6 years and LCOE of 0.671 $/kWh was proposed, designed and simulated. The system presented greater benefits than the figures obtained in the study of [28] and [22] though the economic parameters seem marginally different. This paper proposes a feasible solar PV and wind power system that can be coupled to grid to support existing power generation capacity. Furthermore, the Net Present Value (NPV) is US$ -397403 with an internal rate of return (IRR) of 7.7%, indicating the economic infeasibility of the hybrid system as shown on Figure 13. The profitability of this hybrid PV-wind system is contingent on surplus power being sent to the national grid. The hybrid supply system is expected to generate a yearly cash inflow of $381061.18 as illustrated in Figure 12 by exporting the excess electricity to the grid.

The use of GHG emission to evaluate the technical viability of hybrid RE has seen many phases of studies. Since the global trend of renewable adoption is sustained by the reduction of fossil fuel usage, it is critical for researchers to use GHG emission parameters to evaluate the technical or environmental friendliness of any hybrid RE system. Researchers such as [29]; performed a techno-economic feasibility study of hybrid systems incorporating Diesel generator for a City in United Arab Emirates. The study reported a 69.6% reduction in GHG emission which is equivalent to 682279 gallons of diesel fuel not used. Again, [30] performed similar economic and technical assessment of HES for several communities in Yemen. In this paper, the environmental assessment revealed a GHG emission reduction of 100% for the solar PV and wind energy system whiles a hybrid solar PV, Wind and diesel generator reduced GHG emission by 97.44 %. If Ghana had a GHG reduction credit rate (say \$25/tCO2 emission), then the proposed system will generate a yearly GHG reduction revenue of \$4096.00. This GHG policy would encourage companies to direct efforts and procedures to reduce their GHG emission footprint. This will cumulatively accelerate the National objective of increasing the RE percentage in its energy mix.

5. Conclusion

The increasing focus on sustainability has prompted communities to seek alternatives to traditional fossil fuel-based electricity generating. Renewables help in the modernization of power system operations and can be economical, particularly in nations where renewable resources are abundant. As a result, the current study investigated the economic and technical viability of a solar PV and wind hybrid system to serve the yearly commercial energy requirement of KMA Office in Kumasi, Ashanti region of Ghana. The viability of the designed hybrid system reveals that, when compared to an off-grid solar PV or wind systems, the hybrid system satisfies the energy requirement of the KMA offices better.

The research also highlighted the significant possibility of exporting the system's excess electricity to the available large grids. Furthermore, the designed hybrid system offers an energy cost of 0.671 \$/kWh, which is somewhat higher than the cost of electricity in Ghana, regarding the high interest rate in the country as compared to other countries with lower lending and discount rate.

The following recommendations are aimed at future research into hybrid renewable energy system: the viability of including a battery storage device to store extra generated energy for other parallel applications. It is also recommended that a comparative analysis be undertaken to maximize economic feasibility while reducing the impact of the intermittent nature of renewable energy resources. While considering coupling to the grid, further studies should ponder on the issue of voltage and frequency stability and reliability of grid connected RETs.

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