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About the Journal

The Journal of Digital Food, Energy & Water Systems (JD-FEWS) is a peer reviewed bi-annual publication that publishes recent and innovative deployment of emerging digital technologies in Food, Energy and Water Systems. Food, energy and water resources are interconnected scarce resources that require systems and technologies that will foster their sustainable management and effective utilization. The journal is also interested in articles that explore the nexus between at least two of these resources. The journal considers the following topics as long as they are deployed in the Food, Energy & Water space:

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- Machine Learning
- Mathematical Optimization
- Robotics
- System architectures
- Wireless Sensor Networks

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An Intelligent System for Load Forecasting on a Distribution Network

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Abstract— This paper presents an Adaptive Neuro-Fuzzy Inference system (ANFIS) technique for medium-term load forecasting in a distribution network. This technique is an integrated system consisting of fuzzy logic systems and Artificial Neural network (ANN). The inputs to the system include days of the week, temperature, time, current and previous hourly load on the distribution network. The data collection is within the period of two years. The formulation and mapping of the input data is done using fuzzy logic system and ANN are employed for generation of inference. The experimental results show the average load prediction accuracy of 87.23% and regression coefficient of 0.873. The analysis of the proposed ANFIS for load forecast is effective in planning, managing and organizing the electric load forecast with accurate prediction.

Keywords— electric load, load forecasting, Adaptive Neuro-Fuzzy Inference system, power system.

1 Introduction

Electric load forecasting plays a vital role in determining an efficient operation, planning, maintenance and management of electric power systems [1]. Medium-term load forecasting is highly essential for proper planning, operation and power scheduling decisions for both utilities and consumers in power systems. Owing to the importance of this load forecasting, several approaches have been employed for electric load prediction such as regression, stochastic approach, exponential smoothing and ANN [2]. However, most of these methods exhibit large forecast errors when there is an imbalance in load and weather condition, resulting in severe economic burden to utility company. Therefore, it is important to improve the load prediction accuracy in order to increase the revenue of utility company. To enhance the accuracy of load forecasting, an integrated system which combine the fuzzy logic system and ANN is proposed. Adaptive Neuro-Fuzzy Inference system (ANFIS) technique (ANFIS) is an intelligent system that combines the human reasoning pattern of fuzzy logic and learning approach of ANN. This technique has been applied in automation control and robotics.

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This paper introduced historical loads alongside with other parameters such as weather condition and time in order to provide reliable and accurate load forecasts [3][4]. Historical loads enhance the performance of the forecast and the complexity of the prediction model. This is important for electricity market, real time control, load flow analysis, dynamic planning and energy management in distribution network especially in a deregulated energy sector [5][6].

2 Literature Survey

Load forecasting is the basic facet of decision making in power systems. The main objective is to reduce the risk in decision making and minimize unanticipated cost that may result in black out. So many decades ago, several numbers of researchers have worked on electric load forecasting. Therefore, load forecasting has been divided into three categories: short-term, medium-term and long-term. Generally, there are two methods of load forecasting: parametric approach [7] and artificial intelligence-based approach [8]. Reference [9] proposed a autoregressive moving average (ARIMA) based model for electric load forecasting whilst considering electric vehicles charging demand. Reference [10] presents a new approach for distribution network reconfiguration and genetic algorithm was adopted for load forecasting. In [11], a comprehensive analysis of three intelligent systems for a short-term electric load forecasting in distribution substations was presented. Reference [2] proposed the combination of two intelligent systems for a long-term electric load forecasting for a certain region in Oman. Similarly, Reference [12] presents two intelligent systems for decreasing the prediction errors in load forecasting. The load forecasting considered special days and holidays period to influence error reduction. In [7], a load forecast of a university campus using regression analysis was investigated. Three different methods of regression were developed and used to evaluate the proposed models. Reference [1] presents a hybrid approach for previous hour electric load forecasting considering the non-linearity of the electric load.

This paper presents a hybrid intelligent system called Adaptive Neuro-Fuzzy Inference system (ANFIS) technique that could predict future values of electric load with good accuracy and interpretability for a distribution network in an urban city. This will provide adequate guidance for decision-makers for proper planning of power systems.

3 Adaptive Neuro-Fuzzy Inference System Technique for the Load Forecasting Models

Adaptive Neuro-Fuzzy Inference System (ANFIS) is a hybrid system that combines artificial neural network and fuzzy logic system, which can be applied to electric load forecasting. ANFIS technique utilizes the human reasoning pattern in fuzzy logic and learning structure of the neural network in classifying complex problems as well as providing a proper solution. ANFIS permits the model to obtain different types of load profiles to minimize the prediction errors. A brief outline of the system structure is given below. Acceptance and implementation in the context of this study refer to establishing, adopting, and utilizing an m-agriculture system for accessing poultry-related services.

3.1 Adaptive Neuro-Fuzzy Inference System Architecture

ANFIS is an adaptive network system, which comprises of input and output variables, membership functions, fuzzy rules and an inference method integrated by directional link [13]. Each of these functions depicts a process unit and the links give the relationship between the functions. Here, the input variables are the energy drivers that affect the load profile, while the output variable is determined by some adjustable parameters related to the functions. The membership functions describe the set of the fuzzy and determines the level of membership for a designated value of the input variable. The fuzzy rule specifies how the parameters can be modified to reduce a targeted error that measures the variation between the real output and the target output. Through inference method, the input variables determine the output variables of the system.

3.2 Adaptive Neuro-Fuzzy Inference System Training

Training is a feature of ANFIS, which has the ability to be trained by human knowledge and with historical data through the use of learning algorithms such as least squares or back-propagation. In ANFIS, the hybrid algorithm combines both the back propagation and least squares algorithms to obtain the structured parameters such as consequent and premise sections. In premise section, the parameters involved are membership parameters which is determined by the selected function. In consequent section, the total output is a function of the consequent parameters combination and these parameters are calculated during training.

The hybrid learning process is categorized based on steps which are forward and backward pass. The premise parameters are fixed for forward pass section, while the input data and functional signals move towards calculating the output functional layer and the least square algorithm is utilized to compute consequent parameters. When the consequent parameters are identified, the functional signals keep moving until the measured error is estimated. In the backward pass section, there is propagation of error rates from the output to the input side. Whilst in the premise section, the parameters are updated using the back-propagation method.

3.3 Model Procedure

The modelling presented in Fig.1 is the proposed model structure. This gives the block diagram and a view of how the system modelling was implemented. The four parameters considered are the temperature, time, date and the historical load. These data are fed into the ANFIS technique model, which is a hybrid of fuzzy logic system

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and ANN system. The output of ANFIS model gives the forecasted load, whilst the forecasted load is compared with the actual load to give the estimated error of the prediction.

A Graphical User Interface (GUI) was developed and it comprises of historical input data, the projected output data and the graphical plot axis. This is designed in order to render assistance for accurate prediction based on the inputted information. In the developed GUI system, the inputted data such as average daily load, temperature, area and the day of the year are acquired and analyzed by the system.

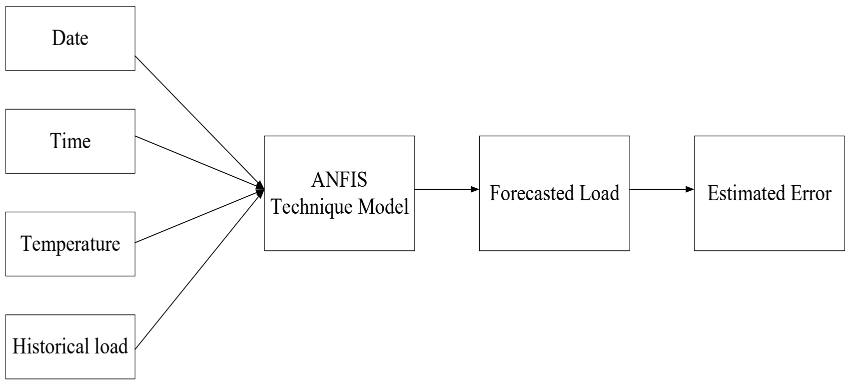

Fig. 1 Model structure

4 Result and Analysis

The load forecasting performance of the medium-term load forecasting utilizes several assessment criteria and these are explained below.

4.1 Data Collection

The data used was collected on hourly basis, which includes the hourly mean temperature, hourly electricity usage, time and days of the year. The daily energy consumption is obtained from National Control Centre (NCC) and the daily temperature was obtained from Nigerian Meteorological Agency (NiMET) for Osogbo city in Osun State, Nigeria. All the relevant information based on the hour of operation are specified. The data collected are for Osogbo, which is a a state capital of Osun state and a city in Nigeria. It has an area of 47 km2 with coordinate of 7.7827° N and 4.5418° E.

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4.2 Performance Evaluation

The developed models are trained with the same data from 2018 and 2019, whilst 2020 was used for testing. The data from the 33kV distribution network are used for both the training and testing purpose. The comparison between the real and predicted load is analyzed and discussed.

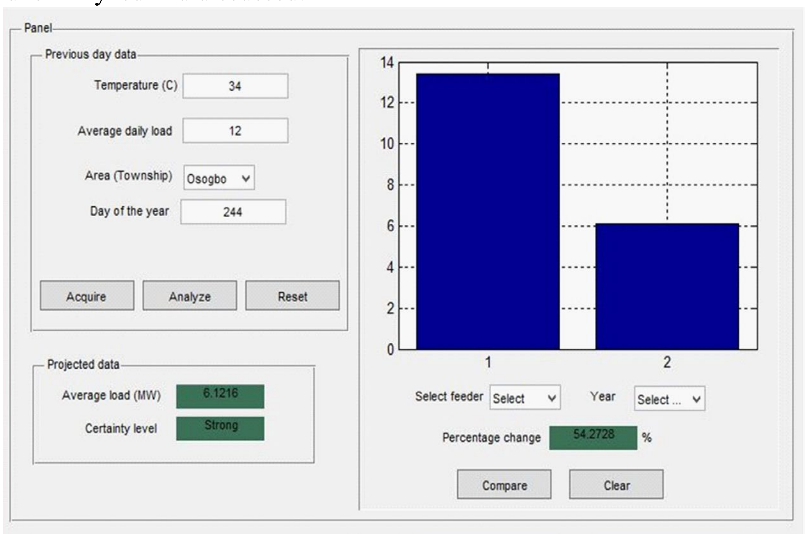

Fig. 2 Graphical User Interface for annual average load and forecasted load

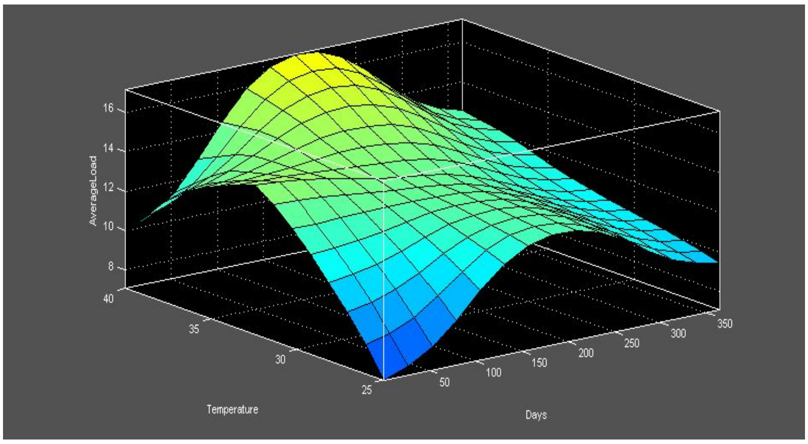

Fig. 3 Interface between the input parameters and forecasted load

From the developed GUI as shown in Fig. 2, the inputted data are acquired and analyzed. The output is displayed showing the predicted average load and the certainty

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level. Fig.3 and Fig.4 present the interface between the input data such as temperature and days of the year; and the predicted average load. It can be observed that the load tends to high between 100 to 250 days of the year. This is an indication that the energy consumption of these days is predicted to be on the high side. Fig. 5 depicts the comparison of the actual load and the predicted load. From the simulation results, it can be seen that the ANFIS system presents a prediction of an average load to be 87.23% accuracy. The regression coefficient R is given as 0.873 reiterating the robustness of the ANFIS in predicting the average load. The predicted are values are closer to the actual values of the electric loads.

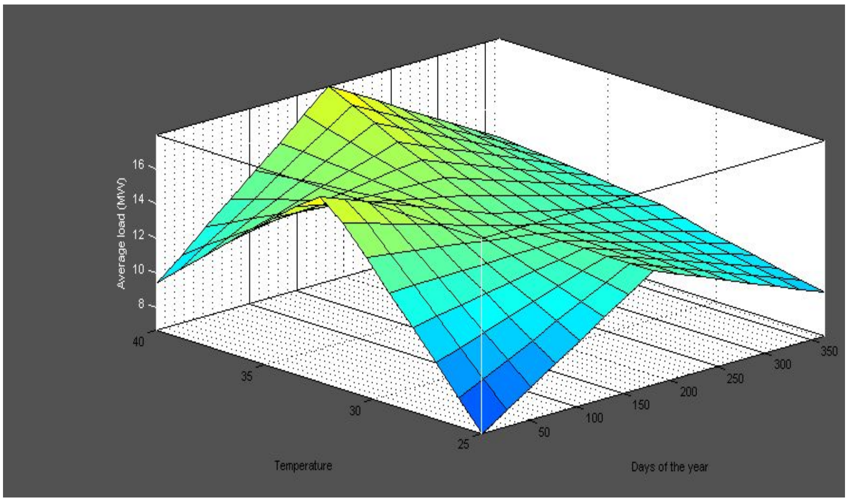

Fig. 4 Relationship between temperature, days of the year and the forecasted load

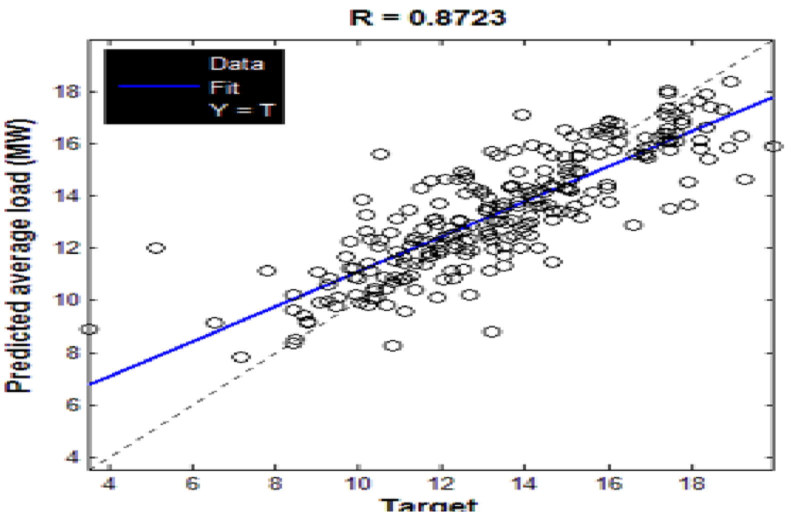

Fig. 5 Comparison of the actual and predicted load.

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To ensure the reliability and validity of our sample size for customers we utilized a standard formula/equation shown in (1) below from Kothari (2004) as follows:

5 Conclusion

Electric load forecasting is an essential factor for distribution network especially when considering an urban grid system. This will improve the power systems security as well as reduce risks. In this paper, an Adaptive Neuro-Fuzzy Inference System (ANFIS) technique for medium-term load forecasting in a distribution network was presented. A graphical user interface was developed to display the predicted values and the certainty level. The simulation shows the effectiveness of the proposed model reiterating 87.23% accuracy. The regression coefficient R is 0.873 showing the closeness of the predicted values with actual values.

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Assessment of the Availability and Penetration of Solar PV, Wind and Biogas in Ghana

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Abstract – Access to energy is pivotal to the socio-economic growth of many developing countries, including Ghana. Energy generation from fossil fuels is not sustainable and leads to global warming, which is detrimental to the environment. This study seeks to establish how renewable energies are embedded and utilised in the Ghanaian energy system and the factors that can expedite the speedy penetration of renewable technologies into the country, particularly solar PV, wind, and biogas. The study adopted a mixed research approach which includes quantitative and qualitative studies. The findings revealed that solar energy is the most available resource in the country compared to other renewables. It was also indicative that integrating solar PV, wind and biogas in the national electricity grid will improve the percentage of energy generation mix, which will help sustain constant power supply, reduce the cost of energy charges, and consequently improve the country's economy. The results also showed the possible factors that affect future penetration of these technologies, including unavailability of consumer financing opportunities, inadequate training facilities, lack of adequate regulations/policies, lack of information on the cost and benefits of renewable energies. The six findings of the paper established the availability of renewables in Ghana and the prospect of their related technology. While solar PV is on the ascendency, biogas is progressing gradually and wind is moving at a snail's pace. This study significantly established the benefits of incorporating solar PV, wind and biogas in the Ghanaian energy mix to improve the electricity supply and further outlined the impeding factors that need to be improved upon through policy.

Keywords: Solar PV, Wind, Biogas, Global warming, Renewable, Energy, Policy.

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1. Introduction

Access to energy is key to development [6], [15]. Power generation is crucial in the development of a nation due to the fact that factories and the economy by extension, operate based on electricity availability. Similarly, health facilities, access to clean water, information sharing, and innovations heavily depend on electricity. Energy demand has known a stiff increase during the last decade due to the rise in human population and modern trends in manufacturing [31]. According to [14], the energy demand in Ghana has surpassed the energy supply in the last decade.

The foreseen solutions to increasing potentials of energy access could be through the adoption of renewable energy technologies (RETs) that will boost power generation capacity in the energy sector [11]. Renewable energy (RE) could play a vital role in improving access to electricity, especially in rural and isolated communities, provided that all stakeholders embrace its benefits [13].

Ghana, amongst other African nations, has challenges of meeting its country's electricity demand. According to the Energy Commission of Ghana [17], the potential drivers of energy consumption in Ghana are industrial growth, petroleum up-stream, and mid-stream activities and mining. Ghana’s population is projected to increase from 25 million in 2010 to about 40 million by 2030 which is expected to increase electricity demand by 2030 [25].

Considering a few factors including the increasing demand for energy, the growing population and the current trend in manufacturing globally, the need for sustainable provision of electricity is becoming crucial. Ghana's energy sector is currently facing high-energy demand challenges, which could be proved by the frequent power outages in the country [1].

On the other hand, there is an abundance of renewable resources available in Ghana especially solar. According to Kemausuor, Obeng, Brew-Hammond, & Duker [29], the average solar irradiation of Ghana ranges from 4.5-6.0 kWh/m2/day, with the Northern part of Ghana recording the highest levels of irradiation in the country. The annual sunshine period in the country ranges from 18000 to 3000 hours per year which presents a high potential for solar electrification to grid connection. According to Zhang, Adu, Fang, Antwi, & Kyekyeku [42], the construction of a 155MW solar power plant in Nzema, Ghana will become the largest solar Photovoltaic plant in Africa and the 4th biggest in the World. When completed, the Nzema solar PV project will provide over 100,000 homes with electricity in the country and increase the percentage of RE in the national energy mix to 6%. In addition, the BXC solar plant in Central region, Ghana which produces 20MW of power since it operation in February 2016 is the largest functioning solar farm in Ghana. It contributes to Ghana’s plan to have 10% renewable in the national energy mix by 2030.

Wind resource is perceived to be marginal in Ghana considering annual average speeds of 4-6m/s at 50 m above sea level in the coastal areas and some selected islands [23]. A few

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areas, however recorded wind speed of up to 8 m/s. Wind energy in Ghana has moderate potential estimated to generate about 406 MW of power for grid connection, water pumping, and off-grid applications along the Northern, Eastern and Western belt of Ghana [28]. The available wind in Ghana can be harnessed for electricity generation [10]. The Ghana meteorological services department also assessed wind speeds in some selected parts of the country to be between 1.7 and 3.1 m/s at 20 m anemometer heights [24].

In Ghana, biomass accounts for around 40.6 per cent of the overall primary energy supply in the national energy mix [5]. Ghana's biomass resource capacity encompasses various energy crops, including agricultural crop residues, forest product residues, animal waste and urban waste [28], [16].

Agricultural residues include maize, rice, cocoa, sorghum, yam, cassava, potatoes, millet, coconut, oil palm and sugar cane residues [16]. The municipal waste category is further divided into subcategories: MSW sewage sludge, food waste, and waste oil [16]. In 1985, Approximately 80 per cent of Ghana's wood fuel was used by households for charcoal and firewood but has since decreased by 50 per cent in 2015 [28], [16]. This reduction can be attributed to the successful promotion of improved cooking stoves such as Gyaba, Enuatem and Ahibenso [28]. The conventional use of biomass is not limited to homes but also industrial and commercial uses.

This study seeks to evaluate the prospects of renewable energy technologies suitable for implementation in Ghana and develop an education programme to promote renewable energy. In acknowledgement of the critical need to increase access to a sustainable global environment, the United Nation General Assembly in 2012, proclaimed the International year of Sustainable Energy for All (SE4ALL). The proclamation implored member states and the UN to raise awareness of the significance of tackling energy challenges through the promotion of mitigation actions on them. A uniform initiative aims to achieve sustainable energy for all by the year 2030 [7] and renewable energy is foreseen as a sustainable means to attain this goal. Renewable energy sources naturally replenish themselves and are technologies that are environmentally friendly [36]. Prominent RES include solar, wind, hydropower, geothermal, bioenergy, and ocean (tide and wave) energy [36].

The 2020 Ghana electricity plan report states that “the transmission system has inadequate transfer capacity to meet the demand requirements of the major load centers (Accra, Kumasi, Tarkwa, etc.), particularly at peak [22]. The situation could result in low voltages, overloading of lines, and increased overall transmission system losses [39]. This indicates the need for the Energy sector to invest in renewables to boost the country's power capacity for social and economic growth.

Even though several attempts have been made to boost the penetration of renewable in the country’s energy mix; there is evidence that renewable energy penetration has not achieved its target as stated in many policy documents. According to the National Renewable Energy Action Plans (NREAPs) 2015-2020, the total renewable energy integration should have reached 10% by 2020 [19]; Meanwhile the real percentage in 2020 was less than 1 %. Other policy documents promised very ambitious percentages including the Ghana Renewable Energy Master Plan [20], and failed one after the other to attain them. What therefore are the barriers to the penetration of renewables in Ghana?

This study investigated the availability or potentials of selected renewable energy resources in Ghana. The study further assessed the penetration into the national grid and the deployment of some related renewable technologies in Ghana, including solar PV, Wind and Biogas.

The rest of the paper is divided as follows: section two deals with the methodology, section three presents the results, section four elaborates on the discussion and section five gives the conclusion.

2. Methodology

This section of the study is divided into subsections comprising the research design, the study population, the sampling technique, the data type and source, and the data analysis instrument and procedure.

In this study, the questionnaire is structured in four sections. The first section contains the demographic information which seeks to know the sex, age and occupation of the participant. The second section seeks information on renewable energy technologies available in Ghana, followed by some open-ended questions to capture participants' suggestions. The final section seeks information on the ranking order of preferred technologies.

2.1 Data Analysis Instrument & Procedure

The study employed both descriptive and inferential tools to analyse the data. The use of these statistical tools offered the researcher the opportunity to analyse the responses descriptively, and also to make inferences. Descriptive statistics utilised frequency counts with percentages for the categorical/nominal data; mean score with standard deviation and relative index (ranking) for the ordinal data (Likert scale). One sample t-test was used as inferential statistics to establish the statistical significance of the parameters.

2.2 Research Design

This research design is explanatory, which is a realistic approach in which the initial effects of quantitative data are further clarified through qualitative analysis. This approach was chosen, given that the purpose of the research was to evaluate the prospect and penetration level of the solar photovoltaic, wind and biogas in order to develop a document for promoting the technologies.

2.3 Study Settings

To achieve the main objective of the study, which is to evaluate the prospect of solar PV, wind and biogas and to identify factors that could affect the future penetration of these technologies in Ghana, the researcher focused on the renewable energy sector of Ghana [20] to gather some of the primary data for analysis.

2.4 Study Population

This study has a national dimension making the study population very large and almost impossible to recruit all stakeholders for data collection within a limited time. As a result of the difficulty in involving all the population, a sample from the population of interest was considered for the study based on convenience.

The study population was concerned with staff of the Energy Commission of Ghana, the Electricity Company of Ghana, the Ministry of power, the Volta River Authority, the Ghana Grid Company. Table 1 presents the study population and their occupations.

Table 1: Occupation of respondents.

	Frequency	Percentage
Sex		
Male	**129**	**73.3**
Female	**47**	**26.7**
Total	**176**	**100.0**
Age		
Less than 20 years	5	2.8
20-29 years	59	33.5
30-39 years	63	35.8
40-49 years	35	19.9
50-59 years	13	7.4
60-69 years	1	.6
Total	176	100.0
Occupation		
Engineer	31	18.0
Administrative Officer	32	18.6
Financial Officer	9	5.2
Research and Quality	14	8.1
Academia and Technologist	71	41.3
Others	19	8.7
Total	176	100.0

Job specification		
Government	104	62.7
Private	62	37.3
Total	166	100.0

2.5 Sampling Techniques

This study used a non-probability technique and the selection technique was based on convenience sampling. This sampling method was adopted due to the ease of selecting participants who are deemed qualified to contribute to the study and are accessible during data collection.

2.6 Data Type & Data Sources

The study adopted questionnaires and interview to collect both quantitative and qualitative primary data respectively. The quantitative data was collected through administering questionnaires on the field and online. The qualitative data was collected from experts in renewable energy at the Energy Commission Ghana through interviews.

3. Results

This section presents the research results, which are organised according to each research question. Each research question is re-called, followed by the presentation of its findings.

3.1 Results in line with Research Question One

Which of the following types of renewables are available in Ghana?

The results of research question 1 which seeks to address the availability of renewables in Ghana are presented in Table 2. The Table shows the mean scores with standard deviations, relative index and test statistics of the scaling of renewable energy technologies. The following are the mean scores criteria;

- Less than 1.5 indicates strongly disagree,
- Between 1.5 and 2.4, indicates “disagree”,
- Between 2.5 and 3.4, indicates “neutral”,
- Between 3.5 and 4.4, indicates “agree” ,
- Above 4.5 indicates “strongly agree”.

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Also the t-value and p-value being lesser than 0.05 will indicate a significant level of agreement (mean score above the hypothesised mean of 3.5).

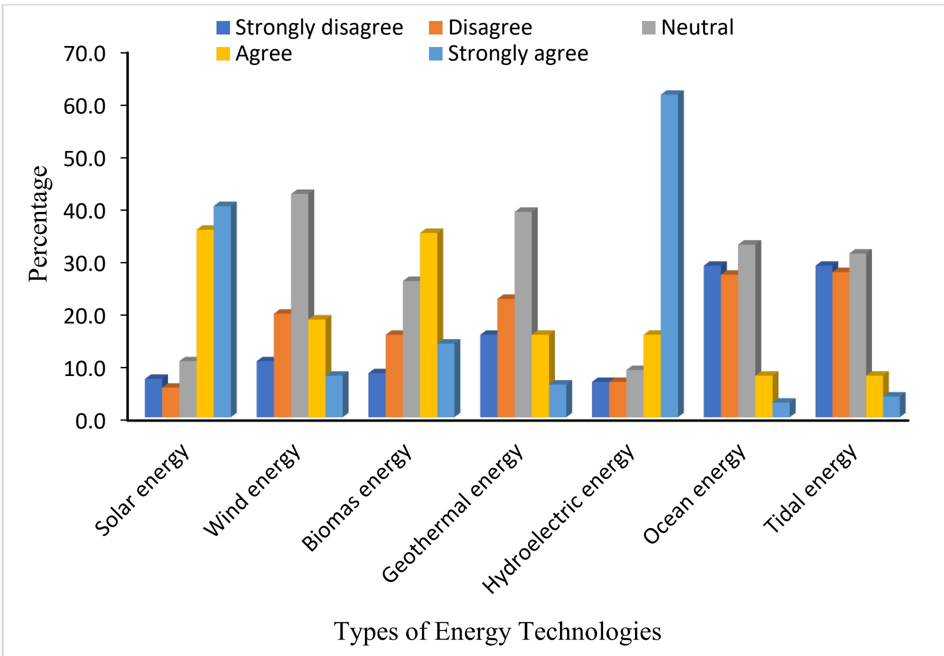

Figure 1: Frequency Distribution of the Types of Energy Technologies

Table 2: Results of Renewable Energy Technologies

	Mean	Std. Dev.	RII	Ranking	t-value	p-value
Solar energy	3.96	1.187	0.792	2	5.142	0.000
Wind energy	2.93	1.067	0.586	4	-7.065	1.000
Biomas energy	3.31	1.155	0.661	3	-2.219	0.986
Geothermal energy	2.74	1.101	0.548	5	-9.178	1.000
Hydroelectric energy	4.18	1.252	0.836	1	7.226	0.000

Ocean energy	2.28	1.058	0.457	7	-15.250	1.000
Tidal energy	2.30	1.093	0.460	6	-14.552	1.000

From Table 2, the responses to the type of renewable energy available and accessible show a high level of agreement to hydroelectric energy, recording a mean score of 4.18 with a standard deviation of 1.252 with a very high relative index of 0.836. This result indicates respondents averagely agreed that hydroelectric energy is available and accessible. The 2nd ranked renewable energy technologies in which respondents averagely agreed is solar energy, with a mean score of 3.96 and a standard deviation of 1.187. Hydroelectric energy and solar energy were statistically significant thus, t-value of 7.226 and 5.142, respectively.

The remaining types of renewable energy technologies; wind energy and geothermal energy are rated averagely as neutral, mean scores are respectively 2.93 and 2.74. The remaining two types of energy technologies, ocean energy and tidal energy are rated as disagreed.

On the other hand, the country's main source of electricity generation is via hydroelectricity. The majority confirms this; almost all respondents agreed to hydroelectricity availability.

3.2 Results in line with Research Question Two

How can renewable energy be integrated in the Ghana National Electricity Grid?

Table 3 shows the results of the respondents to the research question on renewable energy integration into the National grid.

Table 3: How renewable energy can be integrated in the Ghana National Electricity Grid

How can renewable energy be integrated in the Ghana National Electricity Grid	Frequency	Percentage
Encouraging private production and partnerships	13	12.1
Government policies and investment	68	63.6
Education and training	22	20.6
Government subsidies	4	3.7
Total	107	100

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Majority (63.6%) think that government policies and investment constitute the main challenge for the integration of renewable energies in the National Electricity grid.

3.3 Results in Line with Research Question Three

What is the order of preference in ranking renewable energy technologies based on cost and resource availability?

The results for research question three regarding the ranking of renewables is presented in Table 4 and illustrated in Figure 2.

Table 4: Recommended Renewable Energy Technologies in Order of Preference

	Mean	Std. Dev.	RII	Ranking	t-value	p-value
Preferable technologies available	-					
Solar PV	3.36	1.022	0.673	2	-1.770	0.078
Wind energy	2.76	0.980	0.552	3	-10.002	1.000
Biogas	3.99	0.441	0.798	1	14.712	0.000
Cost of capital	-					
Solar PV	3.68	1.101	0.736	1	2.191	0.015
Wind energy	2.89	1.090	0.577	3	-7.472	1.000
Biogas	3.44	1.241	0.689	2	-0.607	0.728
Cost of Importation of Accessories	-					
Solar PV	3.63	1.184	0.725	1	1.401	0.082
Wind energy	2.83	1.216	0.566	3	-7.313	1.000
Biogas	3.45	1.307	0.685	2	-0.549	0.708
Cost of Installation	-					
Solar PV	3.59	1.138	0.717	1	0.993	0.161
Wind energy	2.76	1.086	0.551	3	-9.090	1.000
Biogas	3.53	1.251	0.707	2	0.362	0.359
Cost of operation and maintenance	-					
Solar PV	3.72	1.166	0.743	1	2.457	0.007
Wind energy	2.92	0.982	0.584	3	-7.827	1.000
Biogas	3.47	1.223	0.694	2	-0.308	0.621

Cost of Energy	-					
Solar PV	3.84	1.172	0.767	1	3.796	0.000
Wind energy	2.98	1.126	0.595	3	-6.158	1.000
Biogas	3.45	1.227	0.690	2	-0.553	0.710
Accessibility	-					
Solar PV	3.98	1.178	0.797	1	5.438	0.000
Wind energy	2.84	1.101	0.567	3	-8.009	1.000
Biogas	3.69	1.195	0.738	2	2.082	0.019

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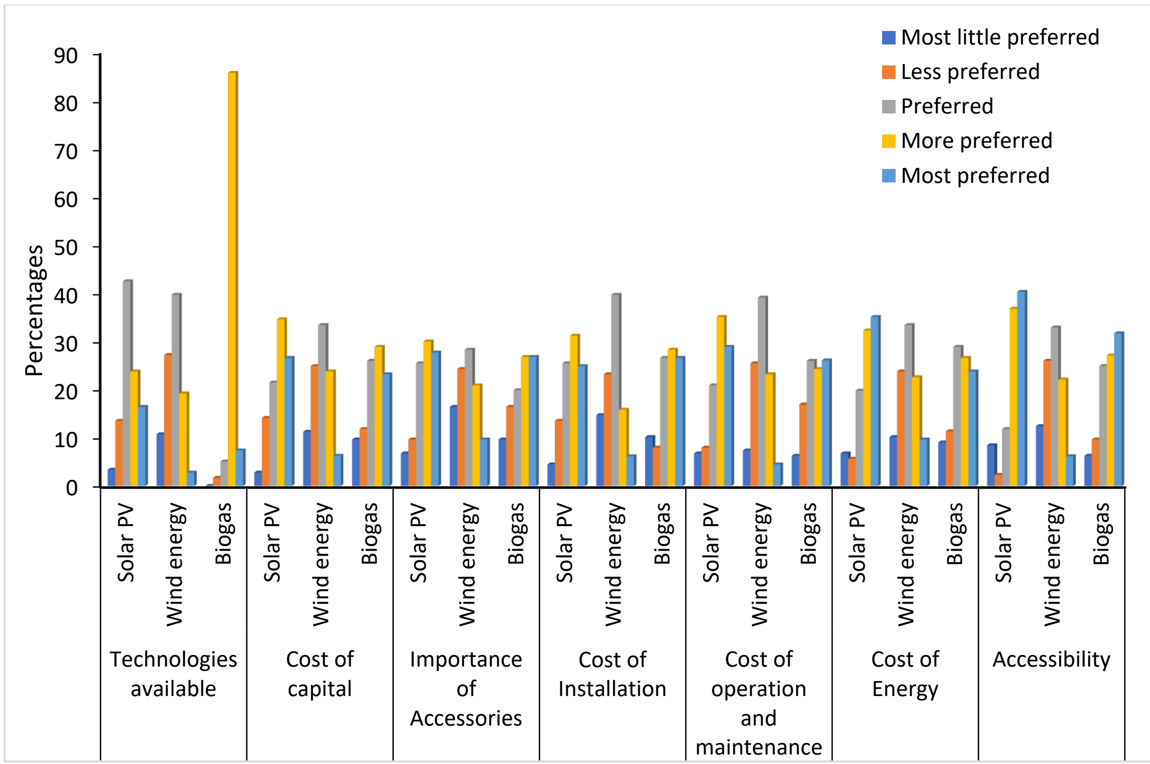

Figure 2: Renewable Energy Technologies Preference (Percentage of preference option)

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Table 4 and Figure 2 present the results of responses on which renewable technologies is the most preferred considering availability, capital cost, accessories, cost of installation, cost of operation and maintenance, cost of energy and accessibility.

- Regarding availability, the results show that Biogas was more preferred as revealed by majority (85.4%) of the respondents followed by solar PV. The mean score of 3.99 with standard deviation of 0.441 (ranked 1st) confirm this assertion.
- In terms of capital cost, most of the respondents preferred Solar PV, followed by Biogas energy.
- Concerning the cost of importation of accessories, findings show that most of the respondents preferred Solar PV (See Table 4). The mean score recorded was 3.63 with standard deviation of 1.184 (relative preference was 0.725); however, this was statistically not significant, with a t-value of 1.401 and p-value > 0.05. To others, the cost of importation of biogas accessories is preferred (see Figure 2).
- Regarding cost of installation, majority preferred solar energy and wind energy (See Table 4). This means that the cost of installation of wind technologies is cheaper as indicated by most of the respondents (39.8%).
- With regard to cost of operation and maintenance on renewable energies, solar PV and biogas energy were indicated as most preferred as revealed by the mean scores of 3.72 (SD = 1.166) and 3.47 (SD = 1.223) respectively (see Table 4).
- In terms of accessibility of these renewable technologies in Ghana, the findings shows that, Solar PV was indicated by majority (40.4%) as most preferred (Figure 2).

3.4 Interview Data

Interviews were conducted with some key officers of power companies to investigate the proposed renewable technologies namely solar PV, wind and biogas in Ghana. Some few selected excerpts are presented in this section and will be thoroughly discussed in the subsequent section.

- Question: How will you analyse the prospects of solar PV integration in Ghana National Grid?

Answer: Excerpt One

"*Importation cost of renewables in Ghana is still very high; there is visibly no effort to enact policy that incentivise customers on integration of renewable; High cost of solar equipment make them a myth to many; there is still lack of skilled people or technicians to handle solar installation and maintenance problems; When I try to picture the future of solar PV in Ghana, I see nothing than a tumult"*

- Question: How will you analyse the prospects of biogas and wind integration in Ghana National Grid?

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- Answer: Excerpt Two

" Biogas seems to have great prospect in Ghana owing to the numerous waste generated dynamically and voluminously but there seem to be very little effort in construction biogas plant on mega scale. Wind is merely inexistent; I do not recall any serious wind farm or wind power plant installed in Ghana; there is however some rumor about wind resources availability along the coastal area. Biogas and wind have limited prospect in Ghana in my view"

4. Discussion

The discussion is organised according to the findings. Each finding is stated and discussed in light of the literature review and implications are drawn.

4.1 Finding One: Solar resource is abundant in Ghana

From Table 3, majority (35.8% and 40.3%) of the respondents agreed and strongly agreed respectively that there exists solar energy abundantly in the country. Solar energy is ranked 2nd renewable energy technology available according to the respondents. The findings substantiate previous studies [2], [9], [25], [30] & [37] relating to solar energy potential in Ghana. According to Asumadu-Sakordie [9] and Aboagye et al [2], the potential for solar energy in Ghana is huge and can help grow the economy; a considerable amount of this potential remains untapped (50-100 MW). Kuamoah [30] supported that the potential for renewable energies in Ghana is huge and still underexploited. Park [37] confirmed that solar energy is highly attractive and promising in Ghana owing to its environmental and social friendliness.

4.2 Finding Two: There is scarcity of wind resource in Ghana.

On respondents' views on wind energy in Ghana, majority (42.6%) insisted that they are neutral as to the availability of this energy (Figure 1). The mean score of 2.93 with standard deviation of 1.067, indicate that respondents are neutral about the availability of wind energy. This presumes that wind energy existence in Ghana is to some extent, a misconception. Even the few ones that may exist are obviously not popular nor utilised as compared to other renewable technologies. This assertion is confirmed by the respondent' views of 19.9% and 10.8% respectively corresponding to "disagreed" and "strongly disagreed" (Figure 1). This finding is supported by many previous studies [3], [4], [10], & [41].

Sun et al. [41] confirmed that Ghana has not officially produced energy from wind even though there is plan to develop a 225 MW wind farm capacity from Ayitepa. There are also plans to develop two wind farms of 150 MW capacity each in partnership with private developers. Other studies [4], [30] document the wind resources available in Ghana and further confirm the scarcity of wind power plants installed in the country. Average wind speeds of 8 m/s at 50m height were confirmed for the coastal areas while in some exceptions, speed above 8 m/s was recorded.

4.3 Finding Three: There is a substantial availability of biomass that can be exploited for energy generation in Ghana though the technology is fairly underutilised

The findings revealed that biomass is considerably available in Ghana. 35.2% and 14.2% of the respondents respectively agreed and strongly agreed on the availability of biomass in Ghana.

Despite the availability of rich forests and biodiversity, most of these resources are underutilised.

Kemausuor et al. [27] established the potential energy that can be extracted from the available biomass in Ghana including crop residues, animal manure, logging residues and municipal waste. The study unfolded a huge amount of equivalent biogas or cellulosic ethanol which can replace more than quarter of the wood-fuel use in Ghana. Similarly [38] found an abundance of biomass sources in Ghana that can lead to a sustainable supply of energy. The potential of biomass resources in Ghana is further emphasised in rural areas where agriculture is a lifestyle. For instance, Nelson et al.[34] demonstrated that there is huge availability of agricultural crop residues that can be exploited for rural development in Ghana.

4.4 Finding Four: There is a need to develop policies and create investment opportunities to encourage the integration of renewable energies in the energy mix in Ghana

Findings revealed that the government needs to initiate a vibrant and workable policy and invest in renewable energy as indicated by most respondents (63.6%) according to Table 3.

In order of scale, 20.6% and 12.1% of the respondents indicated that renewable energy can be integrated through education and training and by encouraging private production and partnerships respectively (Table 3). Education and training are the hallmark of success. The mentioning of private production and partnerships also brings in mind, the need for collaborative decisions and operation between the government and other private entities. Since the government of Ghana cannot be in the full capacity to provide all these renewable energies then it will be necessary if private companies and individuals are encouraged to contribute their quota to the production and development of these renewable energies.

It is worth noting that there exist in Ghana, the Renewable Energy Act, 2011 (Act 882) which provides regulatory framework and cost incentives to promote private sector involvement in renewable energy deployment. Additionally, there was a policy target for renewable to contribute 10% of the total energy mix in Ghana by 2020 meanwhile the reality was far away from the target. According to the 2020 energy commission report, renewable contributions to Ghana energy mix is about 78.6MW in 2019 which represents 1.58% of

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the total generation of year 2019 [17]. The 2021 energy outlook [18] however shows that the contributions from renewable energy is about 1.1%. The above evidences confirmed the finding regarding policies and generation mix.

4.5 Finding Five: Solar PV technology has a high prospect in Ghana

This finding derives from discussions based on excerpt one which is re-called as follows:

"*Importation cost of renewables in Ghana is still very high; there is visibly no effort to enact policy that incentivise customers on integration of renewable; High cost of solar equipment make them a myth to many; there is still lack of skilled people or technicians to handle solar installation and maintenance problems; When I try to picture the future of solar PV in Ghana, I see nothing than a tumult"*

Despite the government of Ghana's commitments to the development and promotion of renewable energy, investment in the renewable energy sector has been restricted.

According to Kuamoah [30], the macroeconomic climate, perceived risk by the banking sector, and financing terms and conditions, such as high commercial interest rates, limited tenor loans, high inflation, and currency depreciation, all pose significant barriers to renewable energy development in Ghana. Furthermore, the risk element associated with the pricing of renewable energy technologies is high, causing banks to avoid financing renewable energy development projects.

Power sector bodies, regulators, financiers, domestic investors, and national technology and service providers all appear to have inadequate understanding and experience with renewable energy technologies development and deployment. There are difficulties getting equipment and spare parts for some technologies, as well as poor facility operations and maintenance, and a lack of infrastructure to enable usage. This challenge has been supported by [35] who identified lack of access to equipment and spare parts for some renewable energy technologies such as wind turbines, parabolic solar trough and tidal turbines as a major challenge to achieving sustainable development goal seven in Ghana.

Again, there is a scarcity of skilled workers to conduct technical and feasibility studies, as well as to build, run, and manage renewable energy projects. People are hesitant to import technology due to the lack of educated professionals to train, show, maintain, and operate renewable energy installations, particularly in low-education areas. According to [33], it is a major factor challenging renewable energy deployment in Ghana. Technically skilled personnel and people with excellent managerial abilities with a practical ‘‘hands on" approach are needed according to [32]. This will lower the expense of hiring high-priced expatriates while allowing for greater investment in renewable energy.

Despite these challenges, some efforts have been made to develop and deploy renewable energy in Ghana. According to Kuamoah [30], Ghana has begun construction of a 155-MW solar plant that would boost the country's electricity generation capacity by 6%.

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Again, the government of Ghana has enacted two main energy policy documents that contain renewable energy goals to improve the country's renewable energy resources for optimal utilisation and generation of electricity. These two policy documents have set targets for renewables in Ghana by 2030 and are the National Renewable Energy Action Plans (NREAPs) [19] and the Ghana Renewable Energy Master Plan [20]. A report by [21] revealed that a total on-grid and off-grid renewable electricity installed capacity as of 2019 was about 78.6 MW. The on-grid accounted for 42.6 MW, representing about 0.8% of the country's total electricity generation in 2019.

4.6 Finding Six: Biogas is promising especially in the rural areas meanwhile wind farms development in Ghana is progressing at Snail's pace

This finding derives from discussions based on excerpt two which is re-called as follows:

" Biogas seems to have great prospect in Ghana owing to the numerous waste generated dynamically and voluminously but there seem to be very little effort in construction biogas plant on mega scale. Wind is merely inexistent; I do not recall any serious wind farm or wind power plant installed in Ghana; there is however some rumor about wind resources availability along the coastal area. Biogas and wind have limited prospect in Ghana in my view"

Bensah & Brew-Hammond [12] confirmed the availability of a considerable amount of residues that can be used to develop biogas across the country; however, most of these have remained unused. According to Arthur, Baidoo, & Antwi [8] indicated that even though biogas is promising in Ghana due to resource availability, the biogas technology has not penetrated the market to gain widespread use because of many factors.

For instance, Ghana can create utility-scale wind energy in specific areas. The minimum wind speed necessary for utility-scale wind farms is 6.4 m/s and this requirement is met in several areas in Ghana especially the coastal areas [41]. Again, according to Sun et al. [41], it has been estimated that Ghana has an annual wind energy potential of 82.8 TWh and a total final electricity usage of 6.9 TWh. There are some obvious potential but there is almost no deployment so far.

Though the potential for wind power deployment and development exists, very little has been done to develop wind energy in Ghana. Globally and locally, the lack of and insufficient access to funding high initial capital requirements for the development of wind energy projects has been a significant impediment to the sector's growth. According to research conducted by [33] it is the third most significant impediment to the development of wind projects.

5. Conclusion

This paper assessed the availability of some selected renewable resources in Ghana (solar, wind and biomass) and further investigated the penetration of related technologies in the Ghanaian energy market namely solar PV, Wind and Biogas. The study established six findings that were derived through a mixed research approach combining quantitative and qualitative studies.

The first finding confirms the abundance of solar resource in Ghana and stressed that most of the available resources are still underexploited. The second finding confirmed the scarcity of wind resources in Ghana and further clarify the unavailability of current wind farms deployed for electricity production in the country. The third finding revealed the profuse availability of biomass in the country that can be exploited to generate energy even though the bigger portion remains currently underexploited. The fourth finding clarifies the issue of lack of adequate policies and financial limitations to the penetration and acceptance of renewable technologies in the Ghanaian market. The fourth finding further explains that the contribution of renewable energies to the national energy mix has not been effective as set in the existing policy documents (1.1% instead of 10% target by 2020). Finding five reveals the promising prospects of solar PV technology in Ghana. Finding six reveals the immensity of biomass while accepting the slow pace at which biogas is implemented. Again, finding six reveals that wind technology is yet to be fully deployed for energy production in Ghana.

The six findings painted the true image of renewables availability in Ghana and the prospect of their related technology. While solar PV is on the ascendency, biogas is progressing gradually and wind is moving at a snail's pace. These findings have far-reaching implications for policies to be developed to stimulate private sector investment and promote renewable integration in the national grid. Further studies should investigate the barriers to the slow pace of biogas and wind and suggest solutions to overcome them.

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