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Energy Integration to Ensure Effective Generation Supply and Distribution in Ghana Corporation Perspective

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The objectives of the research are to examine the awareness and efficiency of the renewable energy law in Ghana; determine the main source for energy generated by the VRA, GRIDCO, and ECG; determine the distribution gap and find out how effectively these corporations are making use of the other resources to generate electric energy in Ghana.
Study Design: Purposive Sampling technique study design.
Place and Duration of Study: Volta River Authority, Ghana Grid Company, Electricity Company of Ghana, Ghana, between April 2016 and August 2016.
Methodology: We included sampled employees from the Volta River Authority, Ghana Grid Company, Electricity Company of Ghana. A total of 300 employees of the three organizations were selected for the research. The study employed a purposive sampling technique in selecting the employees from the three organizations.
Results: Data collected was analyzed using appropriate descriptive and inferential statistics. Results revealed that all employees are aware of the Renewable Energy Law Act 832 and that it is defined as energy obtained from non-depleting sources such as "Wind energy", "Solar energy", "Bio-energy", "Geothermal energy", and "Ocean energy". Also, this study has established that,

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"hydro power sources", "thermal energy sources"; and "renewable energy sources" are the main sources of energy generated by the Volta River Authority and also the type of renewable energy currently generated by the Volta River Authority is the solar energy.
Furthermore, the study has been able to establish that the Volta River Authority currently produce between 2100 to 2499 megawatts of electricity but however, there is a distribution gap or shortfall of about 900 to 1299 megawatts of electricity. Finally, findings from the study revealed that other corporations generate about 900 to 1299 megawatts of electricity.
Conclusion: "High-Cost" and "Lack of trust in the technology" are the factors that will prevent the adoption of renewable energy sources. Also, "Lack of budget funding" and "Unavailability of Gas/Crude oil to power plants" are the barriers to improving energy efficiency. It was however recommended that, the government should endeavor to initiate informative programs aimed at promoting renewable energy and provide capital subsidies and make investments through specialized agencies created for the promotion of renewable energy development and for installation of renewable energy.

Keywords: Energy; generation; supply; distribution.

1. INTRODUCTION

Modern society is critically dependent on its energy supply, in particular the supply of electricity. Electricity provides light, heating, cooling, communication and transportation and powers a wide range of industrial processes. Electrical energy presently comprises about 15% of energy demand in the world [1], but this percentage is considerably higher for developed societies and tends to increase. Nevertheless, governments around the world are increasingly adopting policies to promote the deployment of renewable energies to ensure efficient supply and distribution of energy.

In 2010, more than 100 countries had enacted some type of policy target and/or promotion of policy related renewable energy (Ren21 [2]). However, renewable energies can help in combination with other measures such as energy efficiency and electricity grid expansion to solve the two interrelated energy challenges the world is facing – Climate change and Increase in energy demand. The global concern over environmental climate change linked to fossil fuel consumption has increased pressure to generate power from renewable sources [3]. Although substantial advances in renewable energy technologies have been made, significant challenges remain in developing integrated renewable energy systems due primarily to the mismatch between load demand and source capabilities [4].

Moreover, electricity consumption is strongly correlated with economic growth: Economic growth allows further use of electric appliances which in turn increases electricity demand [5]. In the past three decades, economic growth has been an important factor in tripling the electricity consumption worldwide. The continuing development of economies such as China and India will increase the demand for electrical energy much further, while the United States, Japan and Europe will still need increasing amounts of electricity to provide for growth of consumption and to power the ever-growing number of applications.

However, in Ghana, given the growing concerns about energy security, sky rocketing price of fossil fuel and greenhouse gas emission control, an initiative to get a cleaner and uninterrupted power supply to augment the existing Ghanaian capacity could not be timelier. Considering current literatures that have clearly established the relationship between energy consumption and economic growth: it will be difficult to attain the better Ghana agenda with poor energy production and delivery. It is in recognition of this challenge that the overall national renewable energy policy target is to attain 10% Renewable Energy in the national energy mix by 2020 [6].

The institutional framework has already been setup for the development of renewable energy resources in Ghana. The Parliament of the Republic of Ghana passed the Renewable Energy Bill Into Law, thus Renewable Energy Act 2011 (Act 832) which has a feed-in tariff component and a provision for the establishment of a renewable energy fund. The law also grants Independent Power Producers the privilege to integrate their large share renewable energy generation on the national grid system.

According to the Law, "An operator of a transmission or distribution system shall connect a generator of electricity from renewable energy sources within the coverage of the transmission or distribution system where a generator of electricity from renewable energy sources so requests. This opportunity has heightened the interest of both national and international investors in Ghana's renewable energy sector, with Mere Power Nzema Limited taking the lead by building Africa's largest solar PV power plant (155 MW) at Aiwiaso in the East Nzema district of Ghana (MoE [6]). This could be a positive response by the government toward literatures which shows correlation between energy supply and economic growth or to solve the two interrelated energy challenges the world is facing – Climate change and Increase in energy demand through renewable energy systems.

The output from renewable energy sources like photo-voltaic, wind, tidal and micro-hydro fluctuate on an hourly, daily, and seasonal basis. As a result, these devices are not well suited for directly powering loads that require a uniform and uninterrupted supply of input energy.

Renewable energy systems that employ a regenerative approach to enable intermittent energy sources to service time varying loads rely on the efficient transfer of energy through the storage media. However, due to an insufficient media storage the country has faced multiplex situations on energy supply and distribution by the VRA, GRIDCO, and ECG. Despite the untold effect by government which led the country to successfully attain the Renewable Energy Law; thus Renewable Energy Act 2011 (Act 832) - has a feed-in tariff component and a provision for the establishment of a renewable energy fund, the challenge of supply and distribution of energy appeared not to be completely eradicated.

Ghana is endowed with enormous solar energy resources spread across the entire country. Daily solar irradiation levels range from 4 kWh/m2 to 6 kWh/m2 [7]. Moreover, the integration of electrical energy from sun, wind, coal and natural gas are barely known and as such are not regularly exploited to bridge the gap of energy demand. As earlier noted, the necessary framework for the development of renewable energy by the Ministry of Energy in the country has already been established. However, there hasn't been any similar research work on the Integration of energy to ensure effective generation supply and distribution in Ghana corporation perspective.

This study thus, aimed at finding out how energy can be integrated to ensure effective generation supply and distribution in Ghana. Specifically, to examine the awareness and efficiency of the renewable energy law in Ghana; determine the main source for energy generated by the VRA, GRIDCO, and ECG and find out how effectively these corporations are making use of the other resources to generate electric energy in Ghana.

2. LITERATURE REVIEW

According to Gand [8], the demand for electricity has been increasing at an average annual rate of 12 per cent since the last 10 years. A research study by Aboh [9] reveals that Ghana's electricity demand is expected to experience 23.5 per cent growth rate between 2008 and 2030 as depicted in Table 1.

Though, forecasts of Ghana's electricity consumption have been observed with inconsistencies particularly on the growth rate as argued by different authors, the underlying element is that electricity demand will increase considerably by 2030. The increasing demand for electricity implies the need to step-up investments toward expanding the operational power generation capacity.

Table 1. Electricity requirement forecast for Ghana between 2008 and 2030

Stakeholders	Years			Growth rate (%)	
	1997	2008	2030	1997-2008	2008-2030
Total household electricity use (GWh)	202	288.6	15,094	0.8	18
Total commercial and industrial electricity use (GWh) - VALCO Excluded	570.8	3,433.10	50,145.60	4.7	12.2
Total	772.8	3,721.7	65,239.6	5.5	30.2

Source: Aboh [9]

The response from the Government of Ghana has been diverse. ISSER [10] identifies the electricity generation expansion projects to include the expansion of the Takoradi power station to generate additional 110-MW steam unit and the construction of the Bui hydroelectric dam to generate 400 MW of electricity. The other projects include the 300 MW combined cycle thermal power plant located at Tema of which its operation is intended to be synchronized with the delivery of natural gas through the West African Gas Pipeline Project.

According to DFID [11], any power source that depends on the rainfall pattern is unsustainable due to the effects of climate change. Additionally, Kemfert [12] and Youngquist [13] argue that oil prices are bound to increase substantially due to increasing demand coupled with the highly inelastic nature of supply. Youngquist [13] further pointed out that though there will always be oil, the cost required to exploit the remaining reserves will outpace its value. The result will be substantial increases in the prices with their effects on industries and human welfare in general. From the above, the responses from the government of Ghana to increase the available electricity generation capacity have not been spared by the incidence of global warming and fossil fuel reserve depletion.

Ghana's electricity sector has long been saddled with challenges regarding supply security and power quality. One of the main factors affecting supply is the over-dependence on hydropower in the generation mix. The total amount of energy that can be delivered is constrained by several factors, which include the variability in rainfall that results in variability of the amount of electricity that can be generated from the hydro plants. Almost all of the recent power crises (1998, 2002 and 2007) have been triggered by low rainfall patterns in the Volta basin that supplies water into the Akosombo dam [14]. The low demand/supply gap is also partially responsible for many power outages in the country [15]. Another supply challenge is the unreliable supply of natural gas from the West Africa Gas Pipeline (WAGP), which feeds the country from Nigeria. The WAGP project consists of the development of an onshore/offshore gas distribution network delivering gas from Nigeria to commercial customers in the neighbouring countries of Benin, Togo and Ghana, but unfortunately the project has not been able to provide a reliable supply of the gas [16]. There are also problems related to inadequate and outdated infrastructure; underfunding and underinvestment; managerial problems; and low tariffs coupled with under-recovery and the inability to collect bills all of which have led to unreliable supply and long power outages, high system losses and unsustainable debt levels [17].

3. METHODOLOGY

This research was a cross-sectional survey which is descriptive in nature and employed quantitative techniques. The population of the study was 1432 employees: 520 employees in VRA; 409 in GRIDCo, and 503 employees in ECG Head offices. The Corporate Affairs and the Human Resources Departments of the VRA, GRIDCo and the ECG, respectively, provided this study with database of staff. After careful considerations, sample size of 100 respondents apiece was purposively selected from the three organizations, summing up to 300 respondents.

Self-administered questionnaire was used to obtain data from the respondents. A total of 300 questionnaires were administered and they were all retrieved with no non-responses on all items except the multiple response items which some were not selected. The desired response was obtained because the researchers were at the various workplaces personally by to explain the purpose of the study to the employees. They were made to understand that all information being provided would be treated with confidentiality and used for the purpose of research only. It was a researcher developed analytically derived questionnaire. It was a four point Likert scale type on two items. It is a close-ended questionnaire. Items one to four (section A) deals with the bio data of the respondents. Items five to nine deals with the respondent's awareness of the renewable energy law in Ghana. Items ten and fourteen examine factors that will prevent the adoption/installation of renewable energy sources on a four point Likert scale and other items on the questionnaire examines the amount of energy generated.

Data collected was analyzed using appropriate descriptive and inferential statistics using both SPSS and Microsoft Excel. The descriptive aspect employed frequency tables; pie and bar charts whilst the inferential aspect of the analysis employed binomial test to categorize the proportion of success and the proportion of failure and Multiple Response analysis.

4. RESULTS AND DISCUSSION

This deals with the analysis of pertinent issues related to the respondent's social life. These include gender distribution, age distribution, distribution of respondents by level of education and length of service.

Table 2 shows the gender distribution of the sample respondents of the study. This reveals that 203 of the respondents representing 67.7% were males whereas 97 representing 32.3% were females. The analysis further reveals that the distribution of respondents by age appears to be evenly distributed among four categories with the 26-33; 34-41; 42-49 and 50-57 years' age group recording 19.3%; 37.7%; 20.4% and 16.3% of the respondents respectively. What this means is that about 93.7% of the times, findings in this research can be attributed to employees within 26 to 57 years' age group. Also, out of the 300 employees who responded to the questionnaire, 23 of them which represent 7.7% indicated that they have been working between the past 1 to 3 years; 97 of them which represent 32.3% indicated that they have been at post between 4 to 6 years; 129 of them which represent 43.0% also indicated that they have been at post for about 7 to 9 years and finally, 51 of them which represent 17.0% also indicated that they have been at post for about 10 years and above.

Table 2. Demographic information of the participants (n=300)

Variables	Frequency	Percentages
Gender		
Male	203	67.7
Female	97	32.3
Age		
18-25	19	6.3
26-33	58	19.3
34-41	113	37.7
42-49	61	20.4
50-57	49	16.3
Duration of working		
1-3 years	23	7.7
4-6 years	97	32.3
7-9 years	129	43.0
10 years and above	51	17.0

Source: Field data (2016)

Fig. 1 shows the proportion of respondents by level of education. It could be seen that out of the total 300 respondents, about 29% of them had diploma/HND; 39% of them had bachelor's degree and finally, about 32% of them had master's degree.

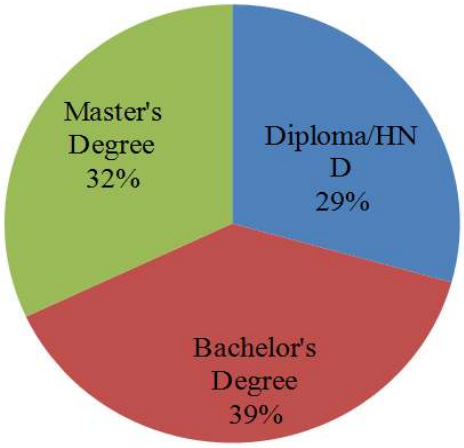

Fig. 1. Proportion of respondents by level of education

4.1 Awareness and Efficiency of Renewable Energy Law

The analysis revealed that all the 300 respondents indicated that they were aware of the renewable energy law Act 832. The output Table 3 gives the definition of the renewable energy under the law Act 832.

Table 3 indicates that there were 1562 responses to these series of questions on how the renewable energy law defines renewable energy in Ghana. Two hundred and seventy-six (276) respondents which represent 17.7% and 92.0% of all response and respondents respectively indicated that the Act 832 defined renewable energy as energy obtained from "wind energy"; 300 respondents which represent 19.2% and 100% of all responses and respondents respectively also indicated that the Act 832 defined renewable energy as energy obtained from "solar energy".

The table further reveals that 291 respondents which represent 18.6% and 97% of all responses and respondents respectively indicated the Act 832 defined renewable energy as energy obtained from "bio-energy"; and also, 257 respondents which represent 16.5% and 85.7% of all responses and respondents respectively indicated that the Act 832 defined renewable energy as energy obtained from "geothermal energy".

Table 3. Definition of renewable energy

	Responses		Percent
	N	Percent	of cases
Wind energy	276	17.7%	92.0%
Solar energy	300	19.2%	100.0%
Bio-energy	291	18.6%	97.0%
Geothermal energy	257	16.5%	85.7%
Ocean energy	239	15.3%	79.7%
Hydro energy (Capacity not exceeding 100 MW)	105	6.7%	35.0%
Nuclear energy	21	1.3%	7.0%
Fossil fuels	73	4.7%	24.3%
Total	1562	100.0%	502.7%

Source: Field Data, 2016

Also, 239 respondents which represent 15.3% and 79.7% of all responses and respondents respectively indicated that the Act 832 defined renewable energy as energy obtained from "ocean energy". Furthermore, 105 respondents which represent 6.7% and 35% of all responses and respondents respectively indicated that the Act 832 defined renewable energy as energy obtained from "hydro power (capacity not exceeding 100 MW)"; also 21 of the respondents which represent 1.3% and 7.0% of all responses and respondents respectively indicated that the Act 832 defined renewable energy as energy obtained from "nuclear energy" and finally 73 respondents which represent 4.7% and 24.3% of all responses and respondents respectively indicated that the Act 832 defined renewable energy as energy obtained from "fossil fuels".

Table 4 indicates that there were 525 responses to these series of questions sources of energy generated by the Volta River Authority. Three hundred (300) respondents which represent 57.1% and 100% of all and response and respondents respectively indicated that the energy generated by the VRA is "hydro power sources".

Table 4. Main source of energy generated by VRA

	Responses		Percent
	N	Percent	of cases
Hydro power	300	57.1%	100%
Thermal energy	214	40.8%	71.3%
Renewable energy	11	2.1%	3.7%
Total	525	100.0%	208.3%

Source: Field Data, 2016

The table further reveals that 214 respondents which represent 40.8% and 71.3% of all responses and respondents respectively indicated the energy generated by VRA is from "thermal energy sources"; and finally, 11 respondents which represent 2.1% and 3.7% of all responses and respondents respectively indicated that the energy generated by VRA is from "renewable energy sources".

Fig. 2 revealed that out of 300 respondents about 96% of them indicated that the renewable energy currently generated by the Volta River Authority is the solar energy whilst the rest 4% of them indicated that the renewable energy currently generated by the Volta River Authority is bio-energy.

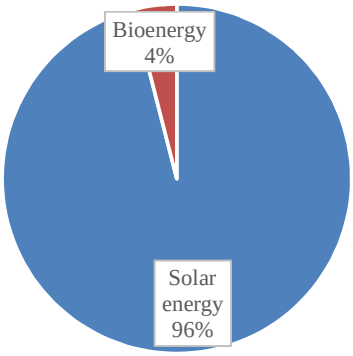

Fig. 2. Type of renewable energy generated by VRA

Fig. 3 revealed that out of the total 300 respondents, 141 of them indicated that cost from renewable sources is very high; 108 of them indicated that cost from renewable sources is just comparable with other sources and finally, 51 of them indicated that cost from renewable sources is low.

The variables in the Table 5 are indicators of the factors that will prevent the adoption of renewable energy sources. From the table, group 1 (<= 2) are those who strongly disagree or disagreed to the variables indicating the factors that will prevent the adoption of renewable energy sources; group 2 (> 2) are those who strongly agreed and agreed. At a significant value of 0.05; it appears that four exact significant values except one are less than 0.05, suggesting that the respondents are unanimous on them. However, only two of these significant variables; "Expensiveness" and "Lack of trust in the technology" has about 86% and 74% agreement respectively whilst the rest two; "Inconvenience" and "Lack of interest" has about 96% and 88% disagreement respectively as

factors that will prevent the adoption of renewable energy sources.

Furthermore, the factor that has a significant value greater than 0.05 is “Lack of awareness”. The implication of this is that the respondents are divided on the effectiveness of these indicators as factors that will prevent the adoption of renewable energy sources.

Fig. 4 showed that 249 out of the total 300 respondents revealed that the Volta River Authority currently produce between 2100 to 2499 megawatts of electricity whiles the rest 51 of them also indicated that the Volta River Authority currently produce about 2500 and above megawatts of electricity.

Fig. 5 revealed that 219 out of the total 300 respondents indicated that there is a distribution gap or shortfall of about 900 to 1299 megawatts of electricity; 63 of them also indicated that there is a distribution gap or shortfall of about 1300-1699 megawatts of electricity whilst the rest 18 of them indicated that there is a distribution gap or shortfall of about 1700 megawatts of electricity and above.

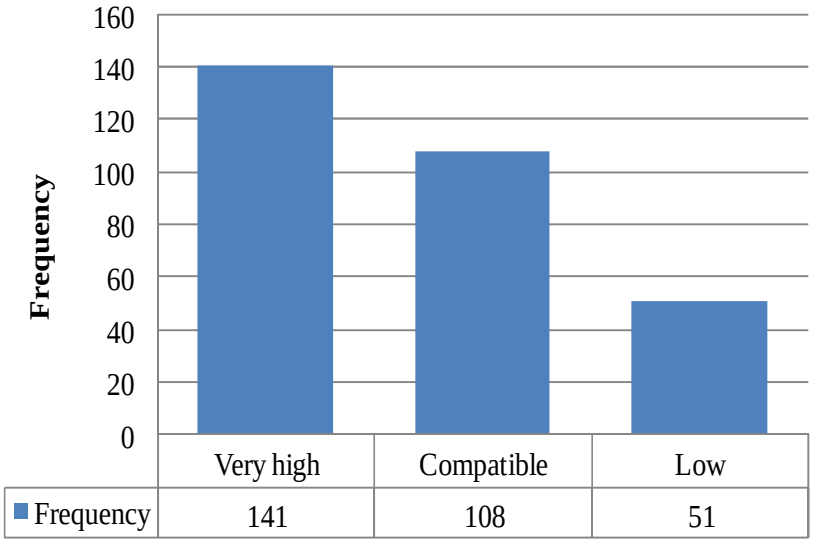

Fig. 3. Cost effectiveness of renewable energy sources

Table 5. Response to the factors that will prevent the adoption/installation of renewable energy sources

		Category	N	Observed prop.	Test prop.	Exact sig. (2-tailed)
Expensiveness	Group 1	<= 2	43	0.14	0.50	0.000
	Group 2	> 2	257	0.86		
	Total		300	1.00		
Inconvenience	Group 1	<= 2	289	0.96	0.50	0.000
	Group 2	> 2	11	0.04		
	Total		300	1.00		
Lack of awareness	Group 1	<= 2	128	0.43	0.50	0.151
	Group 2	> 2	172	0.57		
	Total		300	1.00		
Lack of interest	Group 1	<= 2	263	0.88	0.50	0.000
	Group 2	> 2	37	0.12		
	Total		300	1.00		
Lack of trust in the technology	Group 1	<= 2	79	0.26	0.50	0.000
	Group 2	> 2	221	0.74		
	Total		300	1.00		

Source: Field Data, 2016

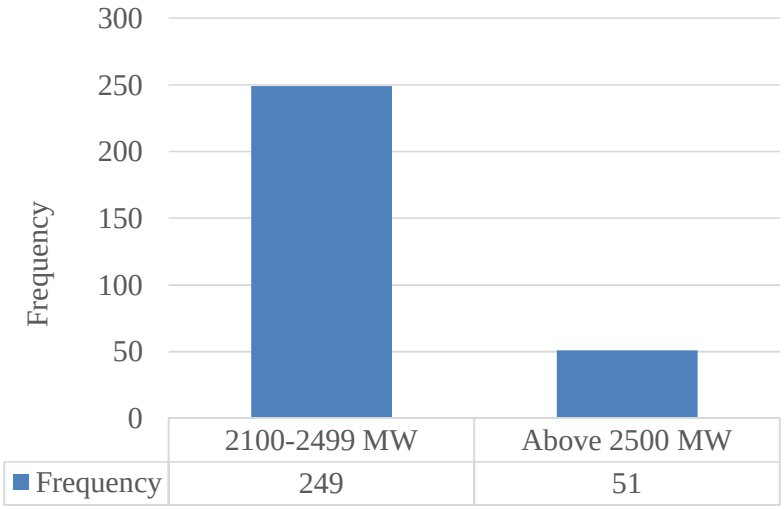

Fig. 4. Amount of energy generated by VRA

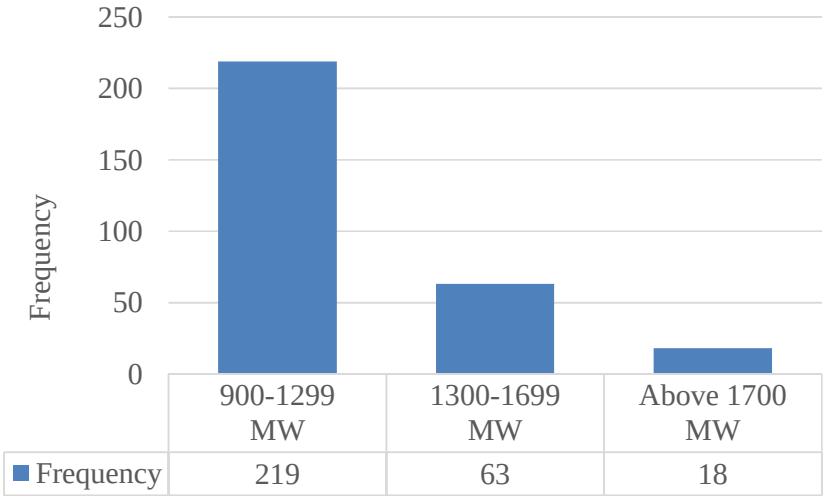

Fig. 5. Shortfall in energy supply to consumers

Fig. 6 revealed that 279 out of the total 300 respondents indicated that other corporations generate between 900 to 1299 megawatts of electricity; whilst the rest 21 of them also indicated that other corporation generate between 500 to 899 megawatts of electricity.

The variables in the Table 6 are indicators of the barriers to improving energy efficiency in Ghana. From the table, group 1 (<= 2) are those who strongly disagree or disagreed to the variables indicating the barriers to improving energy efficiency; group 2 (> 2) are those who strongly agreed and agreed. At a significant value of 0.05; it appears that three exact significant values except two are less than 0.05, suggesting that the respondents are unanimous on them. However, only two of these significant variables; "Lack of budget funding" and "Unavailability of Gas/Crude oil to power plants" has about 83% and 97% agreement respectively whilst the rest one; "Lack of infrastructure" has about 93% disagreement respectively as factors that will prevent the adoption of renewable energy sources.

Furthermore, the factor that has a significant value greater than 0.05 is "Lack of technical skills" and "Ineffective energy law". The implication of this is that the respondents are divided on the effectiveness of these indicators as barriers to improving energy efficiency in Ghana.

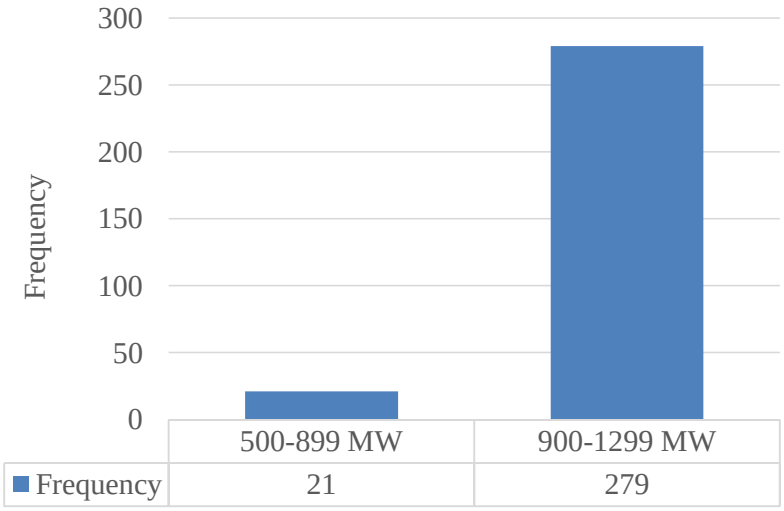

Fig. 6. Amount of energy generated by other corporations

Table 6. Response to barriers to improving energy efficiency

		Category	N	Observed prop.	Test prop.	Exact sig. (2-tailed)
Lack of budget funding	Group 1	<= 2	51	0.17	0.50	0.000
	Group 2	> 2	249	0.83		
	Total		300	1.00		
Unavailability of Gas/Crude oil to power plants	Group 1	<= 2	9	0.03	0.50	0.000
	Group 2	> 2	291	0.97		
	Total		300	1.00		
Lack of technical skills	Group 1	<= 2	147	0.49	0.50	0.237
	Group 2	> 2	153	0.51		
	Total		300	1.00		
Lack of infrastructure	Group 1	<= 2	281	0.93	0.50	0.000
	Group 2	> 2	37	0.07		
	Total		300	1.00		
Ineffective energy law	Group 1	<= 2	184	0.61	0.50	0.071
	Group 2	> 2	116	0.39		
	Total		300	1.00		

Source: Field Data, 2016

5. CONCLUSIONS AND RECOMMENDATION

Conclusively, it was apparent from the findings that, all employees are aware of the renewable energy law Act 832 and that it is defined as energy obtained from non-depleting sources such as “Wind energy”, “Solar energy”, “Bio-energy”, “Geothermal energy”, and “Ocean energy”. Also, this study has established that, “hydro power sources”, “thermal energy sources”; and “renewable energy sources” are the main sources of energy generated by the Volta River Authority and also the type of renewable energy currently generated by the Volta River Authority is the solar energy.

Furthermore, the study has been able to establish that the Volta River Authority currently produce between 2100 to 2499 megawatts of electricity but however, there is a distribution gap or shortfall of about 900 to 1299 megawatts of electricity. Findings from the study also revealed that other corporations generate about 900 to 1299 megawatts of electricity. Finally, results revealed that “High-Cost” and “Lack of trust in the technology” are the factors that will prevent the adoption of renewable energy sources. Also, “Lack of budget funding” and “Unavailability of Gas/Crude oil to power plants” are the barriers to improving energy efficiency.

It was however recommended that, the government should endeavor to initiate

informative programs aimed at promoting renewable energy and provide capital subsidies and make investments through specialized agencies created for the promotion of renewable energy development and for installation of renewable energy. Also, sustainable energy development strategies such as energy savings on the demand side, efficiency improvements in the energy production, and replacement of fossil fuels by various sources of renewable energy should be adopted in order to conserve energy. Finally, government and stakeholders should endeavor to allocate appropriate funds for the repairs and purchasing of new energy generating equipment to aid bridge the distribution gap of supply energy to consumers. This should be carried out in close cooperation with the private sector.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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