Towards the Development of an Energy Audit Program for Residents in Freetown

Bai Kamara

Department of Mechanical and Industrial Engineering Technology
University of Johannesburg, South Africa
baikamara78@gmail.com.

Sheriff Kamara

Department of Mechanical Engineering, Fourah Bay College
University of Sierra Leone, Sierra Leone
mechanicalchair@yahoo.com

Jonas A.S. Redwood-Sawyerr

Department of Electrical Engineering, Fourah Bay College
University of Sierra Leone, Sierra Leone
abiosehrs@gmail.com

Daramy VV Kallon

Department of Mechanical and Industrial Engineering Technology
University of Johannesburg, South Africa
dkallon@uj.ac.za

Abstract

The increasing electricity demand in Freetown, capital of Sierra Leone. has been a burden on the country's electricity sector, since the electricity demanded by residents in Freetown outweighs the electricity generated by the nation's Electricity Generation and Transmission Company (EGTC). This problem has resulted to power shortage leaving many areas within the capital city for hours or days without electricity supply. A major challenge faced by the country's electricity generating sector is the losses on the distribution and transmission networks, which accounts for 34.5% losses in the capital of Freetown alone according to 2017 government electricity report. A 161 kilovolts (kV) of the national transmission network runs from a 250km Bumbuna hydroelectric power plant to the Freetown substations. Another source of electricity loss in Freetown, according to the Electricity Distribution and Supply Authority (EDSA), is non-technical losses resulting from human theft and illegal connections from the national grid by its residents. This paper assesses the development of an efficient energy audit program to minimise electricity loses within Freetown. This study involves the use of a quantitative data collection approach using randomly distributed questionnaires to residents within Freetown. From the data collected and analysed, shows that the development of an effective and efficient energy audit program within Freetown can minimize energy wastage in buildings as well as electricity losses.

Keywords

Electricity demand, power shortage, electricity losses, transmission network, distribution.

1. Introduction

An energy audit process involves an organised scientific study of energy consumption/usage within an organisation/equipment/plant to reduce the energy consumption and cost without altering productivity and consumers comfort, at the same time developing energy saving techniques and cost reduction approach. An energy audit process is carried out in a well-planned systematic manner by an energy generation and distribution management or organisation. Electricity in Freetown and the rest of Sierra Leone is distributed and supplied by the Electricity Distribution and Supply Authority (EDSA) which purchases power from the Electricity Generating amd Transmission Company (EGTC) and other Independent Power Producers (IPPs) to meet the much-needed electricity supply in the country. Fraudulent activities such as illegal connections, wrong tariffs, multiple connections from a single meter are some of the serious challenges faced by EDSA resulting to huge financial losses (Kamara et al, 2019). There is huge amount of revenue loss due to illegal electricity abstraction, electricity tariffs under payment, multiple feeders on a single meter by residents in Freetown make it more challenging by the electricity sector in providing electricity for the growing demand by residents in Freetown. According to the world bank (2019) report, the electricity access rate in Sierra Leone is 16 percent which is far below the 30% sub-Saharan African average. Almost 90 and 30 percent of the customers are in Freetown and district headquarters towns, respectively (Kamara et al, 2021). The main reason for an energy audit (sometimes called an “energy assessment” or “energy study”) is to determine where, when, why and how energy is used in a facility, and to identify opportunities to improve efficiency. Energy auditing services are offered by energy services companies (ESCOs), energy consultants and engineering firms. The energy auditor leads the audit process but works closely with building owners, staff, and other key participants throughout to ensure accuracy of data collection and appropriateness of energy efficiency recommendation. This paper looks into ways of developing an energy audit of buildings in the Freetown area.

2. Relevant Literature on Energy Audit

A powerful tool for uncovering operational and equipment improvements that will save energy, reduce energy cost and lead to higher performance can be achieved through an energy audit process. Energy audits can be done as a stand-alone effort but may be conducted as part of a larger analysis across a group of facilities, or across an owner’s entire portfolio. Energy audits typically take a whole building approach by examining the building envelope, systems, operations, maintenance procedures and building schedules. The most energy efficient industrial improvements can be achieved through changes in energy management and utilisation within the facility, rather than through retrofitting and installation of new technologies (McKane, 2019). The primary objective of Energy Audit includes recommending appropriate policies for bringing down energy consumption per unit of product output or to lower operating costs. Energy Audit provides a ‘bench-mark’ (Reference point) for managing energy in the organization and provides the basis for planning a more effective use of energy throughout the organization (Singh *et* al., 2012). Gupta *et* al. (2015) noted that energy audit can be considered similar to a monthly closing statement of an accounting system that includes one series of entries consisting of mounts of energy which were consumed during the month in the form of electricity, gas, fuel oil, coal etc., and the second series lists how the energy was used, how much energy was used in lighting, in air conditioning, in heating, in process etc. An Energy audit process must be carried out accurately enough to identify and quantify energy cost savings that are likely to be realized through investment in energy saving measures. there are fixed costs associated with preparing an energy audit which include, site coordination, travel, field surveys and report generation, and so economies of scale tend to apply for larger facilities. Residential energy consumption and utilisation can be fully evaluated by carrying out a home energy audit process. An energy audit process gives a clear understanding on the energy consumption from different sources within an industry, as well as identifying areas of energy wastage occurrence. An energy audit is a major concept used in energy management as it involves a comprehensive methodological examination of industrial energy usage. Schneider *et* al. (2012) concludes that an energy audit analysis must include the following steps:

i. Collect and analyze historical energy use.
ii. Study the building and its operational characteristics.
iii. Identify potential solutions that will reduce the energy use and/or cost.
iv. Perform an engineering and economic analysis of potential modifications.
v. Prepare a rank-ordered list of appropriate modifications.
vi. Prepare a report to document the analysis process and results.

3. The energy audit procedure

The energy auditor/engineer would first obtain a minimum one-year electricity bill for the building as to establish a baseline relating to the current energy cost during the audit process. A room-by-room inspection is then carried out to determine the energy consumption as well as energy wasted areas. The auditor would then calculate the total energy demand of the building and hence propose energy saving potential for the build in their recommendations. Energy conservation is very much essential as the demand in the society is increasing day-by-day. An electrical energy audit is a process of checking how energy is used and identifying the areas where wastage can be minimized if not totally eliminated. Energy audit consists of several tasks which can be carried out depending on the type of audit and the function of the audited facility. Every building requires its own unique energy audit., During the energy audit process; an energy auditor would visit the facility to be audited and interview the facility manager and inspect anything that uses electrical energy. Depending on the type of the audit, the auditor may take measurements of the building systems, operations, and maintenance procedures etc. Energy audits can be targeted to specific systems (i.e., lighting, ventilation, and air conditioning). Before beginning an energy audit for a building or portfolio of buildings, a preliminary energy use analysis must be carried out. This analysis requires access to energy bill for the last 24-36 months. The purpose of this analysis is to compare the Energy Usage Index (EUI) i.e., annual energy use of each building with the national average and to identify both high and low energy performers. Once the analysis is completed a recommendation is made as to which buildings should be audited first and the type of audits to be carried out, Table 1.

Table 1. The energy audit procedure

Project phase	Project milestone(s)	Project activities
Preliminary review of energy use	Facility benchmarked against similar buildings Base energy load identified	Collect and analyze utility data Calculate EUI and compare to similar facilities Assess energy efficiency improvement potential
Site assessment	Site data collected Immediate energy savings opportunities identified Exit meeting held to discuss preliminary findings	Interview building staff Visually inspect building and key systems Collect data
Energy and cost analysis	EEMs prioritized according to project and financial goals Savings estimates generated	Evaluate utility and site data Analyze energy and cost savings Develop list of recommended measures
Completion of audit Report	Exit meeting held to walk through final report Action plan developed for next steps	Summarize findings Present recommendations

4. Types of Energy Audits

4.1 Level I

The Level 1 audit alternatively is called a simple audit, screening audit or walk-through audit and is the most basic. It involves minimal interviews with site operating personnel, a brief review of facility utility bills and other operating data, and a walk-through of the facility, all geared toward the identification of glaring areas of energy wastage or inefficiency.

4.2 Level II

A Level 2 audit includes the preliminary Level 1 analysis, but also includes more detailed energy calculation and financial analysis of proposed energy efficiency measures. The financial analysis or Life Cycle Cost Analysis provides the facility owner with comprehensive understanding of the financial benefits of implementing specific energy efficiency measures.

4.3 Level III

This level of engineering analysis focuses on the potential capital-intensive projects identified in the Level 2 analysis and involves more detailed field data gathering as well as a more rigorous engineering analysis. It provides detailed project cost and savings calculations with the high level of confidence required for major capital investment decisions. This audit alternatively is called a comprehensive audit, detailed audit, or technical analysis audit.

These are summarised in Table 2.

Table 2: Summary of level of audits

Type of Audit	Type of Audit Brief Description
Level 1	• Brief on-site survey of the building • Savings and cost analysis of low-cost/no-cost Energy Conservation Measures (ECMs) • Identification of potential capital improvements meriting further consideration
Level 2	• More detailed building survey • Breakdown of energy use • Savings and cost analysis of all ECMs • Identification of ECMs requiring more thorough data collection and analysis (Level 3)
Level 3	• Attention to capital-intensive projects identified during the Level 2 audit • More detailed field analysis • More rigorous engineering analysis • Cost and savings calculations with a high level of accuracy

5. Energy Audit and Cost

By having an energy audit done, you can get a full overview of a resident energy efficiency problem and learn about challenges in areas that are never even suspected. A resident after an energy audit would receive professional advice on how to best improve their home's energy efficiency. Making suggested changes after an energy audit, s can save cost on energy as much as 5% - 30% annually. Andres *et* al. (2018), and Michael *et* al. (2011) suggested that if an energy audit process is properly carried out by professional auditors, there will be the possibility of detecting where the energy is wasted and not being used but is still being paid for. If a proper audit is carried out the results and recommendations from the audit will directly affect the cost. There are fixed costs associated with preparing an energy audit (site coordination, travel, field surveys and report generation), so economies of scale tend to apply for larger facilities. Scheihing (2009) proposed that by upgrading the efficiency of technologies alone cannot achieve optimal savings, but when combined with operational and maintenance practices as well as management systems can lead to significant savings. A systematic procedure with the purpose of obtaining adequate knowledge of the energy consumption profile of a building or group of buildings, an industrial or commercial operation or installation, or a private or public service is known as an energy audit that aims at identifying and quantifying cost-effective energy saving opportunities (Anke *et* al. 2015).

6. Research Methodology

The method used in this research is a survey that involves the distribution of questionnaires to residents within Freetown. This data collection technique was used in collecting data for this research that aid in meeting the research objective. Structured quantitative data questionnaires were used as the major tools to collect the primary data, applying random sampling techniques. Statistical Package for Social Scientists (SPSS) version 23 and Microsoft excel software was used to analyse the data. The primary data was collected by the distribution of 143 structured questionnaires and 120 questionnaires were analysed at various stages in this research.

7. Data Analysis

Table 3: Knowledge about Energy Audit

Response		Frequency	Percent
	Yes	103	85.8
	No	17	14.2
	Total	120	100.0

Table 4: Effect of Energy Audit in Buildings

		Frequency	Percent
	Yes	111	92.5
	No	9	7.5
	Total	120	100.0

In Table 3 respondents are assessed o their knowledge of energy audit processes and Table 4 gives responses of how an energy audit process would impact a building electricity consumption. 111 responded that it would positively impact electricity consumption in buildings

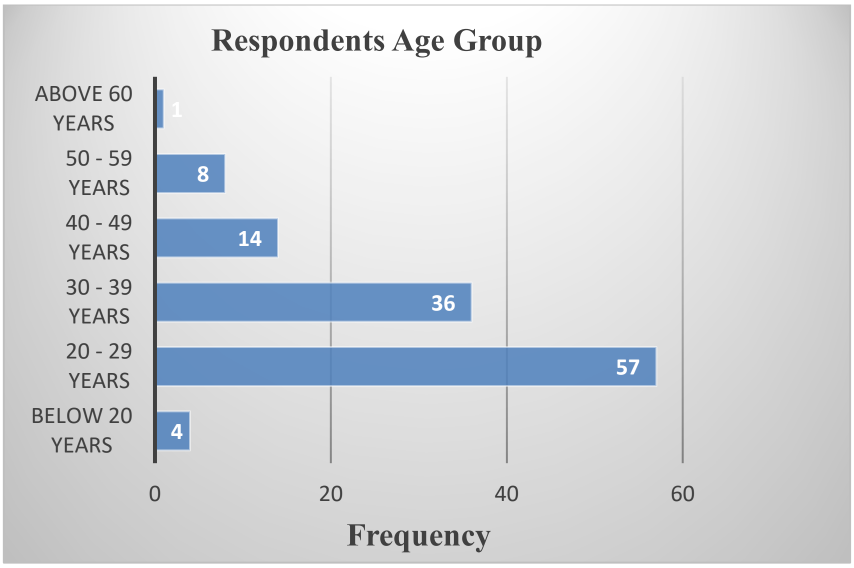

Figure 1: Respondents age group.

Figure1 gives the age category of the respondents. The highest number of responses could be found in the 20 – 29 Years group followed by the 30 – 39 Years group.

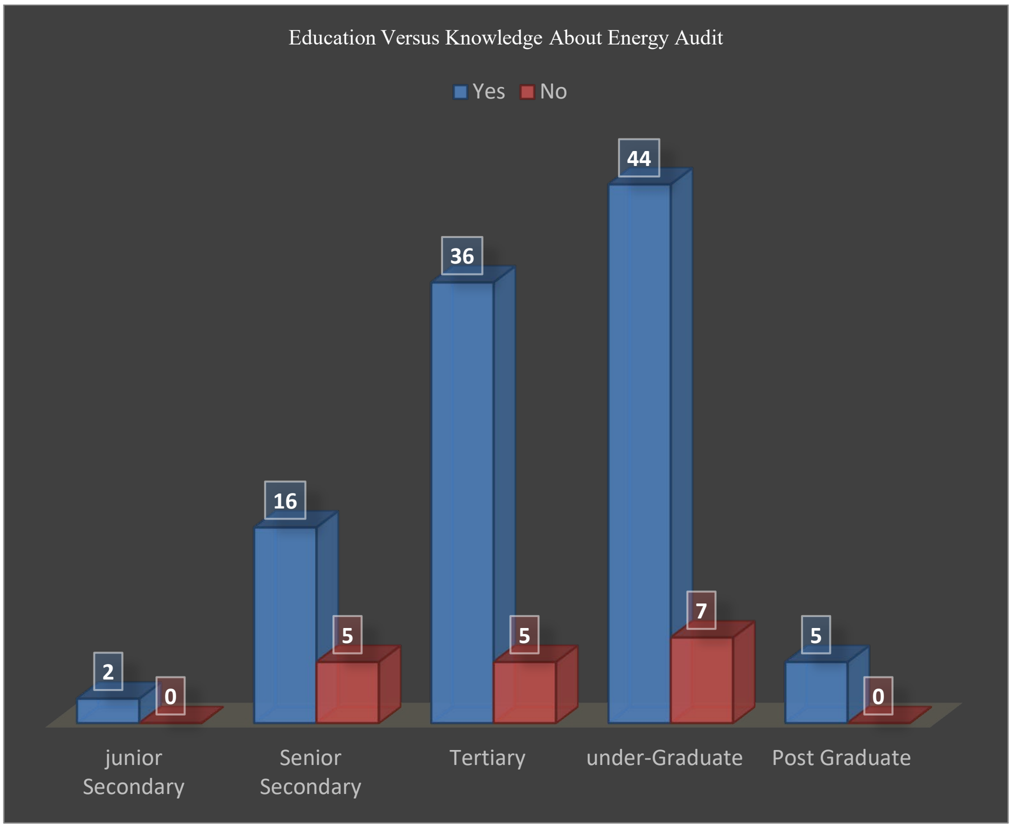

Figure 2: Education and Knowledge about energy Audit.

Figure 2 is a representation of the educational level and knowledge about energy audit. Most of the respondents are knowledgeable about energy audit.

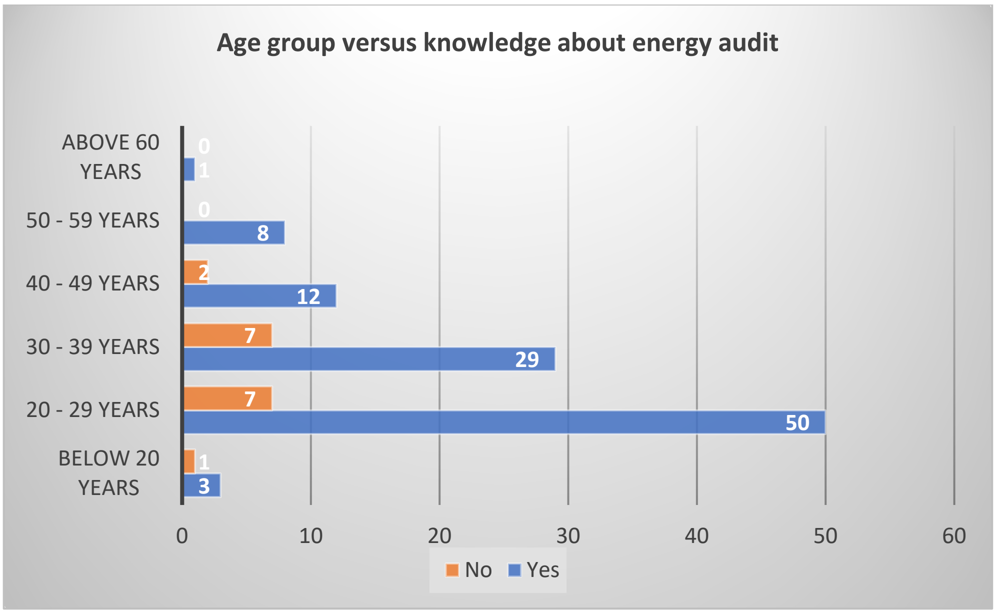

Figure 3: Age group versus knowledge about energy audit.

Table 5 compares the gender of the respondents and their knowledge about an outlined energy audit process. A greater percentage of both male and females are knowledgeable about the energy audit process, this is ploted in Figure 3.

Table 5. Gender and Knowledge about Energy Audit

			KNOWL_ABT_ENE_AUD		Total
			Yes	No	
Gender	Male	Count	72	14	86
		% within Gender	83.7%	16.3%	100.0%
		% within KNOWL_ABT_ENE_AUD	69.9%	82.4%	71.7%
	Female	Count	31	3	34
		% within Gender	91.2%	8.8%	100.0%
		% within KNOWL_ABT_ENE_AUD	30.1%	17.6%	28.3%
Total		Count	103	17	120
		% within Gender	85.8%	14.2%	100.0%

	% within KNOWL_ABT_ENE_AUD	100.0%	100.0%	100.0 %

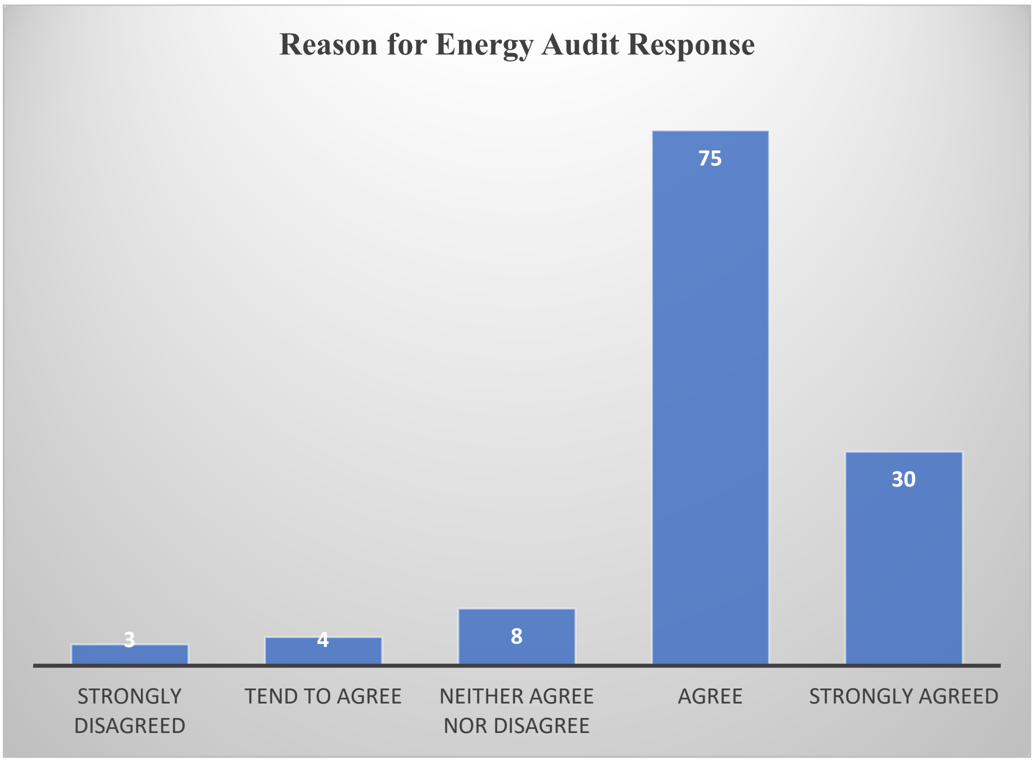

Figure 4: Impacts on energy audit in buildings.

Figure 4 displays the response on the link between an outlined energy audit process and the amount of energy used in a building. It can be observed that a greater percentage of the respondents agreed that there is a direct link between an outlined energy audit and the energy used in buildings.

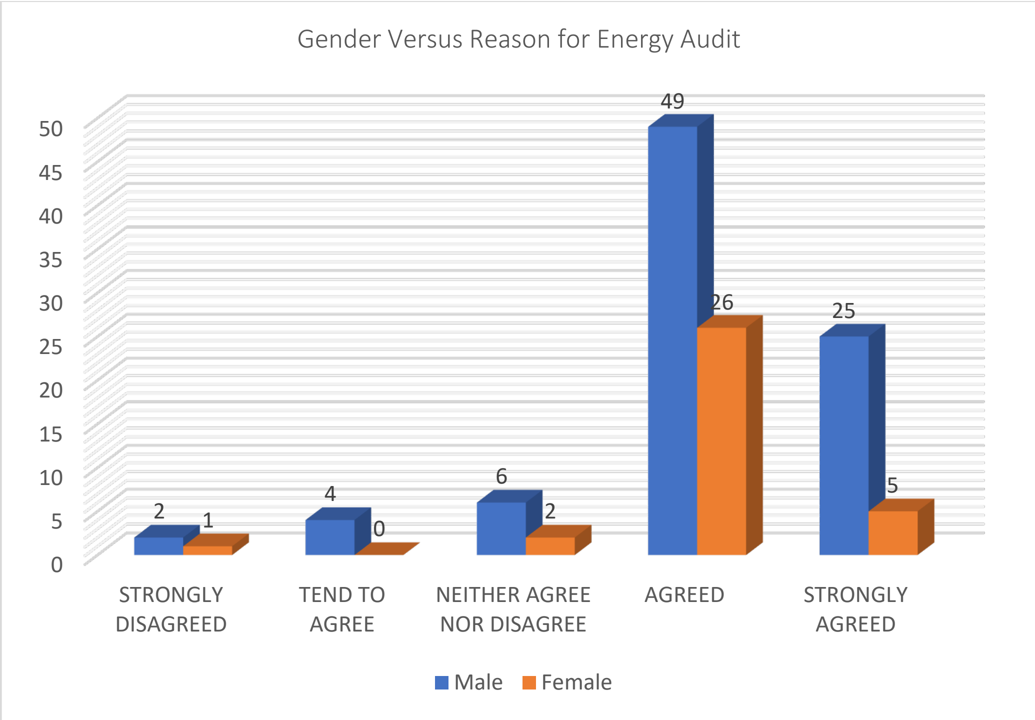

Figure 5: Gender and impact of energy audit in buildings.

Figure 5 displays the response on the reason for an energy audit and gender. It gives the responses by gender to the research question. Majority of both females and males agreed that an energy audit process would reduce a building's electricity consumption, Figure 6.

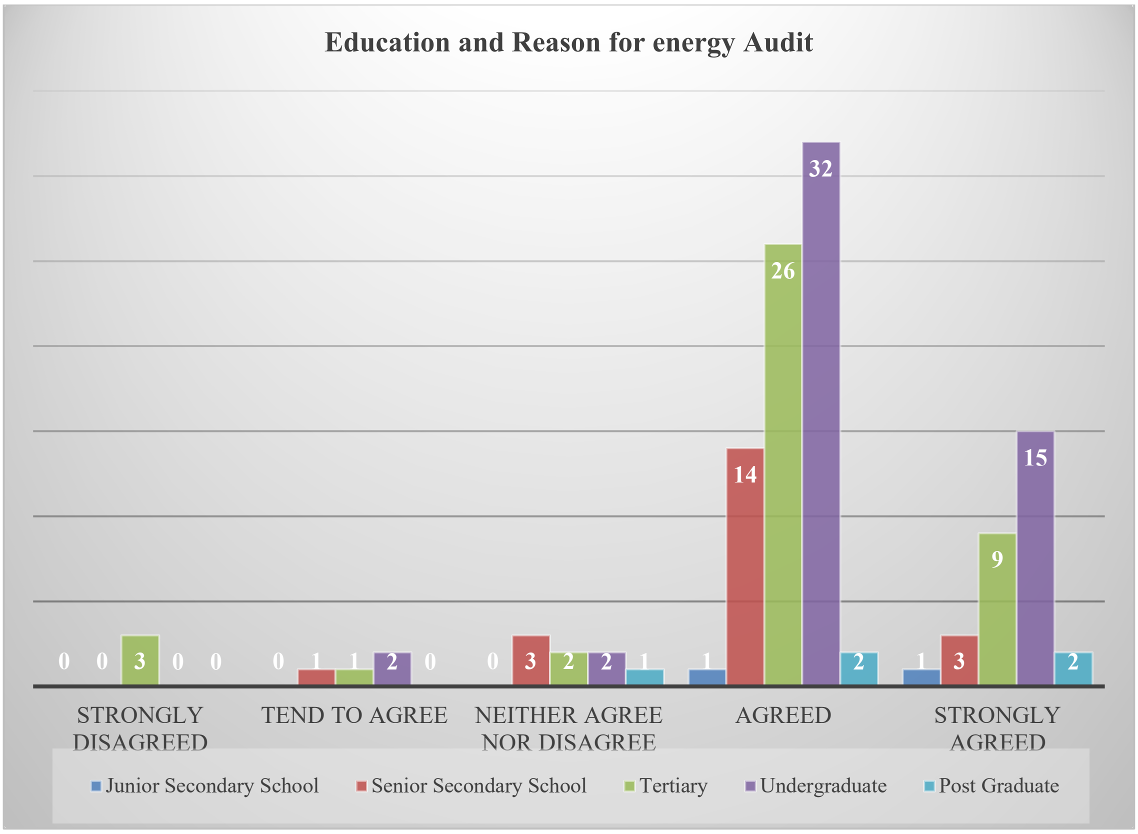

Figure 6: Education level and impact of energy audit in buildings.

8. Recommendation

Based on the responses of data collected from residents within Freetown it can be recommended that a regular and well-planned energy audit process by the Electricity Distribution and Supply Authority (EDSA) and Electricity Generation and Transmission –Company (EGTC) can help minimize electricity losses in buildings, hence the recovered electricity would be used to enhance sustainable electricity supply.

9. Conclusion

The main objective of the paper was to investigate the significance of energy audit, the types and procedure of an energy audit were also discussed with a review on some relevance on the energy audit process. The quantitative data collection method using structured questionnaires and the analysis of various sections on the questionnaires was discussed. Recommendation and conclusions were made.

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Biographies

Bai Kamara is a Sierra Leonean and holds an undergraduate degree (Bachelor of Science with Honours in Physics) and a Master of Philosophy (MPhil) in Energy Studies from Fourah Bay College (University of Sierra

Leone). He is currently a PhD research Student at the department of Mechanical and Industrial Engineering Technology (MIET) Faculty of Engineering and the Built Environment at the university of Johannesburg, South Africa. He is presently working on a research on the development of a Supervisory Control and Data Acquisition (SCADA) program of fouling load for acoustic cleaning of boilers. His research interest has been renewable and non-renewable energy generation, efficient energy utilization for domestic and industrial consumption and energy reform processes.

Dr Sheriff Kamara holds two first degrees in Pure and Applied Economics and Mechanical and Maintenance Engineering from the University of Sierra Leone, 2000 and 2004, respectively. He travelled to the United Kingdom for further studies, where he obtained two master's degrees – Master of Business Management and Master of Science in Management Consultancy (Project Management) from the University of Wales, UK in 2008 and 2009, respectively. Started his PhD studies in Energy Management from 2009 and completed in 2012. Dr. Kamara has worked in industries as well as private practices. He is currently a lecturer in the department of Mechanical and Maintenance Engineering, Faculty of Engineering, Fourah Bay College, University of Sierra Leone, where his current research interests include – Conversion of Wastes to useful products, Design and production of Efficient Cook Stoves, Building Construction project management, etc.

Ing Prof Jonas A S Redwood-Sawyerr is a Sierra Leonean with over 44 years of experience in the University of Sierra Leone. He obtained his BENG degree in Electrical and Electronic Engineering from the University of Sierra Leone, an MSc in Industrial Electronics from the University of London, and a PhD in Electronic Systems Engineering from the University of Essex, both in the UK. His research interests are in bandwidth efficient modulations systems, power sector reform, Energy and sustainable development and Engineering education. He is a former Deputy Vice Chancellor of Fourah Bay College and former Vice Chancellor of the University of Sierra Leone.

Dr Daramy Vandi Von Kallon is a Sierra Leonean holder of a PhD degree obtained from the University of Cape Town (UCT) in 2013. He holds a year-long experience as a Postdoctoral researcher at UCT. At the start of 2014 Dr Kallon was formally employed by the Centre for Minerals Research (CMR) at UCT as a Scientific Officer. In May 2014 Dr Kallon transferred to the University of Johannesburg as a full-time Lecturer and later a Senior Lecturer in the Department of Mechanical and Industrial Engineering Technology (DMIET). Dr Kallon has more than twelve (12) years of experience in research and six (6) years of teaching at University level, with industry-based collaborations. He is widely published, has supervised from Masters to Postdoctoral and has graduated seven (7) Masters Candidates. Dr. Kallon's primary research areas are Acoustics Technologies, Mathematical Analysis and Optimization, Vibration Analysis, Water Research and Engineering Education.