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Framework for Efficient Electrical Energy Management Practice in Public Universities in Southwestern Nigeria

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Abstract
Energy management practices are subject to various worries that impact on achieving electricity saving objectives. This is most apparent in the case of Public Universities in Nigeria due to the number of electricity end users with conflicting interests. Efficient electrical energy management in Public Universities in Nigeria becomes crucial. The present work developed a multidimensional framework of efficient electricity management by considering all relevant measures of performance. To achieve the formation of this evaluation framework, it has considered the case of three relatively old public universities and collected the viewpoints of 4728 respondents comprising students, staff, and business owners involved in the aggregate electricity use in Public Universities in Nigeria. We adopted a quantitative survey and questionnaire as instrument for gathering relevant data. The results of the analysis of data obtained during the survey were used to develop the framework by considering key attributes. The study concluded that the formation of the newly-proposed quantitative efficient electricity management framework for improving the energy performance of public university buildings can provide the university management with an effective tool to benchmark with different university buildings internationally and assist the priority setting of efficient electricity savings.
Keywords: Framework, Efficiency, electrical energy management, Practice, Public universities, Southwestern Nigeria

1. Introduction

In public universities, electrical energy serves as the pillar of wealth creation evident by being the nucleus of almost all operations and activities (Aderemi *et al.,* 2009). Electricity is the bedrock and a propelling force behind any activity in public universities (Oyedepo, 2012a). Electricity usually consolidates the activities of university to provide essential services (Unachukwu, 2010). Despite its importance and indispensability, the demand for electricity in Public Universities in Nigeria has been on the increase in the last two decades (Unachukwu *et al*., 2015).

Available data published by National Bureau of Statistics (NBS, 2013), Nigeria Data Portal (NDP, 2014) and Nigerian Electricity Regulatory Commission (NERC, 2014) revealed that among the high electricity demand and utilisation sectors in Nigeria, university subsector is one of the most important players and its consumption compares favourably with that of residential, commercial and industrial sectors. Data obtained showed that the residential, commercial and industrial sectors' electricity consumption accounted for 938.50 MWh, 489.30 MWh and 398 MWh of the total electricity consumption in the country, respectively (Ekpo *et al*., 2011). The typical monthly electricity consumption of some Nigerian Universities was reported to be 244.55 MWh in Covenant University, Ota (Oyedepo *et al*., 2015), 372.90 MWh in University of Nigeria, Nsukka (Unachukwu, 2010), 384.31 MWh in University of Lagos (Adelaja *et al*., 2008) and 394.46 MWh in Obafemi Awolowo University, Ile-Ife (Olanipekun, 2002; Olanipekun, 2012; Olanipekun *et al*., 2004). These levels of consumption were only superseded by residential, commercial and industrial sectors (Olanipekun, 2002; Adelaja *et al*., 2008; Unachukwu, 2010; Olanipekun, 2012 and Oyedepo *et al*., 2015). By conversion, this equates to 660, 344, 280 and 277 metric tons of carbon dioxide (CO_2) emissions for residential, commercial, industrial and universities, respectively. Although, this high electricity demand could be justifiable due to growth in students' population and development across university campuses, however, if this trend continues, the electricity consumption of Nigerian Public Universities will continue to increase on a regular basis. Thus, energy efficiency and conservation measures are needed and should be implemented and promoted in the public universities to checkmate this problem.

Developing energy efficiency and conservation measures would not only lead to reduction in electrical energy consumption and operating costs, but would indirectly help decrease their environmental impact and act as an example for change across the country (Oyedepo, 2012a). In addition, it will lead to lesser lamps replacements as well as reduction in transmission and distribution equipment and facilities maintenance. Moreover, there will be reduction in accumulated heat generated by facilities, thereby leading to parts of the drive towards mitigating climate change and making buildings more environmentally sustainable (Oyedepo *et al*., 2015).

Energy efficiency means improvement in practices and products that reduce the energy necessary to provide services like lighting, cooling, heating, manufacturing, cooking, transport, entertainment (Oyedepo, 2012a). It

has been described as using energy more efficiently, through behaviour, improved management and the introduction of modern technology (Unachukwu, 2010). Energy efficient practice is a quicker and cheaper source of new energy supply as the cost of providing energy can be several times the cost of saving it (Oyedepo, 2012a). A well-articulated and vigorously pursued energy efficiency policy measures in the university can result in savings in electricity consumption. Unachukwu (2010) and Oyedepo *et al.* (2015) reported savings of about 16% to 20% through energy efficient practices in the universities. They further added that this certainly will ensure sustainable development in the university and possibly eliminate the pressure for the installation of additional electric generators (diesel or gas).

Researchers have also asserted that Nigeria can save up to half of the energy currently consumed in the country if energy is efficiently utilized (Oyedepo, 2012a, 2012b, 2014; Oyedepo *et al*., 2015; Unachukwu *et al*., 2015). Amid the prevailing energy crisis in Nigeria, energy efficiency will play a pivotal role in ensuring access to energy (Community Research and Development Centre - CREDC, 2009). If energy is used efficiently, it will help reduce the building of more power stations, thus the money for building power stations will then be spent on other sectors of the economy (Oyedepo, 2012a). Also, more people will have access to energy: if energy is saved in one part of the country, the energy saved can be made available in another part (Oyedepo, 2014).

Numerous studies (Olanipekun *et al*., 2004; Adelaja *et al.*, 2008; Unachukwu, 2010; Oyedepo *et al.*, 2015, Unachukwu *et al*., 2015) with the intention of consistent, sustained and long-term energy management have been carried out and some policies were recommended. The recommended policies include, but not limited to systematic replacement of incandescent bulbs with compact fluorescent lamps (CFLs), encouragement of energy saving behaviour, and employment of load reducing strategies. In addition, to give effect to the urgent needs for energy efficiency programs in Nigeria and to accelerate implementation programs, a National Centre for Energy Efficiency was established by the Federal Government of Nigeria at the University of Lagos (Oyedepo, 2012a). The Centre is charged with the responsibility for organizing and conducting research and development in energy efficiency and conservation.

These notwithstanding, Oyedepo *et al*. (2015) and Unachukwu *et al*. (2015) reported that inefficient use of electricity still adorns Nigerian public universities. The high trend of electricity consumption witnessed in most Nigerian Public Universities still shows that the recommended policies were either not implemented or were implemented in isolation. However, one of the fundamental reasons given for this unusual trend is that the energy management initiatives were implemented in isolation from each other. According to Muhammed and Budaiwi (2013), deploying energy management (EM) systems in isolation will not bring the desired benefits because it would not reveal the real interaction between the various components. This means that a new measure to improve the electrical energy management practices of public universities is of utmost importance.

Thus, recent studies (Mohammed and Budaiwi, 2013; Carter, 2014; Graham-Hansen, 2014) showed that developing a holistic approach has emerged as an essential component for achieving consistent, sustained and long-term electrical energy management in public institutions. As an important strategy, there is consensus in the literature that holistic approach to EM is one of the most important assets that can consistently manage electricity in buildings for a prolonged period (Carter, 2014; Mohammed and Budaiwi, 2013). To underscore its significance, the underlying logic of the holistic approach is based on the philosophy that the effectiveness of any EM initiative is related to the joint maximization of its social and technical factors (Clegg, 2000). On this basis, energy management initiative is viewed as a system comprising various interrelated, co-dependent subsystems in a state of dynamic interplay (Clegg and Shepherd, 2007).

Therefore, the purpose of this study is to develop a framework for efficient electrical EM practices in public university buildings. Developing a framework will reflect the importance of integration as a key function for bringing together (joint consideration) the people, processes, goals, decision making and resources. Finally, the framework will assist public universities in understanding and identifying key factors, which must be managed to deliver efficient electricity use.

2. Review of Related Works

Several methodologies for the management of energy usage in buildings have recently been presented in the scientific literature. Mo and Mahdavi (2003) presented an agent-based framework for building operators and individual occupants to negotiate their control activities. A prototype in the lighting controls domain was implemented and the simulation results showed that the framework effectively allowed for concurrent evaluation of energy consumption and individual's comfort to achieve balanced control strategies. In Greece, Kolokotsa *et al*. (2005) developed an integrated indoor environment energy management system (IEEMS) for buildings using a fuzzy controller to fulfil, regulate and monitor building users' comfort requirements via a smart card system, which achieved over 30% energy conservation compared to the existing control system. Adelaja *et al*. (2008) discussed four major strategies for reducing peak energy demand. First is load reducing strategies, which reduce demand without affecting the economic benefit derived from that energy use such as load controls for buildings and equipment and behavioural changes such as turning off light. Second is the use of high efficiency equipment

(such as efficient lighting, efficient air-conditioning and efficient refrigeration), which helps to reduce the energy needed to deliver a given level of energy service or produces more energy service per unit of energy. Third is energy source substitution, which encourages the use of other primary energy sources such as charcoal and gas wherever possible for heating due to the relatively low efficiency of energy conversion to electricity (often 30 to 35 per cent) and fourth is the on-site heat and electricity generation enabling reduction in the demands seen by the utility grid, although, it does require additional energy input, examples of which include the use of solar energy for heating purposes and photovoltaic cells for electricity generation. The study however noted that tackling the problem of energy demand from the users' end is quite challenging, but it might be the only hope of public universities in view of inflexibility of supply. Hangras *et al*. (2008) presented Intelligent Control Energy (ICE) system, which uses different computational intelligence (CI) techniques to understand the thermal response of a building to many variables and to minimize the building's energy demand. Karlgren *et al*. (2008) discussed how home appliances might be enhanced to improve users' awareness of energy usage by building and presenting a fully functional prototype home appliance with a socially aware interface to signal the aggregate usage of the user's peer group according to a set of formulated design principles. They opined that since households wish to lead comfortable and manageable lives, balancing this reasonable desire with the environmental and political goal of reducing electricity usage is a challenge that could best be met through the design of interfaces that allow users better control of their usage and unobtrusively informs them of the actions of their peers. Wang *et al*. (2010) developed a multi-agent intelligent control system to minimize the main conflict in smart and energy-efficient buildings in terms of power consumption and customers' comfort. Yu (2010) modelled occupancy behaviour for energy efficiency and occupants' comfort management in intelligent buildings. The study applied genetic programming algorithm to learn the behaviour of occupants in single person office based on motion sensor data, which predicted the presence and absence of the occupants with 80%-83% accuracy on testing data from five different offices. However, the approach may not be suitable in communal occupancy setting like the Nigerian Public Universities. Figureiredo and Coasta (2012) developed and implemented a predictive controller that optimizes the satisfaction of users' explicit preferences coming from several distributed user-interfaces, subjected to the overall constraints of minimizing energy waste. Mamidi *et al*. (2012) implemented a multi-modal sensor agent that is non-intrusive and low-cost, combining information such as motion detection, CO_2 reading, sound level, ambient light, and door state sensing to enable the HVAC system to increase its efficiency by continuously adapting to occupancy forecasts of each room. Rogers *et al*. (2012) demonstrated a home heating management agent that can learn the thermal characteristics of a home and predict local weather conditions, to provide home owners with real-time information about their daily heating costs and how the agent can then optimise heating use to minimise cost and carbon emissions whilst satisfying the home owners' preferences for comfort. Al-Daraiseh *et al*., (2013) proposed an Intelligent Energy Management System for educational buildings using Information Communication Technology (ICT) to optimize the energy consumption in Higher Education Institution (HEI) buildings and reduce carbon dioxide (CO_2) emissions. The proposed project integrates all energy consumption appliances, machines, and devices into a uniform system using Service Oriented Architecture (SOA). This integrated system provides a comprehensive picture of energy consumption and enables the employment of effective energy consumption strategies in a uniform and consistent manner. Babu *et al*. (2013) proposed that the use of energy management slogan as a means of awareness creation is very essential as this motivates users to save energy. A few slogans, which could be used to motivate people to conserve energy include: energy misused cannot be excused; save one unit a day, keep power cut away; the less you burn, the more you earn; when sunlight is bright, switch off the light; today's wastage is tomorrow's shortage; energy earns or simply burns, choice is yours; a thing which burns never returns; manage energy well to avoid damage; one unit of energy saved is two units of energy generated; energy is life, conserve it, and many others. More recently, a comprehensive literature search done by Saleh *et al*. (2014) identified relevant key attributes for efficient energy management, which they grouped into five (5) clusters: Top management support cluster, comprehensive energy management team cluster, stakeholders' involvement cluster, risk management cluster, and raising awareness cluster. The details of the attributes were given in our previous paper.

From the reviewed literature, it shows that there is paucity of research on framework development for electricity management in public universities in the Nigerian context, and there is also a lack of related literature and theories. It is also apparent from the foregoing that developing a holistic approach is the surest way to achieve consistent, sustained and long term efficient energy management in buildings.

3. Methodology

3.1 Research Method

This study adopted a quantitative strategy. Quantitative strategy is a rational choice in this study because it allows researchers to ask all respondents the same questions with predetermined responses. Based on the Nigerian context, this research developed efficient electricity management framework for public universities in Nigeria using structured questionnaire. The need for generalization in the findings across Nigerian public

universities informed and influenced the choice of questionnaire survey. Questionnaire survey enhances consistency of observations and improves replication due to its inherent standardized measurement and sampling techniques (Oppenheim, 2003). Based on analysis of the questionnaire, we obtained information on the electricity end use characteristics, critical success factors and efficient electricity management practices. Through analysis, we developed the framework for efficient electricity management in public universities.

3.2 Research Design

In Nigeria, public universities are predominantly funded by Federal and State Governments. Accordingly, the Nigerian Public Universities selected for investigation in this paper are three relatively old Federal Government owned universities. We followed four principles when determining the universities to be investigated: (1) regular supply of electricity; (2) presence of student hostels for undergraduate students, both male and female; (3) presence of student hostels for postgraduate students, both male and female and (4) availability of staff residence.

3.3 Questionnaire Outline

The structured questionnaire has four main purposes, as follows: first, to understand the relationship between electricity end users and management in the existing electricity use pattern of public universities meticulously; second, to identify electricity end users' attitudes toward the universities' electricity management goal; third, to identify the various factors critical to efficient electricity management in public universities; fourth, to recognize the development of framework for efficient electricity use among all the electricity end users. We sectionalized the questionnaire into three as shown in Table 1.

Table 1. The set of structured questions

Section	**Specific questions**	**Objectives**
Section 1	What activities do you personally achieve with electricity stating the equipment type used, hour of use, period of use and time of the day equipment was used?	To understand the pattern of electricity use in public universities.
Section 2	(i) What actions have been taken in the past two years to reduce electricity usage at this university? (ii) To what extent can you say each of those strategies you selected as being adopted by your university contributed to changing your electricity use behaviour? (iii) What personal effort/action did you make/take to compliment your university's goal to save electricity?	To thoroughly understand the effectiveness of the Nigerian public universities' efforts to save electricity and the willingness of the end users to complement the universities' efforts.
Section 3	How would you rank each of the critical success factors for efficient electricity use in public universities?	To identify the factors most critical to achieving efficient electricity saving in public universities.

3.4 Respondents Selection

To ensure data correctness, reliability and uniqueness, the main means of data collection was structured questionnaire survey. The principles used to screen respondents are as follow: (1) Duration. The respondents should have been bona fide member of the public university for at least one year; (2) Readiness. The respondents should be willing to actively participate in the survey; (3) Attainability. Completion of the questionnaire should be possible within time constraint. The respondents comprised the students, staff and business owners within the university campuses. Table 2 shows the basic information of respondents.

Table 2. General information of respondents

Respondents	Frequency	Proportion(%)
University		
Obafemi Awolowo University	1579	33.4
Federal University of Technology, Akure	1570	33.2
University of Ibadan	1579	33.4
Age Group (Years)		
20-29	2397	50.7
30-39	917	19.4
40-49	563	11.9
50+	19	0.4
Missing ages	832	17.6
Sex		
Male	2799	59.2
Female	1929	40.8
Status in University		
Academic staff	893	18.9
Non-academic staff	778	16.5
Student	2799	59.2
Business owner	258	5.5
Position Held		
Dean/Vice Dean	2336	49.4
HOD	643	13.6
Director/Deputy Director	1749	37.0
Academic Qualification		
HND	1295	27.4
PGD	293	6.2
B.Sc./B.Tech.	227	4.8
M.Sc./M.Tech.	213	4.5
PhD	1343	28.4
Others	1357	28.7
Numbers of Years Stayed on Campus		
0-4 years	2865	60.6
5-10 years	1215	25.7
11-15 years	336	7.1
16-20 years	208	4.4
21-25 years	66	1.4
26 and Above	38	0.8
Location of Stay on Campus		
Staff Quarters	605	12.8
Undergraduate Students' Hostel	1513	32.0
Post graduate Students Hostel	1078	22.8
Off Campus	1532	32.4

Table 2 shows socio-economic characteristics of respondents sampled in three federal universities in Southwestern Nigeria viz-a-vis Obafemi Awolowo University (OAU), Ile-Ife; Federal University of Technology, Akure (FUTA) and University of Ibadan (UI). Four thousand seven hundred and twenty-eighty (4728) respondents were involved in the study. Slightly above half (50.7%) of respondents that participated in the survey were aged 20-29 years followed by age group 30-39 years (19.4%) while the least age group was 50 years and above (0.4%). Over half (59.2%) of the entire respondents that participated in the study were male and 40.8% of the remaining respondents were female. More than half (59.2%) of the respondents that participated in the survey were students, while members of academic staff were 18.9% of all the respondents sampled for the study; the non-academic staff members and business owners accounted for 16.5% and 5.5%, respectively. Also, 60.6% of respondents had stayed on campus up to four years and one-quarter (25.7%) of respondents had stayed on campus between five and ten years; 7.1% had stayed on campus for 11-15 years while very few respondents had stayed on campus for 21 years and above. Meanwhile, respondents who resided in staff quarters were 12.8% while students who stayed in undergraduate hostels and post-graduate hostels accounted for 32.0% and 22.8%, respectively. Among the one twenty management staff that participated in the study, there were twenty top managers equivalent to 16.7% of the sample size, 33 middle level management positions, equivalent to 27.5% of the sample size, and 67 low management positions, equivalent to 55.8% of the sample size. Based on position, status, education, gender, age, residence, work experience and professional background, it can be inferred that the respondents (the electricity end users in the sector) had adequate knowledge and hence the information they provided was suitable for developing a framework for efficient electrical energy management in the Nigerian public universities.

4. The Framework Development

The basic features of efficient electricity use in public universities are collaborations among electricity end users (students, staff, university residents and business units) for integrated efforts to achieve considerable electricity savings. In public universities for instance, the collaborating electricity end users have different end use demands, which determine the role of efficient electrical energy management in reducing overall electricity consumption. Conducive environment is required for a successful learning by students; productivity by staff; comfort by university residents and smooth commercial activities by business units. The implementation and outcome of efficient energy management practices are also influenced by several other factors such as the characteristics (composition, aim and objectives, the roles of end users) of energy management practices and the economic, socio-cultural, technological and other contextual situations within the operational area of the energy management practices. The foregoing argument suggests that an adequate framework for efficient electrical energy management in Public Universities in Nigeria requires in-depth knowledge of the energy management practices for universities, and their overall contribution to reducing energy consumption. Based on this, the framework for the study was developed in four basic stages covering the energy consumption pattern, determinants of high electricity consumption, and electricity management practices in public universities in Nigeria and identification of critical success factors (CSFs). Figure 1 presents the schematic of our proposed framework. Detailed analysis of the attributes in the four stages had been presented in our previous studies.

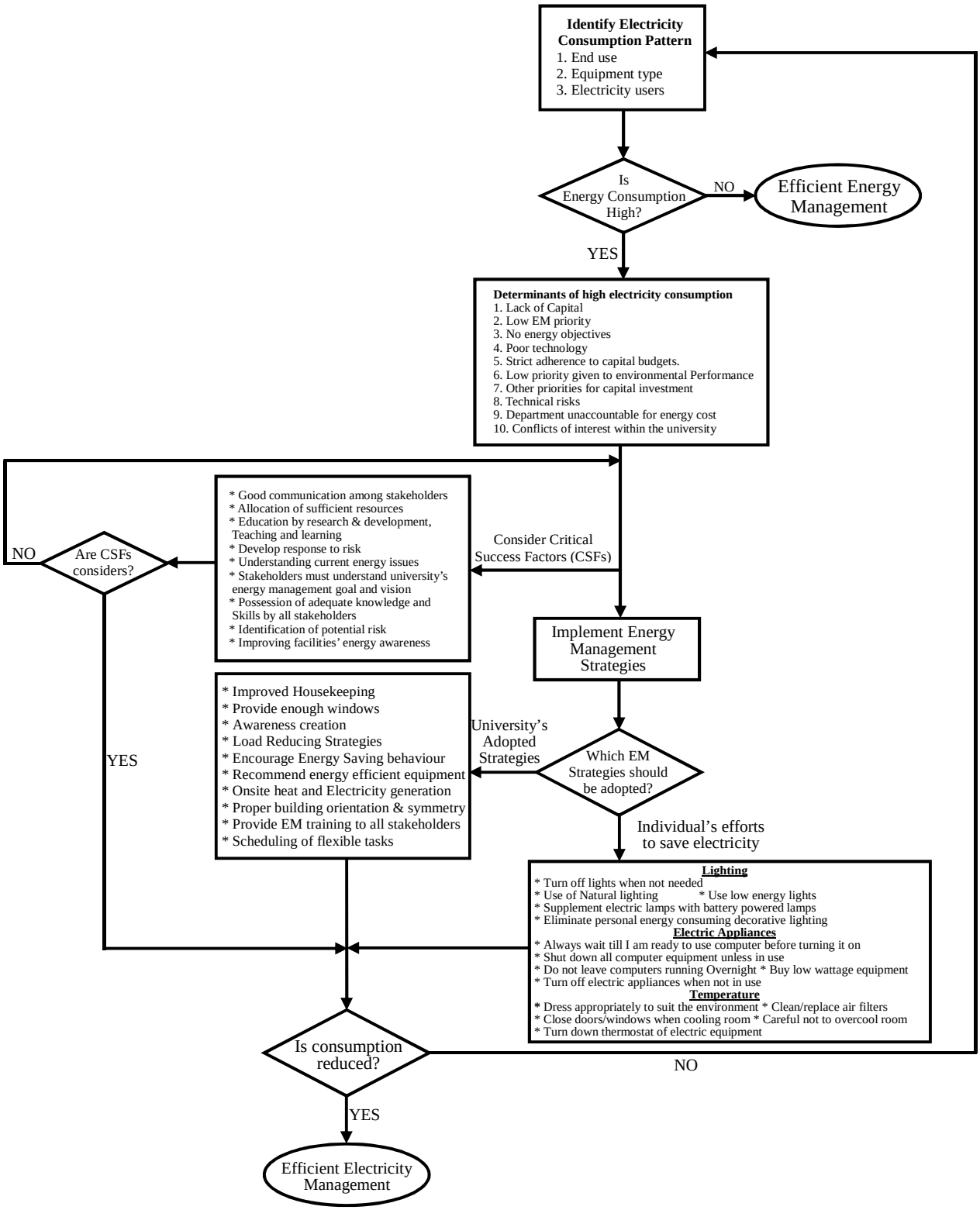

Figure 1. Framework for efficient electrical energy management in Nigerian public universities

5. Discussions

We developed a framework for efficient electrical energy management based on comprehensive results we obtained from our previous studies on various electricity use patterns and management practices, determinant of high electricity consumption and critical success factors for efficient electricity management in public universities in Southwestern Nigeria. Our framework shows the pattern and flow of accomplishing efficient EM in public universities.

Although, we plan to implement (validate) the proposed framework in a comprehensive survey to evaluate its effectiveness, our framework demonstrates that due to well-defined patterns of use, it is possible to accurately predict electricity usage by various end use such as equipment type, sectional/zonal electricity usage among others, which could be achieved by independent monitoring since synchronous electricity usage would make it very difficult to identify the extent of electricity management improvement required of various end use. An additional application of our proposed framework is to provide regular electricity usage information via frequent monitoring, which is a key to achieving electricity saving in public universities.

As indicated in our framework, appropriate efficient electrical energy management measures for reducing electricity consumption in public universities can be designed and implemented based on the determinants of high electricity consumption. Understanding the connections between numerous factors (e.g. lack of capital, low EM priority, no energy objectives, poor technology, strict adherence to capital budgets, low priority given to environmental performance, other priorities for capital investment, technical risks, department unaccountable for energy cost, conflicts of interest within the university among others) offers extensive potential for reducing electricity consumption in public universities.

Furthermore, during implementation of energy management strategies, it is equally important to pay adequate attention to some critical success factors (CSFs), which have been extensively discussed in our paper titled '*Critical Success Factors as a tool for sustainable efficient electricity management in Nigerian public universities*'. These factors include good communication among stakeholders, allocation of sufficient resources, education by research & development, teaching and learning, developing response to risk, understanding current energy issues, stakeholders must understand university's energy management goal and vision, possession of adequate knowledge and skills by all stakeholders, identification of potential risk and improving facilities' energy awareness. Our proposed framework shows that the willingness of public universities' management to consider the CSFs identified when implementing EM strategies would lead them towards achieving success in reducing the electrical energy consumption. The reason is because these CSFs can represent focal points to assist the management of universities to align with electricity use reduction goals of the university.

The last phase of electricity saving in our framework is the implementation of energy management strategies. This includes consideration for both end users' efforts and the university management's efforts to enhance efficient electricity use. From our earlier surveys, the framework presents only key EM strategies that would enhance efficient electricity use in Nigerian public universities.

6. Conclusion

Public university managements are facing a few challenges including rising electricity costs and increasingly unstable electricity supply. This means that they can no longer regard electrical energy as a constant and small running expense. For many public universities, electrical energy consumption must be closely monitored and reduced considerably. Electrical energy management is becoming a necessity in the activities of many public universities. Existing electricity management solutions do not address all the requirements of efficient energy management in a university community because they do not adequately develop in all stakeholders, an awareness of the electricity used in each category.

This paper has presented a new framework for electrical energy management that provides information about the electricity consumption of a public university campus for supporting effective academic, managerial, business and social activities in the university. The proposed efficient electricity management framework would be a useful tool for electricity use assessment and activities prioritization. Based on the quantitative and systematic process of the proposed framework, electricity managers in public universities are enabled to give objective assessment about electricity consumption in a consistent manner. Since the proposed framework can quantify the electricity use status, the energy performance-overtime for public university buildings can be measured and its rate of savings or otherwise can be ascertained. With a predicted target, the electricity saving requirements of public universities can be forecasted and necessary actions and resources can be planned to meet the requirements. Another merit of the proposed framework is that it can give an objective and quantifiable electricity use rating as the desired energy saving level to be performed by the university buildings. Any upsurge in the energy saving level will trigger necessary efficiency practice and improvement actions to bring back the energy performance of the university buildings to the required level. When electricity saving budget is limited and numerous projects are contending for funding to progress, it is essential to set the priority of different projects so that resources are utilized in the most cost-effective manner. In conclusion, the formation of the newly-proposed quantitative efficient electricity management framework for improving the energy performance of public university buildings can provide the university management with an effective tool to benchmark with different university buildings internationally and assist the priority setting of efficient electricity savings.

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