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*Full Paper*

# A survey on the energy consumption and demand in a tertiary institution

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**Abstract:** The need for energy supply, particularly electricity, has been on the increase in the last two decades in developing countries such as Nigeria. Economic and industrial developments have led to this increase in demand for electricity. In universities, much of the electricity consumption is consumed in air conditioning systems, which are used to overcome the indoor thermal discomfort during harsh seasons. An amount of electricity is also consumed by laboratory equipment and machinery used for practical and demonstrations. Thus, if universities are to achieve the goals of teaching, research and community service, then proper management of electricity supplied to the system is needed in view of its limited availability. Since electrical energy in Nigeria is highly subsidised by the government, monitoring and controlling the energy consumption pattern in a university is a major aim in the country. However, there is still a lack of information about electricity end-use consumption in Nigerian universities. This paper presents the results of a walk-through energy audit conducted in a university and recommends means of tackling the problem from the demand end by focusing on the areas of potential savings flagged by the energy audit. It was noted that tackling the problem of energy demand from the users' end is quite challenging, but it might be the only hope of the school in view of inflexibility of supply.

**Keywords:** energy, energy demand, energy consumption

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## Introduction

Reduction of energy consumption in domestic buildings and commercial settings has been a major aim worldwide in view of the limiting of the growing demand for electricity and the efforts to reduce $CO_2$ emissions [1-4]. Investigations have been extensive with active researches carried out in major countries such as Kuwait [2], Sweden [3], Namibia [5], USA [6], Syria [7], Brazil [8] and India [9], among others.

Several energy demand/consumption predictive models have aided in a proper understanding of energy dynamics in both residential and industrial/organisational settings. For instance, Azadeh et al. [10] integrated genetic algorithm (GA) and artificial neural network (ANN) to estimate and predict electricity demand using stochastic procedures. The application of Bayesian approach to energy demand is also an accepted technique in the literature [11]. The use of computer software has also been encouraged. For instance, practical applications using plant simulation programmes as a design tool for carrying out or confirming the performance of building designs encoded within the TRNSYS-IISIBAT environment have been reported [2]. The projection of electricity consumption for the industrial sector based on time series forecasting (multivariate linear regression model) has also been established in the literature [12].

Apart from these mathematical predictive models, an entirely empirical approach has also been used to monitor the energy consumption. An approach involves using a questionnaire survey, supported by the annual gas and electricity meter data and floor-area estimates [13]. Another approach is the use of Model of Analysis of the Energy Demand (MAED). This method has been improved upon by the Grey Prediction with Rolling Mechanism (GPRM) approach, which produces high prediction accuracy, is applicable in limited data environments and requires little computational effort [14].

On a general note, Muneer and Arif [15] studied energy consumption in Pakistan and the issue of security of electrical energy supply. Hossain and Badr [16] considered the prospects of renewable energy utilisation for electricity generation in Bangladesh. Tommerup et al. [17] studied the energy-efficient houses built according to energy performance requirements introduced in Denmark. Yohanis et al. [18] investigated the real-life energy use in the UK with a focus on how occupancy and dwelling characteristics affect domestic electricity use. Ensinas et al. [19] studied the analysis of process stem demand reduction and electricity generation in sugar and ethanol production from sugarcane. Becerra-Lopez and Golding [20] studied the dynamic energy analysis for capacity expansion of regional power-generation systems using the case study of far West Texas. Cai et al. [21] performed a scenario analysis on $CO_2$ emission reduction potential in China's electricity sector. Trygg and Amiri [22] presented the European perspective on absorption cooling in a combined heat and power system using a case study of energy utility and industries in Sweden.

Furthermore, Kaldellis and Zafirakis [23] studied the present situation and future prospects of electricity generation in Aegean Archipelago Islands and Kaldellis [24] made a critical evaluation of the hydropower applications in Greece. Bahaj et al. [25] considered the influence of micro wind turbine output on electricity consumption in buildings while Ozturk et al. [26] reviewed the past, present, and future status of electricity in Turkey. Fung et al. [27] studied the impact of urban temperature on energy consumption of Hong Kong. The study by Peacock and Newborough [28] focused on the impact of micro-combined heat-and-power systems on energy flows in the UK electricity supply industry. McAllister and Farrel [6] investigated electricity consumption by battery-powered consumer electronics using a household-level survey. The impact of ICT investment and energy price on industrial electricity demand was investigated by Cho et al. [29].

The power outage in universities is common in recent times, particularly in developing countries where these outages are closely linked to peak times since electricity is a non-storable commodity and must be supplied at the same time that it is being used. However, there is also a long gestation period associated with adding new capacity. Obviously, advancements in technology have changed the world over the last few years thereby suggesting the obvious need for new methods as regards energy utilisation. One major resource of effective energy management is the actions taken by the end users themselves. In the past, there was little incentive for more efficient energy use due to the availability of energy at low cost. However, the situation is changing and universities have to adjust its energy use habits in order to cope with the current situation of inadequacy of supply as well as rising costs. Since energy demand is a choice, it could be assumed that system outages can be greatly minimised by the use of peak demand-reducing strategies without any increase in energy supply [30]. Having considered the diverse studies on energy demand and consumption, it seems obvious that investigations relating to academic institutions, particularly universities, in developing countries are missing. The need to bridge this important gap has provided the impetus for the current study. This study surveys the consumption of electric energy in the environment of a university whose goal is to achieve excellence in teaching, research and community service.

## Analogue Models of Energy Demand in the University of Lagos

The forms of energy consumed in the University of Lagos for uses other than transportation are electricity, kerosene, charcoal, gas (LPG), firewood and diesel, among which electricity accounts for a major part of the energy used. A walk-through energy audit was conducted in the school to determine the peak energy demand of the school as well as flagged areas for potential savings.

### *Categorisation of demand sectors*

For the purpose of simplicity of the study, the University of Lagos is classified into three sectors. These are:

- Faculty and service areas: these comprise all faculty buildings, administrative buildings, buildings for health and other essential services (library, power, etc), general purpose buildings and outdoor lighting.
- Residential area: this comprises the staff quarters and students' hostels.
- Commercial centres: this comprises all commercial buildings on the campus.

*End use categorisation*

The electrical energy end use in the University of Lagos is categorised [31] as follows:

1. Space cooling – This includes all the energy used for ventilation and air conditioning equipment such as room fans, air conditioners and extractor fans.
2. Refrigeration – Refrigeration comprises energy used by food and drink cooling equipment such as water dispensers, fridges and freezers.
3. Water heating – This category considers energy used by water heaters of all kinds.
4. Cooking – This includes energy utilised by cooking equipment such as electric cookers, gas cookers, electric toasters, microwave ovens, and kerosene stove, as well as those other methods of cooking which utilise the other forms of energy.
5. Personal computer – This includes all computer systems, printers and servers.
6. Office machines – The category of office machines includes all equipment that are typical in office environment, e.g. typewriters, fax machines, photocopy machines, and scanners.
7. Laboratory machines – This takes into consideration energy used by all laboratory equipment and machines. The energy can be in the form of electricity, gas or kerosene.
8. Lighting – This comprises all forms of lighting appliances ranging from incandescent lamps to fluorescent lamps, halogen lamps, rechargeable lamps, street lights and large stage lights.
9. Electronics – This category considers all electronic appliances such as television sets, radio sets, video cassette players, video compact disc players, and decoders.
10. Ordinary machines – This group of machines are the common machines that are not used in laboratories such as water pumps, grinding machines, sewing machines, and washing machines.
11. Others – The category of others comprises those appliances which are not considered in any of the aforementioned categories. They include pressing irons, hair dryers, blenders, etc.

The data obtained during the energy audit are presented in tables and charts in the next section. The strategies for reducing this demand are also discussed.

**Energy Demand in the University of Lagos**

The energy demand in the University of Lagos is shown in Figure 1. Electricity accounts for about 97% of the energy demand in the school. At 16.602 terajoules, it stands at about five times the average monthly energy demand for the year 2005. Figure 2 gives the proportion of this energy demand for different end uses. Since energy demand is a choice, we therefore pursue means of reducing demand. Figure 2 will assist in pointing out areas on which these strategies will be focused.

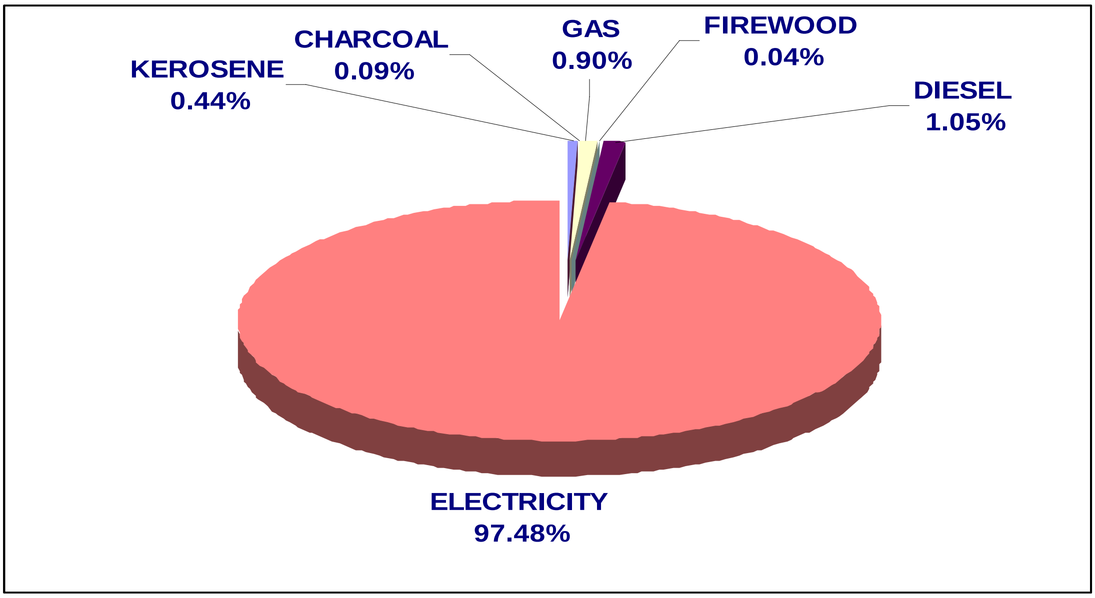


**Figure 1.** Demand for various forms of energy in the University of Lagos

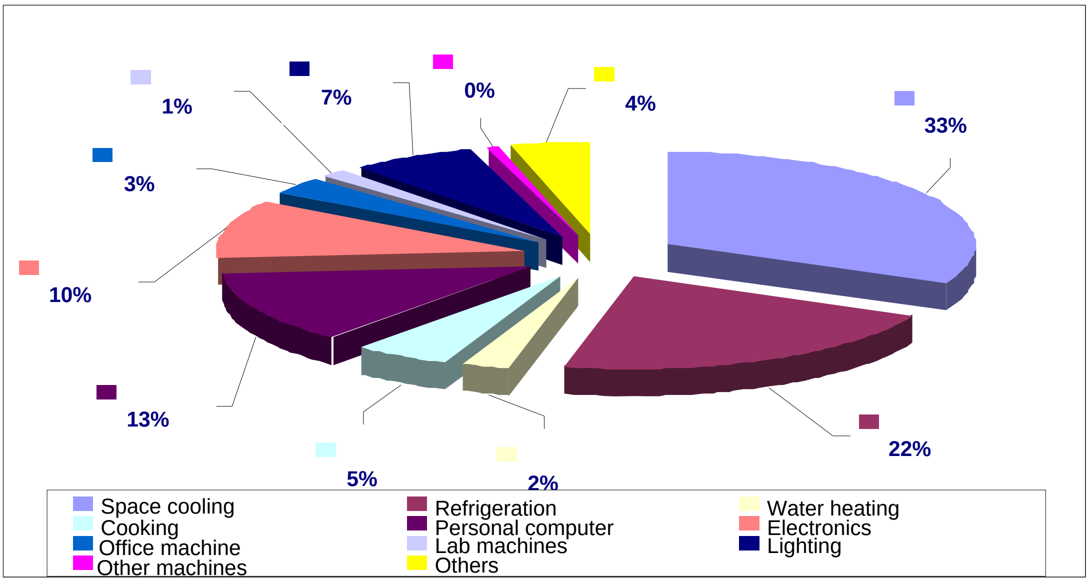


**Figure 2.** Electrical energy demand for different end uses in the University of Lagos

## Peak Demand Reduction Strategies

Four major strategies for reducing peak demand are: load reducing strategies, high efficiency equipment, energy source substitution, and on-site heat and electricity generation [32]. These methods are discussed here.

*Load reducing strategies*

These are strategies that reduce service demands 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 lights. Lighting, which is the easiest load to reduce, accounts for 17% of the energy demand in the faculty and service area as seen in Figure 3, 7% of the energy demand in the residential sector (Figure 4), and 7% of the total electric energy demand of the University of Lagos (Figure 2).

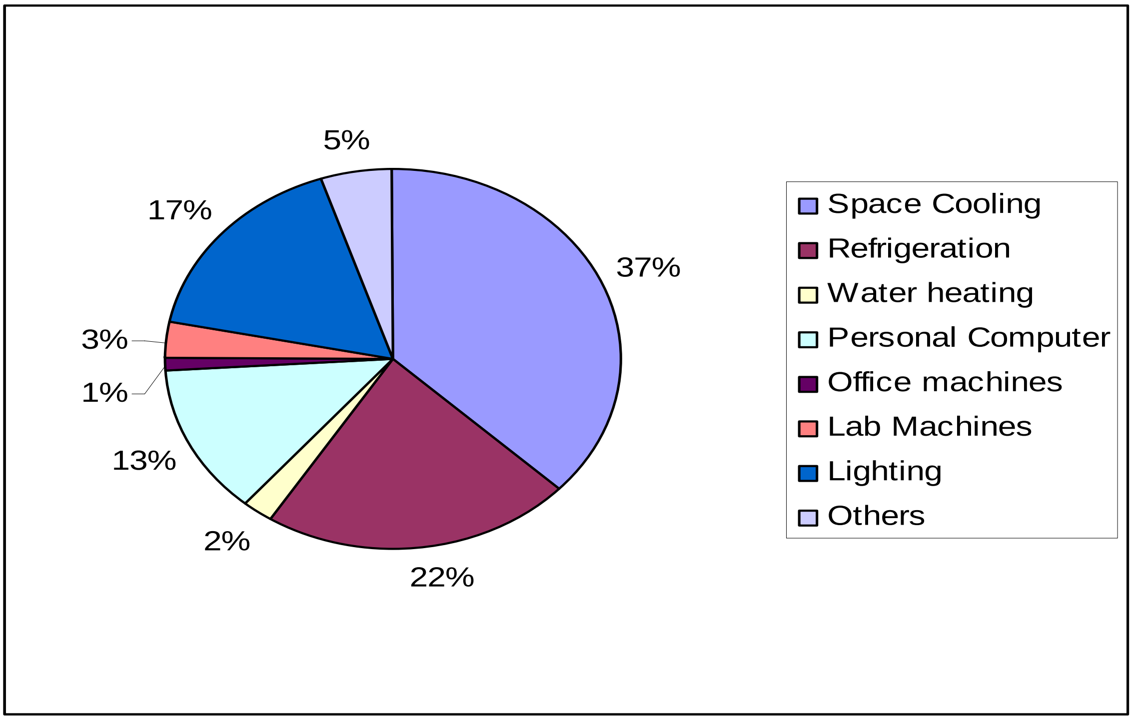


**Figure 3.** Electricity demand in the faculty and service area for various end-uses

Two methods are most common for the reduction of the lighting load, viz. installation of building automation systems and use of daylighting. The traditional on-off toggle switch has been the lighting control of choice in homes. But experience shows that even with convenient light switch locations, lights are often left on when rooms are unoccupied. Building automation systems can help solve this problem. They can be used to automatically turn on, turn off, or dim electric lights around a building. These include occupancy sensors, timers and motion sensors. Daylighting is the use of windows and skylights to bring sunlight into the building. When properly designed and effectively integrated with the electric lighting system, it can offer significant energy savings by offsetting a portion of the electric lighting load.

*High efficiency equipment*

High efficiency equipment reduces the energy needed to deliver a given level of energy services or produces more energy service per unit of energy. A careful observation of Figure 2 shows that space cooling, refrigeration and lighting are items which consume the bulk of the energy supplied to the school, thus flagged areas for potential improvement of efficiency.

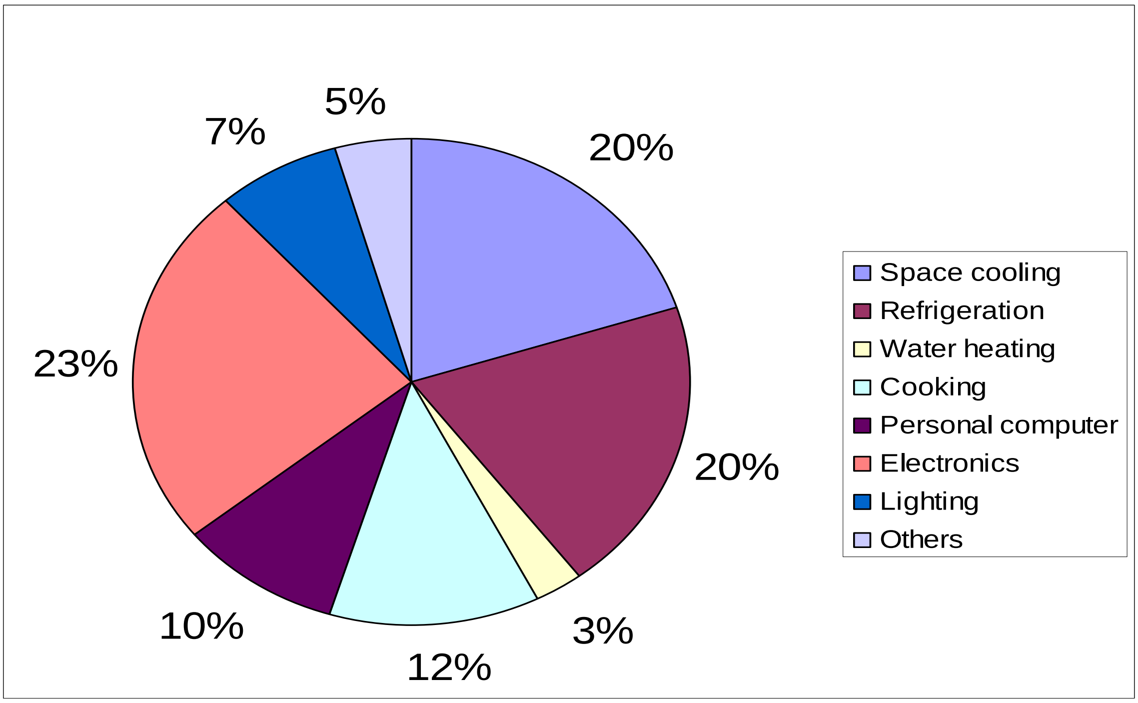


**Figure 4.** Residential energy demand for different end-uses

What lends further credence to this is the fact that the Faculty of Arts and Social Sciences places a higher demand for energy than the Engineering and Science Faculties (Figure 5) even though the latter two make extensive use of laboratory machines that exert heavy loads on the supply system. These machines, however, are only on for a short period of time, in contrast to the extensive use of air conditioning and refrigeration devices that exert smaller loads on the supply system but are on for a longer period of time.

Efficient lighting:

The principal lamp types of interest to the energy manager are incandescent, fluorescent, mercury vapour, metal halide, sodium vapour lamps and sodium lamps. The last three are used for outdoor lighting and fall under the category of high-intensity discharge lamps. In this case, efficient lighting can be achieved by introduction of energy-saving bulbs as replacements of traditional incandescent bulbs. This will reduce the energy consumed by the lighting system as well as the heat generated in the enclosure.

Efficient air conditioning:

Air-conditioning accounts for 37% of the electrical energy demand in the faculty and service area (Figure 3), 20% of the demand in the residential sector (Figure 4) and 42% of the commercial sector's demand (Figure 6). So in almost all cases, it accounts for the largest demand for any single end use and marks a crucial area in the demand for energy services in the University. Measures that are needed to provide an economical, efficient and comfortable heating and cooling system are proper installation, proper sizing, and proper design and sealing of the duct system.

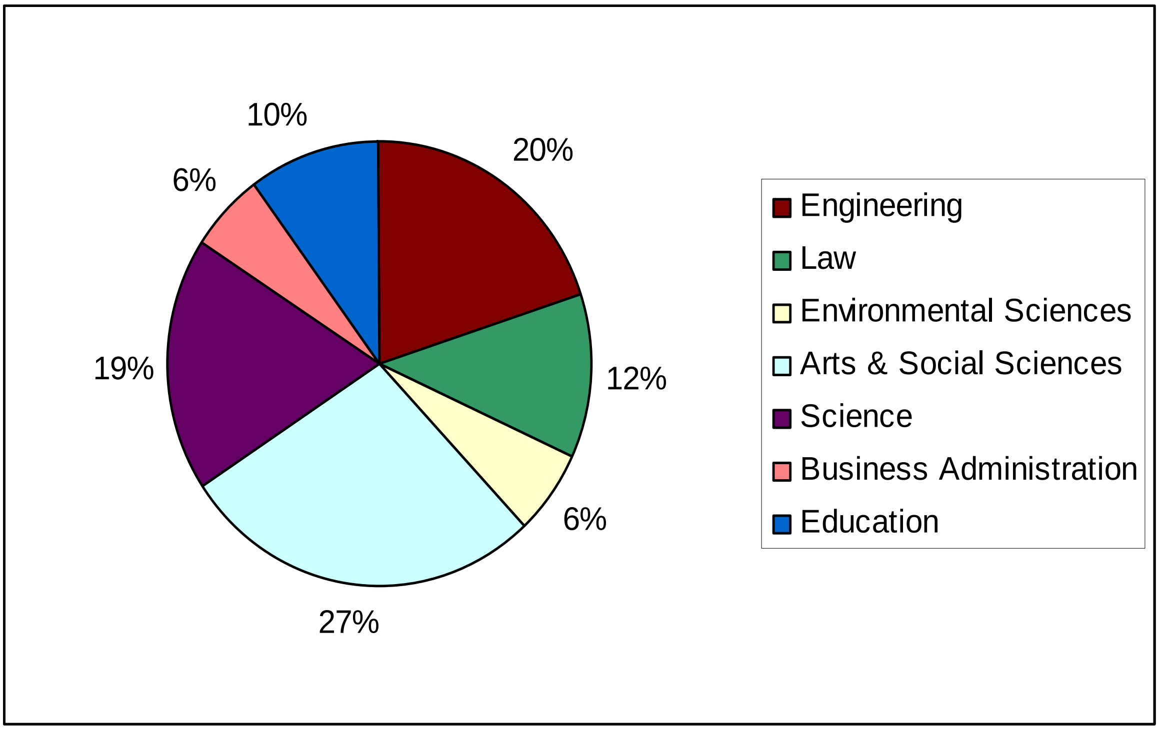


**Figure 5.** Electricity demand by each Faculty

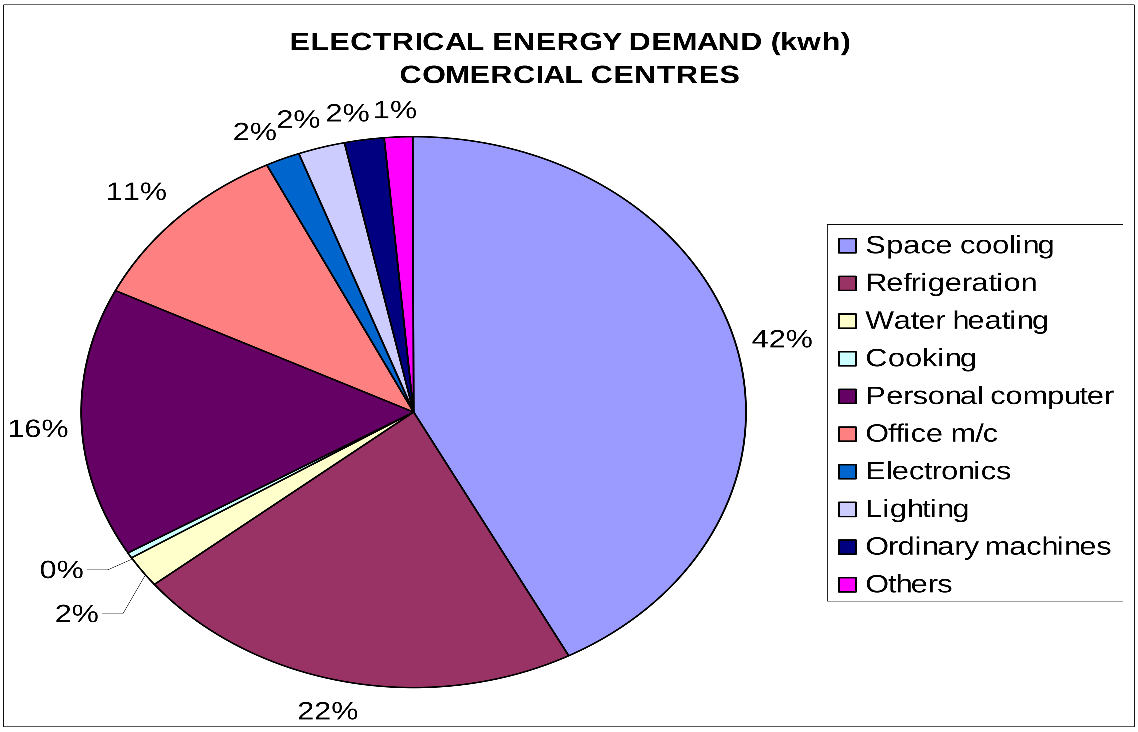


**Figure 6.** Commercial electrical energy demand for different end-uses

Efficient refrigeration:

The demand for energy in the end-use can be minimised by certain no-cost practices such as regular cleaning of the evaporator and condenser coils, proper maintenance of door seals, and immediate loading of items that need refrigeration.

*Energy source substitution*

Due to the relatively low efficiency of energy conversion to electricity (often 30-35 percent), other primary energy sources such as charcoal and gas should be used wherever possible for heating. This will help reduce the demand on the electric power system for the purposes of cooking and water heating. Cooking and water heating account for 15% of the energy demand by the residential sector (Figure 4), a sharp contrast with the commercial sector which demands less than 1% of its electrical energy for cooking and about 2% for water heating (Figure 6). This is obviously reflected in the greater demand of the commercial sector for charcoal (97% as seen in Table 1) and kerosene (65% as seen in Figure 7).

**Table 1.** Monthly demand for charcoal by various sectors of the University of Lagos

| Sector | Total charcoal demand (kg) | Percentage |
|---|---|---|
| Faculty and service area | 0 | 0.00% |
| Commercial center | 922 | 97.36% |
| Residential area | 25 | 2.64% |
| Total | 947 | 100% |

However, care should also be taken to ensure the cost effectiveness when taking this measure. For instance, the data obtained during a walk-through energy audit indicated that much of the commercial cooking in the University of Lagos is done by charcoal. However, commercial operators and residents who do not have the charcoal pots assume that kerosene is a cheaper option compared to butane gas. Charcoal is rightly considered an economical source of energy but the assumption that kerosene is more economical than cooking gas (butane) is false. Based on this survey, a family of five, for instance, who cooks on a fairly regular basis will exhaust a 12.5-kg gas cylinder in two months. The cost of the 12.5-kg gas is about ₦2200. The initial cost of the cylinder and a gas cooker with two faces is about ₦15, 000. After the initial spending, the consumer will only need to be refilling his cylinder. A family of five who uses kerosene will spend about ₦500 on a weekly basis to buy kerosene. This will amount to ₦4,000 in two months. The initial cost of buying a stove is just about ₦2000. However, most of the stoves that are sold in Nigeria are not durable and the consumer may find himself changing

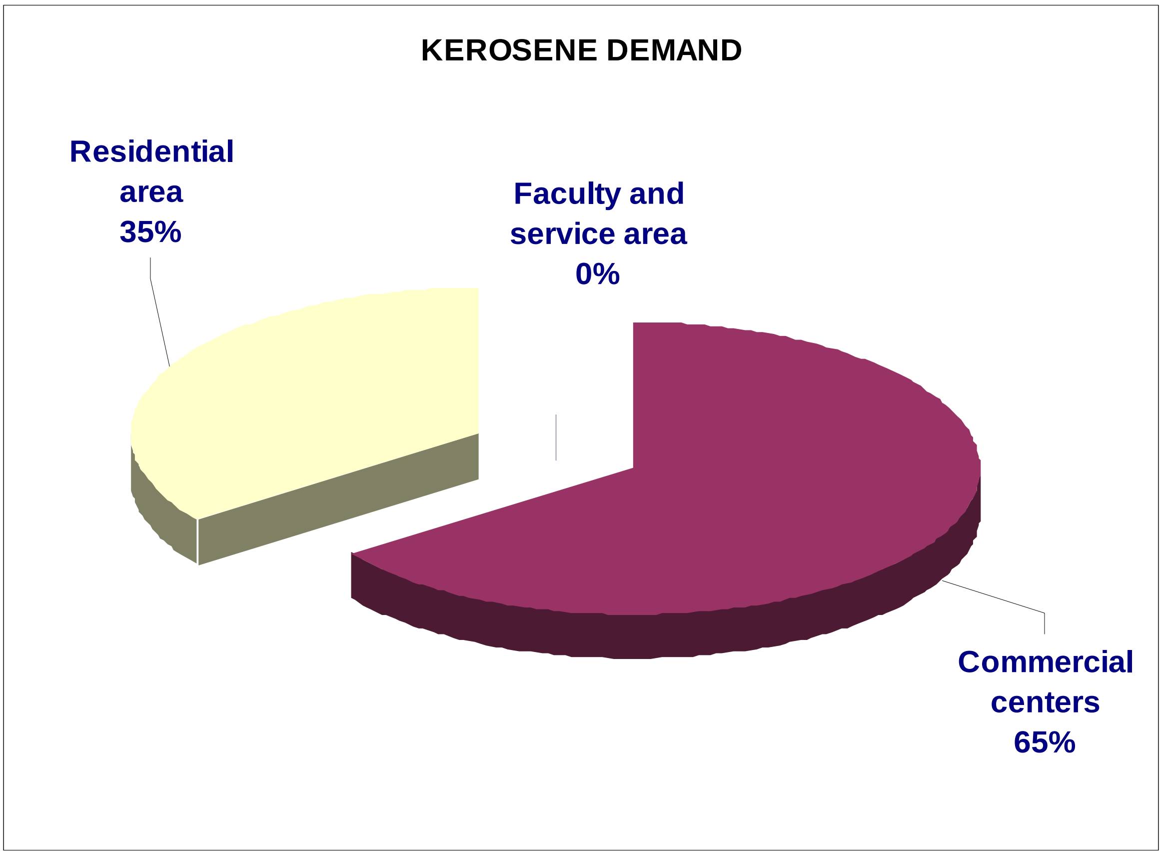


**Figure 7.** Monthly kerosene demand by various sectors in the University of Lagos

the stove after a short time. Furthermore, kerosene cooks slowly as well as blackens the bottom of the pot and leaves the kitchen in a messy form. There is also a higher risk of explosion in the use of kerosene. The monthly demand for gas by the various sectors in the University of Lagos is shown in Figure 8, with residential and commercial sectors placing the highest demand.

*On-site heat and electricity generation*

This method reduces the demands seen by the utility grid, although it does require additional energy input. Examples of application of this method include the use of solar energy for heating purposes and photovoltaic cells for electricity generation.

Figure 9 gives the total peak demand for electrical energy by the various sectors of the University. From Figure 9, it can be seen that the residential sector has the potential to consume as much electricity as the faculty and service area and even more electricity than the commercial sector. Yet the commercial sector pays over 200% more per kilowatt-hour of energy used than the residential sector. The hostel residents do not pay for the energy they use. This perhaps might be a plausible cause as to the reason why the demand from this sector is so high. Another cause could also be that the commercial services rendered in university are not major and so require a minimal amount of energy.

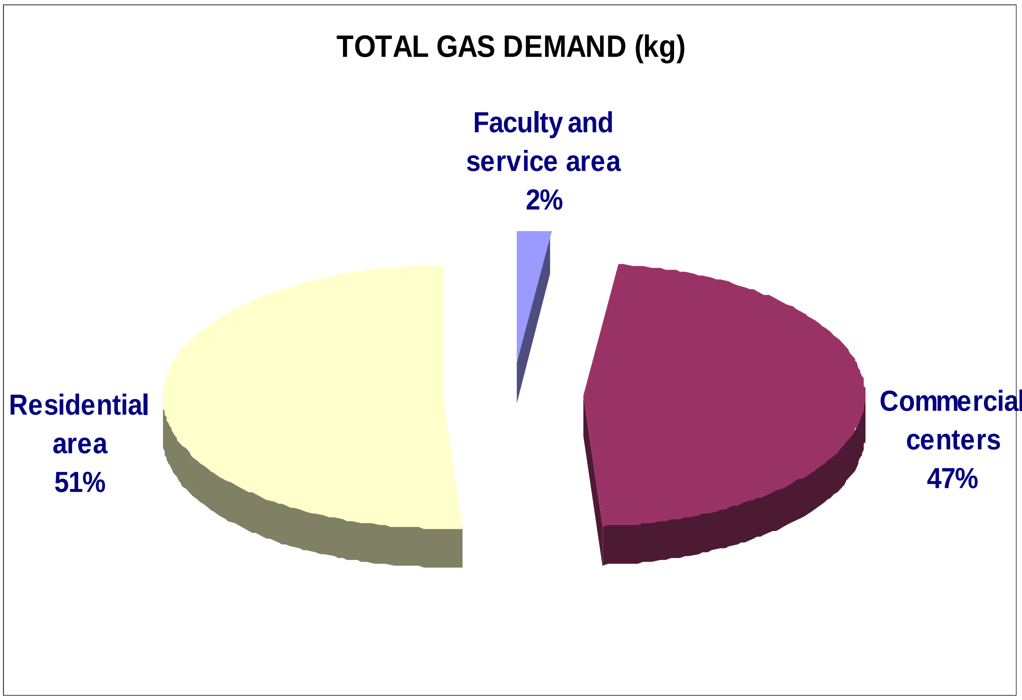


**Figure 8.** Monthly demand for gas (LPG) by various sectors of the University of Lagos

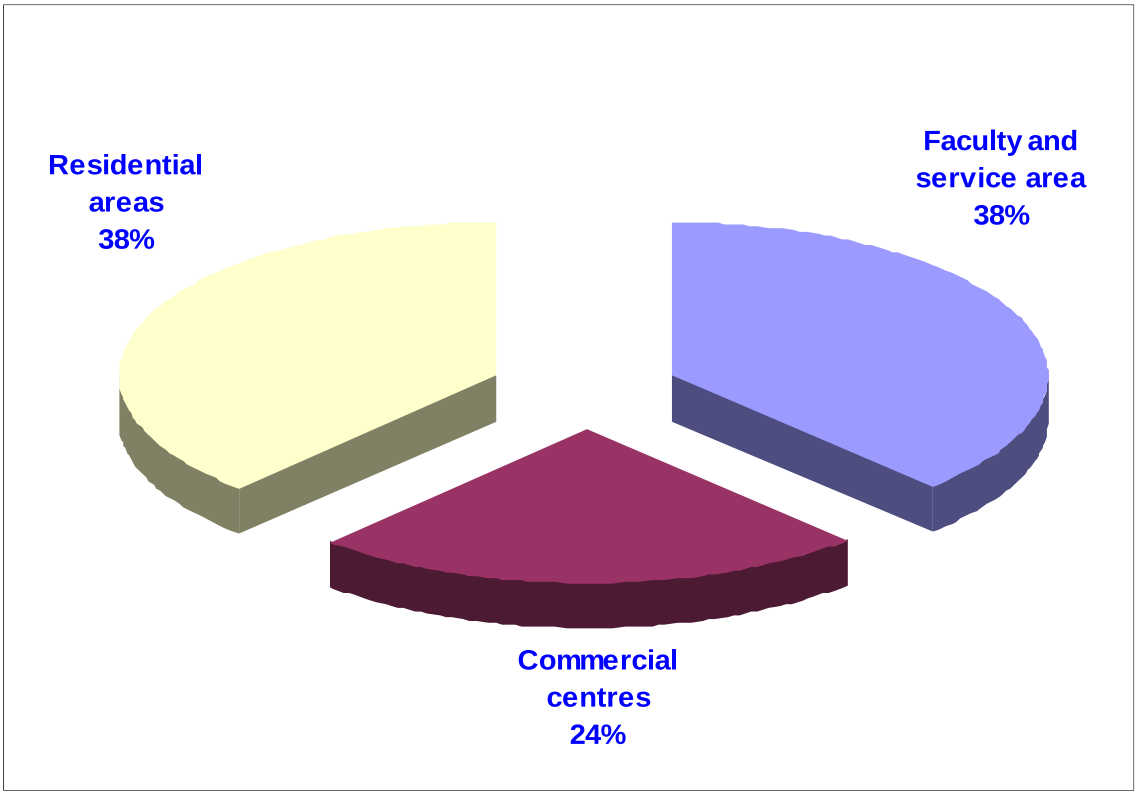


**Figure 9.** Electrical energy demand of different sectors in the University of Lagos

### Concluding Remarks

The need for a proper control of energy consumption has motivated the current study. Thus, this study has provided a walk-through energy audit through a survey conducted in the University of Lagos. To reduce the strain on the school's electrical supply systems and hence prevent system outages, it is recommended that the peak demand reducing strategies highlighted in this study be implemented. Furthermore, improvements in metering systems and energy data processing and storage would help to ensure the effectiveness of this measure. In conclusion, tackling the problem of energy demand from the users end is quite challenging but might be the only hope of the school in view of inflexibility of supply.

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