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Assessment of the Implementation of Energy Conservation Opportunities Arising from Energy Audits; A Study of Four-Star and Five-Star Hotels in Nairobi Kenya

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Abstract

This study assesses the implementation of energy conservation opportunities in four-star and five-star hotels in Nairobi. The Covid-19 pandemic had a significant impact on the Hospitality Industry. Currently, there is a growing inclination to furnish guests with superior and sustainable services in an energy-efficient and eco-friendly way. Comprehensive research was conducted from energy audits gathered from the establishments and contracted auditing companies, on top of this, hotel staff were given digital questionnaires. To add to the data, the researcher surveyed the hotels with engineering managers. The Energy Audits found that all 10 hotels had adopted Energy Conservation Opportunities (ECOs). After further analysis, the mean adoption rate of Energy Conservation Opportunities (ECOs) during the past three years was 55.83%, which was below the aim of 100%. According to studies, hotel staff manages energy to cut costs. The researcher found that hotels use up a lot of energy. However, they have conservation potential, depending on government policies, costs, ease of implementation, and management commitment to sustainable practices. Essentially, Energy Conservation Opportunities (ECOs) reduce energy expenditures and boost reliable revenues, especially during high energy prices and uncertainty.

Keywords

Energy Conservation Opportunities (ECOs), Energy Regulation 2012, Energy Audit, 4-Star Hotel, 5-Star Hotel, Energy Management, Environmental Sustainability, Energy Efficiency

1. Introduction

Due to the current economic conditions, hotel proprietors exhibit greater environmental consciousness than ever before. In Kenya, the escalation in electricity expenses has necessitated the inclusion of natural lighting utilisation and energy-efficient building development strategies in new hotel construction. The magnitude of energy consumption attributed to hotel operations and leisure activities is hefty. In various buildings, energy cost is the second most significant expense after salaries. Proper energy management will boost cost reduction.

Reducing energy costs has been impeded by challenges such as unsustainable practices, inadequate labour expertise, and suboptimal technology. The Hotel Industry's unsustainable practices can be attributed to the four sustainability pillars: the environment, people, energy, and profit.

This study evaluates Energy Audits' energy conservation prospects. The results help corporate executives make smart energy, environmental, and financial decisions. This study helps upscale hotel stakeholders to create frameworks that maximize results with little resources.

2. Literature Review

2.1. Basic Information on Energy Audits

An energy audit is the process of assessing a property's or factory's, or industry's energy consumption to find potential energy conservation possibilities. Incorporating it into a comprehensive energy management plan is critical for success in energy saving initiatives. Aside from energy conservation, the energy audit technique seeks to reduce operational expenses, hence optimising cash returns. Energy audits can be undertaken on a variety of locations, including residential homes, educational institutions, small-scale businesses, and larger commercial entities. The task of scrutinising and analysing energy use trends can be performed by either internal property staff or a trained energy audit professional.

2.2. Steps for an Energy Audit

Energy audits typically entail several steps: Auditors examine papers in desktop studies. This helps identify waste and rising costs. Kilowatt-hours (kWh), fuel volume in litres, heavy fuel oil (HFO) volume in litres, liquefied petroleum gas (LPG) weight in kilogrammes, cubic metres of water used, and energy expenditure. After this, the auditor needs to walk through the property to find energy-saving opportunities. A detailed audit uses specialised energy audit equipment that instantaneously records energy usage data and methods, to evaluate a system component's energy usage. Steam or compressed air system leaks can be discovered by energy auditing software. The results will be used to find energy-saving opportunities. Engineering finance methods examine the project's cost, payback duration, and ROI. Based on this estimate, an investment technique that yields a high ROI and a quick payback period can be developed.

2.3. Audit Instruments and Equipment

The quantity of equipment and tools used rely on facility's energy-consuming equipment and any prospective energy-saving measures that might be taken. Table 1 presents a comprehensive list of the requisite tools and equipment for conducting energy audits and their corresponding anticipated measurement output.

Table 1 was established to illustrate the equipment that are normally used during energy audit. According to Table 1, the measurement output for power and quality analyser includes power factor and voltage current.

2.4. Demographic Information on 5-Star and 4-Star Hotels

A General Manager acts as the hotel's administrative and operational supervisor at each of the establishments. Departments within an organisation are normally organised under the direction of a Head of Department. These people are responsible for the company as a whole. The following departments exist within the Hotel Industry: The Engineering Department, The Housekeeping Department, The Food Production and Beverage Department, The Front Office Department, The Admin and Finance Department, The Sales and Marketing Department, The ICT Department and The Security Department.

Table 1. Equipment used during the energy audit [1].

Equipment	Measurement Output
Power and Quality Analyser/Logger-Single Phase	Power Factor, Voltage, Current, kW, Electricity Consumption, Harmonics, Waveforms.
Power and Quality Analyser/Logger-3 Phase	Power Factor, Voltage, Current, kW, Electricity Consumption, Harmonics, Waveforms.
Combustion Analyser	The efficiency of hot water generators/Steam Boilers/Fossil fuel burning machines
Lux Meter	Light intensity
Safety Equipment	Safety of the energy auditors
Tape Measure	Dimensions of Walls, Ceilings, Windows, and distances between Equipment in the Plant Room
Thermometers (Non-Contact type)	Temperatures in offices & other Worker Areas; the temperature of operating Equipment
Voltmeter/Multimeter/Clamp-Meter	Operating Voltages, Currents in Conductors
Wattmeter/Power Factor Meter	Power consumption and power factor of individual motors and other inductive devices
Airflow Measurement Devices	Airflow from Heating, Air conditioning, or ventilation ducts
Smoke Generator	Air infiltration and leakage around doors, windows, ducts
Fuel Efficiency Monitor	Combustion efficiency
Water Flow Meter (non-contact)	Piped Water Flowrate

2.5. Energy Management Systems in the Hotel Industry

Energy management systems combine, control, and regulate capacities to maximise energy efficiency. They control boilers and chillers, adjusts lighting and temperature in response to demand. The primary systems that consume energy in five-star hotels include; Heating Systems, Air Conditioning and Ventilation Systems, Hot Water Production Systems, Lighting Systems, Electricity and Lift Systems and Cooking Systems.

Hotels rely on electricity for air conditioning, heating, lighting, ventilation, cooking, electrical systems, and hot water generation. Energy costs 3% - 6% of operational expenses. Gas, coal and petroleum are the main sources of greenhouse gas emissions. Limiting energy consumption reduces these emissions. Most hotel Heating, Ventilating, and Air Conditioning System (HVAC) consume 50% of energy consumed. Hotels need 380 - 760 litres of potable water per guestroom each day. The major areas and systems normally audited in hotels are, lighting, electricity distribution system, air conditioning units, cold rooms, boiler and steam systems and LPG consumption [7].

2.6. Post Audit Analysis Giving Energy Conservation Opportunities (ECOs)

During the audit, the auditor records any environmental, social, or governance issues. The auditor must master energy-efficient technology that accomplishes the same operation with less energy and cost. Identifying prospective ECOs during the walk-through helps data analysis and ECO selection. ECO selection involves examining its costs and benefits, then calculating its cost-effectiveness.

2.7. ECO Cost-Effectiveness

Simple Payback Period (SPP) measures cost-effectiveness. The SPP is the period needed to repay the initial investment without considering time value of money. Simple Payback Period is the ratio of Initial Cost to Annual Saving.

Environmental conservation cost-effectiveness can be assessed using the discounted benefit-cost ratio. Discounting and aggregating future savings gives the current value of annual savings over a given period. Dividing the original cost by the present value of savings yields the benefit-cost ratio. The investment will cover its expenditures, including discounted future savings, if the ratio surpasses one.

2.8. Hotel Sustainability

[1] claimed that hotel sustainability is a major issue. Hoteliers have approached sustainability from numerous angles.

According to [1], environmental preservation and climate change management are the most effective ways for hotels to achieve sustainability. Thus, many worldwide hotel chains, especially five-star ones, have taken eco-friendly steps to lessen their environmental impact. This has affected customers' willingness to pay for facilities. Several experts have proven that the rapid growth of the hotel business considerably degrades the worldwide environment. [1] stated that hotels' high electricity and water use for lighting, heating, and cooling causes environmental damage. However, numerous hotels have taken considerable ecological conservation measures to promote sustainability and quality of life. [2] report that the hotel business has adopted several sustainability initiatives. Eco-labels, sustainable behaviour, and environmental management systems are vital. The Brundtland Commission of the UN originally advocated sustainable development in 1987 under the title "Our Common Future," according to [2]. According to [2], the project promoted sustainable tourism by mandating organizations to use eco-friendly materials, maintain economically viable and sustainable operations, respect host populations, and equitably transfer profits.

2.9. Contemporary Hotel Energy Solutions

[3] found several modern gadgets that save hoteliers money and energy. Many solutions claim a 20% - 50% ROI and energy cost savings of up to 30%. According to [4], eco-labelling is a worldwide voluntary certification and labelling of environmental performance. Over 100 hospitality, tourist, and ecotourism eco-label programs exist worldwide. Most hospitality eco-labels focus on preserving resources, water, energy, and trash. Eco-labels can help sell tourism-related products while limiting energy and water use, lowering operator costs. [4] found that eco-labels are both marketing and environmental management tools. Using less power and water saves money.

[5] noted that hotel energy efficiency can be improved temporarily with wireless energy management. According to [6] a commercial wireless network can support laptops, desktops, printers, and portable game consoles. Wireless networks will supply many controllers for HVAC and lighting systems, which use the most energy. The device also wirelessly monitors the structure's kWh use. It also transmits the entire system to the internet, enabling remote management and observation. Wireless energy management solutions minimize guest room energy costs and improve guest comfort.

2.10. Heating, Ventilating, and Air Conditioning System (HVAC)

Hotel HVAC systems use a lot of energy, says [7]. 70% of all hotel energy consumption is attributed to the HVAC system. There are many energy-saving alternatives, such as high-efficiency cooling towers, chillers, heaters, condensing boilers, and variable-speed drives. According to [8], new chillers are more efficient due to their improved controls. Water-cooled turbo compressors with variable speed drives (VSDs) can boost energy efficiency by 400%. On top of this, [8] adds that electronic valves are more efficient than electro-mechanical expansion valves. Bigger cooling towers improve chiller efficiency. A cooling tower's energy efficiency can be improved by installing a variable-speed fan. Condensing boilers for water heating save energy, especially at low loads, boilers with thermal insulation hold water temperatures longer, reiterates [8].

Hotels may use raised platforms for cooking, washing, and swimming. Additionally, an energy-efficient water heater is good. In the off-season, hotels uss less energy since VSDs reduce pumping energy. Pumps and fans should use high-efficiency motors. [8] claims smaller motors are more efficient. VSDs in energy-efficient motors can cut energy use by 50%. High-performance motor lubricants can reduce energy consumption. Automated controls extend motor life. Automated devices can slow or stop engines during idle times. Desiccant HVAC systems can successfully manage humidity. It enhances indoor air quality and conserves electricity.

2.11. Change of Practice in Hotel Management and Operation

[9] found that lighting, air conditioning, housekeeping, and cooking consume a lot of electricity. [9] indicated the lighting system makes hotel personnel and guests feel safe. [9] advocated arranging daytime housekeeping to maximize natural light in hotel guestrooms and public areas. Housekeepers open curtains and blinds to let natural light into guest rooms. Cleaners shouldn't watch TV. [10] identified numerous energy-saving methods. These procedures cost less.

[10] indicates turning off lights in unoccupied rooms is one of the easiest energy-saving methods. In communal places with considerable natural light, lighting must be monitored. To maximize efficiency, public lighting controls like timers and photocells should be maintained and calibrated.

After room preparation, shut curtains and blinds and turn off lights. [10] add that dirty lights and fixtures reduce lighting by 50%. Cleaning lights and lighting fixtures regularly maximizes efficiency. Reduce the number of lamps in over lit areas and add task lighting to save energy. [11] recommends shutting off outdoor and pool area lighting while not in use for safety and security.

2.12. Adoption of Renewable Energy Technologies by the Hotel Industry

[12] states that renewable energy is more environmentally friendly than traditional energy. [12] found that hotels can generate electricity with solar, wind, and hydroelectric energy systems. [12] claims that green energy can lower hotel energy expenses and greenhouse gas emissions. Solar photovoltaic (PV) panels generate clean electricity from sunshine. A meter powers the hotel's electrical network. [12] says wind energy can power hotels sustainably. Small wind electric systems cut electricity prices, provide constant power, and lower remote lodging facility electricity bills. [12] claims PNG's wind resources can reduce greenhouse gas emissions. Wood-burning technology has made wood heating clean, safe, efficient, and cost-effective. According to [13], the price of a solar photovoltaic (PV) system depends on its size, panel type, installation method, and equipment. Hotels can save money on pool heating by installing solar pool heaters. According to [13], solar water heater success depends on solar resource availability, climatic circumstances, local building requirements, and safety. Hospitality wa-

ter heating is expensive and energy-intensive. Solar household hot water systems (DHWS) help hotels cut costs. Solar collectors heat and store cool water in insulated tanks.

[13] explains that automated wood chip and pellet heating systems heat spaces well. Wood chips come from forestry waste. Sawdust, shavings, straw, and biomass crops including maize, rapeseed, and willow are compressed under high pressure to make cylindrical wood pellets [14]. Wood chip and pellet boilers reduce air pollution, energy waste, and wood combustion [15].

Water kinetic energy powers the micro-hydropower system. This system can power small to medium-sized hotels. A turbine powers the micro-hydropower system. This is the cheapest energy source. A ground source heat pump (GSHP) system provides professional hotel space heating, cooling, and hot water. Geothermal energy is extracted from earth's thermal energy. Water or steam transports thermal energy to the surface and drives turbines to generate power. The project demands a large initial investment with a five-to-15-year payback. Hotels that use Ground Source Heat Pumps (GSHPs) save money and minimize carbon emissions. [16] states that the integrated Cogeneration or combined cooling, heat, and electricity (CHP) system generates electrical and thermal energy for heating and cooling. The technology enhances power quality, energy efficiency, and greenhouse gas emissions. [16] defines CHP as micro- to megawatt-scale power sources.

2.13. Research Gap(s)

Previous studies, particularly on post-energy audit scenarios and the factors that influence five-star hotels' ecologically conscientious operations failed to provide precise guidance on fundamental green energy management methods. Thus, this study will focus on energy audits as well as sustainability in the Hotel Industry. Prior research on Hotel Industry sustainable energy sources do not show how they might save costs and enhance environmental sustainability. These simple goals can improve the industry. Investigating hotel staff energy management participation is vital. ECOs from energy audits and measurable energy-saving systems that meet Energy Audit Requirements have not been investigated.

2.14. Problem Design

Kenyan hotels spend more on energy—electrical and thermal. Energy costs the most, followed by materials and labour. Energy sustainability models for 5-star and 4-star hotels are limited by current methods and energy reduction strategies.

The energy audit's advised measures execution rate is crucial. Additionally, variables that affect project performance must be extensively examined. This study examined these factors and suggested ways to improve implementation.

3. Methodology

3.1. Review of Previous Methods

Quantitative and qualitative research paradigms dominated previous methods.

Quantitative research approaches were used for statistical analysis. Data analysis required diagrams, pie charts, and tables. Thus, quantitative data collection and analysis helped calculate accurate and reliable hotel energy economics statistics. Qualitative research was used to explore hotel energy management experiences, attitudes, and conceptions. [17] argues that qualitative methodologies are useful for getting broad viewpoints on energy sustainability in the Hotel Industry.

3.2. Used Methods

Energy Audits and ECOs were carried out after getting a Research License from the National Commission for Science, Technology & Innovation (NACOSTI). This license helped with getting permission for data collection, meetings with hotel engineers, and tours to Nairobi hotels.

3.3. Research Design

The study was based on the use of phenomenology approach. The study prioritized subjective sensations and understood its framework to identify occurrences [17]. Qualitative data is collected, analysed, and used to draw conclusions [17]. [18] believes the design will explain the hospitality industry's sustainability benefits.

The research approach was chosen to create a solid theoretical foundation and effective intervention tactics [19]. In-depth interviews and questionnaires are the best data collection strategies for phenomenology research [20]. This study explained energy sustainability, consumption trends, and energy-saving techniques in Kenyan hotels.

3.4. Data Collection Methods

The study collected original data. Interviewing hotel staff, surveying with energy managers, and using digital questionnaires, ECOs and audit reports were reviewed.

Structured interviews obtained the data. The survey contacted Kenyan 5-star & 4-star hotel managers and staff. Engineering Maintenance, Housekeeping, Front Office, Sales and Marketing, Kitchen and Restaurant, Security, and Finance and Administration staff were chosen for review. The researcher also walked through the case study hotels to evaluate the environmental initiatives. A list of the identified hotels, in this case, the study included: Sarova Stanley Hotel, Crowne Plaza Airport Hotel Nairobi, Radisson Blu Upper Hill, Royal Tulip Canaan Nairobi, Sankara Hotel Nairobi, Villa Rosa Kempinski Nairobi, Somerset Westview Nairobi, Emara Ole-Sereni, Movenpick Hotel and Residences and Ole-Sereni Hotel.

3.5. Conceptual Framework

The study employed a phenomenological research methodology, utilizing both qualitative and quantitative approaches, as illustrated in **Figure 1**.

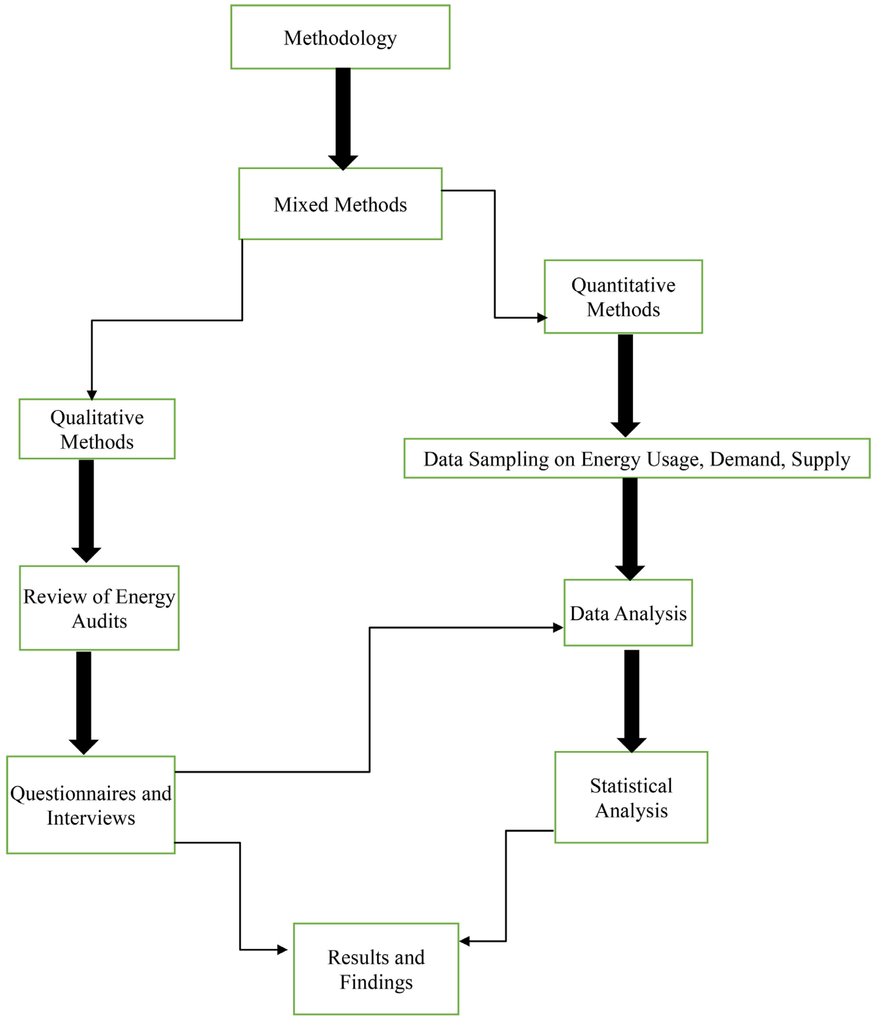

Figure 1. Conceptual Framework [17].

The conceptual framework in **Figure 1** illustrates mixed methods of qualitative and quantitative methods. Qualitative method involves review of energy audits while quantitative methods involve data collection and analysis.

4. Results and Analysis

Energy audits in 4- and 5-star Nairobi hotels were used to evaluate energy conservation opportunities. The study also examined hotel staff's energy management awareness and involvement.

These steps were necessary to achieve these goals:

1) The Energy Audit reports provided by the hotel engineers were analysed during the in-person meeting. Key was to Record and analyse ECO implementation in sampled hotels.

2) Hoteliers from different departments received the questionnaire digitally. This survey assessed their participation and awareness and identified the best energy practices in hotels. The system's design was intended to ascertain the implementation of Energy Conservation measures.

4.1. Background of Findings

The questionnaire showed that the sampled hotels had performed in-house energy surveys and investment-grade energy audits. Figure 2 and Table 2 show these data. Most participants, 98%, reported energy audits in their properties. 2% of respondents reported no energy audits.

According to Figure 2, the questionnaires were mainly about reporting on energy audits by hotels and properties. 50 responses were collected and Table 2 confirmed participation of six hotels. According to Table 2, the types of energy audits done in hotels include in-house energy audit and investment grade audit.

About 70 participants from Nairobi 4- and 5-star hotels received digital questionnaires. 73% of hoteliers responded to the questionnaires. 98% of respondents were from the study's hotels. The second component of the questionnaire asked participants about their gender, age, and hotel departments. This contextual information ensured that volunteers came from all Hotel departments, resulting in impartial and accurate results. Sales & Marketing and Engineering have a higher percentage of hotel staff involved in Energy Management and Environmental Sustainability. The Sales and Marketing department's Request for Proposals (RFPs) feature a large number of prospective clients' environmental and energy questions. Corporate guests choose hotels based on sustainability. Hotel repair and maintenance workers supervise utilities and implement Energy Management systems and technology. Figure 3 demonstrates the participants per department of the hotels studied.

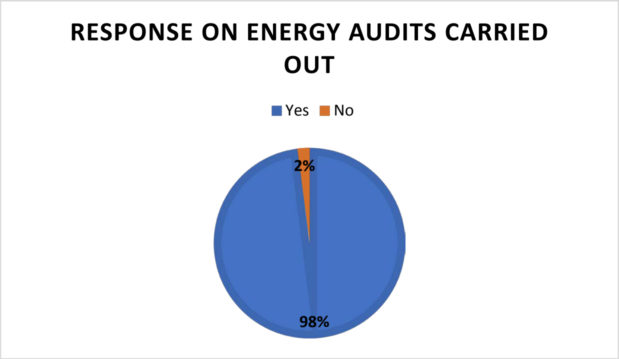

Figure 2. Responses answering; "Are you aware of energy audit(s) of any nature carried out in the hotel?" (50 responses) (obtained from data analysis) [21].

Table 2. Types of energy audits done in hotels under study [21].

	In-house Energy Survey	Investment grade Audit
Hotel 1	√	√
Hotel 2	√	√
Hotel 3	√	√
Hotel 4	√	√
Hotel 5	√	√
Hotel 6	√	√

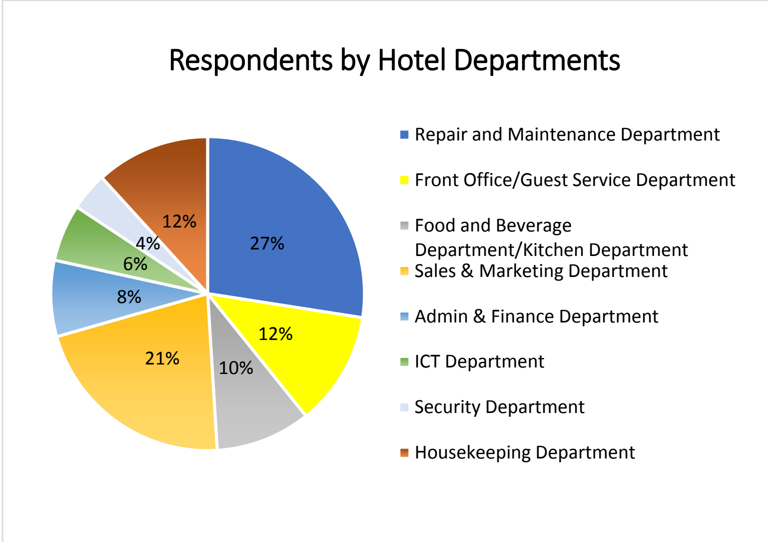

Figure 3. Number of respondents by departmental category (obtained from data analysis) [21].

Figure 3 and **Table 3** illustrates the respondents received from the respondents as per their departments. The data collected confirmed that most hotels are divided into eight major departments that require energy auditing.

4.2. Energy Audit Summaries and Assessment of Suggested ECOs for Each Hotel under Study

Most of the hotels examined were found to have been invoiced under the CI1 tariff. The CI1 tariff exhibits high sensitivity to various factors, including the kVA demand, operating power factor, and energy consumption measured in kWh over the billing period by the electrical loads connected to the grid.

4.2.1. Hotel 1

MaxEng Services Limited audited multiple areas and systems in October 2019 in Hotel 1. Lighting, electricity distribution, cold rooms, air conditioning, boiler and steam systems, and LPG consumption were audited. **Figure 4** shows that the hotel had 52.56 kWh per occupied room in monthly specific energy consumption.

It was further established that most of the ECOs had been implemented. Some of the energy conservation opportunities implemented include Replacement of incandescent, fluorescent, and halogen lamps with LED lamps, Use of motion sensors to control lighting in common Areas such as washrooms, Instal hybrid solar water heating system on the rooftop, Elimination of steam leaks and steam traps replacement, Optimize cold rooms by installing curtains to reduce loss once the door is opened, Instal swimming pool cover, Use of Heat pumps to warm up swimming pool water instead of steam, and Scheduling of Sauna and steam bath operations. The savings achieved include CAPEX budget, Opex budget; 9340 kWh/annum savings, 2400 kWh/annum savings, and 12,080 kWh/annum savings.

4.2.2. Hotel 2

Merculex Energy Solutions Limited performed an energy audit in June 2021 for Hotel 2. HVAC, boiler and steam, electrical distribution, and lighting systems were audited. Figure 5 shows that the hotel consumed 33.49 kWh per occupied room per month.

Table 3. Demographic information of the respondents [21].

Department Representation							Gender	
Engineering And ICT	House Keeping	Food & Beverage	Front desk	Sales & Marketing	Admin & Finance	Security	F	M
15	6	5	6	11	4	2	35%	65%

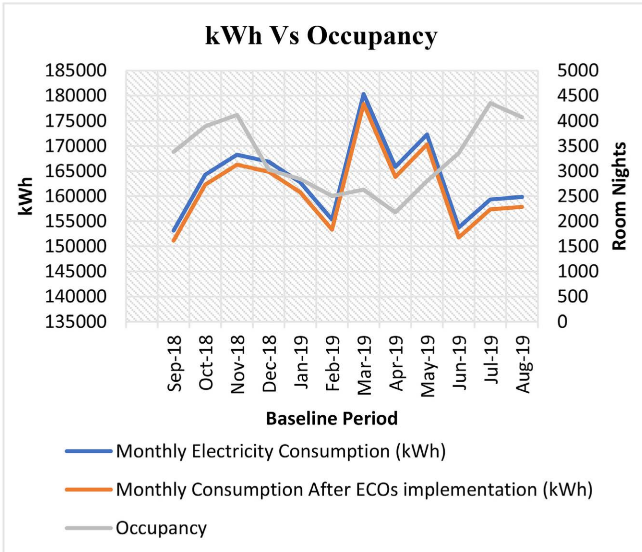

Figure 4. Electrical Energy Consumed against the Occupancy for Hotel 1 during the base period [21].

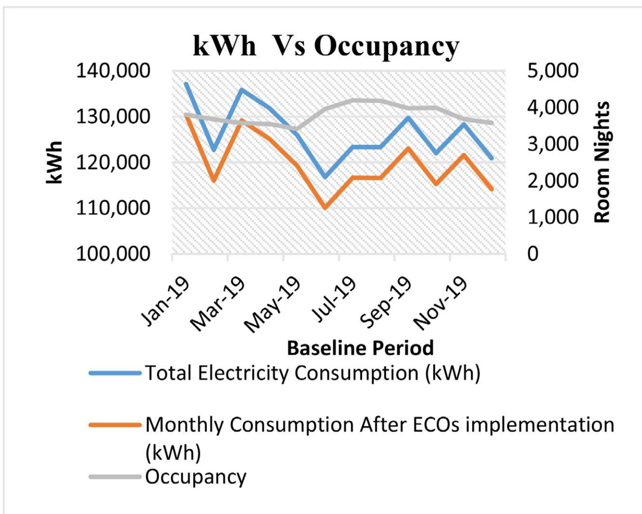

Figure 5. Electrical Energy Consumed against the Occupancy for Hotel 2 during the base period [21].

Optimization of the extractor fans by adjusting the speed-setting positions was implemented and savings of 23,871 kWh/annum was achieved. Implementation of the Optimization of the performance of cold rooms using SMARTech energy hardware/software was still pending for most of the hotels. Automation of the lighting circuitry in common areas and specific offices was also implemented and Savings of 3942 kWh/annum were achieved. Optimize the performance of Solar Water Heaters to save on electrical energy consumed by heat pumps was implemented and savings of 17,199 kWh/annum achieved. However, energy mix improvement where electrical generation is done by the installation of a 60 kWp grid-connected solar PV system was still pending.

4.2.3. Hotel 3

Merculex Energy Solutions Limited performed an energy audit in March 2018 on Hotel 3. HVAC, Lighting, Kitchen Equipment, Laundry, RO Water Treatment Plant, Health Club, ICT, and Water Pumping systems were audited. **Figure 6** shows that the baseline period consumed 6,838,797 kWh of energy, with 65% coming from the electric grid.

Some ECO measures that were implemented by the hotels included lamp automation of common areas, management of baseload during room cleaning, lamp isolation (De-lamping) through lux level mapping program, Building Management System (BMS) installation, and HVAC system; installation of air curtains on all six cold room doors. Annual savings from these measures are between 15,629 kWh and 58,018 kWh. Some of the pending measures include lamp retrofits from fluorescent technology to LED Technology and occupancy sensors in offices to control AC and lights.

4.2.4. Hotel 4

Arica Africa performed an on-site energy audit in December 2021 on Hotel 4. Main distribution boards, laundry, kitchen, boiler room, basement parking, and cold room were audited. The study found that Arica Africa performed a pro gratis audit to identify ECOs and offer energy efficiency improvements for their daily activities. Arica Africa has agreed to obtain cost savings from their recognized ECOs. **Figure 7** shows the hotel's typical monthly electric power usage by section. The kitchen consumed the most due to cold room equipment.

Some of the ECOs implemented include optimizing the performance of the chiller by eliminating heat gain areas along the pipe circuitry and air-conditioned spaces and use of LED lamp technology instead of the existing fluorescent and halogen technologies in the hotel. The opportunities that are still pending include Installation of Automatic Air Curtains in all cold rooms to help conserve energy when the door opens, installation of VFD controllers for the motors under variable loading characteristics, use of regenerative converter drives for the installed lifts to generate energy for the hotel network, and restoring and expanding existing BMS to help monitor and account for energy within the hotel. Automation of the lighting circuitry and the plug loads circuitry through vacancy sensors and motion sensor technologies to bring down the baseload is an on-going implementation measure being adopted by hotels. Savings estimated from this measure is equivalent to 62,344 kWh.

4.2.5. Hotel 5

Merculex Energy Solutions Limited performed an energy audit in November 2022 on Hotel 5. Three energy sources power the entire hotel. Figure 8 shows energy mix by usage at hotel 5.

The ECOs and their implementation as suggested are depicted in Table 4.

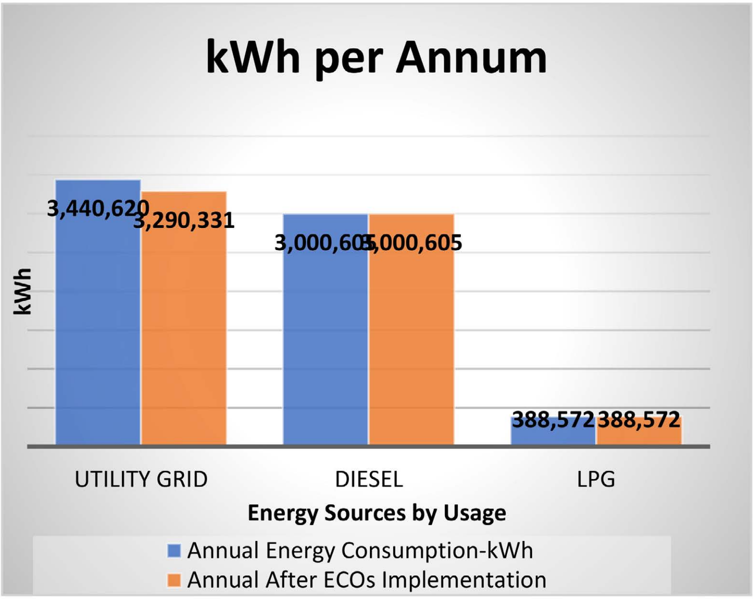

Figure 6. Summary of Energy Consumption for hotel 3 [21].

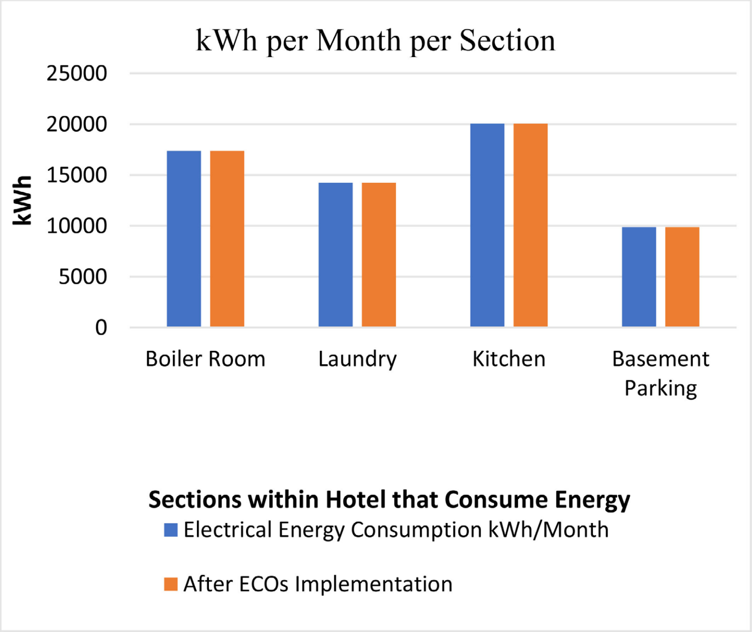

Figure 7. Electrical Consumption per Area audited [21].

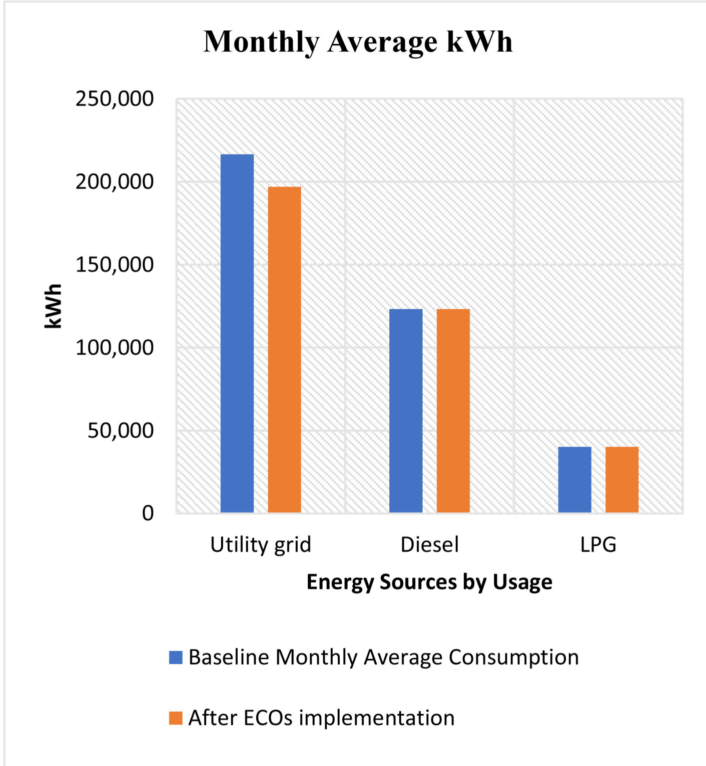

Figure 8. Energy usage mix at hotel 5 [21].

Table 4. Suggested ECOs and their Current Status at Hotel 5 [21].

ECOs	Status	Remarks
Automating all Electrical Systems using BAS	Pending	Investment cost projected at USD 94,910.49
Installation of motion sensors for lighting systems in Public Areas	Implemented	OPEX budget

4.2.6. Hotel 6

Since its 2013 opening, Hotel 6 has performed three Energy Audits in accordance with the Energy Management Regulation 2012. Eenovators Ltd.'s 2015 audit and Energy Advisory Ltd's 2018 audit were used in this study. Lighting, air conditioning, spa, boiler, laundry, kitchen, pump room, basement parking, and lighting were audited. **Figure 9** shows electrical consumption by percentage for various loads. The suggested ECOs and their status are listed in **Table 5**.

4.2.7. Hotel 7

The Hotel Chief Engineer and specialists led an Energy Survey in November 2022. The survey audited significant systems, including: HVAC and lighting systems. **Figure 10** shows that during the baseline period, 6,838,797 kWh of energy was consumed, with 65% coming from the utility grid.

Some of the identified ECOs implemented include; 1) installation of analogue timers on toilet extract fans, kitchen extract fan and fresh air supply fan, laundry extract fan and fresh air supply fan, 2) automating lighting systems in public areas, including guest room corridors, and 3) improving the current power factor reading from 0.9 to unity. Some measures that are still pending include Introducing BMS system for the building, electrical energy demand management, and optimization of building fresh air handling unit using air source heat pumps on site. These measures helped with achieving the OPEX budget and power factor correction bank installation.

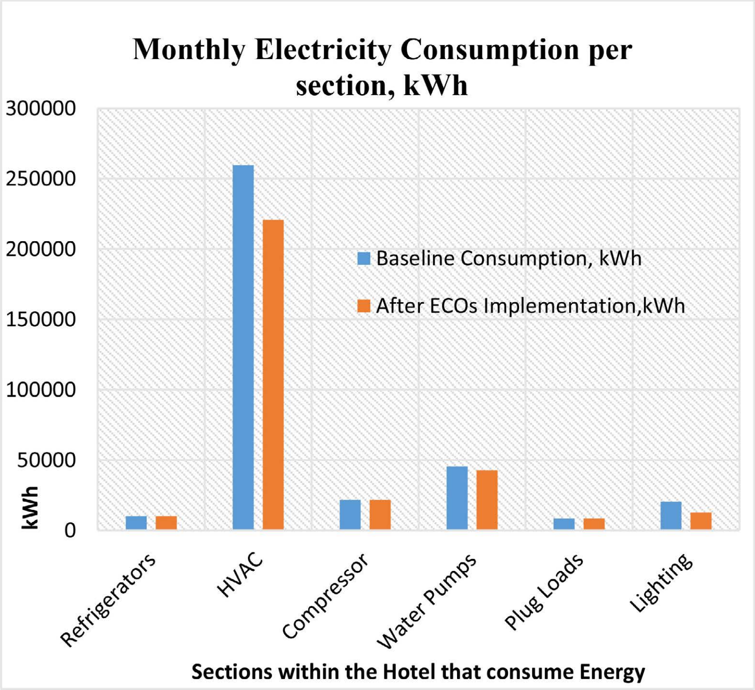

Figure 9. Average Monthly electricity allocation [21].

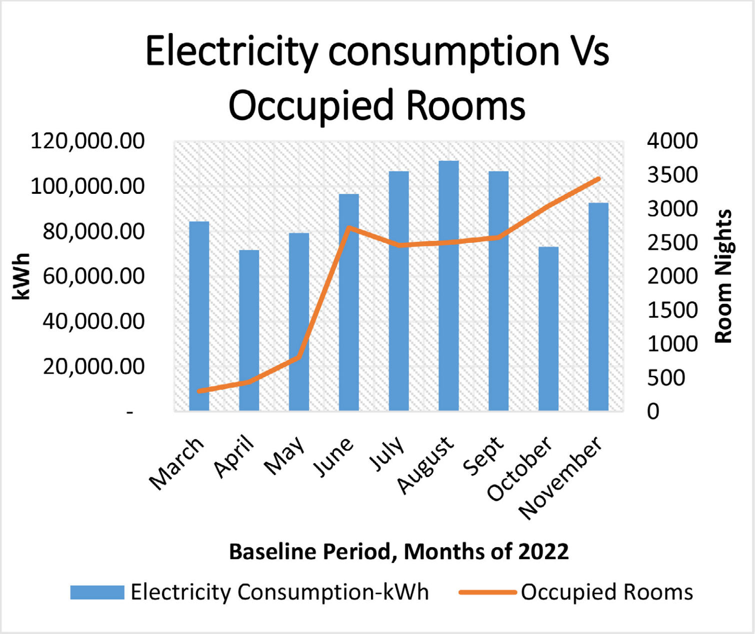

Figure 10. Electricity consumption vs. occupied rooms for hotel 7 [21].

Table 5. Suggested ECOs and their current status at Hotel 6 [21].

ECOs	Status	Remarks
Replace non-LED equivalent LED lights.	Implemented	Savings of 88,993 kWh/annum achieved
Install Vacancy Sensors to operate the rarely occupied sections	Implemented	Savings of 4040 kWh/annum achieved
Receptacles: install power strip to shut down plug loads	Pending	Estimated savings of 876 kWh/annum
VRV Upgrade of AC outdoor units	Ongoing	Estimated savings of 164,182 kWh/annum
Replace inefficient Split unit ACs with efficient ones	Ongoing	Estimated savings of 55,836 kWh/annum
Install Timers on Fan Motors for the extract fans	Implemented	Savings achieved 248,083 kWh/annum
Install the VSD controller for the compressor.	Pending	Estimated 78,840 kWh/annum
Install and implement Energy Management System	Pending	Estimated savings 111,103 kWh
Install Solar Water Heating Systems	Implemented	Savings 31,849 kWh/annum

4.2.8. Hotel 8

In May 2016 and January 2022, Hotel 8 was audited by Eenovators Limited on numerous critical areas and systems. The following sections were audited: Lighting, electricity distribution, cold rooms, air conditioning, and solar water heating systems. The first mean monthly energy usage index was 111.62 kWh per guest, according to data. **Figure 11** shows Hotel 8's two main energy sources. The energy audit baseline was January 2020–December 2021. The suggested ECOs and their status at the time of study are listed in **Table 6**.

Table 6 illustrated the status of various ECOs adopted by hotels. The status is defined as implemented and pending, meaning awaiting implementation.

4.2.9. Hotel 9

Merculex Energy Solutions Limited performed an investment-grade energy audit in September 2019 on Hotel 9. The utility grid, LPG, solar energy for water heating, and diesel for standby generators and steam boilers are used to power the hotel operations. **Figure 12** shows the facility's energy composition and base period energy usage. Electric lamps, kitchen appliances, laundry machines, water pumps, health equipment, and HVAC systems were audited.

Some of the conservations opportunities that have been implemented include boiler optimization through tuning and insulation of the steam line and condensate line and De-lamping various sections of the building to recommend light intensity and lux. The pending measures include improve on insulation level of chilled water circuitry pipes and HVAC plants. Protect the air-conditioned spaces from thermal gain/loss during the day and installation of VFD to help improve the performance of pumps and fans serving the plant.

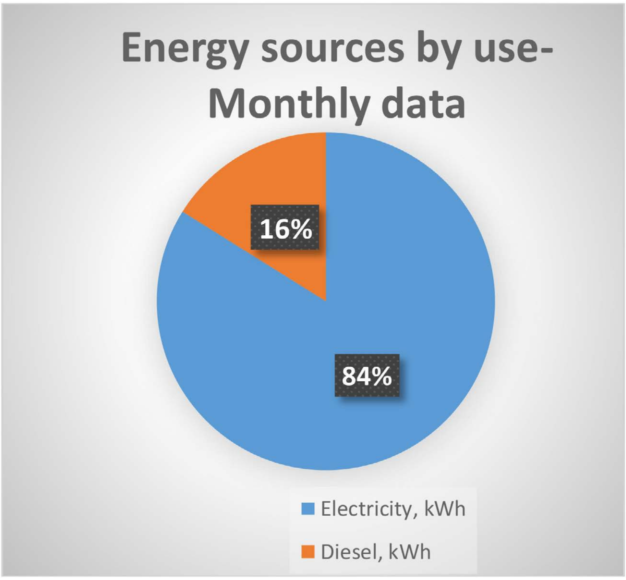

Figure 11. Energy source during baseline period [21].

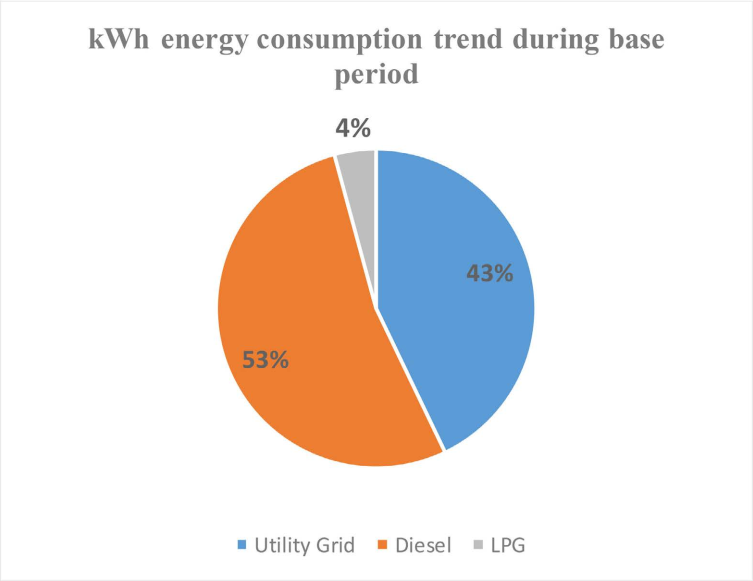

Figure 12. Movenpick Hotel 9 Energy consumption trend on monthly Average during the base period [21].

Table 6. Suggested ECOs and their Current Status at Hotel 8 [21].

ECOs	Status	Remarks
LED Retrofit	Implemented	Executed using OPEX budget in phases
Energy Management System/BMS	Pending	No budget
Electrical Energy Demand Management	Pending	No budget
Power Factor Improvement	Implemented	This was a Statutory requirement
VSD on Kitchen Extractor fan Motor	Implemented	40% savings noted on Fan Motor kWh
Cold Room Energy Optimization	Pending	No budget

4.2.10. Hotel 10

In July and August of 2013, Hotel 10 underwent an energy audit. Electricity, water, LPG, and industrial combustion oil were the primary systems evaluated. The auditors examined high-consumption equipment, including pumps, furnaces, the kitchen, the laundry room, and the lighting system. Figure 13 demonstrates the behaviour of the electricity under various occupancy levels for Hotel 10.

Some of the ECOs that have been implemented include changing the incandescent bulb system to an LED system and solar water heating solution to tap into the abundance of solar energy on the roof area of 130m by 30m. The measures for ECO that are still pending include replacing existing showers with eco showers.

4.3. Change from Incandescent, Fluorescent, and Halogen Lighting Technologies to LED

In the course this study, only four of the six hotels recommended to implement the ECO had done so, after their audit.

kWh per annum is the product Wattage of bulb, Number of fixtures and annual operating hours.

Implementing lighting upgrade initiatives in four hotels has led to a total reduction of 433,955 kilowatt hours in energy consumption. During the visit to said facilities, the engineering managers apprised the researcher that the execution of the ECO, was conducted in different lengthy stages. According to Figure 14, Hotel 8 demonstrated the greatest energy efficiency by conserving 302,400 kilowatt hours of electrical energy annually.

4.4. Lighting Control Such as Motion Sensors, Energy Cards, Timers, and Photocells

Lighting controls were often installed during property development and operation. ECO energy audit recommendations led to operational controls. Energy saver cards control guest room lighting in all visited hotels. This control prevents the lighting system from wasting power during non-occupancy.

All sampled hotels had perimeter wall luminaires that activated at 6:00 PM and deactivated at 6:00 AM.

Before energy audits, excessive lighting in administration offices, employee canteens, washrooms, guest room hallways, conference rooms, and plant rooms wasted a lot of electricity. The above regions had manual light switches. 70% of the hotels suggested occupancy sensors. Electricity usage has dropped due to 85.7% adoption.

Figure 15 shows how occupancy sensors automatically activate room lights upon tenant admission and deactivates them upon departure.

The hotels subject to investigation for the implementation of ECO are Hotel 1, Hotel 2, Hotel 4, Hotel 5, Hotel 6, and Hotel 7. Hotel 3 reported that their energy audit's suggested ECO implementation was hindered by their temporary closure caused by the Covid-19 pandemic.

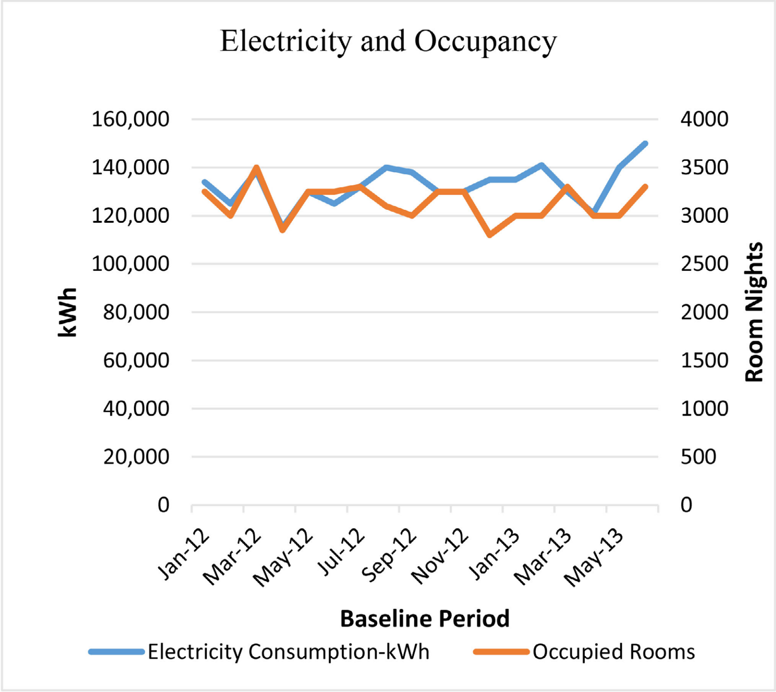

Figure 13. Electricity and occupancy of Hotel 10 during the baseline period [21].

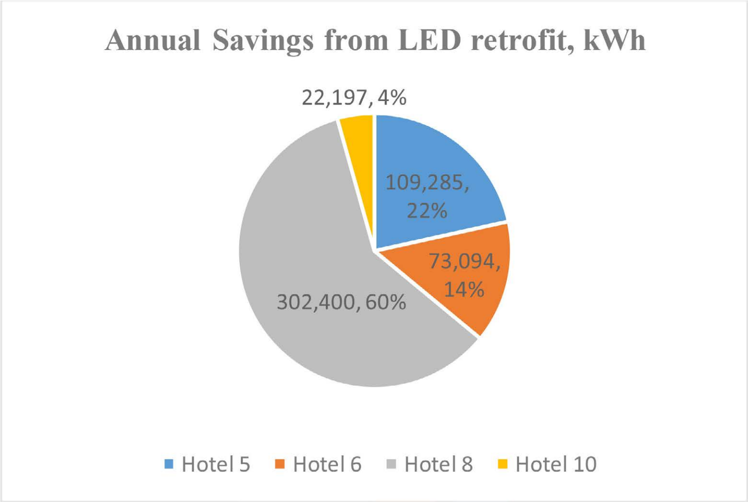

Figure 14. Calculated annual savings from LED retrofits [21].

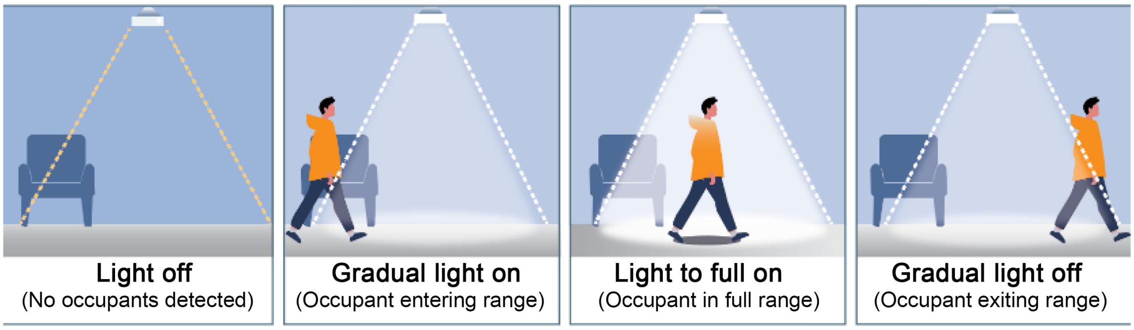

Figure 15. Occupancy sensors automatically turn on lights and turn off lights [22].

Most of the interviewed hotel engineers explicitly stated that occupancy-related projects were executed in stages and within their operational and budgetary constraints without requiring additional capital investments from hotel management.

4.5. Discussion on the Rate of Implementation of the Suggested ECOs

The collected data indicates a variation in the implementation rate across different ECOs. The study determined that the mean implementation rate for the hotels was 55.83% as illustrated in **Figure 16**. **Figure 16** also compares the expected rate of implementation of 100% against the actual rate of implementation.

As per the Energy Management Regulation 2012, designated facilities must execute at least 50% of the energy audit recommendations within three years. According to the data, these Nairobi hotels are performing marginally above the anticipated level of execution. Notably, certain recommended ECOs like solar water heating systems, power factor improvement, and de-lamping have achieved a 100% implementation rate.

According to **Figure 16**, ECOs on Solar Water Heating has a 100% completion rate due to the policy framework supporting the system, despite the high initial investment cost. The Energy (Solar Water Heating) Regulation of 2012 requires all local authority-governed premises with hot water requirements over 100 litres per day to install and use a solar water heating system. The study found that all hotels that proposed the ECO had successfully implemented it. The five hotels not recommended for ECO measures having previously implemented them during construction, especially those built after 2012. SWHS also reduced hotel CO_2 emissions.

The ECO measures reported 100% hotel de-lamping. Implementing this ECO cost only a handheld portable illuminance metre. **Table 7** shows the lux level mapping program for several hotel parts that applied the ECO. Measured values were compared to international standards.

Table 7. Lux level mapping programme adopted by Hotel 3 and Hotel 9 [21].

Area	Standards Lux requirement	Measured Lux Level after implementation.	
		Hotel 3	Hotel 9
Management offices	500	534	512
Plant Rooms	200 - 300	284	256
Escalators	200 - 300	301	298
Meeting Rooms	500	520	542
Guest Room corridor	200 - 300	265	285
Hotel reception	300 - 500	400	430
Living room reading	500 - 750	700	680
Kitchen	300 - 500	420	450
Bedroom general	100	110	102

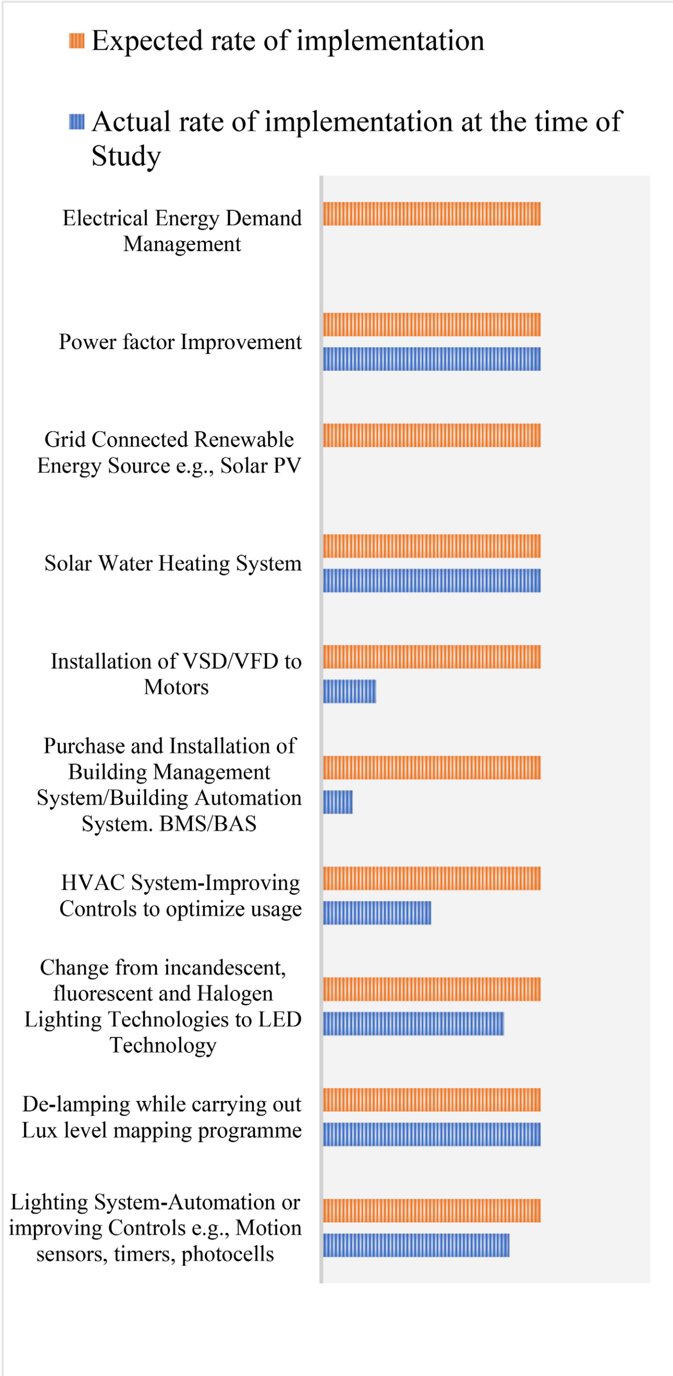

Figure 16. Actual rate of implementation verses the expected rate of implementation [21].

The analysis indicated that the combined de-lamping of nearly 1500 bulbs throughout both hotels did not exceed permitted light intensity. Energy efficiency in a working building is most cost-effective with this method. ECOs power factor enhancement was successful. Three main elements caused this.

1) All hotels have executed this project to meet Energy Act (2019) standards. Following the tariff and pricing schedule for electrical energy delivery, the Ener-

gy Act (2019) requires a customer's electrical installation's power factor to be 0.9 or higher.

2) All hotels use this to avoid power surcharges when the power factor drops below 0.9.

3) All hotels had PFC banks. Installing power factor-enhancing capacitors was cheaper.

The survey also found that Kenya Power and Lighting Company (KPLC) analyses major power consumers monthly with a power factor monitoring system. 85.7% and 83.3% of lighting controls and LED retrofitting ECOs are implemented. Interviews with facility engineering teams showed the two ECOs being implemented gradually. All hotels agreed to provide monies from their operational budgets and implement the planned projects monthly. Due to cost savings and lower utility bills, the installation was quickly adopted. Calculating the power usage difference in the hotel sector before and after the installations was easy to verify these ECOs. Changes in kilowatt-hours and kilovolt-amperes were easier to verify. There was 50% and 25% adoption rates for HVAC system optimization and motor VFD installation ECOs. The HVAC system ensures guest comfort and safety. Optimizing an HVAC system demands moderate capital expenditure. Since no policy or law requires hotels to optimize systems and put VFDs on motors, management holds the power. Despite giving explanations for predicted energy savings, optimisation operations are considered capital expenses that require several approvals and typically fail.

BMS are expensive to install. Three hotels had BMS installed during construction, all the remaining suggested installing an ECO, but none did. Thus, property construction costs included BMS costs. This study found a 14.3% initiative implementation rate. Table 8 shows the costs of establishing BMS in operational hotels. Energy auditors estimated costs.

Table 8 shows that installing a BMS system in a 5-star or 4-star hotel costs USD 31,597.26. This explains the ECOs limited acceptance.

ECOs had a 0% execution rate. Grid-tied photovoltaic solar systems and energy demand management were implemented.

Table 8. Cost of implementing BMS for various hotels [21].

Hotel	Cost estimates for implementing BMS (USD)	Status at the time of study
Hotel 8	15,638.83	Pending implementation
Hotel 7	14;275.52	Pending implementation
Hotel 6	7,137.76	Pending implementation
Hotel 5	21,287.09	Pending implementation
Hotel 4	94,910.49	Pending implementation
Hotel 3	50,693.45	Implemented
Hotel 2	17,237.69	Pending implementation

The ECO for Grid-connected Solar PV is not mandated by law. Green-certified hotels had autonomous solar photovoltaic systems for security and perimeter illumination. The ECO on grid-connected Solar PV has been hampered by its high cost and lack of rooftop space for Solar PV panels. Hotel 1's 1902 architecture has prompted issues. Solar panels on the rooftop may compromise the building's structure. The hotel considered using neighbouring rooftops.

On-demand hotel demand management was hampered by the lack of load increase scenarios. The Hotel Industry's attributes make high-demand periods predictable. Breakfast, lunch, and dinner were peak times. Load growth tactics could affect visitor comfort and lead to bad reviews, thus hotel management was hesitant to use them. KPLC's Time of Use pricing (TOU) is not extensively used by hotels, limiting hotel benefits.

4.6. Validation

The Energy Act of 2019 established the Energy and Petroleum Regulatory Authority (EPRA), and replaced the Energy Regulatory Authority. The Agency regulates electricity production, import, export, transmission, distribution, supply, and consumption. Electrical, fossil, and renewable energy are consumed by hotels. EPRA has various energy restrictions for this sector. The 2012 Energy Management Regulation and 2019 Energy Act are important rules. EPRA must collect and maintain energy data under the 2019 Energy Act.

The hotels' Energy Audit reports were crucial to this research. EPRA reviewed the audits and investment strategy. This study's assessment analysis proved the Energy Management Regulation Act of 2012's requirement that facilities implement half of their energy audit's energy conservation recommendations within three years. Figure 17 shows the annual submission of Audit reports to Kenyan authority by various buildings. Over the past four years, 55.83% of hotels adopted ECOs.

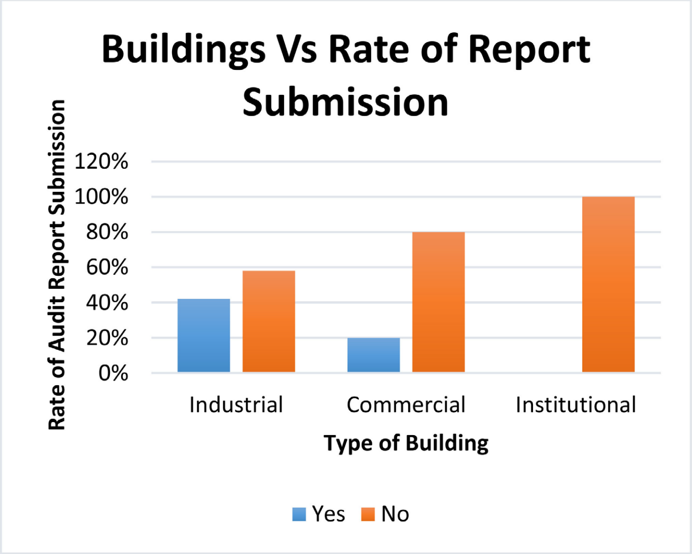

Figure 17. Submission of annual implementation reports to EPRA [23].

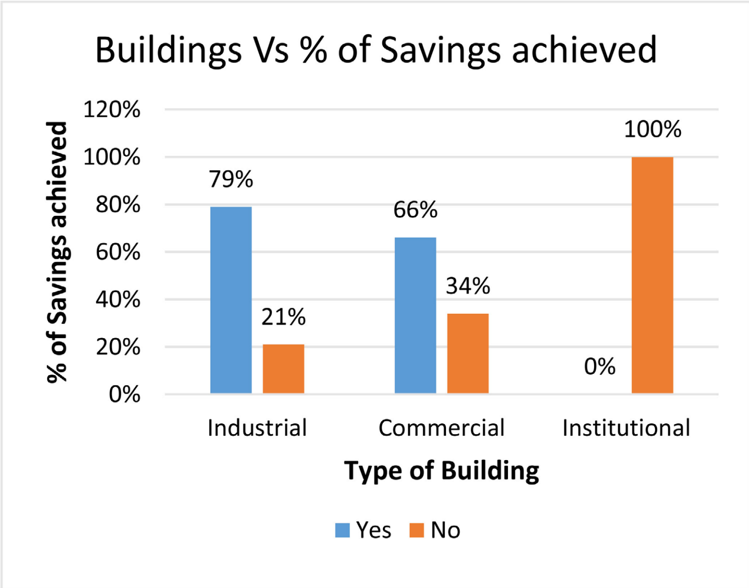

Figure 18. Realization of Projected Savings Documented in the Audit Report [23].

According to the EPRA's study, 66% of anticipated savings were successfully achieved by the commercial buildings encompassing hotels, as depicted in **Figure 18**. This finding exhibits an 11% deviation from the results in this study. This research evaluated the execution of individual ECO in contrast to individual hotels or buildings.

According to the EPRA study, the implementation of ECOs in different facilities was financed through internal budgets. This research however noted a pattern in which brief investment initiatives were funded via OPEX budgets.

The data collection for the EPRA study was conducted using designated facilities as the sample. This investigation on the other hand employed a sample of ten hotels as case studies.

5. Conclusions and Recommendations

Energy audits of 5-star and 4-star hotels in Nairobi, Kenya were used to evaluate Energy Conservation Opportunities (ECOs). Interviews and document analysis were utilized for the research. The study examined ECO guideline efficacy, implementation, and underlying factors.

The study found that hotel sector Energy Conservation Opportunities (ECOs) could be grouped into three investment plans: short-term, medium-term, and long-term investment measures. Short-term measures were considered "low-hanging fruits" by most hotel energy officers. LED retrofitting, lighting controls, De-lamping, HVAC system insulation, and power factor adjustments are short-term ECOs in this study. VFDs and HVAC optimization are medium-term investments. BMS, Grid-connected Solar PV, and SWHS are long-term investments. The investment strategy directly affected ECO initiative execution speed.

Energy audits help hotels create a fiscal year energy management action plan. The energy audit documentation examined Energy Conservation measures' cost of investment, simple payback period, and internal rate of return.

A hotel's appeal to ecologically concerned and sensitive customers helped boost its marketability. New hotel buildings often included excellent practices.

Government policies and laws drove ECO implementation. The Energy Act of 2019 mandates power supply maintenance at 0.9 or higher. The hotels made ECO power factor modifications immediately. Hotels must install SWHS under the 2012 Energy Management Regulations. The Energy Regulations require audited hotels to implement 50% of the recommended ECOs within three years following the recommendation. The analysis found 100% compliance.

Hotel eco-labelling greatly aided environmental conservation goals. Green Certification renewal required ECO implementation.

Implementing new energy-efficiency solutions is expensive. Implementation of suggested ECOs has slowed.

Hotels need in-house energy management policies. The policy allows managers to implement ECOs, sets the annual energy target, and outlines accountability, reporting, and teaching. Hotels with in-house energy policies were more environmentally concerned.

The survey found that hotels used internal budgets to fund projects. No loans or government financing.

5.1. Recommendations

This study has shown that the rate of implementation of the suggested ECOs is not 100% as expected. The implementation is governed by the following parameters: Compliance to government policy, cost of implementation, ease of implementation on existing building and level of commitment of hotel management in going green/Eco-labelling. In this section, the study recommends various ways of improving rate of implementing the suggested energy conservation opportunities.

5.1.1. Sustainable Certification Models for Nairobi 5-Star and 4-Star Hotels

The study recommends that the 5-star and 4-star rated hotels adopt any of the green key certification models as one of the strategies to improve the rate of implementation of the ECOs:

1) EDGE Zero Carbon Certification model

EDGE requires a minimum projected reduction of 20% in energy use, water use and embodied energy in materials and as benchmarked against the EDGE baseline. This model will ensure that the hotels implement some of the ECOs to achieve the targets set by EDGE certification for the annual renewal of the EDGE license.

2) Green Key Certification model

The Green Key criteria checklist has imperative and suggested best practices for hotels. Interested facilities must score 100% on imperative criteria for them to be licensed. Thereafter, the facility must endeavour to implement 20% suggested best practices in order to qualify for license renewal. This model will ensure most hotels implement ECOs in order to achieve the set standards by Green Key team.

3) ISO 50001 Certification Model for Nairobi Hotels

ISO 50001:2011 specifies requirements for establishing, implementing, maintaining and improving an Energy Management System. The purpose of EMS is to enable an organisation to follow a systematic approach in achieving continual improvements of energy performance. This study recommends that Hotels pursue ISO 50001 certification since this model with fast-track the implementation of the ECOs.

4) LEED Certification Model for Nairobi Hotels

Leadership in Energy and Environmental design (LEED) is a green building certification recognized globally as symbol of sustainability. It provides framework for implementing ECOs that are efficient, carbon saving and cost-saving.

5.1.2. Shared Savings Approach for Nairobi Hotels and the Energy Management Stakeholders

The cost of carrying out an Energy audit in 5-star and 4-star hotels is approximately on average USD 2536. This is expensive for an operating hotel. The suggested ECOs also come with additional cost of investment. This study recommends shared savings approach where the hotel management rolls out the installation without using their capital and yet stands to realize savings from a zero-cost basis. The capital realised from savings is shared between hotel management and the energy officer who did the energy audit and recommended the ECO.

5.1.3. Policy Change Intervention

One of the key findings of the study was that all ECOs that had a government Regulation supporting their implementation, had an implementation rate of 100%. The study therefore recommends that some of the ECOs be made part of Energy Management Regulations. Most prominently the LED retrofitting and lighting automation controls should be included in policies governing energy management for facilities such as Hotels.

5.1.4. ECOs Financing

Government and other agencies create a pool of funds for financing ECOs. This should start by providing skills and knowledge to energy stakeholders and financial institutions so that they are able to appraise and evaluate risks associated with implementing some of the ECOs.

5.1.5. Safety Concerns and the Implementation of ECOs

It was noted during the study that implementation of some suggested ECOs such as installation of motion sensors for lighting circuitry can lead to cases of total darkness in some public areas. The study recommends that measures be put in place such as installation of closed-circuit televisions (CCTV) with night visions to enable monitoring of such public areas when there is no motion.

5.2. Recommendations for Further Work

5.2.1. Appraisal of Individual ECO

The energy audit reports reviewed during the study showed that the individual ECOs were not appraised. The ECOs were analysed and investment plan developed in terms of projected Savings, payback period and internal rate of return. Further works need to be done to appraise and evaluate the ECOs fully to discuss the risks associated with their implementation and then suggested mitigation measures to each risk identified. This should be done with aim to advise the energy stakeholders including Financial institutions for possible investment and loaning opportunities.

5.2.2. Study in Monitoring and Verification Processes of Implemented ECOs

The implemented ECOs should be closely monitored, performance measured and recorded. The performance of implemented ECOs needs to be continuously recorded and studied in terms of energy utilization indices. Growth or decay of the energy management systems can be studied by doing further works on monitoring and verification processes.

5.2.3. Study in Optimization of HVAC Systems in Guest Rooms Using Outputs of Heat Pumps

The output of Air-Source Heat pumps can be used to cool the guest rooms during summer. The VRV outdoor units' output can also be used to heat guest rooms during winter. This study should lead to optimization and high efficiency of the HVAC systems.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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