Journal of Physics: Conference Series

PAPER • OPEN ACCESS

# Walk-Through Energy Audit of An Institutional Building

To cite this article: O. E. Atiba *et al* 2019 *J. Phys.: Conf. Ser.* **1378** 032051



# Walk-Through Energy Audit of An Institutional Building

**O. E. Atiba[1*], U. K. Efemwenkiekie[1], R. O. Olatunji[1], O. S. Ohunakin[1,2], D. S. Adelekan[1], O. A. Oyeleke[1]**

[1] The Energy and Environment Research Group, Mechanical Engineering Department, Covenant University, Ota, Ogun State, Nigeria.
[2] College of Natural Resources, University of California, Berkeley, CA 94720, California, USA.
Corresponding author email: opemipo.atiba@stu.cu.edu.ng

**Abstract**
Improving energy efficiency requires detailed information on energy utilization. Many a times, institutional buildings across developing countries are not energy efficient. Thus, they require quantitative energy consumption audit information. This study outlines daily, weekly and annually projected energy consumption in an academic building within Nigeria. Measurements of the energy utilizations of the building were in accordance to ASHRAE Standard 22, ASHRAE/IES Standard 100-2015 and BCA Health Check report guidelines. Results showed that HVAC appliances and electrical motors driven gadgets consumed 36% and 61.9% of the total energy supplied. In conclusion, improving energy efficiency of similar facilities requires energy conservation practice in terms operating motors and other HVAC devices off idle-time and non-occupancy period respectively.

**Keywords**: building; energy audit; energy consumption

## 1. Introduction

Buildings accounts for nearly 40% of annual energy consumption globally. Energy consumption monitoring is crucial to determine where and how power is utilized within buildings per time [1]. In addition, monitoring building energy consumptions are prerequisite for actionable insights on energy conservation, management and economy. Installations of energy management systems within buildings have also been found to improve energy efficiency, minimize waste and emissions in accordance to UNEP/UNIDO's sustainable targets for developed and emerging economies [2].

Energy impact assessment for occupant buildings at different seasons can be observed through the energy consumption, thus activities such as building design and analysis that ensures optimal facility use cannot be underestimated. The opportunity of saving 15% to 30% of useful energy in homes further makes energy utilization and conservation a requirement for present and future buildings. Energy audit is a management tool used to evaluate facility efficiency and minimize wastes in buildings [3]. According to Woo & Moore, energy audit process involves (i) preliminary survey of facilities (ii) data collections, and (iii) analysis and inference of data for recommended solutions [1]. The recommendations from EA analysis addresses energy efficiency gaps for residential buildings [4], [5], and enables prioritization of energy conservation measures in commercial and industrial buildings [6]. Also, policies and regulatory frameworks from detailed energy auditing of facilities raises public awareness on energy management and reduction of energy losses [7].

With the increasing concern to improve building efficiency, identification of energy consumption within university campus is vital to reducing carbon footprint and foster environmental awareness. Joshi et al. researched techno-economic energy conservation measures in academic structures, industrial space and commercial building using virtual EA analysis through multi-physics simulation. The multi-physics approach suggested that practical application sensitizes each consumer on energy efficient practices [6]. A similar academic electricity audit was conducted across Chandigarh University, Gharuan Mohali using power system analysis software to recommend optimum electricity consumption and also limit power losses [8]. Leiva et al. performed a periodical assessment within a university environment through the manual 'off-and-on' and power analyzer to ascertain the equipment with peak demands. Low power factor motor was identified as the major equipment for improvement [9]. Roberts et al. accessed the impact of energy legislation informed by energy savings opportunity scheme (ESOS) energy audit and realized occupants' behavioral change when cost minimization was presented [10]. An energy conservation practice of Curtin University, a leading power consumer in Sarawak state of Malaysia showed how load profile and time-series data produces insight on load scheming and balancing [11]. This study outcome reveals that HVAC devices has the most share of energy consumption all year long with about 23% energy savings on 676 kWh/CDD.

However, evidences from literature presents less awareness on energy-efficiency measures in the service sectors (office buildings, hostels, supermarkets and hotels) as opposed to the industrial side [12], [13] which are obliged to provide a database for energy use. This lays evidence to Akinbami & Lawal's claim that more survey data is required to analyze the energy consumption of commercial facilities in Nigeria. In this work, an energy audit was conducted for the mechanical engineering department of Covenant University, Ota, Nigeria with the view of identifying EMOs. Level 1 energy audit, walk-through analysis, is conducted on a two floor building with the aim of obtaining vital energy consumption for each specified area in the building. Afterwards, it is intended that the summary delivers conscious management action plan that will make most users to conscious of energy efficient practices. The results would further improve the power planning and control unit in the application of detailed energy consumption audit across the university.

## 2. Methods and Data Collection

Many of the energy audit pack recorded are through data logger and important energy end-use devices to capture energy data. The building user energy utilization profiles were determined with questionnaire, and interview. In the case of this report information designed were drawn mostly from walk-through the departmental building and. The energy auditing took place between the 15$^{th}$ and 29$^{th}$ of June, 2018 in the tropical region of Ogun State Nigeria where the annual mean temperature ranges from 28 - 33°C. We visited offices, workshops and laboratory and procured necessary energy usage information in a bid to obtain a rough estimate of daily consumption.

The general formula associated with energy audits calculations followed summation approach contained in the work of Boharb et al. [14]. The technical energy conversions used in reporting data are shown in Table 5. Table 2-5 shows each category of appliances and their relative share in the total energy consumption. Details from nameplates of electrical and electronic components are noted with respect to power their ratings as shown in Figures 1 and 2.

Table 1: Average building occupancy and mechanical services

| Area Served | Gross Area (m$^2$) | No of Occupants | | Mechanical Services |
|---|---|---|---|---|
| | | Weekdays | Weekends | |
| A. Laboratory | | | | |
| Corrosion Lab | 72.50 | 35 | 10 | HVAC, Lightings |
| Refrigeration & Air conditioning | 71.75 | 32 | 10 | Motors, HVAC & Lightings |
| Physical Metallurgical Lab | 75.00 | 40 | 10 | Plug loads, Lightings & HVAC |
| Simulation Lab | 71.75 | 32 | 20 | Plug loads, Lightings & HVAC |
| Strength of Material Lab | 75.00 | 40 | 10 | Plug loads, Lightings & HVAC |
| Mechanics of Machine Lab | 72.50 | 32 | 10 | Motors, HVAC & Lightings |
| Thermodynamics & Heat Transfer | 71.75 | 40 | 10 | Plug loads, Lightings & HVAC |

| | | | | |
|---|---|---|---|---|
| Automobile Lab | 63.75 | 15 | 6 | Motors, Fans & Lightings |
| Aerodynamics Lab | 68.00 | 35 | 10 | Motors, HVAC & Lightings |
| B. Classroom | | | | |
| Town & Gown | 95.00 | 80 | 25 | Plug loads, Lightings, & HVAC |
| 500 Level | 63.75 | 60 | 25 | Fans, Lightings & Plug loads |
| 400 Level | 63.75 | 60 | 25 | Fans, Lightings & Plug loads |
| 300 Level | 63.75 | 60 | 25 | Fans, lightings & Plug loads |
| C. Offices | | | | |
| Big Offices | 38.75 | 10 | 3 | Plug loads, Lightings & HVAC |
| Small Offices | 26.50 | 15 | 5 | Plug loads, Lightings & HVAC |
| D. Others | | | | |
| Library | 54.75 | 8 | 4 | Plug loads, Lightings & HVAC |
| Toilets | 98.00 | - | - | Lightings |
| Workshops | 150.00 | 12 | 4 | Motors, Fans & Lightings |
| Conference Room | 88.00 | 25 | 2 | Lightings & HVAC |

Note: All records were captured at the same time daily

Table 1 shows the various sections within this facility with the assumption that occupants use the listed facility's space for at least 8 hours. This is choice was taken as the mean time each respondents gave in their questionnaire; the standard deviation was within 0.12 from a sample size of 47 persons randomly selected in the departmental building. The table also shows the area of the space and the type of mechanical services that accounts for the energy use in that zone.

Table 2: Office plug loads

| Equipment type | Model or size | Total no | Wattage | Hours of use per day | Total kwh | How equipment is controlled |
|---|---|---|---|---|---|---|
| Computer | Laptop and Desktop | 120 | 150 | 8 | 18 | Self-monitored |
| Printer | Laserjet | 8 | 50 | 2 | 0.4 | Dependent on the operation of staff and students |
| Photocopier | Hp / Sharp (Medium) | 4 | 250 | 3 | 1 | Dependent on the operation of staff and students |
| Projector | Dell | 3 | 300 | 10 | 0.9 | Regulated by number of lecture |
| Interactive Board | Newline | 4 | 250 | 12 | 1 | Regulated by number of lecture |
| Personal Devices | Mobile Phone | 70 | 20 | 9 | 1.4 | Dependent on the operation of staff and students |
| CAD/CAM Device | 3D Printer | 2 | 150 | 1 | 0.3 | Based on technician operation |
| **Average total kilowatts consumed daily** | | | | | 22 | |

Table 3: Energy survey – lights

| Light & fixture | Location | No | Watts per fixture | Hours operated per day | Days operated per week | kWh per week | Comments |
|---|---|---|---|---|---|---|---|
| Mercury MV 175 | Workshops | 18 | 100 | 10 | 6 | 1.08 | Lighting more than 5 years old |
| CFL 4ft Rapid Start | Classrooms | 36 | 60 | 12 | 7 | 3.02 | Schedule Relamping |
| CFL 4ft Rapid Start | Pathway | 48 | 40 | 16 | 7 | 5.38 | Hours/days left on |
| CFL 4ft Rapid Start | Big Offices | 23 | 60 | 12 | 5 | 1.38 | Some unnecessary outdoor lighting |
| CFL 4ft Rapid Start | Departmental Office | 5 | 60 | 12 | 5 | 0.30 | Dimmers can used |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| CFL 4ft Rapid Start | Small Offices | 15 | 40 | 12 | 6 | 1.08 | Some ceilings and walls painted with high reflectance |
| CFL 4ft Rapid Start | Conference Room | 8 | 60 | 9 | 4 | 0.29 | Delamping is required |
| CFL 4ft Rapid Start | Town & Gown Class | 12 | 60 | 9 | 4 | 0.37 | In good condition |
| CFL 4ft Rapid Start | Library | 6 | 60 | 16 | 7 | 0.58 | Relamping is required |
| CFL 4ft Rapid Start | Toilets | 16 | 60 | 16 | 7 | 1.56 | Lighting controls needed |
| CFL 4ft Rapid Start | Buttery | 2 | 40 | 8 | 5 | 0.08 | Requires more daylighting |
| Metal Halide MH 250 | Exterior | 15 | 250 | 8 | 7 | 0.84 | Some lamps need replacement |
| CFL 4ft Rapid Start | Laboratory | 42 | 60 | 6 | 5 | 1.26 | More lighting controls needed |
| | **Average total kilowatts consumed weekly** | | | | | **17.22** | |

Table 4: Air-conditioning equipment

| Light & Fixture | Item No | Location (Area) | Wattage (kW) | Hours operated per day | Days operated weekly | kWh per week | Comments |
|---|---|---|---|---|---|---|---|
| Split wall unit (5 hp) | 12 | Departmental Office (42m$^2$) HOD's Office (45m$^2$) Dean's Office (47 m$^2$) Professor's Office (42 m$^2$) | 6.70 | 7 | 5 | 281 | Some Air-conditioners needs Services |
| Split wall unit (2.5 hp) | 6 | Big Offices (38.75 m$^2$) | 3.35 | 9 | 5 | 90.4 | Working properly |
| Split wall unit (1.5 hp) | 18 | Small Offices (26.5 m$^2$) PG Room (27.50 m$^2$) | 2.00 | 10 | 5 | 180 | Inspection of the outdoor units |
| 1 Tonne Stand-alone unit (12 hp) | 4 | Town & Gown Hall (95m$^2$) Conference Room (88 m$^2$) | 15 | 6 | 5 | 180 | Inspection of the outdoor units |
| 1 Tonne Stand-alone unit (12 hp) | 5 | Laboratories Library (54.75) | 15 | 6 | 5 | 225 | Working properly |
| Split wall unit (5 hp) | 12 | Departmental Office (42m$^2$) HOD's Office (45m$^2$) Dean's Office (47 m$^2$) Professor's Office (42 m$^2$) | 6.70 | 7 | 5 | 281 | Some Air-conditioners needs Services |
| | | **Average total kilowatts consumed daily** | | | **956.4** | | |

Table 5: Drive information

| EQUIPMENT ITEM | ITEM NO | ELECTRICAL | | | | | | | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|
| | | Speed (rpm) | Phase | Voltage | kW | Hours Operated Per Day | Days Operated Per Week | kWh Per Week | |
| Lathe Machine | 8 | 1800 | 3 | 440 | 57 | 6 | 4 | 1368 | Adjustable Speed drive needed |
| Milling Machine | 2 | 1200 | 3 | 440 | 46 | 4 | 4 | 147.2 | Adjustable Speed drive needed |
| Drilling Machine | 3 | 1580 | 3 | 440 | 24 | 3 | 4 | 86.4 | Adjustable Speed drive needed |
| Shaping Machine | 1 | 700 | 1 | 220 | 5 | 1 | 4 | 20 | Functioning properly |
| Multi-cylinder test bed | 1 | 900 | 1 | 220 | 35 | 0.2 | 1 | 7 | To be used at stable voltage |
| **Average total kilowatts consumed daily** | | | | | | | | 1628.6 | |

Table 2-5 shows that the energy consumption for the listed energy equipment at different locations of the building. These values were estimated form the main plate and manufacturer's rating of certain devices over time.

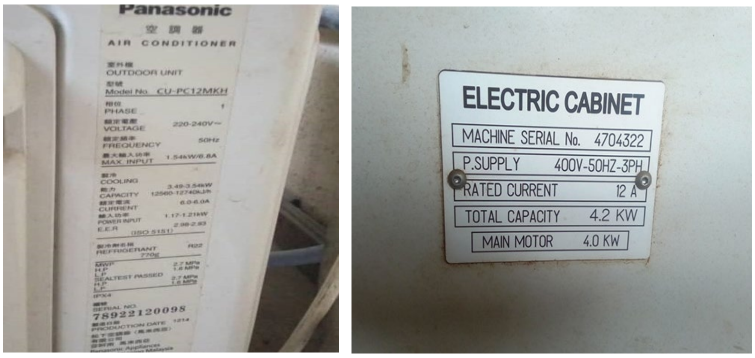


Figure 1: Component power specification for (a) air conditioner, and (b) shaping Machine

Table 6: Energy use performance metrics and conversion factors

| Performance Metric | Unit |
|---|---|
| Whole Building Site Energy Use Intensity | 65°F minus mean temperature, °F |
| Whole Building Source Energy Use Intensity | 760 mm (mercury per cubic centimetre) |
| 1 kilowatt (kWh) | 1.341 horsepower |
| 1 kilowatt hour (kWh) | 3412 Btu |
| Paid Electricity Usage | $8.97 \times 10^6$ Btu |


Figure 2: Nameplate specification of 3 Phase motors for (a) milling machine, and (b) drilling machine

## 3. Discussions

This Audit reports identifies economically feasible strategies such as scheduled motor operations, turned off air-conditioners at no occupancy period and opting for LED lighting replacements. The building floor area lighting consists mostly of T8 fluorescent and compact fluorescent fixtures accounting for 0.65% of total energy consumption. Some fixtures are controlled with on/off switches. There is also need to employ the daylights through use of incandescent lamps with low reflectance within most of the corridor areas which stays lit all day. Other specific action plans are presented in sections.

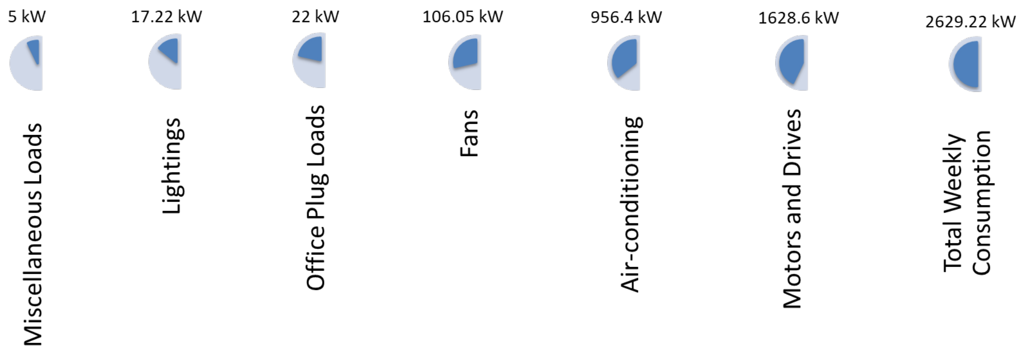


Figure 3: The Chart displaying the summary of energy unit used in total

### 3.1 Lightings

Higher efficiency LED fixtures and bulbs should replace the common T8 light bulbs to save energy costs in W/h. Dimming bi-level controls could be used along the corridor and staircase areas to maximise the energy savings by keeping this lights on all through the day thus prolonging their functional life [15]. The artificial lighting scheme in this establishment remain below the global average of 20-40% especially for small offices and toilets areas. Yet, some savings can be made when lighting systems are operated with respect to the norm efficacy and reflectance of the operating space as given in Tables 7-8.

Table 7: Standard for lighting efficacy

| Source | Lumens Range Watt |
|---|---|
| Metal halide (175 watts to 1,000 watts) | 80 to 125 |
| Fluorescent (30 watts to 215 watts) | 74 to 84 |
| Mercury (100 watts to 1,000 watts) | 42 to 62 |
| Incandescent (100 watts to 1,500 watts) | 17 to 23 |

Table 8: Recommended Reflectance Values of Surfaces

| Surfaces | Reflectance (%) |
|---|---|
| Ceiling Lightings | 80-90 |
| Walls | 40-60 |
| Desks and Bench tops | 25-40 |
| Floors | < 20 |

### 3.2 Office Equipment

Most of the equipment like computers, fax machines, printers and electronic devices represent the fastest growing part of the electrical loads in this building. Office gadgets are in the top 4 main energy consumption category. They reflect the most unpredictable energy consumption pattern, much dictated by owners of the gadgets. It is economical for users to automatically switch to a low power 'sleep mode' or off mode when non-operational and opt for more energy efficient electronic devices where possible.

### 3.3 Motors

Control of the motor output to match demand requires efficient technology and practices. A method to deliver cost savings with motors are installation of permanent magnet synchronous motors in most heavy equipment. This approach has high pay off cost particularly when equipment are underutilized, a better implementation in the machine shops would be retrofitting variable speed drives along the 3 phase induction motors used for the lathes, drill machines and other rotating devices [16]. This conservative approach would be beneficial if this equipment has less than 10 years of operational life.

The results data captured for fans have the indoor fans operating for shorter periods at set speeds and predictable consumption as opposed to the extractor fans which run chiefly at intermittent speeds of the room.

***Extractor fan data***

| | |
|---|---|
| Number of fan | 9 |
| Design capacity (cfm) | 750 |
| Power Rating (kW) | 0.35 |
| Special Phase Coil | No |
| Speed (rpm) | Variable |
| Return fan | Yes |

***Indoor fan data***

| | |
|---|---|
| Number of Fan | 68 |
| Speed (rpm) | 15 – 50 |
| Power Rating (kW) | 0.25 |
| Operating Temperature (°C) | 25-38 |

### 3.4 Component Conditions (Visual Inspection)

Other motors and machinery within the laboratories that were not operated within three months were not factored into this audit. The frequency of operation and load profile are not precise and are subjected to the use of some personnel. There was no high efficiency motor found in the workshop except for the ones present in the CNC machine. Also, it is almost impossible to have a benchmark of the number of some plug-in loads like the amount of computers in the building per time [17]. Thus a linear average over a week is reported.

### 3.5 New Technologies

Some key measures to improve the energy performance of both primary and secondary equipment in the engineering block include:

- *Inserting back up thermostat:* This add-on is very useful in the HVAC equipment. It setbacks the cooling temperature in old air-conditioners that are without thermostat, thus regulating the cooling load in a space. With this implementation energy savings during unoccupied periods would be accounted for easily.
- *Energy Management Controls:* This refers to new forms of automated controls that can be made available in places like the simulation laboratory and offices. With an energy management and control system (EMCS) having sensors and actuators, energy consumption within a facility can be continuously controlled and monitored. This would initiate real-time adjustment in the way electrical power is consumed generally.
- *Auxiliary Elements:* More energy meters to capture both electrical and thermal energy should be made available in cases where EMCS is not so affordable. It

would mean the introduction of manifolds, pressure safety valves and essentials valves in the thermodynamics and air-conditioning laboratories for long term sustainability of the products and systems within the facility.

Many of these efficient appliances appear to be cost-effective at currently projected manufacturing costs, with simple payback times that are shorter than the typical appliance lifetimes of 10–20 years. With the technological advances the costs of efficient devices are fast decreasing and future energy prices being fairly stable, potential energy savings in commercial building are technically possible and economically attractive [18]. Reduction in consumption can be achieved through retrofits of some electrical systems to decrease space cooling loads and lighting loads. Also installations of automatic controls to optimize the operation of several compressors found in the by reducing part-load operations [19], [20].

## 4. Conclusion

This energy audit identified some energy conservation approach for an academic building and recommended actions for energy management. It acts as a preliminary study leading to implementation of campus specific energy use database and national energy management programme. Different observations noticed during the exercise were made into a report and submitted to the physical planning department of the university in order to implement them after a careful economic analysis and prefeasibility study. The results from the walk-through survey showed that adjusting the motor drive speed during operating hours serves as the best technical approach for energy savings. Also building envelope should be well insulated from heat exchange, with more building sealing to effectively utilize the air-conditioner within each specified space and operating hours. This would be the second most economical saving on energy annual cost. In addition, if all suggested lighting recommendations are performed, the engineering block would be on its way to being the most energy efficient building on campus despite its high-energy use.

## 5. Recommendation

In future energy audits, analysis and simulation step (engineering calculations, heat and mass balances, theoretical efficiency calculations, computer analysis and simulation) would better evaluate the energy management options in terms of kWh and other energy efficiency indices. In all, having appliances in the department rated according to their energy efficiency index is an economic and sustainable investment.

**Acknowledgments**
Authors of this research work are grateful for the funding by the Covenant University Centre for Research and Innovation Discovery, Covenant University Ota. We would like to thank the Physical Planning and Development (PPD) department which gave approval to conduct inspection on facilities mainly installed by them. The support of the departmental head of Mechanical Engineering, Covenant University in delivering follow-up decisions and recommendations are well appreciated. In all, this work was made possible by the cooperation of esteemed members of the department.

## References

[1] Woo, J., & Moore, T. (2019). An End-User-Focused Building Energy Audit: A High-Density Multi-residential Development in Melbourne, Australia. *Energy Performance in the Australian Built Environment*, pp. 75–90.
[2] Cho, K., & Kim, S. (2019). Energy Performance Assessment According to Data Acquisition Levels of Existing Buildings. *Energies*, 12, p. 1149.
[3] Fedorczak-Cisak, M., Knap, K., Kowalska-Koczwara, A., Pachla, F., & Pekarchuk, O. (2019). Energy and Cost Analysis of Adapting an Existing Building to 2017 Technical Requirements and Requirements for NZEB. *IOP Conference Series: Materials Science and Engineering*, 471, p. 112094.

[4] Gamtessa, S., & Guliani, H. (2019). Are households with pro-environmental behaviours more likely to undertake residential energy efficiency audits? Evidence from Canada. *Energy Efficiency*, 12, pp. 735–748.
[5] Sanka, I., & Petras, D. (2019). Indoor Air Quality and Energy Audit and in an Apartment Building in Slovakia. *IOP Conference Series: Materials Science and Engineering*, 471, p. 062022.
[6] Joshi, A., Mundada, A., Suryavanshi, Y., Kurulekar, M., Ranade, M., Jadhav, N., … Despande, Y. (2018). Performance Assessment of Building by Virtual Energy Audit. *2018 International Conference and Utility Exhibition on Green Energy for Sustainable Development (ICUE)*. https://doi.org/10.23919/icue-gesd.2018.8635695
[7] Nabitz, L., & Hirzel, S. (2019). Transposing The Requirements of the Energy Efficiency Directive on Mandatory Energy Audits for Large Companies: A Policy-Cycle-based review of the National Implementation in the EU-28 Member States. *Energy Policy*, 125, pp. 548–561.
[8] Soni, S., Kaur, I., & Kumar, D. (2019). Optimization of Electricity Bill on Study of Energy Audit by Using Grid Integration of Renewable Energy Sources. *Cognitive Informatics and Soft Computing*, pp. 669–676.
[9] E. Leiva, S. Villacreses, and D. S. Benitez, "Electrical Energy Audit of University Buildings: Case Study at Universidad San Francisco de Quito," 2018 IEEE ANDESCON. 2018.
[10] Roberts, C., Bobrova, Y., & Marjanovic-Halburd, L. (2019). Impacts of energy legislation on organizational motivation: a case study. *Building Research & Information*, 47(2), pp. 234–244.
[11] TWen, T. W., & Palanichamy, C. (2018). Energy and Environmental Sustainability of Malaysian Universities Through Energy Conservation Measures. *International Journal of Energy Economics and Policy*, 8(6), 186–195.
[12] Wohlfarth, K., Klobasa, M., & Eßer, A. (2019). Setting course for demand response in the service sector. *Energy Efficiency*, 12, pp. 327–341.
[13] Akinbami, J.-F., & Lawal, A. (2009). Opportunities and challenges to electrical energy conservation and CO2 emissions reduction in Nigeria's building sector. *Fifth Urban Research Symposium, Cities and Climate Change: Responding to an Urgent Agenda*, 28–30.
[14] Boharb, A., Allouhi, A., Saidur, R., Kousksou, T., & Jamil, A. (2017). Energy conservation potential of an energy audit within the pulp and paper industry in Morocco. *Journal of Cleaner Production*, 149, pp. 569–581.
[15] Doukas, D. I., & Bruce, T. (2017). Energy Audit and Renewable Integration for Historic Buildings: The Case of Craiglockhart Primary School. *Procedia Environmental Sciences*, 38, pp. 77–85.
[16] Ghadi, Y. Y., & Baniyounes, A. M. (2018). Energy Audit and Analysis of an Institutional Building under Subtropical Climate. *International Journal of Electrical and Computer Engineering*, 8(2), p. 845.
[17] Belussi, L., Danza, L., Salamone, F., Meroni, I., Galli, S., & Svaldi, S. D. (2017). Integrated smart system for energy audit: methodology and application. *Energy Procedia*, 140, pp. 231–239.
[18] McNeil, M. A., Feng, W., de la Rue du Can, S., Khanna, N. Z., Ke, J., & Zhou, N. (2016). Energy efficiency outlook in China's urban buildings sector through 2030. *Energy Policy*, 97, pp. 532–539.
[19] Johansson, M. T., & Thollander, P. (2018). A review of barriers to and driving forces for improved energy efficiency in Swedish industry– Recommendations for successful in-house energy management. *Renewable and Sustainable Energy Reviews*, 82, pp. 618–628.
[20] Krarti, M. (2016). *Energy Audit of Building Systems: An Engineering Approach, Second Edition*. CRC Press.