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ENERGY CONSERVATION THROUGH ENERGY AUDIT IN U-TEC: A CASE STUDY

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ABSTRACT

An energy audit is a systematic process used to assess energy consumption patterns and identify opportunities for enhancing efficiency and reducing operational costs. This study focused on conducting a comprehensive energy audit at United Technical College (U-TEC), Chitwan, with an emphasis on lighting systems, ceiling fans, and solar integration. The total connected load was found to be 174.07 kW, with a maximum active power demand of 11.74 kW and a low load factor of 36.13%, indicating underutilization of installed capacity.The audit proposed replacing traditional lighting and fan systems with energy-efficient alternatives such as LED tube lights and BLDC fans, resulting in an estimated annual energy cost saving of Rs. 282,594.77 and a payback period of 2.38 years. Additionally, the integration of a 20-kW solar photovoltaic system was recommended, offering further savings and a projected payback period of 4.3 years. These findings demonstrate that strategic energy interventions can significantly reduce energy consumption, enhance sustainability, and lower operational costs for educational institutions.

Keywords: *Energy audit, load analysis, energy efficiency, lighting audit, solar integration*

1. Introduction

Electrical energy is a vital resource that powers various sectors including education, industry, healthcare, and residential buildings. As institutions expand their operations, their energy consumption increases, often resulting in inefficiencies, higher costs, and environmental impacts. Energy audits serve as a strategic approach to evaluate when, where, and how energy is used in a facility, enabling the identification of wastage and proposing targeted efficiency improvements (Capehart, B.L., Turner, W.C. and Kennedy, W.J., 2020).

An energy audit is typically carried out in phases—preliminary, detailed, and post-audit—each providing insights into consumption patterns and system performance (Bhagwan et al., 2020). By identifying inefficiencies and recommending alternatives such as energy-efficient equipment or operational changes, audits can significantly reduce energy bills, improve performance, and contribute to sustainable practices (Mathur, A. and Muthukumaraswamy, S.A., January 2017).

In the context of educational institutions, where lighting, fans, and computing devices contribute significantly to the total energy load, energy audits are particularly beneficial. This study presents a case-based energy audit of United Technical College (U-TECH), Chitwan. The uniqueness of this audit lies in its comprehensive approach—combining lighting and fan system upgrades with the proposal for solar photovoltaic (PV) system integration and cost-benefit analysis.

The main objective of this study is to assess the current energy consumption pattern, identify major inefficiencies, and propose feasible, cost-effective energy-saving measures. By doing so, this paper aims to provide a replicable model for energy conservation in similar institutional settings.

1.1 Literature Review

ASHRAE Energy Audit Levels

Energy audits are an essential tool for assessing and improving energy efficiency in buildings and industrial facilities. According to ASHRAE, energy audits are categorized into three levels: Level 1 (Walk-through Audit), Level 2 (Detailed Energy Survey), and Level 3 (Investment-Grade Audit). Each level provides varying depths of analysis and recommendations based on the complexity of energy systems and organizational needs. (Mathur, A. and Muthukumaraswamy, S.A., January 2017)

Audit of Al Azhar School – Wicaksono (2022)

Research conducted by Agung Wicaksono, a student at Tanjungpura University, Department of Electrical Engineering, in 2022 with the title "Energy Audit and Opportunities for Saving Electrical Energy at Al Azhar Islamic Elementary School 21 Pontianak “which discussed the size of IKE and PHE at SD Islam Al Azhar 21 Pontianak in 2019. From the calculation of IKE, it was still relatively efficient in 2019. The difference in electricity consumption before and after PHE was carried out was 7,614.484 kWh/m^2 per year. (Khabaranus, Y., Purwoharjono, P. and Gianto, 2023).

Energy Audit & Management – Capehart et al.

Research by Capehart, Turner, and Kennedy (2020) in their book Guide to Energy Management highlights that energy audits not only identify inefficiencies but also help organizations meet sustainability goals, reduce operational costs, and ensure compliance with energy regulations. (Capehart, B.L., Turner, W.C. and Kennedy, W.J., 2020).

Building Audits & Climate Impact – Santamouris (2016)

Studies, such as those by Santamouris (2016), emphasize the importance of energy audits in buildings to mitigate climate change impacts. Building energy audits are shown to reduce energy consumption by 15-30% on average through measures like improved insulation, efficient lighting, and advanced HVAC systems. (Santamouris, 2016)

Residential Audit Using E-TAP – Kumar et al.

Awanish Kumar et al. the audit was conducted in 2015 for 25 residential houses. In this they gave recommendations for using E-TAP software. From the layout of the house the daily power utilization chart and the graph for equipment wattage, age analysis and tariff analysis of house were drawn. There are 3 types of recommendations they are recommendations without investment which gives 20% saving and the second one is recommendations with savings in this the units saved is 7244.1 which in turn can save Rs22876.7 and the third one is recommendation with distributed generation (D.G) estimated savings in unit consumption is 25% of present tariff with payback period of 5 years. (Kumar, 2015)

Engineering University Audit – Arya et al.

Abhishek Arya et al. The audit was conducted between 2015-2016 in an engineering university. The installation of 5250MW which is equivalent to Rs 1800 corers/year energy can save through energy auditing. Through this it can be known how much energy wasting and how to reduce that energy usage. The recommendations used are ESA program, e-man, automation, rearrangement and wastage reduction awareness program. By using these recommendations with a minimum investment of Rs50000 per annum and savings of Rs54000. (Arya, A., Bhattacharya, A. and Biswas, P.K., 2024)

UTU Campus Energy Audit – Desai et al.

A case study conducted by Desai et al.(2017)show that the building of Uka Tarsadia University devoted a monthly average electrical energy of 1.3 laces kWh and having a potential to save 0.3 laces kWh of energy, a 21%electrical energy saving potential The energy audit was carried out on the lighting system, air conditioning system and PC'S and fan in UTU the systems consuming 11%, 37% and 34% of total electrical energy consume respectively and the equipment were found to be operating at low energy efficiency. (Desai, U., Patel, J., Patel, J., Rana, A. and Vora, D., 2017)

Area-Based Audit in Finland – Heinonen et al.

Jukka Heinonen et al. conducted audit in 2016 at Finland. They separated the total area into two areas. The first one is rural area, and the second one is Urban area. This area is further classified into three, they are detached houses, apartment building, terrace/row building. The products that are taken as perceptive are home and communal electricity, heating oil and firewood. They presented the result in per household, per capita, which gives the best outcome of about 70%. (Heinonen, J. and Junnila, S., 2014, 2014)

2. Materials and methods

2.1 Overview

The methodology for conducting an electrical energy audit involves a structured and systematic approach to assess and improve energy usage across the facility. The process begins with defining the audit scope and objectives, followed by data collection, site inspection, and technical measurements. Consumption patterns are analyzed to identify inefficiencies and propose energy-saving opportunities, such as equipment upgrades or process optimization. A financial analysis is then conducted to prioritize the most cost-effective measures based on return on investment (ROI) and payback period. Finally, a comprehensive audit report is generated with actionable recommendations, and post-implementation monitoring ensures sustained performance improvements.

2.2 Methodological Approach

The following steps outline the methodological approach adopted for the energy audit at United Technical College:

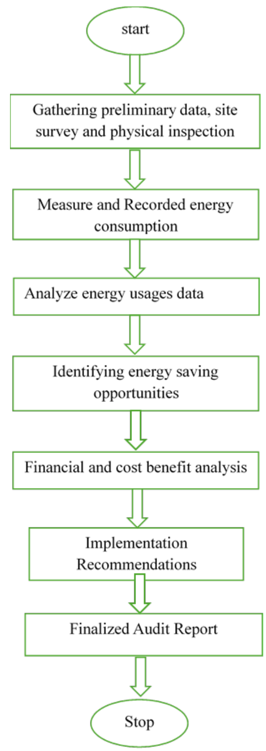

Figure 1 Methodological Approach

1. Gather Preliminary Data

Collected basic information about the campus, including total floor area, types of rooms (classrooms, laboratories, faculty offices) and typical electrical equipment in use.

Reviewed past 12 months of electricity bills to understand monthly consumption patterns, load factors and tariff rates.

2. Site Survey and Physical Inspection

A complete walkthrough of the college buildings was performed.

All energy-consuming appliances such as ceiling fans, lights, air conditioners, computers and projectors were identified and logged.

Each room's appliance inventory was recorded by type, quantity and location.

3. Measure and Record Energy Consumption

To ensure technical accuracy, the following instruments were used:

Clamp Meter (AC/DC): For measuring current flowing through live conductors.

Digital Multimeter: For voltage, resistance, and current verification.

4. Analyze Energy Usage Data

All data was compiled into spreadsheet models.

Total energy consumption for each appliance type and room was calculated using the formula:

$$\boldsymbol{Energy}\ (\boldsymbol{kWh}) = \frac{Power\ (W) \times Operating\ hours\ per\ day\ \times\ Days\ per\ Month}{1000}$$

High-consumption areas and anomalies between expected and actual consumption were identified.

5. Identify Energy-Saving Opportunities

Outdated equipment was identified inefficient such as:

Ceiling fans (80W)

Tube lights (40W)

CFLs (18–24W)

Recommended replacement included:

BLDC fans (30W)

LED tube lights (18W)

These replacements offer the potential to reduce overall energy consumption and electricity costs significantly.

6. Financial and Cost-Benefit Analysis

Energy savings per device were calculated.

Cost savings were estimated by multiplying energy savings by the applicable electricity tariff.

Payback period was calculated using the formula:

$$Payback\ Period = \frac{Initial\ Inevstment}{Annual\ Savings}$$

7. Prepare Audit Report

A detailed report was prepared including:

- Room-wise and floor-wise load inventories
- Energy-saving suggestions
- Estimated annual savings
- Payback period and ROI

This report serves as a guide for the college administration to make informed decisions regarding energy efficiency improvements

8. Implement Recommendations

Implementation strategies include:

- Procurement and installation of energy-efficient fans and lighting
- Awareness programs for staff and students to encourage responsible usage
- Recommendation for energy monitoring systems to ensure continuous performance tracking

2.3 Monthly Energy Consumption Pattern

A monthly energy consumption pattern was assessed using historical electricity bills (in kWh) and plotted in a pie chart.

The pie chart presents the monthly energy consumption pattern (in kilowatts, kW) at United Technical College over a one-year period based on the Nepali calendar. The data visually illustrates the distribution of electricity usage across each month, revealing significant variation in consumption levels.

From the chart, Ashadh records the highest energy consumption at 3216 kW, followed closely by Jestha (3054 kW) and Shrawan (2468 kW). This suggests peak electricity demand during the summer monsoon period, likely due to increased cooling loads such as fans, air conditioning systems, and other electrically powered ventilation equipment.

In contrast, the lowest consumption is noted in Chaitra (987 kW), followed by Kartik (1068 kW) and Falgun (1262 kW). These months fall in the cooler seasons, where reduced dependency on artificial cooling and possibly fewer academic or operational activities may contribute to lower electricity usage.

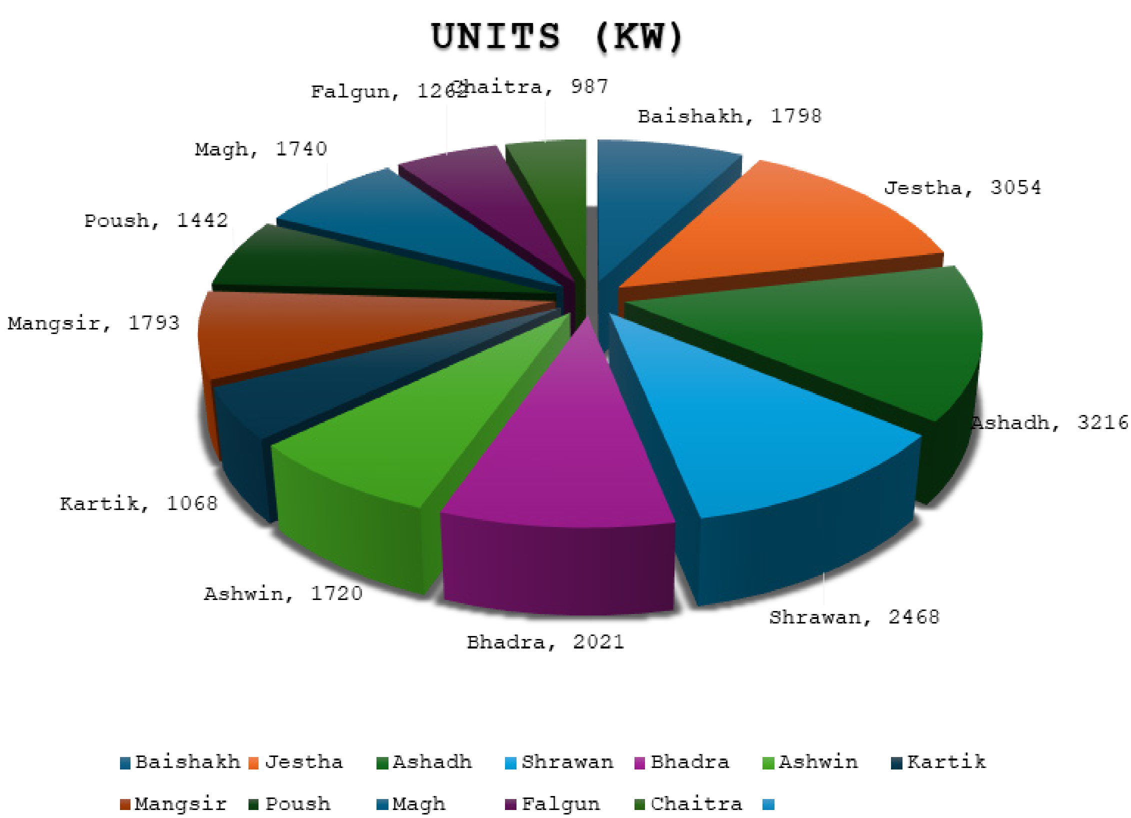

Figure 2 Monthly energy consumption pattern

Intermediate levels of energy consumption are observed in months like Baishakh (1798 kW), Mangsir (1793 kW), Ashwin (1720 kW), and Magh (1740 kW), indicating moderately active energy demand during transitional periods.

Overall, the data highlights clear seasonal trends and underlines the importance of load management and targeted energy efficiency interventions, especially during high-demand months, to ensure optimized energy use and cost savings.

2.4 Energy Consumption of Different Section of College

Energy audit consists of several tasks which can be carried out depending on the type of audit and the size and the function of the audited facility. Therefore, an energy audit is not a linear process and is rather iterative. The audit described in this paper was carried out within a six-month time frame based on the following functional activities.

- Building data analysis.
- Walk through survey
- Base line for building energy use.
- Evaluation of energy saving measures

For this audit, the primary focus was on replacing conventional lighting and fan systems with more energy-efficient alternatives. Fluorescent lamps and CFLs were replaced with equivalent LED fixtures. Similarly, standard ceiling fans were proposed to be replaced with BLDC (Brushless Direct Current) fans.

Table 1 Energy uses of different floors and blocks

S. N	Different sections	Load in watt	Yearly Saving (Rs)
1	Ground floor	13713.5	64713.7
2	1st floor	16033	33675.19
3	2nd floor	5484	60344.13
4	3rd floor	5536	50060.77
5	4th floor	31183	30021.39
6	5th floor	6680	0
7	Mechanical workshop	21468	0
8	Electrical engineering lab	19514	866.36
9	Electrical and Electronic lab	15176	761
10	Thermal lab	7303	263.67
11	Block B	15844	291.92
12	Block C	7886	8475.3
13	Block D	10203	33091.34
Total		**174071**	**282594.77**

For this audit, the primary focus was on replacing conventional lighting and fan systems with more energy-efficient alternatives. Fluorescent lamps and CFLs were replaced with equivalent LED fixtures. Similarly, standard ceiling fans were proposed to be replaced with BLDC (Brushless Direct Current) fan.

$$Payback\ period = \frac{Investment}{Total\ saving} = 2.38\ yrs$$

As part of the proposed improvements, the integration of solar photovoltaic (PV) systems is recommended to further reduce the college's dependence on grid electricity and to promote sustainable energy use.

Since U-TECis situated in a prime location having average sunny hours per day. Due to the availability of rooftop space, investing in 20KW solar system could be the best alternative. To produce 20KW of solar energy, approximately 100m2 of shadow free installation space is required, which is available. Estimated daily energy generation of 142 kWh. Total expenses of solar will be Rs.2580000.

$$Payback\ Period\ = \frac{2580000}{604756.18} = 4.26$$

So, the payback period for solar is nearly 4.3yrs.

3. Results and Discussions

Through our energy audit and technical analysis, the following key findings and interpretations were made:

3.1 Load Analysis

The maximum active power record was 11.74 kW at 6:30 AM, as shown in Table 2.1.

The average demand was calculated as:

$$Average\ demand\ = \frac{203.579}{48} = 4.24KW$$

The total connected load of the college was found to be 174.07 kW.

From this,

$$Load\ Factor\ = \frac{4.241}{11.74} * 100\% = 36.13\%$$

$$Demand\ Factor\ = \frac{11.74}{174.071} * 100\% = 6.74\%$$

These low load and demand factors indicate that the actual utilization of installed capacity is very low. Therefore, energy efficiency improvements and optimization of equipment usage are necessary.

3.2 Energy Saving and Financial Analysis

With proposed replacements, the projected annual saving is = Rs. 282594.77

The initial investment required for energy-efficient installations is = Rs. 672675

Thus,

$$Payback\ period\ is\ = \frac{672675}{282594.77} = 2.38\ yrs$$

This shows that the investment can be recovered in just over two years, making the project financially viable.

3.3 Recommendation of Solar with Net Metering

Total unit consumption by college in year = 22,461

Total unit generated by proposed solar system = 51,859.20

NEA purchase rate per unit = NRs 4.95

Yearly saving from solar = 29,398.2* 4.95 = NRs 144,051.18

Yearly Collage Expenses = NRs 412,665

Yearly expenses of using DG = NRs 148,040

Yearly Saving = 144,051.18 + 412,665 + 148,040 = NRs 704,756.20

Min Power Demand Rate per month = NRs 350/kVA

Total Power demand cost per year = 350*25*12 = NRs 105,000

Total Payback Return = 704,756.2 – 105,000 = NRs 599,756.20 yearly

So, the payback period for solar is 4.30 yrs

Hence, solar installation with net metering is highly recommended as it not only covers current consumption but also generates excess power for revenue.

3.3 Discussion

The energy audit highlights major inefficiencies in usage and demand planning. Energy-efficient replacements and solar installation offer short payback periods and significant long-term savings. Overall, the combination of efficient electrical equipment, solar power with net metering, and strategic load management will make the college more energy-resilient and cost-effective.

Proposed air conditioning fits within the current NEA demand contract, optimizing usage without extra cost.

4. Conclusions

The energy audit conducted at U-TECH successfully identified key areas where energy consumption can be optimized, leading to significant cost savings and improved energy efficiency. Through detailed load analysis, it was found that lighting systems, ceiling fans, and air conditioning units contributed heavily to the overall energy use. By recommending the replacement of traditional appliances with energy-efficient alternatives such as LED lights and BLDC fans, as well as suggesting the installation of a solar PV system, the project demonstrated feasible methods to reduce energy consumption and operational costs.

Economic analysis further supported the practicality of these solutions, showing a favorable payback period for the proposed investments. Additionally, the load factor analysis revealed potential for improved load management, which can contribute to more efficient energy usage and reduced peak demand charges.

In conclusion, this project emphasizes the importance and effectiveness of energy audits in industrial and institutional settings. By implementing the recommended changes, U-TECH can not only achieve substantial energy and cost savings but also contribute to environmental sustainability by reducing its carbon footprint.

This audit was limited to electrical energy consumption; future audits could incorporate thermal systems or real-time smart monitoring solutions

5. Conflict of Interest

No conflict of interest.

6. Acknowledgement

We would like to express our heartfelt gratitude to United Technical College for providing the opportunity and support to complete this project. Our sincere thanks go to the faculty members, administrative staff, and the Department of Electrical and Computer Engineering for their valuable guidance and encouragement throughout the project. We also extend our appreciation to the entire college community, including security personnel, cleaning staff, and maintenance workers whose contributions, though often behind the scenes, were essential to our work. Finally, we are thankful to our friends and families for their constant support and motivation.

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Appendix

A Load Distribution Plan of College Building