Energy Conservation in a Hospital Building through Energy Audit - A Case Study

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Abstract
In the face of rising energy demands and environmental concerns, energy conservation has become a crucial imperative across all sectors. In particular, healthcare facilities such as hospitals are among the most energy-intensive building types due to their continuous operations, stringent indoor climate control, and reliance on advanced medical equipment. This study presents the findings of a detailed energy audit conducted at a medium-sized tertiary-care hospital in a humid tropical region of southern India. The facility operates 24×7 and consumes energy at rates 2–3 times higher than standard commercial buildings. The audit involved systematic data collection, end-use energy monitoring, load profiling, and the identification of ten energy conservation measures (ECMs). The key contributors to energy consumption were found to be HVAC systems, lighting, and UPS equipment. The proposed ECMs including LED retrofitting, HVAC upgrades, solar integration, and operational changes were estimated to yield annual savings of approximately 4.48 million with a total investment of 8.92 million and a payback period of about 24 months. The study highlights the critical role of targeted audits in promoting energy efficiency in healthcare infrastructure and offers recommendations for sustainable operational improvements through both technical and behavioural interventions.

Keywords: Energy Conservation, Energy Audit, Energy Conservation Measures (ECMs), Hospital, HVAC, Sustainable, Energy Efficiency

Introduction

Energy audits are indispensable for optimizing energy consumption and curtailing operational costs, particularly in buildings and hospitals that operate around the clock. Several studies emphasize that conducting a detailed energy audit and occupant survey is essential for reducing uncertainties in building energy simulations; however, inherent variability persists due to the stochastic nature of input parameters such as occupant behaviour, internal loads, and environmental conditions (Ahn et al., 2016). The escalating energy demands of healthcare facilities, particularly specialized cancer hospitals, necessitate a comprehensive understanding and implementation of energy-efficient strategies. These institutions, characterized by their energy intensive operations involving advanced medical equipment, stringent environmental control requirements, and extended operational hours, contribute significantly to overall energy consumption. Given the resource-intensive nature of hospitals, encompassing electricity, water, food, and construction materials, the adoption of sustainable measures is crucial for mitigating their environmental impact (Dhillon & Kaur, 2015). The healthcare sector globally contributes a substantial 4.4% to global emissions, with a significant portion originating from developed economies and China (Liu et al., 2020). In light of these factors, a thorough energy audit and the subsequent implementation of conservation measures are not merely cost-saving initiatives but also ethical imperatives for responsible resource management and environmental stewardship (Liu et al., 2020).

An energy audit serves as a foundational step towards identifying and quantifying energy consumption patterns within a healthcare facility, enabling the formulation of targeted energy conservation measures. This process involves a systematic evaluation of energy-consuming systems, including HVAC (heating, ventilation, and air conditioning), lighting, medical equipment, and building envelope, to pinpoint areas of inefficiency and potential energy wastage (Mahajan & Badgujar, 2020). The audit further facilitates the development of a comprehensive energy management plan, encompassing strategies for optimizing energy utilization, reducing energy costs, and minimizing environmental impact. Furthermore, a well-executed energy audit can reveal inefficiencies in building systems, equipment operations, and energy usage patterns, paving the way for targeted interventions that enhance energy efficiency and reduce carbon footprints (Fotovatfard & Heravi, 2021). Ensuring the proper functioning of physical assets is essential for optimizing performance, and addressing this through energy audits can lead to the development of effective energy management strategies (Lazim et al., 2015).

Hospitals are among the most energy-intensive building types, due to 24×7 operation, stringent indoor climate needs, and intensive equipment use (Hwang et al., 2019). Typical hospitals consume around 423 kWh/m²•year, roughly 2–3 times the energy of commercial buildings. This high energy use makes efficiency a key policy and management objective in healthcare. An energy audit; an analysis of energy flows to identify efficiency opportunities is a critical first step in this context (Bensouda et al., 2023). Hospitals, in particular, demand stringent environmental controls and rely on an array of energy-intensive equipment to deliver optimal patient care, making them substantial energy consumers (Kyriakarakos & Dounis, 2020).

In this study, an energy audit was conducted for a medium-sized tertiary-care hospital located in the humid tropical region of southern India. Established in 2001, the facility operates round-the-clock and has demonstrated prior commitment to sustainability, having received a state-level energy conservation award. For confidentiality, the hospital's name is withheld; only its general location, functional category (specialized cancer care), and scale (approximately 224 beds, with planned expansion to 250) are disclosed. The audit aimed to quantify current energy consumption and costs, and to identify Energy Conservation Measures (ECMs) capable of reducing both without compromising patient care. The approach was informed by relevant literature, including previous hospital audit studies and established guidelines for detailed energy audits.

Methodology

The audit followed a standard detailed energy audit process as per Bureau of Energy Efficiency Govt. of India.

- Energy consumption data for 12 months both electricity and fuels if applicable were collected and analyzed to develop baseline energy use. By using portable energy meters on site measurement of electricity consumption for major energy systems like Chillers, A/c s, pumps and lightings were measured and recorded.
- Apportion overall energy use to end-uses. For example, motor-driven pumps and blowers were logged over 15-minute intervals to determine load factors.
- Based on the load profile and plant performance, list potential measures (e.g. LED lighting retrofit, pump optimization, HVAC tuning, capacitor banks, renewable generation).
- Estimate savings and costs for each ECM. For instance, lighting and HVAC improvements were evaluated for annual kWh savings and payback.

This methodology (data gathering, field measurements, analysis, reporting) follows recognized audit guidelines. All measurements were done with calibrated instruments A base case annual energy use and cost were established from utility bills and generator records, against which potential savings were calculated.

Rationale for Choosing a Healthcare Facility

The selection of a public-sector tertiary cancer care hospital in a humid tropical region of southern India, as the case study for this research was guided by several critical factors. Firstly, the hospital operates 24×7 with a high patient load and energy-intensive equipment, making it a representative example of facilities with substantial and continuous energy demands. Its classification as a a medium-sized tertiary-care hospital, funded and managed under the Health and Family Welfare Department of a humid tropical region of southern India, reflects the broader challenges faced by public healthcare infrastructure in balancing clinical excellence with operational sustainability. Furthermore, the facility's demonstrated commitment to energy-conscious practices evident in its receipt of the a humid tropical region of southern India State Energy Conservation Award, makes it an ideal setting for evaluating the impact of structured energy audits and interventions. Its integrated care model, which includes radiotherapy, chemotherapy, and surgical oncology, ensures the presence of diverse energy-consuming systems, from HVAC and sterilization units to diagnostic equipment. These characteristics provide a robust platform for assessing the feasibility, cost-effectiveness, and replicability of energy conservation measures in healthcare settings across India. The important point associated with the case study data collection are as follows: The hospital meets its substantial energy demand primarily through electricity supplied by the a humid tropical region of southern India State Electricity Board (the regional electricity supply utility), supplemented marginally by a 15 kWp solar power plant and, occasionally, diesel generators during power outages.

Energy Audit Observations and Data Interpretation

Electrical and Operational Insights from Energy Audit: The hospital meets its high energy demand primarily through grid supply from the regional electricity supply utility, with limited support from a 15 kWp solar plant and occasional use of diesel generators during outages. Consuming around 3,381 MWh annually at an average rate of 7.0/kWh, the facility incurs an energy cost of approximately 2.4 crores per year, highlighting the need for effective conservation measures.

Study on Electricity Consumption

Data have been collected towards electricity consumption pattern of this Centre for the past 3 years and are tabulated below in Table 1. It can be seen from the above figure that there is a steady increase in the electricity consumption year - on – year.

Table 1 Monthly Electricity Consumption at the Hospital (kWh) for a Typical Three Years

Month	Year-1	Year-2	Year-3
Jan	2,30,040	2,42,310	2,40,260
Feb	2,12,886	2,30,070	2,49,070
Mar	2,48,418	4,192	2,78,040
Apr	2,40,054	2,68,460	2,91,140
May	2,54,490	2,70,640	3,11,640
Jun	2,22,576	2,35,830	2,73,320
Jul	2,16,926	2,33,240	2,61,250
Aug	2,27,410	2,32,490	2,65,800
Sep	2,18,290	2,60,590	2,58,460
Oct	2,39,500	2,56,270	2,75,740
Nov	2,45,970	2,53,350	2,84,470
Dec	2,43,390	2,53,670	2,95,430
Total	27,99,950	27,36,920	32,60,020
Avg	2,33,329	2,48,811	2,71,668

Table 2 Computed Load Factor (July 2nd Year to February 3rd Year)

Month	Recorded Demand (kVA)	Average Demand (kVA)	Load Factor (%)
Jul-19	592	337	56.9
Aug-19	598	369	61.7
Sep-19	616	398	64.6
Oct-19	630	375	59.5
Nov-19	620	402	64.8
Dec-19	681	440	64.7
Jan-20	622	365	58.7
Feb-20	716	453	63.2
Avg	—	—	**62.2%**

Load Factor

The Load Factor is a measure of how efficiently the hospital utilizes its sanctioned electrical demand. It is calculated as the ratio of the average power (kVA) used to the maximum recorded demand over a period. A higher load factor indicates better utilization of the connected load, while a lower value implies underutilization or inefficiencies. For the period from July (2nd Year) to February (3rd Year), the average load factor was 61.6%, suggesting a moderate level of demand utilization. The month-wise load factor varied between 56.9% and 64.8%, as shown in Table 2.

Energy Cost Spent

The energy charges payable to the electricity utility comprise three primary components: (i) Energy Charges (kWh-based), (ii) Demand Charges (kVA-based), and (iii) Other Charges, which include electricity duty, penalties, interest, and incentives. Table 3 and Figure 1 present the component-wise cost share, derived from monthly billing data. The energy charges constitute the largest share at 79.4%, followed by demand charges at 12.0% and other miscellaneous charges at 8.6%. These figures suggest a reasonably balanced consumption pattern and optimized utilization of contracted demand. Nevertheless, demand-side improvements and load optimization can further reduce recurring costs.

Table 3 Energy Cost Share Pattern – Average

Component	Cost (₹/ month)	Share (%)	Remarks
Energy Charges	15,62,589	79.4	kWh contribution + Power Factor (PF) incentives
Demand Charges	2,34,042	12.0	Based on kVA contribution
Other Charges	1,71,582	8.6	Electricity duty, interest, meter charges, etc.
Total	**19,68,213**	**100.0**	

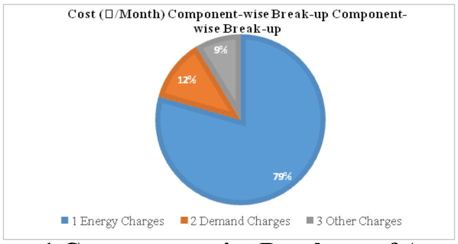

Figure 1 Component-wise Break-up of Average Monthly Energy Cost

Section wise Energy Distribution

To better understand how energy is distributed across the hospital campus, a consolidated group-wise analysis of energy consumption was conducted. The built environment was categorized into four functional groups: Group 1: Administration Block, Treatment Block, and In-Patient Block, Group 2: Open Well, Transfer & Sewage Pumping Stations, Group 3: Canteen and ATM and Group 4: Residential and institutional buildings such as the Director's Residence, Doctor Residences, Nurse College, and Dormitory. Group 1 emerged as the dominant energy consumer, accounting for approximately 92.4% of the total monthly consumption (2,65,057 kWh/month out of 2,86,707 kWh/month). In contrast, Groups 2, 3, and 4 collectively consumed only 7.6%, highlighting their relatively minor contribution as shown in Table 4.

Table 4 Energy Consumption – Groupwise (Consolidated)

Group ID	Buildings	Energy Consumption (kWh/month)	Share (%)
1	Administration Block, Treatment Block & In-Patient Block	2,65,057	92.4
2	Open Well, Transfer & Sewage Pumping Stations	13,080	4.6
3	Canteen & ATM	3,302	1.2
4	Residence Director, Residence Doctor, Nurse College, Nurse Hostel & Dormitory	5,268	1.8
	Total	**2,86,707**	**100.0**

This consumption pattern is visually represented using a Pareto Chart (Figure2), which confirms the "80/20" principle, where a small portion of the facility is responsible for a majority of the energy usage. Given this insight, the focus of energy conservation strategies was directed toward the utilities and operations within Group 1 buildings, where maximum savings potential lies.

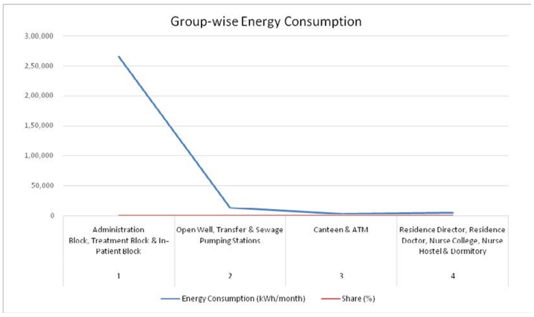

Figure 2 Pareto Chart of Group-wise Energy Consumption

Electrical Measurements on Motors – An Analysis

A detailed assessment of motor loading based on kW and ampere measurements was carried out to evaluate operational efficiency and identify potential risks of electrical failure. Out of 20 motors examined, 6 motors (30%) were found to be overloaded beyond 100% of their rated kW capacity, posing a high risk of breakdown due to overheating or coil damage. These motors require immediate attention and corrective measures. In the optimal range (90–100% kW loading), 3 motors (15%) were operating efficiently but must be monitored regularly to prevent creeping into overloading conditions. The remaining 11 motors (55%) fell under the normal or acceptable loading range (70–90%), indicating satisfactory performance with scope for improvement. On the amperage front, 7 motors exceeded 100% current draw, further emphasizing the urgency of checking alignment between electrical and mechanical loadings. While overall performance trends toward the satisfactory region, the objective must be to bring all motors into the "good" or "optimal" loading category to ensure long-term reliability and avoid service disruptions. Table 5 categorizes 20 motors based on their percentage loading levels, classifying them as normal, optimal, good, or overloaded to help prioritize maintenance actions.

A bar chart as represented in Figure 3 indicates the number of motors in each kW loading category, highlighting the concentration of motors in the optimal and overloaded ranges. Furthermore, Figure 3, a graphical represents motor performance across different loading conditions, useful for visualizing distribution and identifying extremes requiring attention.

Table 5 Motor Loading (kW) - Consolidated Summary

% Loading	No. of Motors	Remark
70–80	4	Normal
80–90	7	Optimal
90–100	3	Good
> 100	6	Overloaded
Total	20	

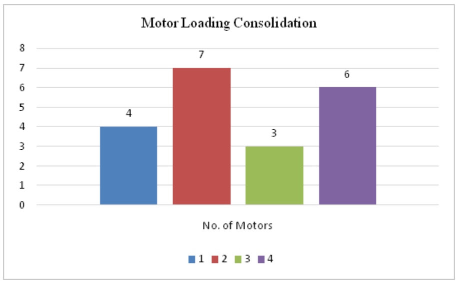

Figure 3 Histogram of Motor Loading Consolidation (kW Front)

Utility-Wise Energy Performance

A comprehensive performance analysis was conducted across eight key utility systems within the hospital: transformers, air-conditioning systems, UPS units, water pumps, STP aeration blowers, water heating systems, illumination, and capacitor banks. The findings highlight both strengths and areas requiring immediate intervention. Older air conditioners demonstrated poor performance and should be replaced with newer energy-efficient models using R407A refrigerant. The UPS systems particularly oversized and under loaded, contribute significantly (about 7%) to daily energy loss and require rationalization. Pump performance was suboptimal, with low operating efficiencies (20–30%), necessitating better monitoring infrastructure. While solar water heaters perform well, additional installations can offset high electricity use from sterilizers. The STP blowers were found under performing, with efficiencies far below expected norms. Illumination systems show potential for major savings through LED retrofitting and voltage optimization. Capacitor banks maintain a high power factor (0.99), though minor functional issues remain. Collectively, the study underscores the importance of targeted retrofits, system resizing, operational adjustments, and equipment upgrades for improving energy efficiency across utilities.

Findings and Recommendations

The audit revealed the hospital's energy usage pattern and cost drivers. Consistent with literature, HVAC systems dominated electricity use, on the order of ~50%, with lighting (≈15%) and medical equipment (≈10%) as significant shares. Other loads included water pumping, steam boilers, and laboratory equipment. Measured power factors were generally low (0.80–0.90 range), and some motors ran under low load (reducing efficiency). Power from the grid (the regional electricity supply utility) was supplemented by diesel generators during outages, incurring higher costs.

Energy Conservation Measures (ECMs)

A comprehensive six-day energy assessment was conducted across all major utility systems of the healthcare facility using advanced instruments. The audit revealed substantial potential for energy savings through targeted, system-level interventions. Based on the findings, 10 Energy Conservation Measures (ECMs) were proposed and organized utility-wise to support informed, techno-economic decision-making by the management. As summarized in Table 6, the full implementation of these ECMs could result in annual savings of approximately 4.48 million, against a one-time investment of 8.92 million yielding a payback period of around 24 months and a return on investment (ROI) of 50%. Notably, three of the ten ECMs required minimal or no investment, yet offered savings of 0.59 million annually, while the remaining seven measures with moderate investment delivered the bulk of the financial return. Key proposals included retrofitting LED lighting, optimizing HVAC operations, relocating or resizing UPS systems, installing solar water heating solutions, improving motor and pump efficiencies, and enhancing power factor through capacitor banks.

Table 6 Utility-wise Energy cum Cost Conservation Proposals

Utility	Proposal Summary	Cost Savings (₹/year)	Investment (₹)	Payback Period (months)	ROI (%)
Air Conditioning	Replace R-22 A/Cs with R407A efficient models	21,70,000	45,00,000	25	48
Air Conditioning	Avoid placing UPS in A/C rooms	5,88,000	Marginal	Immediate	-
UPS Systems	Switch off UPS for diagnostic loads during idle hours	1,46,300	Nil	Immediate	-
Fans	Replace ceiling fans with BEE-rated BPDC fans	3,67,500	12,00,000	39	31
Illumination	Retrofit LED lights	29,10,600	5,00,000	21	57
Water Heating	Replace electric geysers with solar heaters	95,550	2,00,000	25	48
Water Heating	Preheat feed water to sterilizers using solar heating	57,085	1,50,000	31	38
Water Heating	Use solar thermal tech to meet steam requirements	6,30,000	20,00,000	38	32
Blowers & Compressors	Replace V-belts with energy-efficient cogged belts	24,500	70,000	34	35
Thermal (LPG)	Install bio-methanation plant for biogas use in canteen	1,10,250	3,00,000	33	36

Grouping of Energy Conservation Measures (ECMs)

The bar chart as shown in Figure 4categorizes the ten proposed ECMs based on their required investment levels. Three ECMs fall into the high investment category (≥ ₹12 lakhs), four require medium investment (₹1.5-5 lakhs), and three require nil or minimal investment (≤ ₹0.7 lakh). This classification helps prioritize actions based on financial feasibility and expected impact.

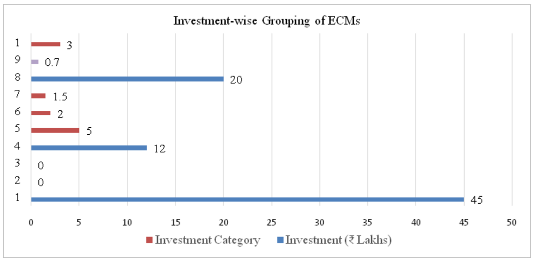

Figure 4 Investment-wise Grouping of Energy Conservation Measures (ECMs)

Key Insights

The analysis identified ten actionable Energy Conservation Measures (ECMs) with a combined potential annual savings of approximately ₹44.8 lakhs. With a total investment of ₹89.2 lakhs and an average payback period of just 24 months, the proposed measures are financially sound and offer an attractive return on investment. It is recommended that the management prioritize the implementation of low or no-investment ECMs for immediate gains, while simultaneously planning for medium- and high-investment measures to maximize long-term energy and cost efficiency.

Future Directions

To build on the identified energy savings and ensure long-term sustainability, the healthcare facility should prioritize the phased implementation of the proposed Energy Conservation Measures (ECMs), beginning with low or no-investment actions for immediate impact. Future strategies should focus on integrating the following:

- Implement Renewable Energy: On-site solar PV or wind to supplement grid power can cut both costs and carbon footprint. For example, a rural Indian hospital cut energy use by 58% using solar and efficient design.
- Deploy Smart Controls: Upgrade to intelligent HVAC and lighting controls (occupancy sensors, advanced thermostats) and integrate a Building Energy Management System. Such technologies can adapt to occupancy and weather, maximizing efficiency.
- Continuous Monitoring & Benchmarking: Install sub-metering and energy monitoring systems, and benchmark performance against peer hospitals. Regular re-audits and data-driven tracking will sustain gains.
- Staff Training & Engagement: Educate staff on energy-saving practices (e.g., equipment shut-off, efficient use of devices). Behavioral measures complement technical fixes and help embed a culture of conservation.
- Further Research: Study occupant comfort and indoor air quality impacts of ECMs to ensure patient care is maintained. Investigate new technologies (e.g., waste heat recovery) specific to healthcare settings. Evaluate long-term reliability of proposed measures under hospital operating conditions.

By pursuing these steps, the hospital can continue to improve sustainability and resilience, in alignment with healthcare sector goals for environmental responsibility.

Conclusion

This energy audit of a a medium-sized tertiary-care hospital in a humid tropical region of southern India identified significant opportunities for efficiency improvements. Hospitals are known to consume energy at rates 2–3× higher than typical buildings, and this case was no exception. By following a rigorous audit methodology, the study quantified baseline energy use and pinpointed measures that could reduce annual energy expenses by roughly 50% of the current bill (savings ~₹4.48 million/year with ~2-year payback). The detailed analysis underscores that systematic audits are powerful tools: they reveal hidden inefficiencies and make business cases for investment. The hospital's prior recognition for energy conservation (state award) indicates a culture of sustainability, which this audit can build upon. Overall, the study reinforces that comprehensive energy audits – coupled with appropriate ECMs,can drive meaningful cost and emissions reductions in healthcare facilities.

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