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Energy Audit and Conservation Strategies in Public Sector Buildings: A Case Study Approach

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Abstract: ***Energy auditing has been identified as one of the key measures for public sector infrastructures to cut down on their costs and energy usage. The infrastructures referred to include administrative offices, institutions, as well as establishments providing services, all of which use substantial amounts of energy. In this research, we present an energy audit study of a representative public sector infrastructure facility so as to identify the ways of improving energy usage and saving energy in such infrastructures. Energy consumption is categorised into lighting, ventilation, air conditioning, and office appliances. Thereafter, efforts are made to identify all possible energy savings in a systematic manner. It is shown that several measures may be implemented to achieve these objectives; these include zero, low cost, and medium cost measures. Results indicate that a decrease of about 20% in energy consumption per year may be achieved via proper energy management measures.***
Keywords: Energy Audit, Energy Conservation, Public Sector Buildings, Energy Efficiency, Demand-Side Management.

I. INTRODUCTION

Rapid infrastructure growth and rising service demands have led to a big rise in energy use in public sector buildings. Most of the time, electricity is used for lighting, air conditioning, computers, and other services [1]. Using energy inefficiently in these kinds of buildings raises costs and wastes resources that don't need to be wasted. So, it is very important to optimise how much energy is used [2-4]. Energy auditing is the organised process of keeping track of, analysing, and improving how a building uses energy. It helps find energy losses and gives useful advice on how to make things more efficient. The main idea behind this process is that saving energy is the same as making energy, which is the same as saying that energy saved is the same as energy produced [5]. Public sector buildings, which often have to work with tight budgets, can greatly benefit from good energy management plans.

II. ENERGY CONSUMPTION MODEL

The total electrical energy usage of the building may be defined in terms of mathematical equations by taking into account the individual load usages.

$$E_{total} = \sum_{i=1}^{n} P_i \times t_i$$

Here, Pi is the power rating of the ith load and ti is the time taken by the load [6].

The chosen public sector establishment uses the transformer with capacity of 500kVA and contract demand of 300kVA. The annual electricity cost incurred by the establishment is INR 40,71,576. Tariff system includes a demand tariff at a rate of INR 400/kVA and energy tariff at a rate of INR 6.5/ kWh. Penalties occur due to the increase in maximum demand and low power factor. The penalty problem is avoided using capacitor banks, and the average power factor is 0.92. The overall connected load of the plant is about 701 kW, spread throughout various blocks that operate in the plant. Table 1 gives details on the distribution of the load in each block [7-8].

Table 1: Load Distribution Across Facility Blocks

Block	Connected Load (kW)
A	193.28
B	226.32
C	143.77
D	138.11
Total	701.48

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The load is categorized as lighting, ventilation system, air conditioning, computers, and other electrical loads. Out of all, air conditioning and other electrical loads constitute the major portion of the load.

III.ENERGY AUDIT METHODOLOGY

The energy audit process involves a methodology that encompasses the stages of planning, data collection, analysis, and the identification of energy conservation possibilities as given in [9]. The initial stage involves gathering information about energy usage and the profile of the loads used. Thereafter, the information gathered is analyzed in order to identify problems of waste and inefficiency. Finally, energy conservation techniques are suggested.

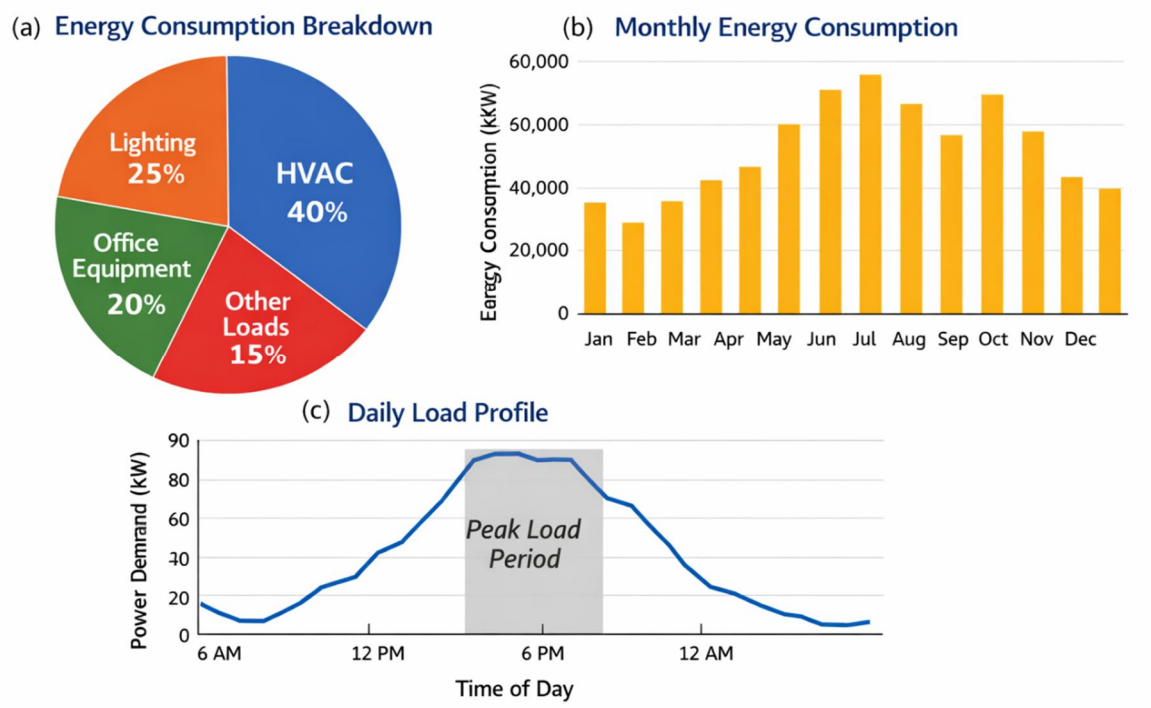


Figure 1: Representative Energy Consumption Pattern in Public Sector Buildings A: Energy Consumption Breakdown B: Monthly Energy Consumption and C: Daily Load Profile

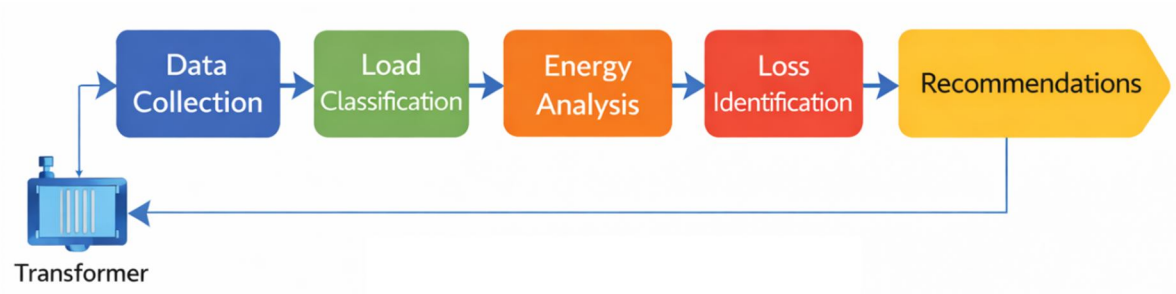


Figure 2: Energy audit methodology

The graph represents the distribution of energy consumption for various loads, which proves the fact that the largest portion of energy consumed is contributed by HVAC and equipment loads [10]. The analysis shows that there are certain ways to save considerable amounts of energy by optimizing lighting, ventilation, air conditioning, and office equipment use. For instance, using LED light bulbs instead of the traditional incandescent bulbs will help to save a lot of energy when it comes to lighting solutions [11-13]. Using LED lights also contributes to more efficient ventilation and air conditioning solutions, as the temperature should be set within the comfortable 23°C-25°C range. Office equipment, like personal computers, can be optimized by using their power-saving mode and reducing idle time.

The energy savings potential can be quantified using the following expression:

$$\text{Energy Savings} = E_{baseline} - E_{optimized}$$

where E_{baseline} represents the initial energy consumption and $E_{optimized}$ denotes the consumption after implementing conservation measures.

IV. ENERGY SAVING POTENTIAL

The proposed measures are categorized based on implementation cost and expected savings. The overall estimated savings are summarized in Table 2.

Table II: Energy Saving Measures and Impact

Category	Annual Energy Savings (kWh)	Cost Savings (INR)	Payback Period
No-Cost	94,921	6,17,000	Immediate
Low-Cost	8,391	54,543	10 days
Medium-Cost	41,048	2,67,402	1–2 years
Total	1,44,360	9,38,945	—

The results indicate that approximately 20% reduction in energy consumption can be achieved through the implementation of these measures. The results clearly show that an effective energy audit can greatly improve the efficiency of government buildings. It should be noted that the greatest part of energy savings comes from efficient operations and not from expensive installations. Thus, awareness plays a crucial role in energy saving. Moreover, using renewable energy, such as solar power, would bring positive changes to energy efficiency.

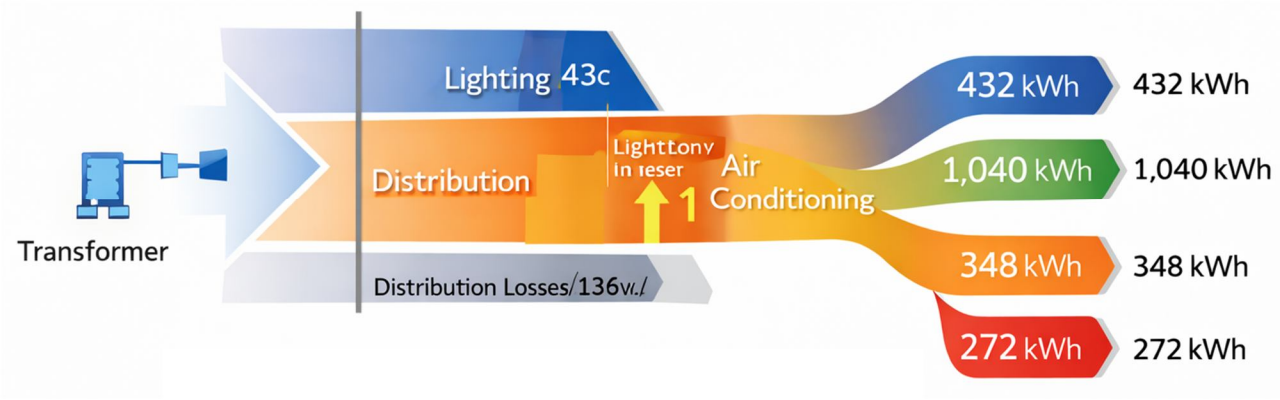


Figure 3: Energy flow in the public sector

The findings from the energy audit clearly show that there is an intense concentration of energy consumption in particular load types that dominate energy utilization. In this regard, HVAC systems make up the largest proportion of the total energy demand. This assertion is consistent with building energy audit experiences where the HVAC systems alone can consume more than half of all the electricity used. In the current case, the high proportion of HVAC loads was because of excessive use of air-conditioning during extended periods, poor thermostat settings, and lack of proper maintenance measures. This situation means that simple measures like ensuring temperature regulation between 23°C and 25°C would help realize considerable energy savings while keeping occupants comfortable.

V. DISCUSSION AND ANALYSIS

The study also shows that there is uneven energy consumption among various building blocks since some are more equipped than others and have higher loads on account of HVAC utilization. This finding shows that energy optimization can be achieved by using location-specific measures instead of blanket policies. Additionally, the analysis of the electrical parameters shows that the mean value of the power factor is 0.92, a good value; however, it will nevertheless generate fines and additional demand charges.

By making proper use of capacitors to make the power factor equal to one, it would be possible to further minimize the apparent power and eventually cut down on electricity costs. This proves that in addition to reducing the consumption of real power, managing reactive power becomes equally important.

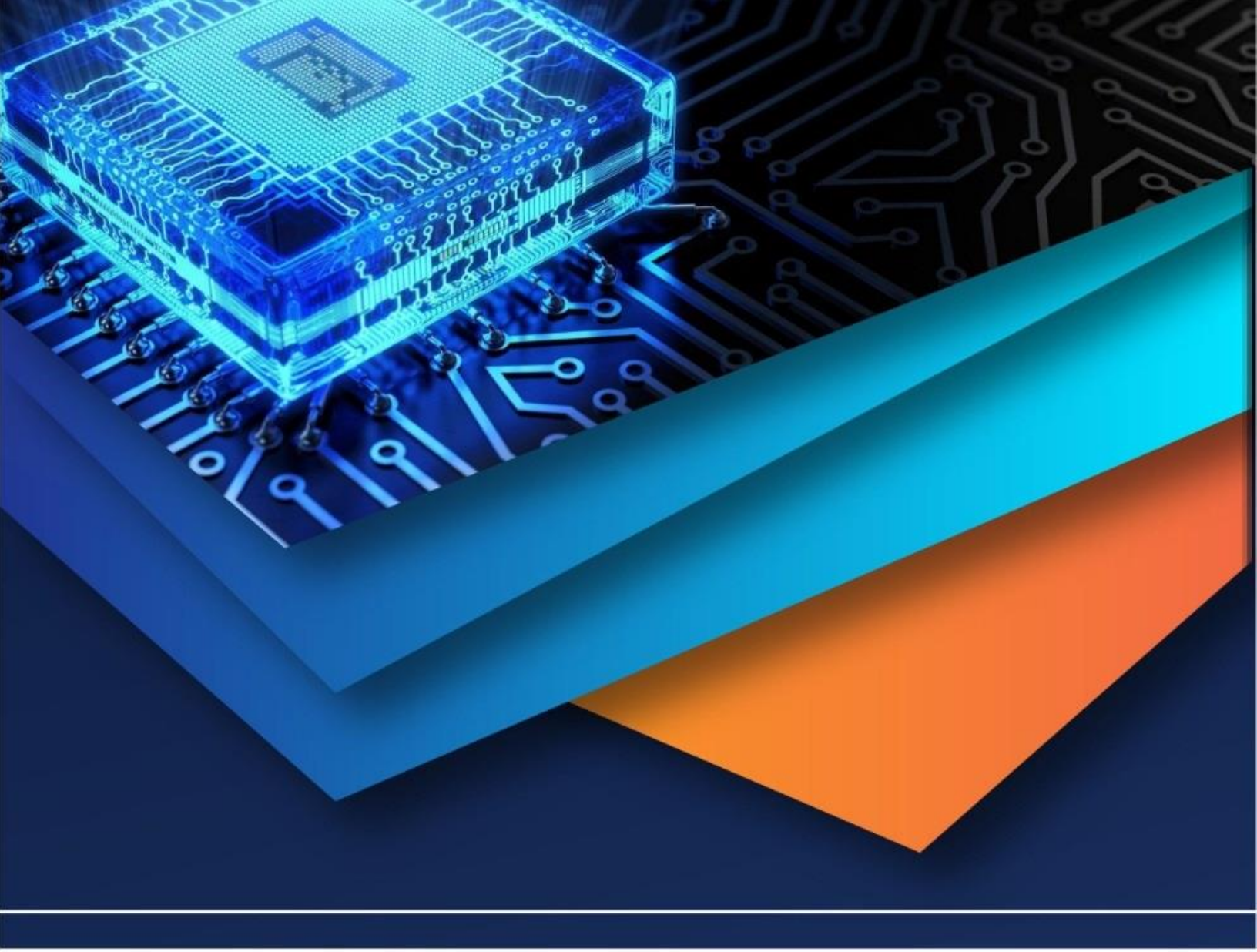
The contrast between the energy consumption in the facility before and after implementing improvements reveals that a considerable amount of savings can be done using low-cost and even free solutions. The modification in behavioural practices, such as turning off idle devices and putting computers on energy-efficient settings, plays an important role in the energy savings process. Another significant finding from the research is the fact that the lighting systems do not contribute to the highest energy consumption, but they can provide rapid and economical savings by using retrofits. The substitution of regular lighting systems by LED technology results in immediate advantages in power saving and extended service life. In addition, the use of occupancy sensors contributes towards additional energy savings by ensuring their optimal utilization. The analysis of the economic feasibility of the measures proposed demonstrates that majority of them have short payback periods and are economically feasible for implementation within the public sector where financial limitations are a crucial factor. The total energy savings, which are estimated at about 20%, show the efficacy of conducting energy audits in order to lower operational expenses. At the same time, the financial savings gained through implementing these solutions can be redirected to purchasing innovative equipment or alternative energy sources. Moreover, there is a possibility of further optimization by incorporating energy management systems. These can be designed based on the analysis conducted to monitor the system's functioning and conduct preventive maintenance. In turn, they can help to convert standard buildings into smart facilities, where energy consumption can be controlled effectively. Thus, as can be seen from the results, the conducted study helps to emphasize the role and importance of energy audits, which can be viewed as an efficient solution for increasing the energy efficiency of the buildings managed by the public sector.

VI. CONCLUSIONS

This research study conducted an extensive energy audit for identifying key aspects of energy usage and ways of reducing wastage. As seen from the analysis of the distribution of loads, operational characteristics, and electricity, a notable quantity of the consumed energy was focused in some key systems including the air-conditioning system, lighting system, and auxiliary facilities. Thus, through a thorough evaluation of these components, the researchers were able to find the inefficiencies and suggest methods for optimizing energy consumption. From the above discussion, one can easily deduce that it is possible to achieve significant savings in terms of energy consumption and cost by means of planning, implementing, and monitoring energy conservation techniques. Indeed, a number of measures ranging from no to low and medium cost were found to produce tangible results without any need for changing the existing infrastructure and its components. The study further indicates that energy efficiency does not necessarily rely only on technological advancements but also on efficient energy management strategies and user consciousness. The incorporation of systematic energy auditing along with constant monitoring leads to improved decision-making processes and promotes sustainability within the construction of public buildings. From the perspective of the economic assessment, it is evident that most of the suggested interventions will have quick paybacks, thus being extremely viable and implementable. The future scope for research may encompass the implementation of intelligent energy management systems that utilize smart technologies like Internet of Things-based sensors, artificial intelligence-based optimization, and real-time control systems. This will increase energy efficiency through predictive analytics, automation of decisions, and adaptability in controlling building energy systems. Another avenue for exploration could include the utilization of renewable energy sources such as solar energy and hybrid energy systems to decrease reliance on traditional energy sources.

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