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"A Study on Energy Efficiency in Tertiary Healthcare Institute with Special Emphasis on Energy Consumption Pattern and Energy Saving Opportunities"

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I. INTRODUCTION

Hospital buildings require continuous functioning without interruption, which leads to ranking them to be second most to use a large amount of energy in the building sector. The energy consumption in the new hospital buildings is increased compared to older building due to usage of sophisticated equipment

Since the hospital buildings operate 24 hours, 365 days a year for the treatment and restoration of patients, they are approximately 2–3 times more energy-intensive than normal buildings [1]. It is extremely difficult to reduce the energy consumption, because spaces that have various operating hours and usage patterns co-exist, such as wards, outpatient clinic, operating rooms, ICU (intensive care unit), offices, and convenience facilities, there is a characteristic that the cooling/heating load ratio and fluctuation are complex. HVAC (heating, ventilation, and air condition) is the main end use with a weight close to 45%, lighting follows with 15% and medical devices with 12% [2]. Nevertheless, in most cases, hospital buildings' HVAC systems are designed and operated relatively simply in comparison with the use and size, and the patient-oriented environment is maintained, the energy saving technique is carried out manually. The energy performance of buildings needs to be monitored and maintained. A well-developed energy management system in the building can help to identify failures in a timely manner and reduce excessive energy consumption.

High energy prices are forecast to continue due to limited supply and refining capacity, a tense global political climate and brisk worldwide demand for fossil fuel. Energy consumption per square foot in hospitals is much higher than many other types of buildings, primarily due to 24x7 hours of operation and demanding requirements for air filtration and air exchange.

Energy expenditure is a significant component for healthcare providers after manpower and consumables costs. This clearly signifies the opportunity for hospitals to cut costs and also contribute to reducing India's carbon footprint. There is a pressing need for hospitals, particularly those under construction, to adopt the 'Green Hospital' concept to make maximum use of natural light and solar energy.

Consequently, this reduction in power costs may also translate into lower consumer bills and healthcare expenses.

Energy Conservation Building Code (ECBC) of India shows that hospitals in India have a potential to achieve 42% energy saving by implementing energy efficient measures.

AIM

The overall aim of my study is to build energy efficient hospital with the help of energy saving opportunities.

OBJECTIVES

1. To evaluate the existing system by observing energy consumption patterns and analysing past electricity bills.
2. To measure the energy performance of the hospital by calculating EPI (Energy performance Index) and to compare with the performance with benchmark of BEE (Bureau of energy efficiency)
3. To identify Energy Saving Opportunities (ESOs) and evaluate new technologies that improve efficiency.
4. To calculate the reduction in energy consumption with energy saving opportunities and thus the reduction in CO_2 emission.

II. REVIEW OF LITERATURE

Ru ji and Shilin Qu [3] conducted a study in 2019 on Investigation and Evaluation of Energy Consumption Performance for 100 Hospital Buildings in China.

It is observed that for hospitals in hot summer, there is a significant disparity among the four climatic regions. It can be seen that for hospitals in warm winter zone annual electricity consumption is 140.7 kWh/m, while the value is 45.2 kWh/m in frozen zone,67.9% decreased. It can be concluded that annual electricity is higher in the southern area in China than in the northern area, which is caused by a lot of use of air conditioning systems in summer. Therefore, the south hospitals play the largest part in total electricity consumption accounting for 39.1%.

Rajavel.et al studied on energy consumption pattern in Chengalpattu medical college, Chennai. Energy consumption pattern for lighting, fans, computers and air conditioners at various locations of Chengalpattu Medical College Hospital (CMCH) was studied for 30 days and standard deviation was computed for the operating hours.

It is observed that lighting consumed about802.70 kWh/day, fans consume about 643.56kwh/day, computers about 123.20kwh/day, Air conditioners about 1602.00kwh/day, medical laboratories about 491.47kwh/day, DG sets about187.50kwh/day and motors about 51.60kwh/day.

By implementing Energy savings opportunities such as use of energy efficient lights, installation of high frequency electronic ballasts in place of conventional copper chokes, air conditioning installation of inverters in air conditioners, using fans along with ACs, installation of electronic regulators for ceiling fans economic and environmental benefits could be achieved:

Reduction of power cost at Chengalpattu Medical College Hospital (CMCH) is Rs.9,02,070/-. Prevention of atmospheric emissions of carbon dioxide to the tune of about 1,11,565 kg per year.[4]

A study on energy consumption in Hiranandani hospital, A Fortis network hospital, Mumbai was done. It is a 148 bedded hospital which is focusing on super specialities. The facility has 11kV supply from MSEDCL to the hospital through one feeder and 2x360kVA transformers. In addition to this 2 DG sets of 725kVA each as a stand by source power. Electricity consumption in 2012-2013 was 38.03 lacs kWh for an area of 13490 sq.mt or 23.49 kWh/sq.m/month.[5]

Energy-efficiency in commercial buildings has a significant impact on both initial HVAC costs and the entire building energy consumption. Egypt's policymakers should, therefore, consider implementing the energy code to establish minimum energy performance levels for buildings under construction and retrofitting of existing buildings that eventually leads to lower energy consumption and fuel consumption.[9]

Justo García-Sanz-Calcedo conducted Analysis on Energy Efficiency in Healthcare Buildings.The percentages of the average distribution of the consumption of energy by end-use, can be seen, which shows that air conditioning and the heating system represent 50% of annual demand for energy from a healthcare centre, 30% for lighting, 8% for hot water and 12% for the equipment.

Analysis of the average energy consumption demonstrates the existence of a correlation between the average final annual energy consumption and the built surface area in each healthcare centre.[6]

Christian Davies studied Barriers to Energy Efficiency in Hospitals by conducting a sub-metering consulting project at the University of California San Diego (UCSD) Medical Center. Through constructing a baseline for energy consumption and drawing on a variety of academic resources, the project was able to build a successful business case for sub-meter installation.

Its Energy Use Intensity (EUI), which is energy use per square foot, is much higher than the median, showing that it consumes 331.5 kBtu per square foot compared to 273 at the median hospital. Because EUI is standardized by account for square footage, it better accounts for the size of the building. A large hospital using a lot of energy will not necessarily have a worse EUI than a small hospital using a lot of energy. In addition to having a EUI well above the median, UCSD's EUI has grown by 3.79% from 2011 to 2014. While this information is bad news from an energy management perspective, it further solidifies their financial argument for the implementation of sub- metering systems.[7]

Ioan Silviu Dobosi et.al conducted a study on Building energy modelling for the energy performance analysis of a hospital building in various locations in Romania. The simulation results for the building energy model considering the baseline location (Mioveni), using the climate data available for the nearest location (Bucharest). The lighting consumed about 18.68kwh/m2 year, cooling consumed about 13.00kwh/m2 year and heating consumed about 74.22kwh/m2 year.[8]

Ebru Hancıoğlu kuzgunkaya conducted a study on Energy performance assessment in terms of primary energy and exergy analyses of the nursing home and rehabilitation center in Turkey. The Center was analyzed using the actual energy consumption data derived from several energy audits. Energy efficiency (according to the primary energy ratio) and exergy efficiency of the facility were calculated to be 59% and 14%, respectively. The results have indicated that the exergy efficiencies of space heating and cooling have the lowest values compared with the other units of facility. Specific primary energy consumption and specific energy consumption of the facility were found to be 271.91 kWh/m2 year and 290.23 kWh/m2 year, respectively.[9]

Abhishek Bhatia and Hemant Raj Singh did a study on Energy performance assessment of a multi super specialty hospital building in composite climate zone in India.The Energy Performance Index of the hospital building was calculated to be 290.98 kWh/m2/year, which was near the empirical benchmark of 264 kWh/m2/year specified by a BEE-UNDP study from 2017.[10]

According to BEE, the EPI of North central railway hospital in Allahabad, Uttar Pradesh is 197.28 kwh/m2/year in the year 2012-2013. With implementation of energy saving opportunities like the automatic power factor corrector (APFC) panel has improved the PF of the hospital from 0.90 to 0.98 resulting in substantial saving of electric energy. LED lights were fitted in place of old fashioned street lights based on HPSVs, metal Halide and T12 lights. Then the EPI was improved to163.18 kWh/m2/year in 2013-2014[11]

III. METHODOLOGY

Analysis of past electricity bills and bed occupancy over a period of one year (Oct 2020- Sep 2021), estimation of contracted maximum demand and knowing power factor.

Based on the result of the analysis, the proposals to Low-Cost Measures and Cost-Effective Investments for energy efficient building development in hospitals are presented..

The following key energy parameters were taken into consideration:

I. Monthly electricity consumption (kWh) for a period of one year.
2. Annual electricity consumption and price (bills).
3. Specific energy consumption (kWh/bed /day).
4. Energy performance index(kWh/sq m/year)

ANALYSIS OF ENERGY CONSUMPTION:

Month		KWh consumption	Total billing amount(Rs)

The above data is collected under these parameters for a period of one year from October 2020 to September 2021.

FORMULA FOR CALCULATING ENERGY PERFORMANCE INDEX:
Energy performance index = Annual energy consumption (kWh) / Total built-up area(sqm)

METHODOLOGY FOR CALCULATING ENERGY SAVINGS:

Existing appliance(kw)	Energy efficient appliance/ energy saving measure(kw)	Annual operating hours	Energy savings achieved kwh (existing appliance wattage- energy efficiency wattage)x annual operating hours	Annual cost savings (Rs) = Achieved energy savings x electricity tariff

FORMULA FOR CALCULATING REDUCTION IN CO2:
Reduction in CO2 in kg = Total annual savings in kWh X 0.82 kg

INSTRUMENT USED TO MEASURE ENERGY: 3 phase portable load manager and analyzer.

STUDY SETTING:
Nizam's Institute of medical sciences – a tertiary care teaching hospital in Hyderabad

STUDY DESIGN: Observational analytical study

STUDY PERIOD : The study period is about 1 year from Oct 2020 to September 2021. Retrospective analysis of energy consumption is done by analysing past electricity bills of one year.

IV. OBSERVATIONS AND RESULTS

NIMS receives electricity supply at 33kv from TS SPDCL and the same is stepped down at the 33/11kV substation located within the NIMS Facility. The Substation has 2X8000 kVA, 33/11kV Transformers. There are 4 numbers of 11kV feeders each feeding to 11/0.433 kV Substation near individual blocks.

ANALYSIS OF ENERGY CONSUMPTION :

Month	KWh consumption	Total billing amount(Rs)
Oct 2020	649300	58,45,125
Nov 2020	652050	58,71,401
Dec 2020	612450	55,17,416
Jan 2021	605250	54,40,787
Feb 2021	629850	56,14,610
Mar 2021	661750	58,53,273
Apr 2021	859450	66,11,433
May 2021	903500	76,59,482
Jun 2021	873050	74,43,722
Jul 2021	886950	75,46,899
Aug 2021	881750	74,84,951
Sep 2021	867000	73,71,800

Table 1: Annual energy consumption from October 2020 to September 2021

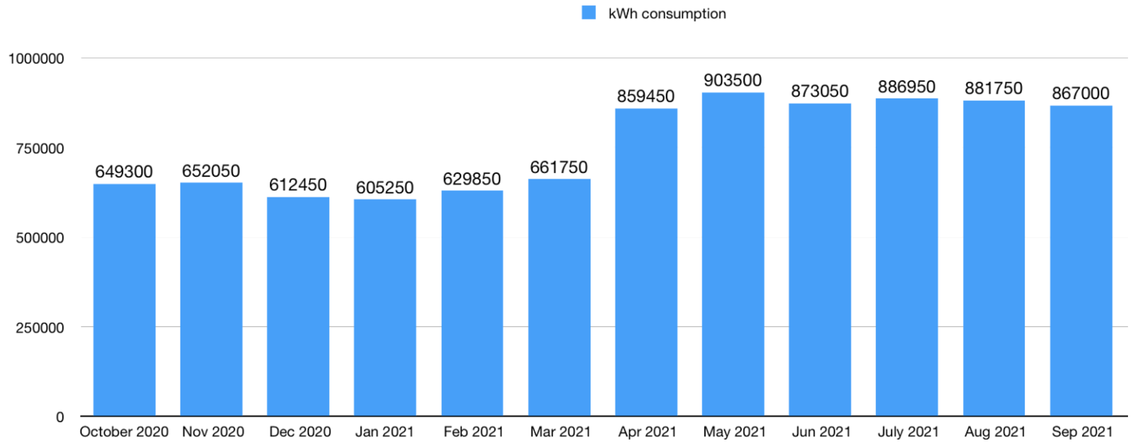

Fig 1: Bar diagram showing annual energy consumption

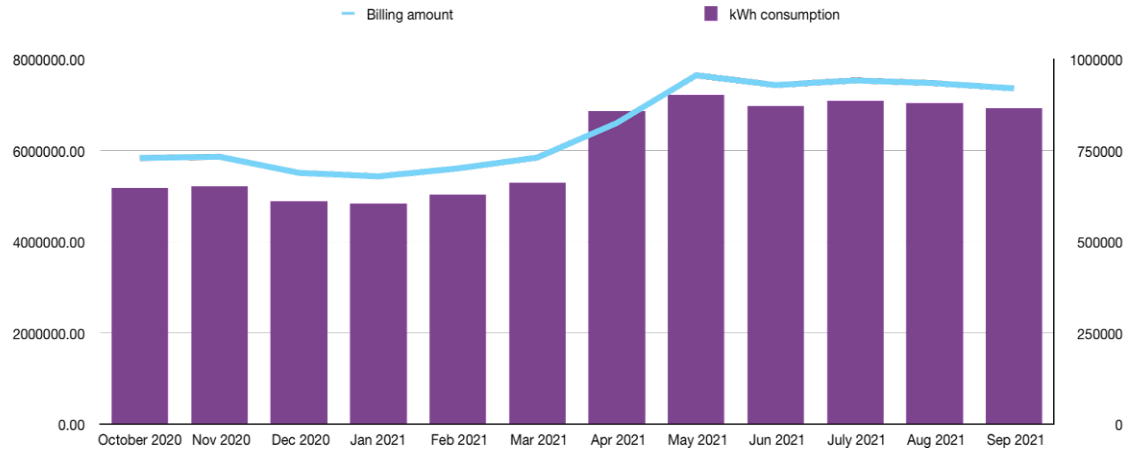

Fig 2: Bar diagram of annual energy consumption and electricity cost

Annual energy consumption (kWh/year): 90,82,350kwh/year and annual electricity cost is (90.8 lakhs kWh/year)

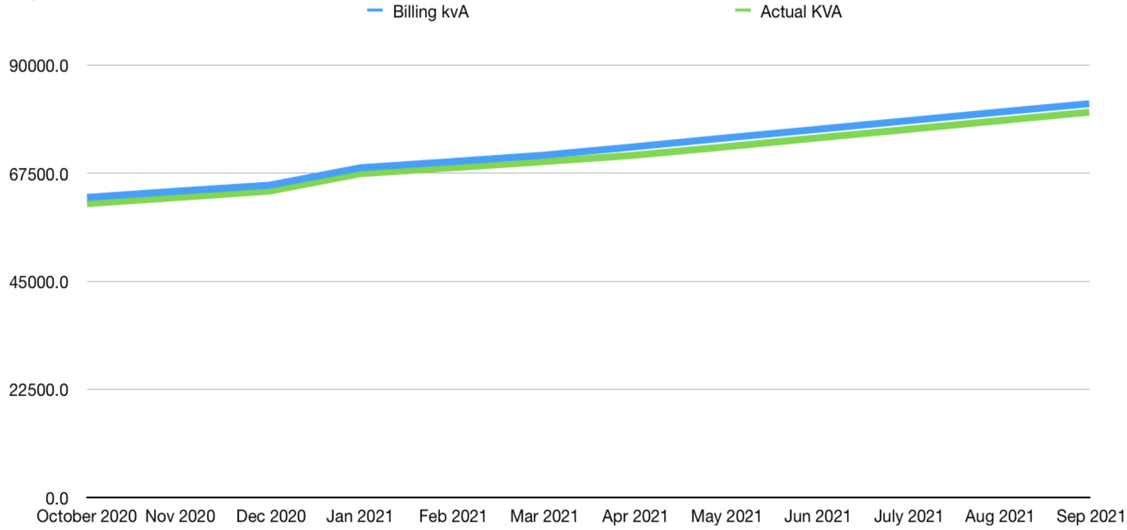

Fig 3: Relationship of actual KVA and billing KVA

ENERGY PERFORMANCE INDEX:

Nizam's institute of medical sciences has Trauma/ Emergency block, Millenium block and old OPD and core block. The total built up area of NIMS is 1,10,767 Sqm. Among these blocks, the energy performance index of Trauma and Speciality block can be calculated as these two buildings have air conditioned space. Rest of the blocks have less than 30% air-conditioned space of total built-up space where the energy performance index can't be calculated according to ECBC.

The energy consumption of the Trauma and speciality buildings:

Month	Energy consumption
October 2020	6,13,040
November 2020	5,90,010
December 2020	6,21,000
January 2021	6,11,578
February 2021	6,08,459
March 2021	6,12,456
April 2021	6,80,487
May 2021	7,04,476
June 2021	6,24,690
July 2021	6,30,563
August 2021	5,86,786
September 2021	6,00,564
Total	**74,84,109**

Table 2: Energy consumption of Trauma & Speciality block

The energy performance index of Trauma and speciality buildings is Total annual energy consumption(kWh)/ Total built up area(sqm) = 74,84,109/30,652 = **244kwh/sqm.**

According to BEE, The national benchmark of energy performance index is **180kwh/m²**. The buildings with EPI less than 180kwh/m² are ECBC compliant. The energy performance index of Trauma and specialty buildings is 244kwh/sqm. More energy saving opportunities should be implemented to reach the benchmark of 180kwh/sqm

ENERGY SAVING OPPORTUNITIES:
Retrofittings are being done in Nizam's institute of medical sciences in order to conserve energy. 3000 LED lights were replaced in place of old lights, old fans were replaced by 2,400 BLDC fans and 40 old window AC were replaced by energy efficient split ACs

1. ENERGY CONSERVATION BY REPLACING THE EXISTING LIGHTING FIXTURES WITH ENERGY EFFICIENT LED LIGHTINGS:

S.No	Parameter	Units of measurement	Value
1	Total number of fixtures replaced till now	Nos	3000
2	Power consumption of original fixture	W	36
3	Power consumption of LED fixture	W	20
4	Average Running Hours	Hrs/day	15
5	Average running hours	Hrs/month Hrs/year	450 5475
6	Baseline Energy consumption with original fixture	kwh/month kWh/year	48600 591300
7	Energy consumption with LED fixture	kwh/month kWh/year	27000 328500
8	Energy savings	kwh/month kWh/year	21600 262800
9	Electricity tariff	Rs/kvAh	7
10	**Cost savings**	Rs/month Rs/year	**1,51,200** **1839600**
12	**Reduction in Co2**	kg/month Kg/year	**17,712** **2,15,496**

Table 3. Energy conservation with LED light

2. ENERGY CONSERVATION BY REPLACING OLD CEILING FANS WITH ENERGY EFFICIENT BLDC FANS:

The ceiling fans installed at the facility are very old and have undergone rewinding. The power consumption of such ceiling fans is as high as 97W. Based on sample measurement the average power consumption is around 78W. These fans can be replaced with BLDC fans (28- 32 W).

S.No	Parameter	Units of measurement	value
1	Total number of BLDC fans replaced till now	Nos	2,500
2	Power consumption of original fans	W	80
3	Power consumption of BLDC fans	W	55
4	Average running hours	Hr/day	12
5	Average running hours	Hr/month Hr/year	360 4380

6	Baseline energy consumption with original fan	KWh/month kWh/year	72000 876000
7	Energy consumption with Energy efficient fan	kWh/month kWh/year	49500 602250
8	Energy savings	kWh/month kWh/year	22500 273750
9	Electricity tariff	Rs/kvAh	7
10	Cost savings	Rs/month Rs/year	**1,57,500** **19,16,250**
11	Reduction in CO2	kg/month Kg/year	**18,450** **2,24,475**

Table 4. Energy conservation with BLDC fan

3. ENERGY CONSERVATION BY REPLACING EXISTING WINDOW AC WITH 5 STAR SPLIT ACs:

. Parameter	units of measurement	. value
Number of window ACs replaced till now	No.s	40
Power consumption of 3 star AC as per BEE star label	kw/1.5Tr	1.71
Average running hours	Hr/day	12
Number of days	Days	300
Energy consumption of one window AC	kwh/day kWh/month kWh/year	20.49 512 6146
Energy consumption of 40 window ACs	kwh/year	246240
Power consumption for 5 star split AC	kw/1.5Tr	1.17
Energy consumption	kwh/day kWh/month kWh/year	14 366 4220
Energy savings for 40 split AC	kwh/year	168480
Annual energy savings	kwh/year	77760
Electricity Tariff	Rs/kVAh	7
Annual cost savings	Rs lakhs	5.4
Reduction in CO2	kg	63,763

Table 5: Energy conservation with replacing old window AC with 5 star split AC

Following Energy conservation opportunities were studied with simulation and energy savings is estimated as following:

4. ENERGY CONSERVATION BY REPLACING THE EXISTING OLD REFRIGERATORS WITH ENERGY EFFICIENCY 5- STAR REFRIGERATOR

Parameter	Units of measurement	Value
Number of refrigerators (Before 2015 model)	No.s	9
Average power consumption as per BEE notification 12th Jan 2009	kWh/year	486
Average running hours	Hr	24
Number of days	Days	365
Energy consumption for 9 refrigerators	kWh/year	4374
5 star refrigerator power consumption for one refrigerator	kWh/year	104
Power consumption for 9 refrigerators	kWh/year	936
Estimated Energy savings	kWh/year	3438
Electricity Tariff	Rs/kVAh	7
Annual cost savings	Rs Lakhs	0.24
Reduction in CO2	kg/year	2,819

Table 6: Energy conservation with Energy efficient 5 star refrigerator

5. ENERGY CONSERVATION BY REPLACING 3 STAR SPLIT AC WITH 5 STAR SPLIT AC

Parameter	Units of Measurement	Value
Number of split Acs	No.s	181
Power consumption for 3 star AC as per BEE star label	KWh/2Tr	2.14
Average power consumption	KW	2.13
Average running hours	Hr	8
Number of days	Days	300
Baseline energy consumption	KWh/day kWh/month kWh/year	17.10 428 5131
Power consumption for 5 star split AC	kWh/2Tr	1.56
Energy consumption of 5 star split AC	kWh/day kWh/ month kWh/year	13 325 3751
For 181 No's split AC(5 star) Energy savings	kWh/year	679015
Estimated energy savings	kWh/year	249729
Electricity Tariff	Rs/KVAh	7
Annual cost savings	Rs lakhs	17.48
Reduction in CO2	Kg	**2,04,777**

Table 7: Energy conservation with old AC with 5 star AC

6. ENERGY CONSERVATION BY SEALING LEAKAGES TO SEE ENERGY SAVING IN AC CONSUMPTION:

The Energy consumed by the Air conditioner is measured before and after sealing all the leakages using an energy analyser for a period of one hour.

Parameter	Units of measurement	value
Energy consumed before intervention	kWh	**2.1**
Energy consumed after sealing all the leakages	kWh	**1.5**
cost saved	Rs/hr	**4**
Reduction in CO2	Kg/hr	**0.4**

Table 8: Energy conservation in AC with sealing leakages

7. ENERGY CONSERVATION BY SETTING THERMOSTAT: This study is done by measuring energy consumption with an energy analyser and again studied after setting the thermostat for 1 hour.

Parameter	Units of measurement	Value
Energy consumed when thermostat at 18ºC	kWh	**0.7**
Energy consumed after setting thermostat at 27ºC	kWh	**0.5**
Energy saved	Rs/hr	**1.4**
Reduction in CO2	kg/hr	**0.16**

Table 9: Energy conservation with setting thermostat

8. ENERGY CONSERVATION BY USING FAN ALONG WITH AC:

This study was done in a room with dimensions 12x 20 feet room with 1.5ton AC. Energy consumed is measured with an energy analyser for a period of one hour post stabilization. The energy is measured when AC is set at 22ºC with fan off and then with 26ºC with fan.

Parameter	Units of measurement	Value
Energy consumed by AC with fan switched off	Wh	1.4
Energy consumed by AC with fan	Wh	1
Energy saved	**wh**	**0.4**
cost saved	**Rs/hr**	**2.8**
Reduction in CO2	**kg/hr**	**0.32**

Table 10: Energy conservation using fan along with AC

V. CONCLUSION

Nizam's institute of medical sciences is a **1500** bedded hospital with a total built up area of **110767 sqm**. Annual energy consumption during 2020-2021 was **90,82,350 kWh/year** and electricity cost was about **Rs.7,82,60,899/-**. Average monthly electricity cost is **Rs 65,21,741/-.**

Average energy consumption per day is **24,888kwh/day.** Average energy consumption per bed is **17.8kwh/bed/day.**

So far **2,400 BLDC fans** ,**3000 LED lights** and **40** window ACs were replaced by **split ACs** as Energy conservation measures. The total **annual cost saved with LED** is **Rs.18,39,600/-** and there is reduction of **2,15,496kg**. The annual cost saved with BLDC fans is **Rs.1,57,500/-** and **2,24,475kgs** of CO2 is reduced. The annual cost saved by replacing window ACs with split ACs is **5.4lakhs** and **63,763kg** reduction in Co2.

Further, there is scope of implementing more Energy saving opportunities to save energy and reduce CO2. The estimated energy savings by **replacing old refrigerators with 5 star energy efficient refrigerators** is **0.24lakhs** and **2,819kg of CO2** reduction. The estimated cost saving with **replacing old split AC with 5 star AC** is **17.48 lakhs** and **CO2 reduction** of **2,04,777kgs.**

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