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# ENERGY AUDITING AND CONSERVATIVE MEASURES OF A TYPICAL RESIDENTIAL BUILDING IN CHENNAI

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**Abstract**: Energy plays a prominent role in human sustenance and growth. The increase in the Demand of energy and Shortage in power generation is day by day the gap between demand and supply of electric energy is widening. It is very difficult and expensive scheme, bridging this crack from the resource side. To handle this crisis, identifying opportunities for reducing the amount of energy used and ensuring that the available energy is used efficiently. Systematic method in checking energy usage and wastage is the "Energy Auditing". Energy audits have several goals, including reducing energy consumption, management costs, and environmental effect. The audited building is a four – story, residential apartment building, Chennai, Tamil Nadu. To recommend the ways with or without financial investment, to attain estimated saving energy and it's cost. Considerable energy saving is possible through proper choice of equipment's, and their effective use & involvement of conservation measures. Daylight, thermal and acoustic analysis, water usage, carbon estimation and finding the annual energy cost can be done by using Ecotect. This paper presents such energy saving methods in a methodological approach, practiced during a detailed energy audit of a residential building.

**Keywords:** Energy audit, Residential building, Energy efficiency

## I. INTRODUCTION

Energy is one of the major inputs for the economic development of any country. Power capacity has risen at the rate of 5.87% per annum over the last 25 years. In recent times, terms such as sustainable building, green building, eco design building, bioclimatic design building and any more have become popular in the building sector. The terminology and their meanings vary somewhat, but the aim is the same with intents on promoting more efficient use of natural resources, especially energy and water, and using renewable energy in the running of the buildings. In general energy conservation in buildings can be achieved by retrofit actions on space side heating, cooling, lighting, window glazing's, occupancy sensors, electrical equipment, lifts, escalators, cold deck temperature set point and reduced ventilation air, etc., Energy conservation means reduction in energy consumption without making any sacrifice of quantity or quality. A successful energy management program begins with energy conservation; it will lead to suitable rating of equipment's, using high efficiency equipment and change of habits which causes enormous wastages of energy. Also limited energy resources, scarcity of capital and high interest costs for the addition of new generation capacity is leading to the increased cost of electrical energy in India. The only viable way to handle this crisis, apart from capacity addition, is the efficient use of available energy, which is possible only by continuously monitoring and controlling the use of electrical energy. Hence

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energy management program is a systematic and scientific process to identify the potential for improvements in energy efficiency, to recommend the ways with or without financial investment, to achieve estimated saving energy and energy cost.

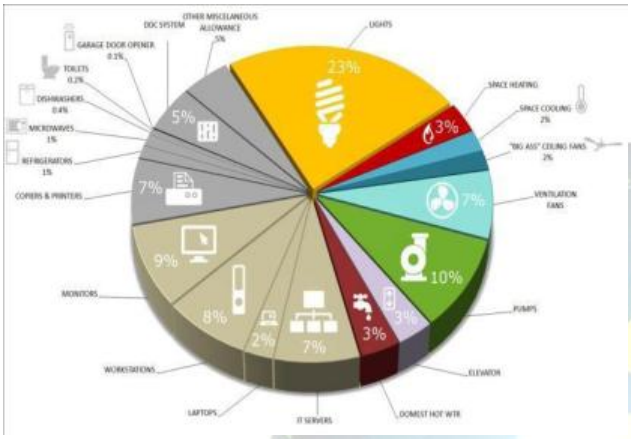


Figure.1 energy consumption of household

Due to peak demand, strain on power generation and utilization equipment increases which result into Increases in energy cost. Considerable energy saving is possible through proper choice of equipment's, and their effective use & involvement of conservation measures. Electricity is the main energy source used in most building. Indeed, electricity is required for the operation of numerous appliances in all residential building. Residential or domestic load consists of lights, fans, and appliances like radios, heaters, electric irons, refrigerators, coolers, electric water heaters, washing machines, amongst others. The demand for electricity continues to rise as population grows. Electrical energy demand refers to the maximum amount of electrical energy that is being consumed at a giving time. It is necessary, for system planning and operation, to know the total electrical energy requirements and the duration of various loads in residential apartments. This is necessary to give residential consumers and building owners a proper sense of how much energy different appliances and activities consumed, because most people consistently overestimate the impact of less energy consuming appliances and less effective conservation activities and under estimate the impact of energy of more energy consuming appliances and more effective conservation activities.

## II. ENERGY AUDTING

Reducing the resource consumption of an existing building is often possible and convenient. However, initiating the process of implementing the changes is not simple if the customer has little skill and little or no awareness of the energy status of their building. So some steps are required to conserve the energy worldwide using systematic approach. However a more wide-ranging method in checking energy usage and wastage is the "Energy Audit". Energy audits do not provide the final answer to the Problem. This identifies where the potential for improvement lies, and therefore, where energy management efforts must be directed. An energy survey and audit of buildings is the process by which a building is inspected and analyzed to determine how energy is used in it, with the aim of identifying opportunities for reducing the amount needed to operate the building although maintaining comfort level. The process is periodic in nature, and it assesses changes in building use, the condition of existing equipment, and the applicability of new energy-efficient technologies.

A. *Need for energy audit.*

Energy Audit will help to understand more about the ways energy and fuel are used in any industry, and help in identifying the areas where can occur and where scope for improvement exists.

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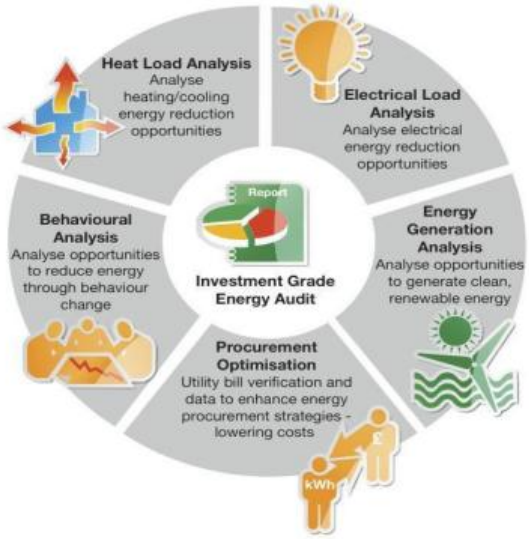


Figure.2 Investment Grade Energy Audit

The Energy Audit would give a positive orientation to the energy cost reduction, preventive maintenance and quality control programs which are vital for production and utility activities. Such an audit programme will help to keep focus on variations which occur in the energy costs, availability and reliability of supply of energy, decide on appropriate energy mix, identify energy conservation technologies, retrofit for energy conservation equipment etc. In general, Energy Audit is the translation of conservation ideas into realities, by lending technically feasible solutions with economic and other organizational considerations within a specified time frame.The primary objective of Energy Audit is to determine ways to reduce energy consumption per unit of product output or to lower operating costs.

B. *Audit activities in general order include:*

- Identification of all energy systems
- Evaluation of conditions of the systems
- Analysis of impact of improvement to those systems.
- Preparation of energy audit report.

## III. GENERAL BUILDING CHARACTERISTICS

It is a residential apartment building of a G+4 story RCC structure of area 4491.27sq.ft in a latitude of 13.379 N, longitude of 80.138 E is a four – flat apartment where all the customers in the building have different tariff plans.


Fig.3 floor plane of apartment building.

## IV. METHODOLOGY

Methodology is the systematic, theoretical analysis of the methods applied to a field of study. It comprises the theoretical analysis of the body of methods and principles associated with a branch of knowledge. Figure1.4 shows the project methodology. A methodology does not set out to provide solutions - it is, therefore, not the same thing as a method.

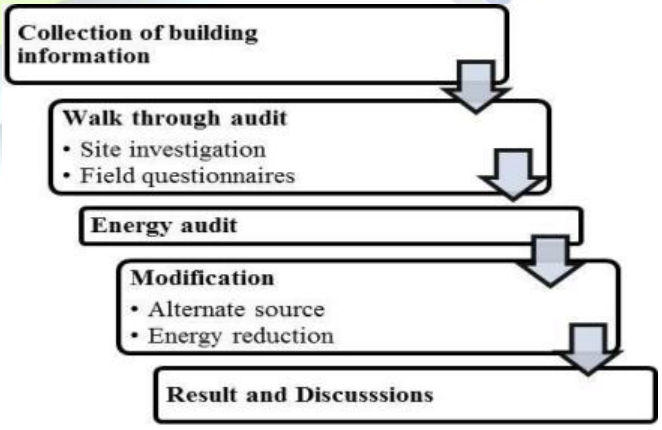


Fig.4 Project Methodology

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A. FIELD QUESTIONNAIRES

This was directed to each of the flats in the apartment to identify how electricity supply was received by each flat, the appliances used and the number of hours they operated.

B. ENERGY AUDIT

The energy outlets in all the rooms were identified. The energy ratings of all the appliances were noted and the mean operating time was taken. The domestic load consists of lights, fans, and appliances like radios, heaters, electricirons, refrigerators, coolers, electric water heaters, washing machines and others were calculated and tabulated. The total energy consumption of the block was found.

C. ENERGY REDUCTION

The energy requirement was found from the audit and was to be reduced by suitable methods. Various fixtures like LED lights were substituted instead of conventional fixtures. The total energy reduction was calculated. The effectiveness of each of the improvements was studied. The total energy requirement after making necessary improvements was computed and solar power was suggested to replace it. The effectiveness of the alternative was studied.The normal tube lights are to be replaced optimally by LED lamps. LED lights are to replace fluorescent lamps, as the fluorescent lamps consume more electricity. A light-emitting diode (LED) is a semiconductor device that emits visible light when an electric current passes through it - essentially it converts electricity into light. The comparison of different lights is shown in the Table1.5. The following are the benefits of using LED: Long Lasting - LED bulbs last up to 10 times longer than compact fluorescents, and far longer than typical incandescent. Durability - LEDs do not have a filament and they are not damaged under circumstances when a regular incandescent bulb would be broken. LED bulbs hold up well to jarring, bumping, shock and vibration. Additionally, they have excellent cold weather performance. Cool - LED light bulbs do not cause heat build-up; LEDs produce 3.4 BTU/hour, compared to 85 for incandescent bulbs. Because common incandescent light bulbs get hot, they contribute to heat build-up in a room. LED light bulbs prevent this heat build-up, thereby helping to reduce air conditioning costs in the home. Mercury Free - No mercury is used in the manufacturing of LED light bulbs. Efficient - LED light bulbs use only 2-17 watts of electricity (1/3rd to 1/30th of Incandescent or CFL). LED light bulbs used in fixtures inside the home save electricity, remain cool and save money on replacement costs since LED light bulbs last so long. Small LED flashlight bulbs will extend battery life 10 to 15 times longer than with incandescent bulbs. Cost Effective - although LED light bulbs are initially expensive, the cost is recovered over time and in battery savings.

| Characteristic | Incandescent | Halogen | Compact Fluorescent | LED | Smart LED |
|---|---|---|---|---|---|
| Energy Savings | 25% | 25% | 75% | 85% | 94% |
| Lifespan (in hours) | 1,000 | 2,000 - 3,000 | 8,000 - 10,000 | 30,000 - 50,000 | 30,000 - 50,000 |
| Instant On | Yes | Yes | Warm up time required | Yes | Yes |
| Dimmable | Yes | Yes | Only select models; can be difficult to dim | Yes | Daylight can be dimmed; LEDs cannot |
| Color | "Warm" yellow to white | "Warm" yellow to white | Yellow to white; some dislike bluish color quality | Multiple color options (white, yellow, blue, red, etc.) | "Warm" yellow |
| Contains Toxic Materials | No | No | Yes | No | No |

Table1.1 Comparison of different lights

The non - star rated A/Cs are replaced by 5 – star rated A/Cs. Star ratings have been developed to provide

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consumers with an easy way of comparing the energy efficiency of different models. Energy efficiency is defined as the "energy service per unit of energy consumption". It is a simple and fair way of comparing the energy consumption of products that perform a similar task. 5 - Star A/Cs are the most energy efficient systems that help save significant money on electricity bills throughout the lifecycle of the A/C.

The life cycle cost of an air-conditioner is a combination of initial cost, running cost and maintenance cost. Most make a decision on buying a particular AC based only on the initial cost, without knowing that it contributes to just 11% of the total expense of owning an A/C. The running cost of an AC contributes to over 60%. The energy efficiency ratings for different classes of A/C are as shown in Table1.2

| New BEE Energy Efficiency Ratings (EER) for Room Air Conditioners | | | | | |
|---|---|---|---|---|---|
| STAR RATING LEVELS - Jan 1, 2014 - Dec 31, 2015 | | | | | |
| EER (W/W) | | | | | |
| WINDOW AC | | | SPLIT AC | | |
| Star Rating | Minimum | Maximum | Star Rating | Minimum | Maximum |
| 1 Star ★ | 2.50 | 2.69 | 1 Star ★ | 2.70 | 2.89 |
| 2 Star ★★ | 2.70 | 2.89 | 2 Star ★★ | 2.90 | 3.09 |
| 3 Star ★★★ | 2.90 | 3.09 | 3 Star ★★★ | 3.10 | 3.29 |
| 4 Star ★★★★ | 3.10 | 3.29 | 4 Star ★★★★ | 3.30 | 3.49 |
| 5 Star ★★★★★ | 3.30 | - | 5 Star ★★★★★ | 3.50 | - |

Table1.2 Energy Efficiency Ratings for A/Cs

## V. APPLICATION OF SOFTWARE

ECO-tect is used for planning whole buildings including outdoor spaces. Merging of indoor and outdoor light planning. Tuning of the light scenes enables exact adjustment of dimming values after calculation. Planning with colour filters, coloured light sources and coloured materials. Revit is Building information modelling software for architects, structural engineers, MEP engineers, designers and contractors. It allows users to design a building and structure and its components in 3D, annotate the model with 2D drafting elements and access building information from the building models database. Both Revit and ECO-tect were used for lighting solutions and carbon emission calculations. Also the effectiveness of light placement, wall texture and color were worked.

## VI. ANALYSIS AND RESULTS

### A. CALCULATION

Electricity consumption is measured in kilowatt-hours (kWh), and one kWh equals 1,000 watts of electricity used during one hour. To determine the total electricity consumed in the home by an electrical appliance over a given period of time, it is first important to determine the amount of power (watts) of the appliance. Manufacturers typically indicate the wattage on the back of the appliance. If the wattage is not given, look for the amperage (amps) and voltage (volts) listed on the appliance. The multiplication of the amperage with the voltage of the appliance will give the power (Watts) rating of the appliance.

The power $P$ in watts is equal to the voltage $V$ in volts, times the current $I$ in amps:

$P(\mathrm{W}) = V(\mathrm{V}) \times I(\mathrm{A})$

The full apartment building was surveyed thoroughly and the energy outlets were identified. The energy ratings (power requirements) for different items were noted. The power consumption was calculated in a simple way as in an Equation given below

Power Consumption/Day (kWh) = N x P x T / 1000 Where,

N is No. of Outlets (Items)

P is power (W)

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T is Operating Hours (hrs)

The cost was fixed at an average of Rs. 3 based on the electricity tariff and bill data of the residential. The increased cost due to operation of diesel generator during the frequent power cuts and maintenance shutdowns were not considered during these calculations. If considered would only increase the cost and thereby increase the credibility and requirement of this audit.

Table1.3 calculation of actual energy consumption

| S. NO | LOCATION | Power Consumption / Day(kWh) | Cost/ Day @ Rs.3/ U |
|---|---|---|---|
| I | LIGHTS | | |
| 1 | GROUND FLOOR | 7.68 | 23.04 |
| 2 | FIRST FLOOR | 19.39 | 58.17 |
| 3 | SECOND FLOOR | 23.99 | 71.991 |
| 4 | THIRD FLOOR | 15.97 | 47.971 |
| 5 | FOURTH FLOOR | 18.117 | 54.35 |
| | TOTAL | 85.174 | 255.52 |
| II | FAN | | |
| 1 | FIRST FLOOR | 21.025 | 63.075 |
| 2 | SECOND FLOOR | 17.75 | 53.25 |
| 3 | THIRD FLOOR | 15.925 | 47.775 |
| 4 | FOURTH FLOOR | 18.27 | 54.85 |
| | TOTAL | 73.08 | 218.625 |
| III | AIR CONDITIONERS | | |
| 1 | FIRST FLOOR | 104.2 | 312 |
| 2 | SECOND FLOOR | 181.65 | 544.92 |
| 3 | THIRD FLOOR | 128.66 | 386.28 |
| 4 | FOURTH FLOOR | 138.24 | 414.52 |
| | TOTAL | 552.75 | 165.72 |
| IV | TELEVISION | | |
| 1 | FIRST FLOOR | 14.91 | 44.73 |
| 2 | SECOND FLOOR | 17.78 | 53.34 |
| 3 | THIRD FLOOR | 14.95 | 44.85 |
| 4 | FOURTH FLOOR | 14.95 | 40.8 |
| | TOTAL | 62.59 | 183.72 |
| V | REFIRGIRATOR | | |
| | FIRST FLOOR | 57.2 | 171.5 |
| | SECOND FLOOR | 47.16 | 141.48 |
| | THIRD FLOOR | 57.8 | 173.48 |
| | FOURTH FLOOR | 56.66 | 169.8 |
| | TOTAL | 218.82 | 656.62 |
| VI | WASHING MEACHINE | | |
| | FIRST FLOOR | 5.1 | 15.3 |
| | SECOND FLOOR | 4.2 | 12.6 |
| | THIRD FLOOR | 3.6 | 10.8 |
| | FOURTH FLOOR | 5.2 | 15.6 |
| | TOTAL | 18.1 | 54.3 |
| VII | COUMPTER'S / PC'S | | |
| | FIRST FLOOR | 11.6 | 34.95 |
| | SECOND FLOOR | 4.22 | 12.66 |
| | THIRD FLOOR | 6.44 | 19.32 |
| | FOURTH FLOOR | 6.34 | 19.65 |
| | TOTAL | 28.6 | 86.54 |
| VII I | OTHER APPLIENCES | | |
| | FIRST FLOOR | 14.91 | 44.85 |
| | SECOND FLOOR | 11.6 | 34.95 |

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| | | | |
|---|---|---|---|
| | THIRD FLOOR | 12.3 | 36.9 |
| | FOURTH FLOOR | 15.12 | 45.36 |
| | TOTAL | 54.53 | 162.06 |
| | | | |
| IX | TOTAL | 1071.38 / day | 3274.974 Rs. / day |
| | | 30505.62 /month | 93371.25 Rs / month |

The basic power requirement for the building was obtained from the energy audit. After the retrofit of energy efficient material's in the building.

The total power is reduced to-746.233 kWh / day Cost is also reduced to 2238.69 Rs / day.

In order to make the block more energy efficient, certain improvement measures were tried out analytically. The lights used in the block were normal fluorescent tubes T12 category, CFLs and some incandescent lamps. These lights were replaced by LED tubes and LED lights with comparable light intensity respectively. The A/Cs in the block was quite old, belonging to the non-star rated category. These were replaced by 5 - star A/Cs of comparable tonnage.

The advantages and cost – benefit analysis for the replacement of lights and A/Cs is given the investment return is 7 years and 3 years in the case of LED lights and 5–star A/Cs respectively

## VII. CARBON EMISSION ANALYSIS

The entire structure was modelled using Revit. The energy outlets were added as per the actual structure. Then a carbon emission analysis is carried out to find the carbon rating of the structure.


Figure.5 monthly electricity consumption

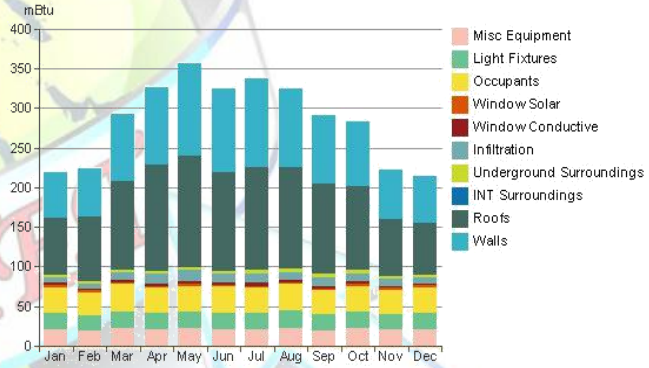


Figure.6 Monthly Cool Load Components

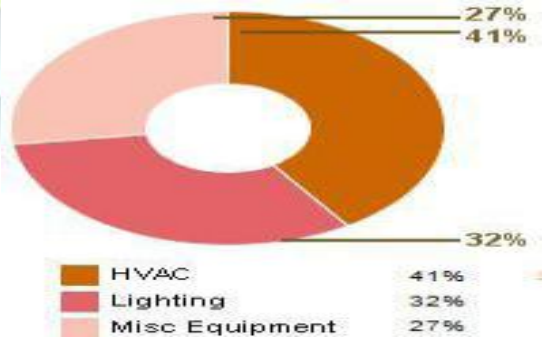


Figure.7 Electricity End Uses

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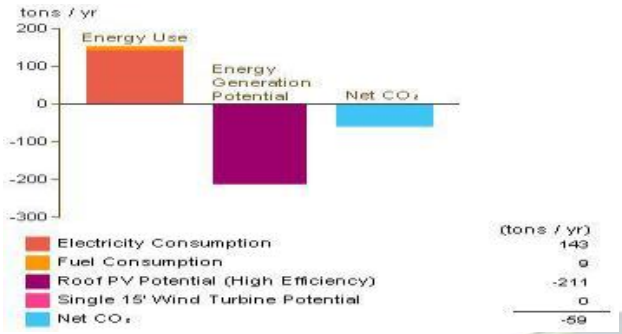


Figure.8 annual carbon emission

## VIII. CONCLUSIONS

The following conclusions are useful to overcome such problems at the consumer level in the building under consideration. The conventional lights can be replaced by LED lights. This is a highly efficient solution as seen with the analysis. Normal A/Cs can be replaced by 5-Star A/Cs. In the mean wise retrofitting the energy efficient appliances in the household by reviewing of star rating.

Alterations in the interior and exterior wall colouring, flooring, and glazed windows can increase the energy efficiency of the structure. Proper positioning and orientation of lights can ensure improved efficiency.

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