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Assessment of Energy Consumption and Life Cycle Energy of the Existing Residential Building and Implementation of Energy Efficient Concepts

Pooja D Prasad

Department of Construction Technology and Management, Sri Jayachamarajendra College of Engineering, JSSSTU, Mysuru, Karnataka, India

ABSTRACT-The investigation provides a general overview on how to reduce the energy consumption in residential buildings by efficient and effective utilization of energy. The total life cycle energy of the building is being calculated with the help of some standard measures and thereby attempts have been made to reduce the operational energy of the concerned residential building. The energy consumption may be reduced by the use of renewable sources as well as conventional resources in the buildings sector which constitute important measures that are needed to reduce energy dependency and greenhouse gas emissions which results in the global warming and unprecedented rates in climate changes. Even attempts have been made to address the effect of implementation of some concepts of zero energy on the comfort condition of Residential buildings

Keywords: Greenhouse gas, total life cycle energy, Comfort conditions, energy efficiency, Net Zero energy

I. INTRODUCTION

The building sector represents the third largest domain of total energy consumption after the industrial and transportation sectors. According to the International Energy Agency (IEA), buildings account for approximately 28% of global energy-related CO₂ emissions. Buildings account for around 40% of total energy consumption and 36% of CO₂ emissions (Energy Conservation Building Code of India (ECBC)); Buildings have an enormous impact on environment, human health and economy. The energy used to heat and run our buildings is large, mainly comes from burning of fossil fuels, oil, natural gases and coal, which generate significant amounts of carbon dioxide, the most noted greenhouse gas. The major consumption of Energy in buildings is during construction and later entire life span of building i.e. operational phase (enhancing comfort conditions).

The present study focuses on existing concepts, building standards and analysing the main methodological challenges faced by the reference residential building, its implications for the net Zero energy building. Finally, the study concludes by arriving at an outlook on necessary steps towards a successful implementation of nearly Zero-Energy Buildings. It is seen that the result of new model concluded is significantly more efficient, more productive, and more cost effective than the current system. Results may also be highlighted implementation of challenges as this relates to simultaneously reducing greenhouse gas emissions and minimizing its impacts on human health and the environment.

II. METHODOLOGY

The study builds on existing concepts and building standards, analyses the main methodological challenges faced by the reference residential building, by carrying out a research proposal on energy efficient building.

- An audit survey was carried out on an existing residential buildings in Mysore locality.
- Based on the survey, the conclusions were drawn compiling a possible set of principles and assessing their impact on the concerned residential building and thereby measures were taken to rectify the problems faced.
- Subsequently the technological, financial and various building material implications intended are used to calculate the total life cycle energy and thus the life cycle cost analysis (LCCA) of the building.
- Investigation will be carried out to assess the energy efficiency of a residential building.



III. EXPERIMENTAL INVESTIGATION

3.1. Residential building energy audit survey: An energy audit/survey is one of the first steps to obtain savings. The goal is to understand the basic trends of the building throughout the year to determine if energy consumption is increasing and if there are seasonal trends.

3.1.1. HOUSE 1: Basic Information

Date of energy audit:		12-3-2023	
Department/Building /Area covered:			
Occupied area:	✓	Unoccupied area:	
Cleaning times:		10AM, 4PM	

3.2. ENERGY EFFICIENCY & CONSERVATION

Energy Conservation: Energy conservation refers to reducing energy through using less of an energy service. Energy conservation differs from efficient energy use, which refers to using less energy for a constant service. For example, driving less is an example of energy conservation. Energy efficiency, sometimes called efficient energy use, is using less energy to provide the same level of performance, comfort, and convenience. Reducing energy use reduces energy costs and may result in a financial cost saving to consumers if the energy savings offset any additional costs of implementing an energy efficient technology. Reducing energy use is also seen as a solution to the problem of reducing carbon dioxide emissions. Energy efficiency and renewable energy are said to be the twin pillars of sustainable energy policy.

3.2.1. ENERGY CONSUMPTION OF RESIDENTIAL BUILDINGS DURING THEIR LIFE CYCLE

Energy used during the lifespan of buildings consists of consumed energy in production, management, occupation and destruction phases' i.e. initial and recurring embodied energy, operational energy and demolition energy. In the present study, the total energy use of two residential buildings during their life cycle is investigated and their energy consumptions are calculated for all temporal phases separately.

METHOD

Life cycle of building includes the manufacture of building materials, transportation of building materials to construction site, erection of building, occupancy, renovation, and demolition and removal phases. Energy demand during the life cycle of the building LCE (kWh), is the sum of the different energy demands during the different phases and calculated as below:

$$LCE = Q_{\text{manufacture}} + Q_{\text{transportation}} + Q_{\text{production}} + Q_{\text{renovation}} + Q_{\text{operating}} + Q_{\text{demolition}}$$

Since there is not enough data about the energy gained by reuse, recycling or combustion, the value of the left over products are neglected. The procedure used for calculating energy consumption in all these phases is described below.

3.2.1.1. Energy consumption in production phase

Energy is required for manufacturing any construction material.

Manufacture:

$$Q_{\text{manufacture}} = \sum m_i M_i (1 \pm E_c / 100)$$

Where,

i = the material of concern

m_i = amount of the building material i (ton)

M_i = energy required for manufacturing the building material i (kWh/ton).

E_c = the factor for waste of the building material i produced in erection (%)



Energy use for building materials:

Energy use for transportation of building materials:

Transportation and production:

Q transportation, production = $\sum m_i (1 + E_c/100) d_i T_c$ Where,
 i = the material concerned; m_i = amount of the building material i (ton);
 w_i = factor for waste of the material i produced during erection of the building (%);
 d_i = distance from the manufacturer of material i to the building site (km) and
 T_c = energy required for the conveyance concerned (kWh/ton km).

3.2.1.2. Energy consumption in renovation and repairing phase

Renovation:

Q renovation = $\sum m_i (1 + E_c/100) M_i ((L_b/L_{m_i}) - 1)$

Where,

L_b = life span of a building

L_{m_i} = life span of material

The life spans of construction materials:

Therefore the constant value of energy consumed is taken as Q renovation = 85.25 for house-1

3.2.1.3. Energy consumption in operating phase

It is the energy required for maintaining comfort conditions and day to day maintenance of the buildings. Energy used in occupation has many components but in the present study only heating and electricity energy are considered.

Calculation for total wattage consumption for existing devices (1Unit =1 kWh=1000 W-h):

House 1:

Sl No	Equipments	No.	Watt	Duration of usage (hrs)	Wattage consumption (kWh or units)
1	T12 Tube Lights	6	55	4	1.32
2	Ceiling Fans	5	80	12	4.8
3	Refrigerator	1	200	24	4.8
4	Air Condition	1	1060	5	5.3
5	Heating: Electric Iron	1	1100	1	1.1
6	Entertainment: Television	1	200	14	2.8
7	Desktop Computer	1	250	5	1.25
8	Mixer	1	200	2	0.4
9	Washing Machine	1	1500	2	3
10	Water Pump	1	750	1	0.75
Total power consumed per day					25.52

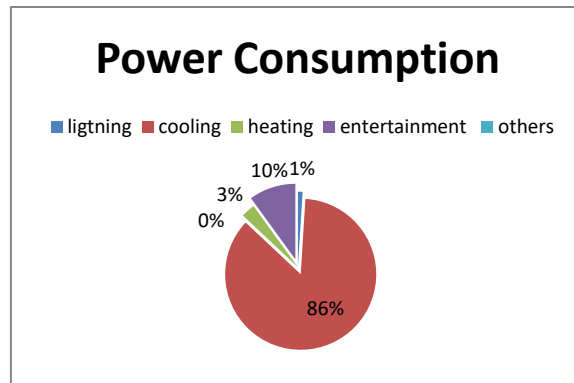


Fig: Power consumption pie chart

By using Energy Efficient Equipment:

Therefore,

1. There is nearly 10.313 kWh units savings per day i.e.,
2. 10.313 kWh * 30days = 309.4 kWh units saved per month
3. 309.4 kWh * 12 months = 3712.7 kWh units saved per year.

3.2.1.4. Energy consumption in destruction phase

Destruction phase includes demolishing, removing and transporting the waste materials from the building site to landfill sites or recycling plants.

Demolition

$$Q_{\text{demolition}} = E_d + E_t$$

Where,

E_d = energy incurred for destruction of building

E_t = energy used for transporting the waste materials

- It is seen that most of the energy is consumed in operational phase for both the buildings.
- Therefore the constant value of energy consumed is taken as $Q_{\text{demolition}} = 2.5$ for house-1

Some characteristic properties of residential buildings are summarized in Table 5.

	Building 1
Floor Area (m ²)	276
Number of floors	1
Number of residents*	4
Source of heat	District Heating
Heating system	Radiators

3.3. Life -cycle cost analysis (LCCA)

Life-cycle cost analysis (LCCA) is a method for assessing the total cost of facility ownership. It takes into account all costs of acquiring, owning, and disposing of a building or building system. LCCA is especially useful when project alternatives that fulfil the same performance requirements, but differ with respect to initial costs and operating costs, have to be compared in order to select the one that maximizes net savings. Lowest life-cycle cost (LCC) is the most straightforward and easy-to-interpret measure of economic evaluation.



Cost assessment of the power consumption in house 1:

- With normal appliances the units consumed are: 25.52 kWh units per day
i.e. monthly = 765.6unit = 50 + 50+100+565.6 units
- Replacing normal appliances with Energy Efficient Appliances the units consumed are 15.207kWh units only.
i.e. monthly =456.21 units = 50+50+100+256.21 units
- There is nearly 10.313 kWh units savings per day
i.e. monthly =309.39 units = 50+50+100+109.39 units

In Karnataka As per tariff order approved on 02nd Mar 2021

With normal appliances the cost is:

Condition (x)	Rate (in Rs) per unit.(y)	Units	Cost per day (x * y)
Consumption less than 50 Units	4.15	50	207.5
Consumption between 51 & 100 Units	5.60	50	280
Consumption between 101 & 200 Units	7.15	100	715
Consumption more than 200 Units	8.20	565.6	4637.92
Total:			Rs: 5840.42

Replacing normal appliances with Energy Efficient Appliances the cost is:

Condition (x)	Rate (in Rs) per unit.(y)	Units	Cost per month (x * y)
Consumption less than 50 Units	4.15	50	207.5
Consumption btw 51 & 100 Units	5.60	50	280
Consumption between 101 & 200 Units	7.15	100	715
Consumption more than 200 Units	8.20	256.21	2100.92
Total:			Rs: 3303.422

Therefore the savings in cost is: 2536.998 Rs. Per month i.e. per year in savings =2536.998*12 months=30,767.86 Rs.



IV. RESULTS AND DISCUSSION

4.1. Life cycle energy and life cycle cost assessment:

Calculated Energy consumption in operating phase

Our homes and businesses are filled with lots of things that use electricity, but how we use them is as unique as we are. From readings equipped at residential houses we could diminish the measured energy consumption by implementing Energy Efficient Equipment. By using Energy Efficient Devices we can save and reduce shortage of Power and can reduce power inflation.

Total power consumed by appliances		
	Regular kWh	Energy efficient kWh
House1		
Per day	25.52	10.313
Per year with energy efficient equipments	10.313 kWh * 30days * 12 months =3712.7	
House2		
Per day	15.974	6.213
Per year with energy efficient equipments	6.213 kWh * 30days * 12 months =2236.68	

✓ It thereby affects the overall **operational cost** of the building by an appreciable amount according to the assessment:

- Per month with normal appliances the cost is:

House1: 5840.42 Rs

- By replacing normal appliances with Energy Efficient Appliances the cost is:

House1: 3303.422 Rs

- Therefore, the overall savings in cost is:

House1= 2536.998 Rs

Resulting Life cycle energy of buildings:

Energy use during life cycle of buildings:

	House-1 (276m ²)
Phases	kWh/m ²
Production: Manufacture Transportation and production	266.4 7.73
Renovation :	85.15
Operational/Management: Occupancy, 50 years	1608.5



Destruction: Demolition Removal	2.5 5.25
Total kWh/(m ² .50 years)	1975.53
Total kWh/(m ² .year)	39.51

On using energy efficient equipments in the operational phase of the buildings:

	House1 (276m ²)
Phases	kWh/m ²
Production: Manufacture Transportation and production	266.4 7.73
Renovation :	85.15
Operational/Management: Occupancy, 50 years	962.63
Destruction: Demolition Removal	2.5 5.25
Total kWh/(m ² .50 years)	1329.66
Total kWh/(m ² .year)	26.59

On using energy efficient equipments we have got a great downfall in the units consumed by these residential buildings per year.ie the resulting total energy use of buildings reduce to 26.59 kWh/ (m².year).

V. CONCLUSION

Based on the results obtained, the following conclusions can be drawn:

5.1. Life cycle energy and life cycle cost assessment:

The total energy use during the life cycle of the reference residential building in Mysore region is investigated. The purpose is to gain an insight into total energy use for buildings during its lifecycle when current equipments are being replaced by energy efficient equipments, thereby adopting feasible measures for individuals and society to reduce energy consumption in their houses by reducing operational energy effectively.

It is also observed that total energy use of buildings is 39.51 kWh/ (m².year) and energy use is increasing when the total useful area of building is decreasing.

The results show that operational phase is the highest energy consumption phase for all buildings. For this reason, using less heating and electricity energy is very important for minimizing life cycle energy. On using energy efficient equipments we have got a great downfall in the units consumed by these residential buildings per year.ie the resulting total energy use of buildings reduce to 26.59 kWh/ (m².year).

Energy Audit deals with verification, monitoring and analysis of use of energy including submission of technical report containing recommendations for improving Energy Efficient with cost benefit analysis and an action plan to reduce energy consumption.



Energy Saving is a Social Responsibility for every individual. In this report we have analyzed the amount of wattage consumed by different devices and suggested necessary replacements and showed the net savings. By this analysis, through Energy Efficient Equipment power consumption can be minimized with current devices without disturbing the output and thereby reduce the life cycle cost of the residential building.

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