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Energy Audit and Benchmarking of Single-Family Residences

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Abstract: Residential buildings in India are the second-largest energy-consuming sector in India. Electricity consumption in the residential sector has increased by 53 percent in the period between 2012-17 according to the energy policy review report. This can be ascribed to extensive electrification and an upsurge in the amount of thermal comfort providing cooling appliances. Energy savings mandate the management of residential buildings' energy consumption for its substantial role in accomplishing the energy proficiency targets. The first step towards energy conservation is an energy audit of buildings to recognize the pattern of electricity use viability of energy-saving and prospects that can be explored for evolving an energy management program. The most suitable energy benchmarking for plotted residential buildings by way of data collection of case study is established.

Index Terms **– Energy Performance Index (EPI), Post-occupancy Assessment, Residential buildings, Energy Audit, Benchmarking.**

I. Introduction

The residential buildings are accountable for 30 percent of India's total final consumption. Major components of residential energy use are bioenergy, oil, and electricity. A large increase in the use of electricity especially for thermal comfort has been witnessed since 2012. (India 2018, Energy Policy). An intensive electrification campaign with the tremendous increase in air conditioners to a rate of nearly 50 percent in the last 5 years is the causation of the rise in electricity use. Currently, India is still far behind many developed nations when compared to per capita energy consumption. But witnessing the existing inclination of air-conditioners and appliances penetration rate in residential buildings is suggestive of an energy-intensive future.

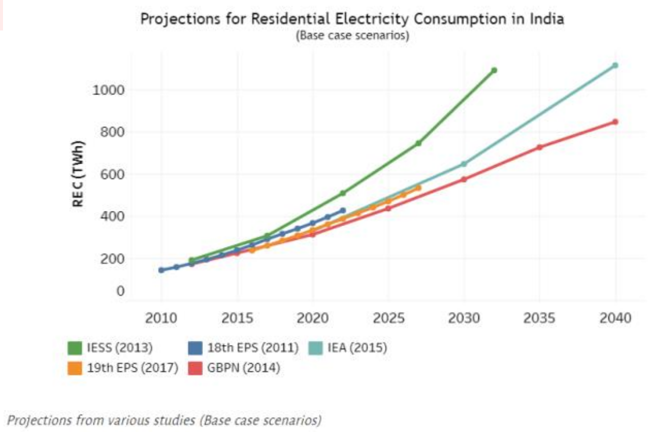


Fig.1. Electric Energy consumption projection in Indian Residences (Source: Centre for policy research(cprindia.org)

The ecological and commercial problems are driving forces for investigative studies for reducing energy usage and associated greenhouse gas emissions in diverse sectors. Building energy utilization evaluation is a way to reap the goal of energy optimization and emissions reduction means to achieve the target. The energy performance of built structures is complex subsequently it relies on various variables connected to the building characteristics, systems and structures, weather, occupants, and socio-cultural stimuli. The conservation actions need a circumstantial evaluation of energy and its pattern of use by buildings. This information can be obtained by a primary survey of historical data collection and analysis in form of an Energy Audit. The process of Energy Audit is a systematic instrument for the operative organization of energy. As consistent with the Energy Conservation Act, 2001, Energy Audit is described for the verification, tracking, and evaluation of the use of power along with submission of technical description containing pointers for enhancing power performance with price advantage evaluation and an effective framework to lessen power intake. It includes a sequence of events such as pre-survey statistical information collection, walk-through examination, data assemblage, analysis of the data amassed, and devising of energy productivity solutions. Subsequent to this sometimes-physical buildings' internal thermal setup monitoring, residents' response, and utility usage is also data which is compiled. analysis of all this data is purposive of an energy audit for energy management program which maintains the energy use at an optimum level, diminishes waste and utilization without impacting production, quality, and living environment. There are various stages provided by the Bureau of Energy Efficiency (BEE) for Energy Audit and can be classified into the following two types.

1. Preliminary Audit: It uses current, or effortlessly obtained data. It is a prompt way to determine energy consumption in the case study, approximation of reduction potentials, component for consideration, and best option for improvements for efficiency. It also helps to set a 'reference position and recognize areas that need detailed assessment.
2. Detailed Audit is an all-inclusive audit that affords a comprehensive energy scheme execution plan for a facility, subsequently its analysis of all main energy utilizing systems, it proposes the utmost precise estimate of energy savings and financial implications.

Preliminary energy audit as per BEE accordingly, can be useful to understand energy consumption patterns in residential buildings and can be conducted with easily available information like collecting electric bills of residential buildings and details of the basic overall building This will be useful to derive comparisons and understand the cause of an increase in units used in different seasons and the slump periods.

II. Research Methodology and Objectives

Energy optimization in residential buildings has developed into an area of extensive research in recent decades and vast literature is available with a diversity of techniques of evaluation for programs management of energy. The literature studies and research work entails energy audit necessity as usage of benchmarking by EPI (energy performance index) for assesses the energy performance of the existing single-family residential buildings to classify building proficiency. This study is conducted using case study methodology taking random samples for collecting electric bills of plotted residential buildings in a Tier II city where this typology is in larger proportion.

Energy audit framework for the current research:

1. Collect electricity usage data in form of electricity bills for a period of 12 months years of the study sample.
2. Analyze the data by studying the pattern of energy usage as a part of pre-audit.
3. Organize historical data collected
6. Calculate the Energy/Demand Intensity by benchmarking
7. Correlate consumption with occupancy, built-up area, and cooling or heating energy systems.

The objective of the current study is to

To evaluate the quantitative information of electricity use in residential buildings with nationally acceptable benchmark EPI for determining the energy efficiency of plotted residential buildings.

III. Case Study

India's tropical climate evident characteristic is managing heat in four climatic zones that is composite, hot and humid, warm and humid, and temperate except for the cold zone which accounts for a very small area. Jammu with an expanse of 240 km^2, is the winter capital has of the state of Jammu and Kashmir and is the second-most populous city of the union territory. It is positioned at 32.73°N 74.87°E. with a mean elevation of 300m. The motives for selection of the case for investigation and plotted single- family residential typology are as follows:

- Jammu city witnessed a rise in maximum annual temperature in the last 30 years, the recorded maximum high temperature in the month of May in the 1980s was around 42 ⁰ C but in the recent decade, it is 47.2º C.
- There is an acute power crisis in the state of Jammu and Kashmir- long periods of power cuts during extreme summer and winter months.
- Acute power crisis long period of power cut in extreme climates in Jammu - leading to loss of productivity and adverse effect on the health of the occupants as well as the use of diesel generators adding to environmental degradation.
- The consumption of electricity, as per the electricity department goes up considerably during the summer months (as per data collected).
- Shift from low-rise residential buildings to Mid- rise/high-rise buildings with housing flats have been allowed after the amendment in bye-laws in the year 2000. So a major portion of existing residential buildings is plotted residential buildings.
- A matter of concern is that there has been no focused effort for planning and designing of building for energy efficiency in this region as there are no guidelines for energy efficiency in the Master Plan.

The study is of plotted residential buildings and is low rise with a maximum ground, first floor and second floor. These residential buildings operate (MM) mixed-mode for thermal comfort. The MM means a combination of naturally ventilated zones with areas that are air-conditioned (AC)by individual units that are split AC or window AC and some areas in a building are air-conditioned (AC) based on programmatic requirements while the rest of it is naturally ventilated (NV). Occupants in the NV zone frequently visit the AC zone and are well aware of the conditions there. They can be detached, semi-detached, and row houses (NBC,2016)

3.1. Climate

Jammu has a composite climate though shown in the cold zone as per the climate distribution map of the National Building code. The composite climate of the Jammu region is most challenging as some part of the year is hot and humid, some cold and cloudy, some hot and dry, and cold and sunny. The average yearly precipitation is about 42 inches with most of the rainfall being from June to September, and it rains winters as well. In wintry weather dense smog reasons, a whole lot of inconvenience and temperature even drops to 2 °C. In summer, principally in May and June, extremely strong sunlight or hot winds can increase the temperature to 46 °C and this zone is experiencing frequent heatwaves. The mean maximum and minimum temperatures with monthly precipitation are given in Fig.2.

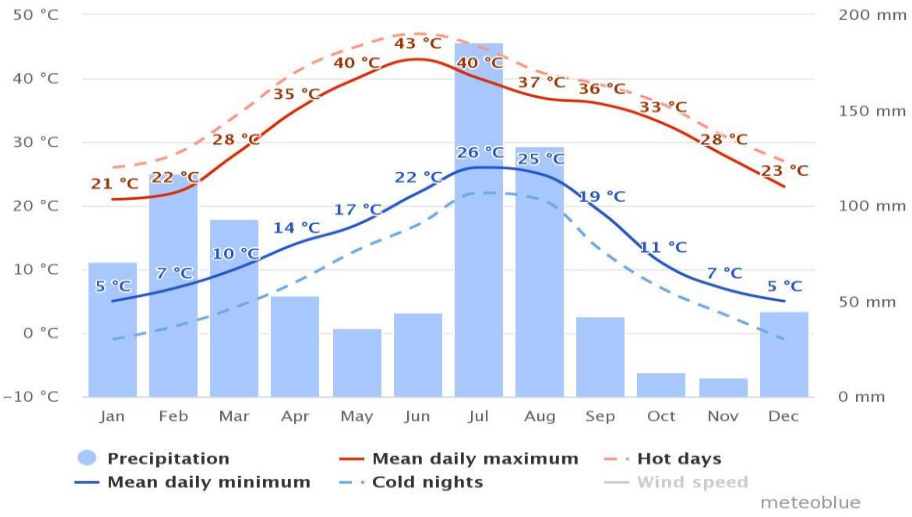


Fig.2. Climate of Jammu city (source: www.meteoblue.com)

3.0. Preliminary Energy Audit Survey

The present study is specific to residences of plotted development in Jammu city. The main aim of the study is to conduct an energy audit of residential electricity consumption with specific attention to the energy required for thermal comfort in the summer season. This is a Preliminary Audit as specified by BEE. The houses are more the twenty years old and are from the oldest colonies of the city from the post-independence era. No building energy audit has been carried out in this union territory so far. The research entails auditing six samples of the plotted single-family residential buildings for quantifying the use of electrical energy in the city. The sample of six residential buildings was selected by random sampling. The electricity bills for one year were collected along with information of plot size, built-up area, number of air conditioning systems, number of bedrooms, number of occupants, and year of construction.

3.1. Survey results & analysis

The plotted residential buildings have a large built-up area and few occupants. The occupancy rate is on an average of 4 persons. The bedrooms are on an average of three in number. The present system of rating building is on the EPI score which is annual energy use / square meter built-up area.

Table3.1. Residential Building Energy Labeling Program by Bureau of Energy Efficiency (Source: ECBC website)

Residential Building Star Rating				
Period: 14 December to 31 December2024				
Star Rating	Energy Performance Index* (E1+E2) of Dwelling Unit			
	Composite	Warm & Humid	Hot and Dry	Temperate
1-Star	52 <EPI ≤60	58 <EPI ≤64	55 <EPI ≤67	28 <EPI ≤31
2-Star	45 <EPI ≤52	49 <EPI ≤58	47 <EPI ≤55	24 <EPI ≤28
3-Star	37 <EPI ≤45	39 <EPI ≤49	38 <EPI ≤47	31<EPI ≤24
4-Star	29 <EPI ≤37	30 <EPI ≤39	29 <EPI ≤38	17 <EPI ≤21
5-Star	EPI ≤29	EPI ≤30	EPI ≤29	EPI ≤17

*E1 (EPI) is for Airconditioned area and E2(EPI) non-airconditioned zone

The E1 and E2 are not taken for the present study because only one electric meter is there for the entire household and separate electricity units' data for airconditioned and non-airconditioned space is not available.

The Energy Performance Index is also a benchmark for the energy efficiency component of Green Rating Integrated Habitat Assessment (GRIHA) and the values for residential buildings for different climatic zones are given in Table 3.2.

Table 3.2: EPI for GRIHA rating

Energy Performance Index Benchmark (EPI)-kWh/m2/year	
Climate Classification	Residential Buildings/Hostels
Moderate	50
Composite/warm and humid /hot and dry	70

Table 3.3; Data Collected by Survey of plotted residential buildings in Jammu city

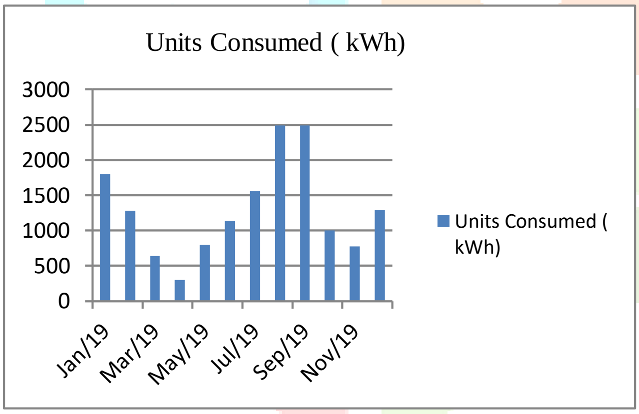
Study Sample	Units Consumed in a year(kWh)	Built-up area m^2	EPI	Star Rating	No. of persons	Per Capita	No. of bedrooms	No. of A/Cs
Case 1	15569	280	55	1-Star	4	3892	4	4
Case 2	11003	220	50	1-Star	2	3667	3	2
Case 3	8651	190	45	2-Star	5	1730	3	3
Case 4	12554	200	62	-	6	2092	4	4
Case 5	14124	210	67	-	4	3531	4	3
Case 6	11746	300	39	4-Star	5	2348	4	4
Average						2877		

All the case studies are within the range of star rating as per BEE except for case studies 4 and 5(Table 3.3). These two case studies have EPI s more than 60 which is not included in the star rating. Energy use per person is very high, even though the prescribed EPI is equivalent to a star rating. All the case studies are suitable for the energy efficiency component of GRIHA, green building rating.

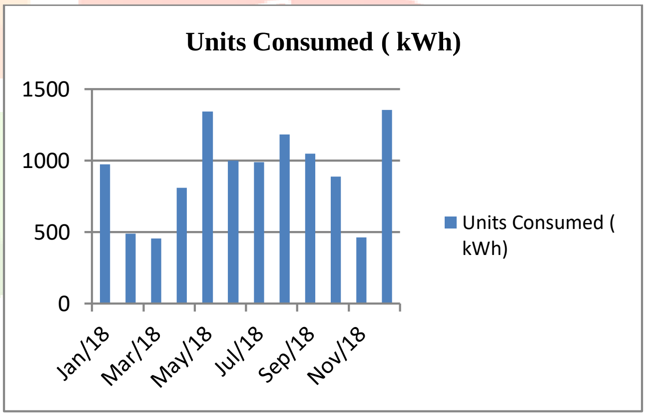
Table 3.4: Electric energy consumption per capita ((Source: World Bank.org)

Country	Most Recent Year	Most Recent Value
India	2014	805 kWh per capita

For context, the global per capita consumption was 3,130 kWh in 2014, according to data listed by the World Bank, which puts India's consumption that year at 805 kWh per capita. In the sample houses the per capita energy use on an average is 2877kWh, which is more than double the national average.



Case 1



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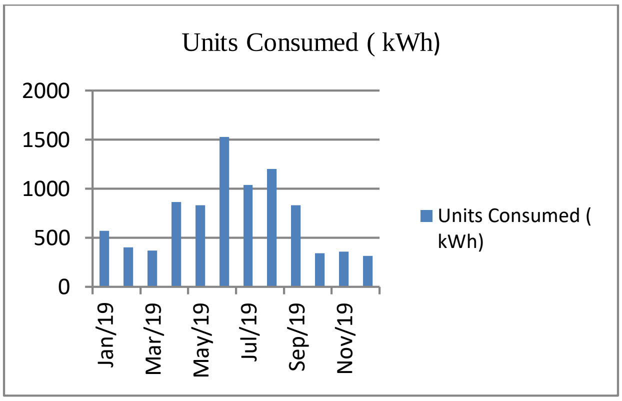
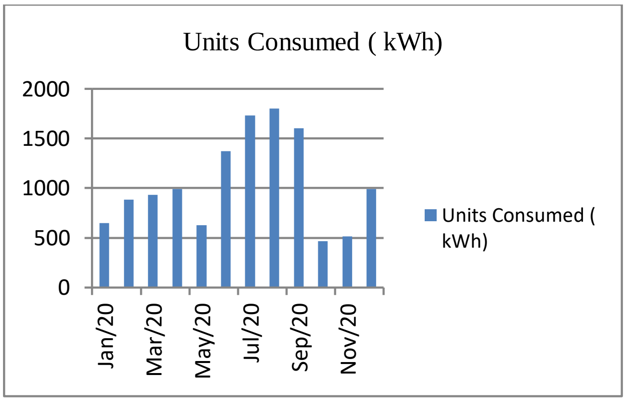
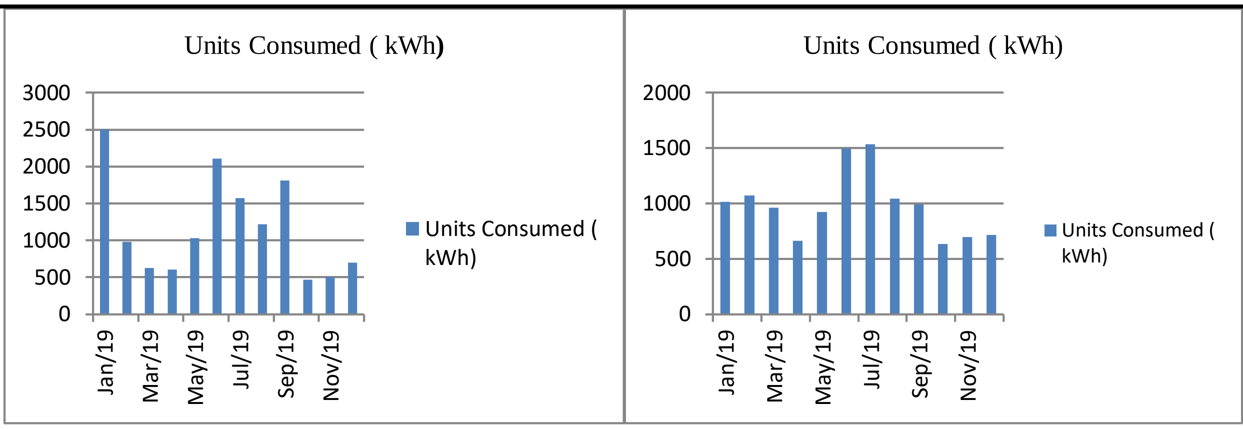


Case 3



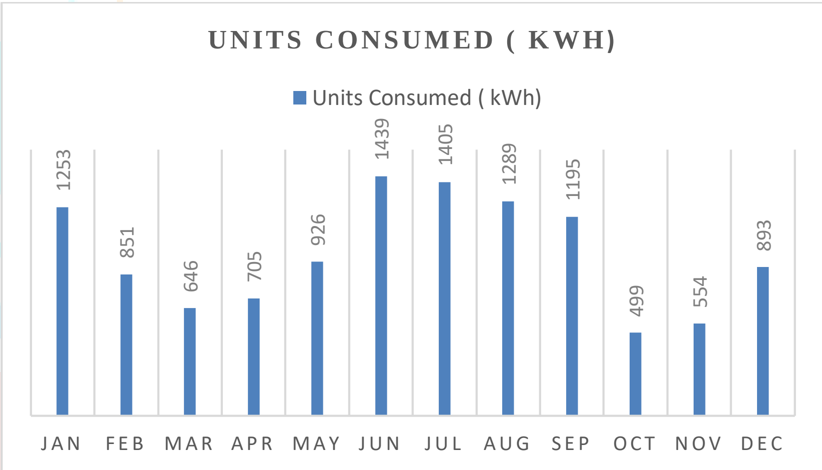
Case 4



Case 5 **Case 6**

Fig.3 Graphs showing units used in Sample houses.

The analysis of the six samples shows an average increase of nearly more than 50 percent increase in energy use from May to September. The winter months of December and January also show a considerable increase in electric energy consumption.



Eig.4 Average Monthly electricity consumption in sample households

The average monthly electricity consumption graph of the sample house shows that there is a baseload of nearly 600kWh, which can be ascribed to lighting, appliances other than those used for thermal comfort that is heating and cooling. The increase in units consumed can directly be related to external temperatures either below or above the thermal comfort zone range of 18 degrees centigrade to 24 degrees centigrade as per ASHRAE. Further, the occupants are not very satisfied with thermal comfort levels inside their residences during the summer and monsoon seasons. So, EPI of electricity normalized with an area is not a very effective benchmarking technique. It had been brought forward by some studies (Fokaides et al.2017) that quantification of EPI as kWh per capita is more appropriate as energy efficiency measures for building's energy performance than the current practice of measurement of kWh per unit area. Nearly 50 percent (TERI) of heating and cooling load can be ascribed to the building envelope to a large extent. If the building envelope load is managed through passive design techniques the seasonal cooling and heating load can be reduced and electricity consumption can be further optimized.

IV. Conclusion and Recommendations

According to the Energy Audit of plotted single-family residential buildings in Jammu city, the following inferences can be drawn:

1. In addition to the built-up area, which is a standard consideration according to guidelines, the number of Air conditioners, number of bedrooms, and number of occupants are very significant variables to understand the pattern of energy use.
2. It has been found from the data that EPI with respect to the built-up area may not be the best option for plotted residential HIG group as per capita energy consumption is very high, so these buildings cannot be energy efficient as their EPI scores are in the range of star ratings as per BEE and GRIHA (standard codes for energy efficiency and sustainability.
3. The chart for average monthly units consumed shows variations of which can be correlated with the climatic variations, so building envelope retrofit would be a viable option to be explored for energy efficiency.

REFERENCES

[1] Centre for Policy Research, https://www.cprindia.org/

[2] EIA's International Energy Outlook 2017 (IEO2017), [Online], Available: https://www.eia.gov/outlooks/ieo/pdf/0484(2017).pdf

[3] Energy Conservation Act, 2001, [Online], Available: https://powermin.gov.in/sites/default/files/uploads/ecact2001.pdf

[4] Bureau of Indian Standards (BIS) (2016). National Building Code of India 2016,(NBC). [Online],Available: http

[5] http//: www.worldbank.org

[6] Green Rating for Integrated Habitat Assessment. (GRIHA, https://www.grihaindia.org/

[7] Jammu, Master Plan,2032, [Online], Available: https://www.jmcjammu.org/JMP2032.pdf

[8] Bureau of Energy Efficiency, A statutory body under the Ministry of Power, Government of India, [Online], Available:beeindia.gov.in

[9] Energy Audit and Management, https://www.beeindia.gov.in/content/energy-auditors

[10] Climate details of Jammu, http//:www.meteoblue.com

[11] Roadmap for Incorporating Energy Efficiency Retrofits in Existing Buildings, The Energy and Resources Institute, 2013, The TERI Website, [Online]. Available: http://cbs.teriin.org/pdf/Energy_Efficiency_Retrofits_in_Existing_Buildings.pdf

[12] Roadmap for Incorporating Energy Efficiency Retrofits in Existing Buildings, The Energy and Resources Institute, 2013, The TERI Website, [Online]. Available: http://cbs.teriin.org/pdf/Energy_Efficiency_Retrofits_in_Existing_Buildings.pdf

[13] Fokaides, Paris A.; Polycarpou, Kyriacos; Kalogirou, Soteris (2017). The impact of the implementation of the European Energy Performance of Buildings Directive on the European building stock: The case of the Cyprus Land Development Corporation. Energy Policy, 111(), 1–8. doi:10.1016/j.enpol.2017.09.009,