

Analysis of Operational Energy in Residential Buildings of Hassan City, Karnataka

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ABSTRACT: This paper aims to find out the monthly average household electricity consumption and seasonal variations in this consumption for the months of summer, winter and monsoon weather for Hassan city in Karnataka state, India. The factors which influence the electricity consumption of a household have been examined by using a survey of questionnaire based study of 170 Hassan households selected via stratified random sampling technique. Multiple regression models using MAT lab have been run to describe the pattern of household electricity consumption. The results from the study show that the stock of appliances in a household contributes the most to the variation in the dependent variable. An inverted double U-shaped non-linear Temperature- Electricity Curve has been derived from the primary data used in the study. This study also emphasis that using energy efficiency applications ,usage of solar energy, alternate materials and methods of construction , we can reduce the consumption of energy which will be a costly in year ahead and prosperity of the country and also reduce pollution issues. This paper also gives the total embodied energy required for the construction extracted from literature and operational energy consumed for 50 years lifespan of the buildings.

KEYWORDS: Operational energy ,Embodied energy , Hassan.

I.INTRODUCTION

Energy, Embodied energy and Operational Energy.

Energy is an important input in all sectors of the economy of any country. Buildings even consume energy during construction, after the completion of construction, and even in the demolition of constructions. Hence abundant amount of energy is consumed, in these ways energy has been interlocked with the buildings. The standard of living of a given country can be directly related to per capita energy consumption.

The EE and OE assessment here presented was carried out considering the definitions provided by the International Energy Agency (IEA), Solar Heating & Cooling Program. The OE is the annual amount of non-renewable primary energy required for use during the life of a building. OE refers to Primary Energy Demand (PED) for heating, ventilation, cooling, hot-water production and for lighting. The EE is the amount of non-renewable primary energy required for the extraction of raw materials, their transformation into semi-finished and finished products (initial EE), the replacement processes (recurring EE) and the disposal processes (end-of-life EE).

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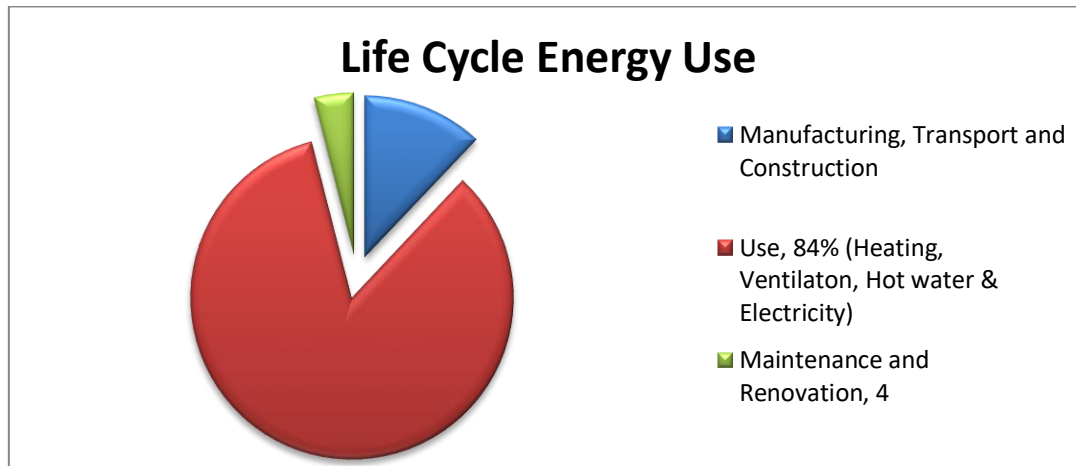


Figure 1.1: Life Cycle Energy Use

Benchmarks are applied mainly to heating, cooling, air-conditioning, ventilation, lighting, fans, pumps and controls, office or other electrical equipment, and OE consumption for external lighting. The benchmarks used vary with the country and type of building.

Energy efficiency of building by:

- 1 Energy monitoring:
- 2 Energy modeling:
- 3 Energy efficient materials and technologies

Energy Conservation and Energy Efficiency are separate, but related concepts. Energy conservation is achieved when growth of energy consumption is reduced, measured in physical terms. It is imperative that measures are taken to reduce the energy demand of buildings. One of the most promising ways of energy conservation is through efficient use of the available energy which can be achieved through proper management and control especially at the architectural design stage of building creation. Other measures include the use of energy efficient technology, alternative energy sources, buildings that can generate surplus energy and feed it into an intelligent grid infrastructure.

Efficiency in building involves reduced energy consumption for acceptable levels of comfort, air quality and other occupancy requirement. Energy efficiency in buildings provides a wide range of societal benefits including significant consumer cost savings, reduce energy demand and improved electric system reliability. The building sector alone represents about 35% energy consumption. Realizing the situation, the need of the day is to adopt sustainable green building design approach which is the ultimate solution to reduce the energy demand of the building. Over usage of conventional building materials not only cause global warming but also affects the natural resources. Green or sustainable building use key resources like energy, water, materials, and land more efficiently than buildings that are just built conventionally. The major part of the energy is consumed by the electrical energy which facility has been consumed by equipments used, lighting systems, and HVAC (Heating Ventilation Air-condition) systems which consumes additional amount of energy for the thermal comfort.

By keeping the inferences from literature review these following objectives were set for this study

- To analyze the usage of OE in Residential Building of Hassan City.
- To examine Seasonal variation of consumption of OE, how different season will affect the usage of OE in residential buildings.

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- To analyze the effect of parameters like income of the occupants, area of the residential building, number of occupants in building and number of electrical appliances on the usage of OE.

1.2 SIGNIFICANCE OF THE STUDY

From the study of literatures, the EE of buildings are the initial investment which takes around 15-20% of the total life cycle energy of buildings. The rest 80% of the energy will be utilized for the residence operation and maintenance. Demolition energy is very much negligible.

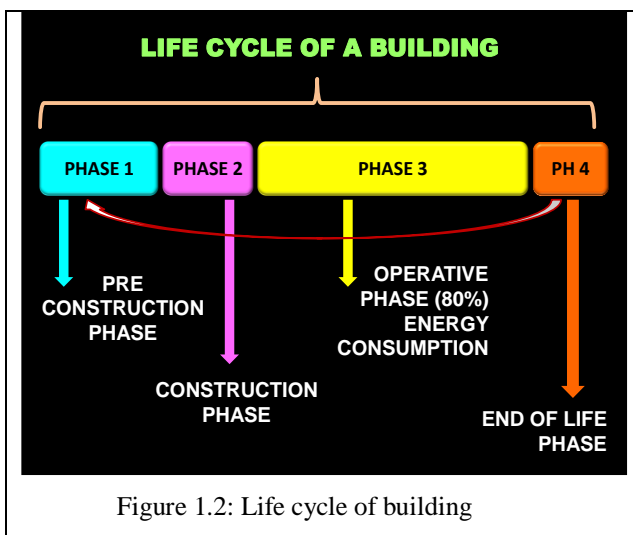


Figure 1.2: Life cycle of building

In a semi urban city of Hassan it's important to access energy consumed by the residential buildings for operation and maintenance in order to predict the rate of growth of city towards urbanization. It is important to know the parameters which are affecting the OE consumption that has been done by using regression analysis. The significance is to study the variation in electrical usage in different weather season like summer, winter and monsoon. After analyzing the result obtained one can know how the energy efficient techniques can be inculcate the energy efficient techniques in adopting energy efficient methodology in construction, energy efficient material used in construction and energy efficient appliances to be adopted in order to optimize the energy usage in residential buildings.

II. RESEARCH METHODOLOGY

Hassan is located at the latitude 13.0068° north and longitude 76.0996° east, whose elevation is 980m (3220 ft) above mean sea level. It is the town and district head quarters of Hassan District in the Indian state of Karnataka. It is surrounded by Bangalore, Mysore and Mangalore district. Hassan is surrounded by rich historical tourist palace like Belur, Halebeedu and Shravanabelagola.

The demographic details are:

Area	26.5 (km ²)
Number of wards	42
Population	133436 (as per 2011 census)
Population Density	261 inhabitants per km ² (680 per m ²)
Population Growth Rate over the decade	2001-2011 was 3.17%

Table 2.1: Information of Hassan City^[c]

The reason why Hassan is chosen for research work, presently Hassan is a semi urban city, which has a potential to grow towards complete urbanization. Since its located near to Bangalore, Mysore and Mangalore. Hassan is a second choice city for the residency. The supporting weather conditions, less polluted city (according to central

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pollution control board [CPCB] India in 2015)^[4]. So if the population growth increases with the same rate the radius of city will be increase, which impacts the energy consumption driving towards, urbanization. “Precaution is better than cure”, hence the necessary care can be taken to make energy efficient building [EE and OE] instead of conventional methodology (construction material, methodology and OE).

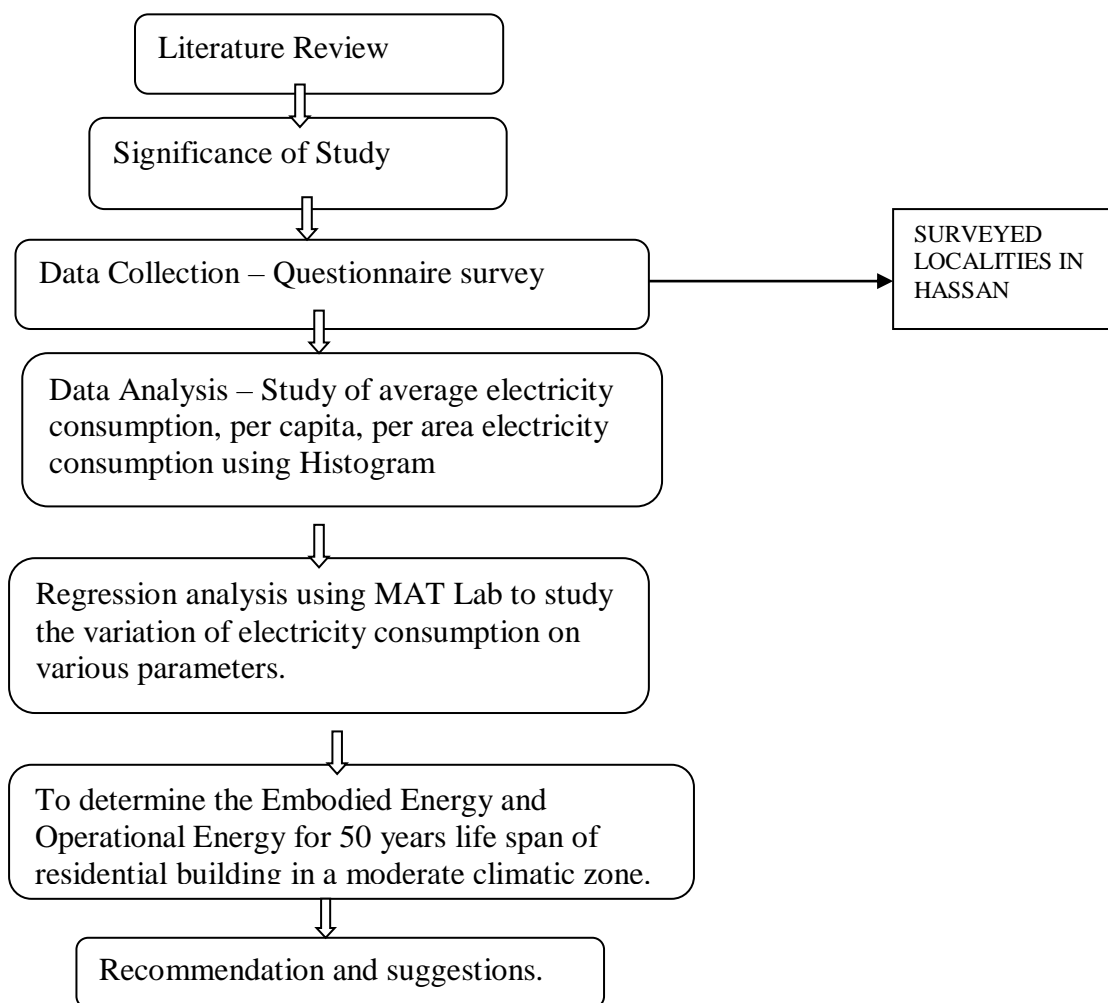


Figure:2.1 Flowchart showing different phases of the Research Methodology

In addition to this, the temperature of Hassan city from Hassan environment board was collected (Table: 2.2). This was utilized to find the energy consumption pattern and analyzed through graph given below (Fig 5.2 and 5.3). The graph shows that, maximum temperature and the energy consumption patterns are quite familiar with each other for most of the months of the year 2017 but the graph pattern are not matching in the month march and December may be because of load shedding.

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Month	Maximum Temperature degree celsius	Minium Temperature degree celsius	Average Temperature degree celsius	Maximum Rainfall in mm	Minium Rainfall in mm	Average Rainfall mm	Maximum Humidity	Minium Humidity	Average Humidity
January	36.40	7.50	21.07	6.40	0	7.19	100	0	60.34
Feburary	37.20	8.60	23.17	2.50	0	0.06	100	8.10	57.44
March	38.70	9.30	25.77	67.50	0	18.79	100	4.60	58.72
April	39.90	15.10	28.82	68.00	0	46.66	100	9.20	59.21
May	39.30	16.20	27.17	102.50	0	149.36	100	11	66.59
June	34.10	17.70	24.93	104.00	0	123.35	100	39	74.32
July	33.50	17.20	24.68	131.00	0	149.38	100	39.30	73.73
August	34.00	17.70	24.89	107.00	0	179.39	100	38.70	74.73
Septem ber	35.60	15.80	25.31	161.50	0	239.95	100	32	74.61
October	36.60	13.20	24.96	147.00	0	109.37	100	22.90	73.12
Novemb er	34.30	11.50	23.68	64.5	0	14.64	100	29.50	70.43
Decemb er	35.70	7.30	22.20	27.0	0	6.01	100	15.80	66.47

Table 2.2: Table of temperature, Rainfall and humidity data in Hassan City from Jan 2017 to December 2017

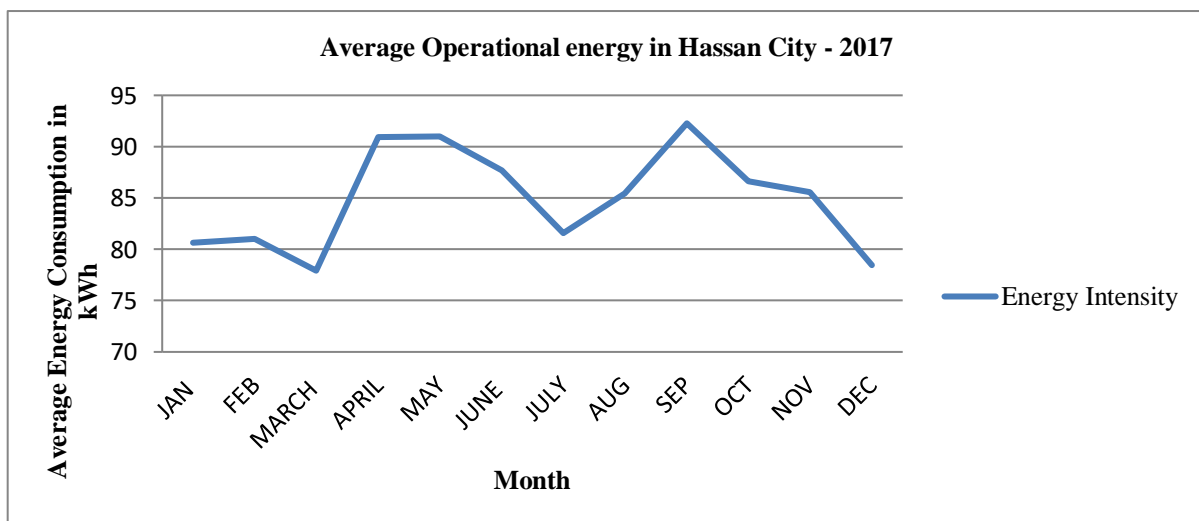


Figure 2.2: Average Monthly Household OE Consumption (in kWh)

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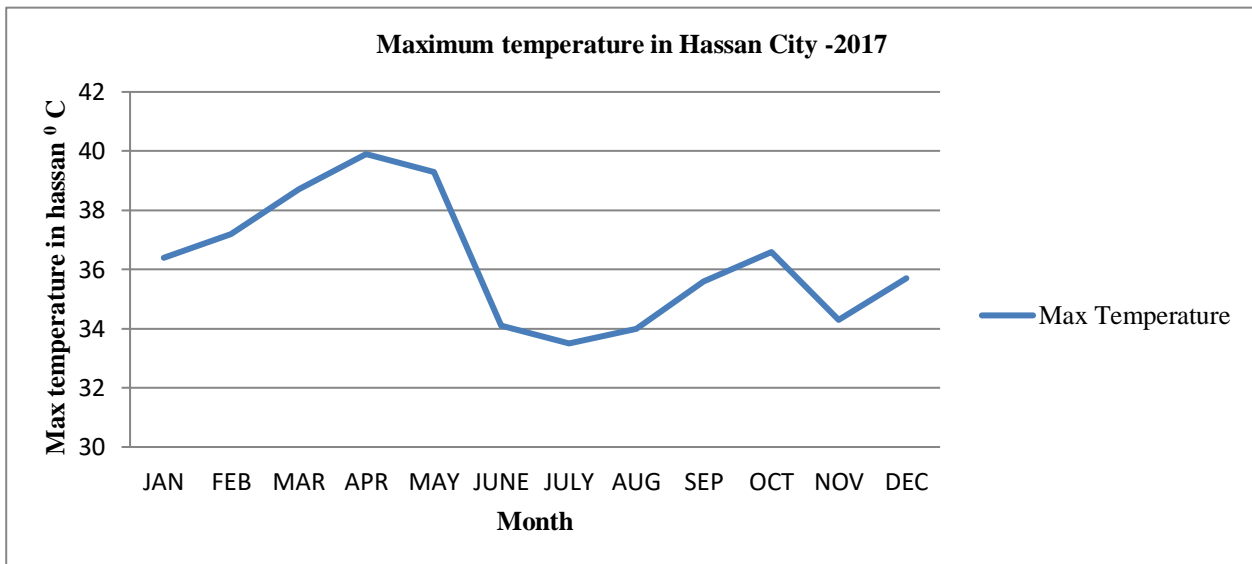


Figure 2.3: Pattern shows the maximum temperature and the energy consumption pattern.

N=170 N=Number of samples	Mean (OE consumption in kWh)	Standard Deviation	Coefficient of variation
Overall monthly consumption	89.42	61.42	68%
Summer season	91.19	68.09	74%
Monsoon season	85.73	59.08	68%
Winter season	91.33	63.34	69%

Table 2.3: Table of Mean, standard deviation and coefficient of variation of all the three seasons.

The above table 2.3 shows the OE consumption in average for 170 residential houses for different seasons. By observing the standard deviation value we can infer that the OE consumption value how much deviating from the mean value. Standard deviation was found to be high for summer and low for monsoon seasons with values of 68.09 and 59.08 respectively. Coefficient of variation indicates how much percentage of the OE consumption value is scattering. High and low coefficient of variation was obtained for summer season with 0.74 and monsoon season with value of 0.68 respectively.

III.DATA ANALYSIS AND DISCUSSION

Fig 3.1 shows histogram of OE consumption per annum and it indicates occurrence of OE consumption per annum for different class intervals. It shows the distribution of energy consumption.

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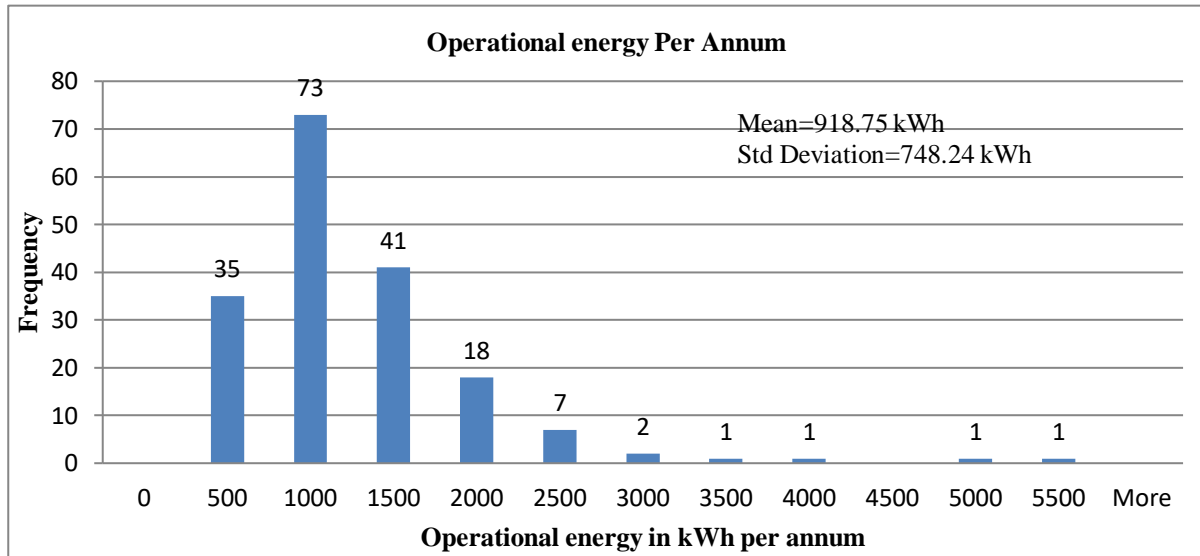


Figure 3.1: ENERGY CONSUMPTION PER ANNUM

From the above histogram we can infer that, in a city like Hassan the maximum number of houses utilizes the OE of 1000 kWh/annum. The maximum value of OE has been used by less than 6 houses of the range 3000-5500 kWh/annum. OE consumption mainly depends on the factors like number of appliances, area of the house, income of the occupant and number of occupants. This analysis was useful to select independent variables for the regression analysis and details about this analysis are provided in the coming section.

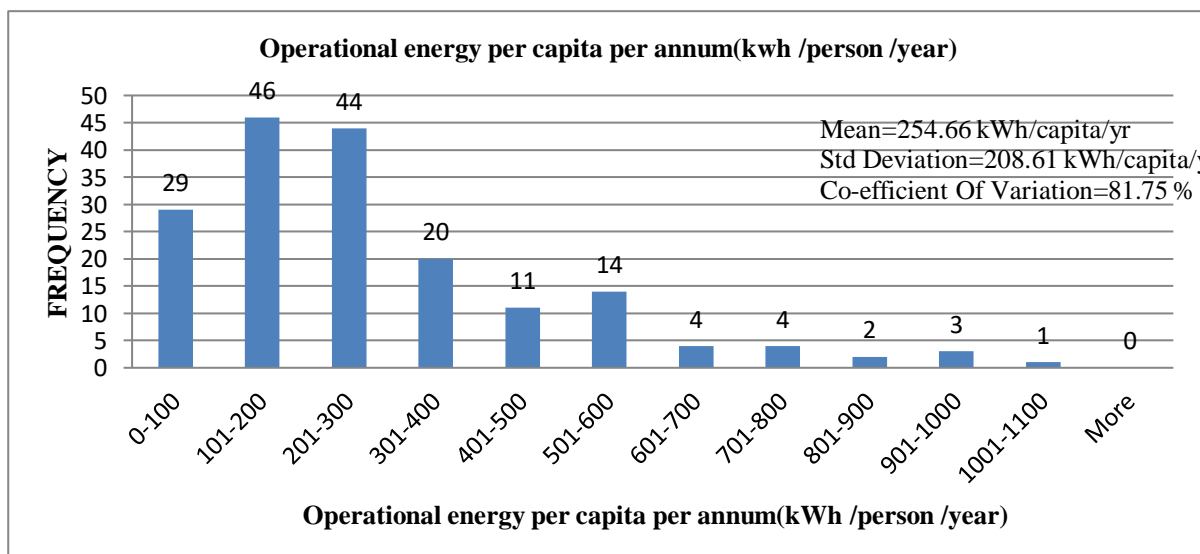


Figure 3.2: OE CONSUMPTION PER CAPITA PER ANNUM

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From the above histogram we can infer that, in a city like Hassan the maximum number of persons use around 100 to 300 kWh/capita/annum . Very less people uses higher OE of range 600 to 1000 above kWh /capita/annum.

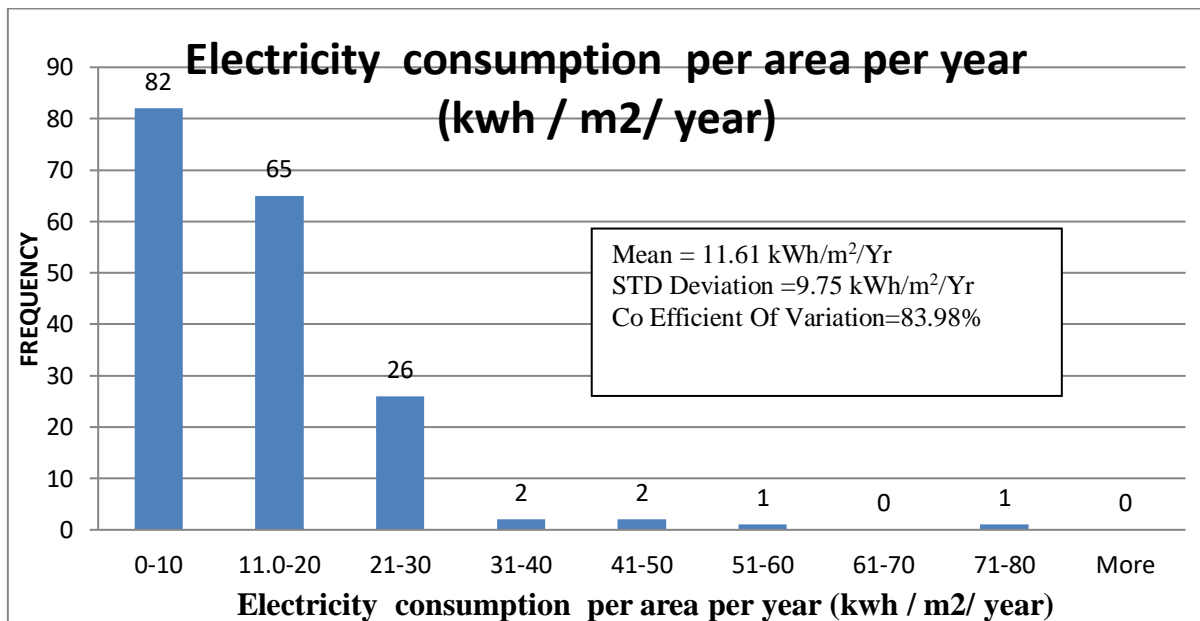


Figure 3.3: ENERGY CONSUMPTION PER AREA PER YEAR

From the above histogram we can infer that, maximum number of houses using the OE of order 0 to 30 kWh/m²/annum. Very less number of houses (6) is using the OE between 31 and 80 kWh/m²/annum. From this analysis, we can understand that the OE consumption never depends completely on the area of the house.

IV. REGRESSION ANALYSIS OF DATA USING MATLAB

The data collected from the questioner method of survey was quantified to analyze the OE consumption in different weather seasons and variation due to different variables. The selected factors are household monthly income (I), area of individual houses (A), number of occupants (O), and stock of electrical appliances (E). In this study, multiple linear regressions has been used to obtain relationship between OE consumption and considered factors such as I, A, O, E.

The consumption function for OE is hence defined as follows:

$$OE = f(I, A, O, E)$$

Where,

OE = Average Monthly household OE consumption (in kWh)

I = Monthly average income of the household (in Rs.)

A = Area of the house

O = Total number of occupants.

E = Stock of electrical appliances

The multiple linear regressions between OE consumption and considered factors can be given as follows:

$$\ln E = a + \beta_1 I + \beta_2 A + \beta_3 O + \beta_4 E \quad (1.1)$$

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The intercept term “a” in the model gives the average value of E. Where $\beta_1, \beta_2, \beta_3$ and β_4 are the coefficients of I, A, O and E. Most importantly, β_1 represents income elasticity of OE consumption which bears an important implication for future OE consumption. In order to capture the seasonal variation in the OE consumption pattern of the households, a similar models are employed for three seasons namely, summer, winter and monsoon weather separately. Hence the dependent variable E takes three forms now, i.e., ES, EW and EM where ES is the average monthly household OE consumption in summer (in kWh), EW is average monthly household OE consumption in winter (in kWh) and EM is the average monthly household OE consumption in monsoon season (in kWh). The independent variables remain the same.

The models are:

$$E_f = a + \beta_1 ES + \beta_2 EW + \beta_3 EM \quad \dots\dots 1.2$$

Where, E_f is energy consumption factor for different seasons such as S (Summer), W (winter) and M (monsoon).

Multiple regression analysis was used to obtained relationship between energy consumption and I,A,O,E using model 1.1. To achieve this data was divided into 70% and 30% for calibration and validation of the considered model. Results of regression analysis by combining all seasons are provided in table 7.1 we can infer that the model is a good fit with the R squared value of 0.42. It indicates 42 per cent of variation in dependent variable is explained by all the independent variables considered in the model.

Explanatory variable	Co-efficient	Std error	t ratio	p value
Constant	6.45	12.38	0.52	0.60
Income	4.23×10^{-4}	1.70×10^{-4}	2.48	0.01
Area	0.18	0.042	4.39	1.98×10^{-5}
Occupants	3.61	2.44	1.48	0.14
Appliances	1.79	0.40	4.45	1.54×10^{-5}

Table 4.1: Table showing the result obtained by the multiple linear regressions between OE consumption and considered factors

N=170

R squared =0.42

Adjusted R squared=0.41

The same model is applied for the OE consumption in different seasons. The results of Model 1.2 presented in Table below. It can be observed that the results are similar to those of model 1.1.

Explanatory variable	Co-efficient		
	Summer	Monsoon	Winter
Constant	4.51	-2.97	-6.54
Income β_1	5.9×10^{-4}	5.16×10^{-4}	4.54×10^{-4}
Area β_2	0.06	0.055	0.105
Occupants β_3	3.72	4.19	3.75
Appliances β_4	2.79	3.07	2.97
R	0.78	0.73	0.79
R squared	0.297	0.314	0.34
Adjusted	0.27	0.29	0.31
RMSE	61.69	56.39	44.81

Table 4.2: Table showing the result obtained by the multiple linear regressions analysis for different seasons.

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It can be inferred that the household income, stock of electrical appliances with a household, usage of the appliances, size of the house and family size explain the variation in the dependent variable significantly with R value of 0.78, 0.73 and 0.79 for summer, monsoon, winter season respectively. R squared value found to be more for winter season compared to other seasons. Root mean squared error (RMSE) value found to be low for winter season with the value of 44.81 kWh, indicating multiple regressions could estimate OE consumption more accurately than other seasons.

Embodied And Operational Energy of Residential Buildings

From the literature [1] Embodied Energy Of Residential Buildings in moderate climatic zone is as follows.

- Rubble stone masonry foundation, RC frame structure with burnt brick infill, RC roof and ceramic, mosaic tile flooring has the embodied energy of 3.79 GJ/m².
- Rubble stone masonry foundation, RC frame structure with burnt brick masonry infill, RC roof and flooring using vitrified tiles, ceramic tiles, granite, cement concrete and clay tiles, the embodied energy for this is 4.25 GJ/m² [1].

Table 4.3: Comparison of results from present study and literature on EE and OE of buildings From present study and From literature

Sl no	Energy	Energy value GJ/m ²	Remarks
1	Embodied Energy	3.79-4.25	from literature
2	Operational Energy (for 50 years)	0.209-13.27	from survey and data analysis

V.CONCLUSION

From this paper, I conclude that the people in urban areas of Hassan consume additional energy than required for basic needs. People in urban areas need to shift to alternative energy resources to reduce their consumption of energy provided by the government. where as alternative source of energy like Roof Top Solar, wind wheel and others. As Hassan city is located in moderate climatic zone of India, the value of Embodied energy can be considered as 3.79-4.25 GJ/m². Data has been analyzed to arrive to find the approximate OE for 50 years will be around 0.209-13.27 GJ/m²

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