BENCHMARKING THE ELECTRICITY USAGE INTENSITY OF BANKING SECTOR BUILDINGS IN PAKISTAN

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ABSTRACT

Energy consumption benchmarks help in evaluating energy performance of similar type of buildings. In this paper, an annual electricity consumption benchmark for the banking sector buildings in Pakistan has been established using statistical techniques. In this study data were collected from 98 bank branches of different sizes, located in different cities of Pakistan. Electricity consumption of each bank branch was normalized using Degree Days method and respective annual normalized Electricity Usage Intensities (EUI, kWh/m^2/year) were calculated. The observed values of EUI (EUI_{obs}) were standardized using the standardized coefficients. Three means of central tendency were analysed to determine a centralized value of standardized EUI (EUI_{std}), Median of EUI_{std} dataset was found to be the suitable measure and therefore, has been selected as annual electricity consumption benchmark for Pakistan's banking sector buildings. Finally, the EUI of Pakistan bank branches has been compared with same of other countries and some suggestions have been made.

1. INTRODUCTION

Energy Consumption Benchmarks help in comparing energy performance of similar type of buildings [1]. Unfortunately, there are no such energy benchmarks available for the buildings sector in Pakistan, a sector which consumes 55% of Pakistan' annual electricity [2]. For bank branches, despite their high energy intensive nature, there has been a limited research undertaken to investigate the energy consumption of banking sector buildings [3].

This study attempts to fill this knowledge gap by establishing electricity consumption benchmark for the banking sector buildings in Pakistan in the form of annual electricity usage intensity, EUI (i.e. kWh/m^2/year) and adds knowledge with original and comprehensive data and information collected from 98 bank branches of different banks in Pakistan.

2. BACKGROUND

Pakistan is suffering from a serious energy crisis [4]. Although Pakistan has made efforts to tackle this issue, unfortunately, most of such constructive efforts have been lost without achieving their goals [5]. According to experts, two major factors behind these futile efforts are poor policies and weaker financial management [5-9].

Nearly 55% of country's annual electricity consumption occurs in the building sector, mainly domestic (47%) and commercial (8%) [10]. Fig. 1 shows the variation in electricity consumption in domestic and commercial sectors of Pakistan over a period of six years for the period 2006-07 to 2011-12.

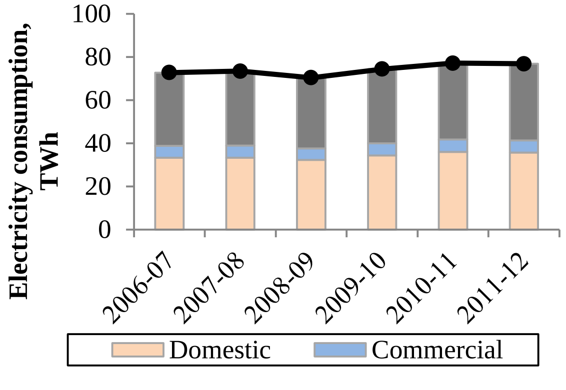

Fig. 1. Electricity consumption in Pakistan's domestic and commercial sector [10]

At present there are no government policies or mechanisms in place which regulate building owners to reduce their buildings' energy consumption. In addition there are no data for annual EUI (kWh/m^2) which could help one to compare the performance of their building.

2.1. Relevant Literature Review

Energy consumption profiles are different for different types of buildings, e.g. a bank building has a different energy consumption profile when compared with a hospital. For the evaluation of a building's energy performance, benchmarks play an important role.

Two important variables i.e. electricity consumption (kWh) and the Net Internal Area (NIA, m^2) of the building have been extensively used by researchers in the development of EUI. Such EUI enable the energy managers or building owners to compare their building's energy performance with that of a similar type of building or against an established standard value of the best practice. Once the building's performance is compared with a standard set value, it informs the building owners how good or bad their building is performing, thus providing them an opportunity to improve their buildings' performance through different initiatives such as energy efficiency measures.

For example, in the UK, based on the historical energy consumption data, Chartered Institute of Building Services Engineers (CIBSE) have developed annual EUI also called energy benchmarks in their document TM46 for different types of buildings including offices, domestic buildings, schools etc. [11]. These energy consumption benchmarks in the UK have gained importance in recent years when it became part of the obligatory Display Energy Certificate (DEC) scheme under the Energy Performance of Buildings Directive [12]. Similarly, the Higher Education Environmental Performance Improvement (HEEPI) group [13] developed EUI for the Higher Education sector buildings in the UK.

A number of researchers have used regression analysis method to develop energy consumption benchmarks for different types of buildings.

Giorgos and Constantinos [3] investigated energy performance of 39 office buildings being used as bank branches in Greece and established a benchmark for the annual electricity usage intensity of 337 kWh/m^2. Chung et al. [14] developed an energy consumption benchmarking procedure using multiple regression method for the commercial buildings in Hong Kong. A similar approach was used by Edward and Roberto [15] as they developed energy consumption benchmarks for banking sector in Brazil using the linear regression technique for 1890 number of bank branches in Brazil. Using the building area and building's energy consumption data, Fillipin [16] developed energy benchmarks for school sector buildings in the Central Argentina.

Zhao et al. [17] used multiple regression method and central tendency method to establish energy consumption benchmarks for commercial buildings in China. Sharp [18] used CBECS 1992 database and developed electric use intensity for the office buildings in USA and used linear regression modelling to identify the significant variables and for standardization purpose. Wu et al. [19] used multiple regression technique for benchmarking the energy consumption of hotel industry in Singapore. However, they agreed that due to small sample number of dataset, the EUI may not be the robust value for the hotel industry.

The above literature review confirms that the energy consumption benchmarks i.e. EUI can play a significant role towards the energy efficiency and sustainability in the buildings sector. Therefore, more the robust EUI is, an accurate evaluation of buildings operational energy efficiency can be carried out [20].

2.2. Analysis Method

Statistical analysis machine learning methods are frequently used for establishing reliable energy consumption benchmarks. Multiple Regression (MR) analysis is a popular statistics based method while Artificial Neural Network (ANN) is a machine learning method. Both methods have certain limitations and therefore, these limitations must be considered before a method is selected.

Zhao and Magoulès [21] compared different methods for estimating energy consumption in the buildings based on model complexity, ease of use, running speed, the inputs needed and accuracy. They found that MR methods are less complex, easy to use with a high running speed, require historical data and offer a fair level of accuracy. ANNs are complex models and are not easy to use. However these offer higher accuracy.

MR is a common statistical method used by researchers for modelling building energy consumption. Owing to their characteristics, such as straightforward form, ease of use and generally high level of statistical significance, regression models have become a broadly adopted technique for forecasting of building energy consumption. However, the accuracy of a regression model depends entirely on the accuracy and extent of data used to create the model. Using a small sample of data for developing the regression models can, unfortunately, lead to significant errors in the prediction of the energy consumption [22].

Shabunko et al. [23] developed electricity consumption benchmarks for the domestic buildings in Brunei Darussalam using datasets for 356 buildings. By using the statistical method, they established a benchmark value of 56kWh/m^2 for the yearly electricity consumption for the domestic buildings.

Sharp [18] used multiple regression method to establish relationship between 75 different factors and the energy consumption of a commercial building. In the final model, only six independent variables were selected which were found significant. Based on this model, the EUI value was predicted and standardized by using the standardized errors. A similar method was used by Chung et al. [14] for the establishment of energy consumption benchmark. Alfanso et al. [24] used multiple regression method to estimate the annual energy consumption in the Spanish banking sector based on the data from 55 bank branches. Zhao et al. [21] used multiple regression method to identify the significant variables and for the standardization of the observed EUI and then established an energy benchmark based on the central tendency measures.

It is evident from the literature review that MR method had been widely applied in the benchmarking research studies and therefore, in this research study, MR method has been used along with the central tendency method to establish a EUI for the Pakistani banking sector.

3. PROCEDURE AND TESTING

For the purpose of establishing EUI for bank buildings in Pakistan, site visits were made to 98 branches of different banks in Pakistan. Electricity consumption data were collected in the form of monthly electricity bills whereas building information were collected through the interviews with the branch managers. Collected dataset of energy consumption was statistically analysed in order to develop an annual electricity usage intensity, EUI i.e. kWh/m^2.

The procedure consisting of following steps has been followed:

- Data collection;
- Weather normalization of electricity consumption;
- Calculation of normalized EUI;
- Identification of significant explanatory variables;
- Standardization of normalized EUI;
- Results based on the measure of central tendency method; and
- Determining the electricity benchmark.

These seven steps for establishing a EUI value for banks buildings in Pakistan have been discussed in detail as below.

3.1. Data Collection

Data collection is one of the essential and important components of a research project. There are mainly two types of data required for a research, i.e. quantitative and qualitative.

Quality of data is an important factor which plays significant role in maintaining the reliability of the research.

For this research, data were collected through site visits and interviews with the branch managers of 98 bank branches situated in different parts of Pakistan. Although it is a very small proportion, yet it provides significant information about the energy consumption in banking sector of Pakistan, especially when there is no published research in this sector. It is believed that the analysis presented for this data can readily be applied to other banking regions of Pakistan.

In terms of the data, about 75% of the data came from the following banks.

a) Habib Bank Limited (HBL); b) Allied Bank Limited (ABL); c) Muslim Commercial Bank (MCB); d) United Bank Limited (UBL); and, e) National Bank of Pakistan (NBP)

After interviewing the bank managers, the premises of the building were visited to check and verify the correctness of the data and to avoid any mistake and therefore, the data can be regarded as reliable data.

Table 1 shows an overall picture of the collected data for 98 bank branches in Pakistan.

Table 1. Overview of collected data from different banks

	HBL	ABL	NBP	UBL	MCB	Miscellaneous
Total no. of branches visited	18	10	15	18	14	23
No. of Branches with A/C	16	10	12	18	10	23
No. of Branches with ATMs	12	10	6	14	5	21
Total No. of A/Cs	85	73	47	97	47	154
Total No. of ATMs	13	10	8	14	5	21
Total No. of Work Stations	111	92	95	181	76	174
Total NIA,m^2	5,035	3,069	1,734	2,966	3,410	6,103
Total Staff	166	129	133	182	136	291
Total Annual kWh of all branches	539,446	531,786	415,865	594,952	425,692	1,227,685
Total Grid kWh of all branches	257,412	217,338	230,490	232,606	239,562	551,020
Total kWh of Generators	282,034	314,448	185,375	362,346	186,130	676,665
Grid Electricity	48%	40%	55%	39%	54%	51%
Generator Electricity	52%	60%	45%	61%	46%	49%

Fig.2 has been developed after taking the average of monthly consumption of 98 banks and it shows the monthly electricity consumption profile of a typical bank in Pakistan as the percentage of its annual electricity consumption. It is apparent that electricity consumption is higher, i.e. 10% during the summer months due to high cooling demand whereas it is as low as 6% during the winter months.

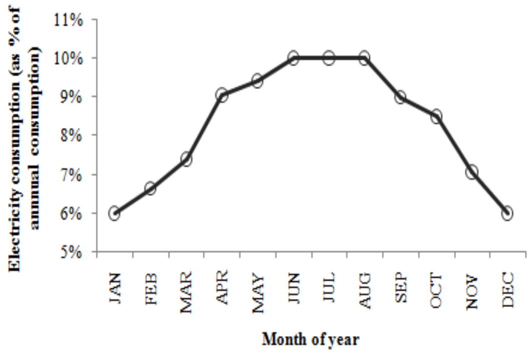

Fig. 2. Monthly electricity consumption profile of a typical bank in Pakistan

3.2. Weather Normalization of Electricity Consumption

Electricity consumption was normalized using Degree Days Method. Degree days are usually used as a measure of heating or cooling. Degree days have been vastly used by researchers for the purpose of forecasting and normalization of energy consumption in different sectors [25-29]. In colder climate e.g. UK, the monthly energy consumption is usually normalized based on the Heating Degree Days (HDD) as heating requirements are much higher than the cooling energy requirement. On the other hand, in warmer climatic regions, e.g. Pakistan, monthly Cooling Degree Days (CDD) could be used to normalize the weather effect of the monthly actual electricity consumption.

Monthly Cooling Degree-Days (CDD) can be calculated using the formula as shown in Eq. (1):

$$CDD = \sum_{i=1}^{y} (t_i - t_b) \qquad (1)$$

Where, CDD are the number of monthly cooling degree days, t_i is the mean daily temperature of day i and t_b is the base temperature. the base temperature is the reference temperature below which there will be no requirement for cooling *i.e. if* $t_b > t_i$, *then* $(t_i - t_b) = 0$.

The recommended cooling base temperature is between 23 and 25.5˚C [30]. Keeping these facts in mind, it has been assumed that below 25˚C, there will be no cooling demand and therefore, 25˚C has been selected as the base temperature for the calculation of CDD in this study.

Average monthly CDD data for five years, i.e. 2009 to 2013 and actual monthly CDD data for 2014 were downloaded and plotted for a base temperature of 25°C. Both the average CDD and actual CDD in 2014 based on 25˚C base temperature have been used in the weather normalization of monthly electricity consumption of each individual bank branch.

Weather normalization was repeated 98 times in order to normalize the monthly electricity consumption of each individual bank branch. Strong relationship (i.e. $R^2 = 0.68$ to 0.95) was observed among the five years averaged monthly CDD and actual monthly electricity consumption.

Using the respective regression equations for each individual bank branch, weather adjusted, i.e. weather normalized monthly electricity consumption was calculated. Fig.3 shows a comparison between the actual and weather normalized electricity consumption for all 98 bank branches.

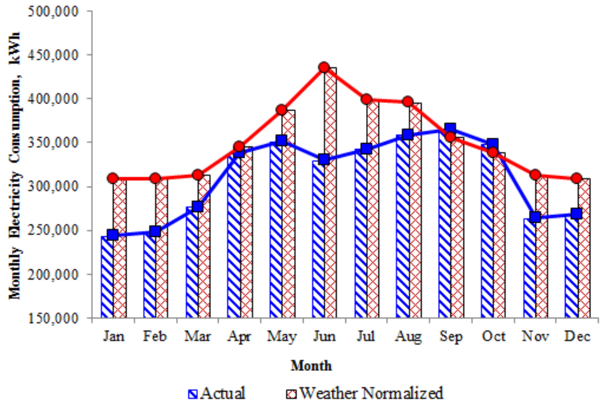

Fig. 3 Actual vs weather normalized monthly electricity consumption of all 98 bank branches

Normalized annual electricity consumption for all 98 bank branches was observed 12% higher than the actual electricity consumption of all 98 bank branches. This is mainly because the actual number of CDD in 2014 exceeded by 71 compared to five years average numbers of CDD.

Using the aforementioned weather normalization process, an Annual Normalized Electricity Usage Intensity has been calculated for each individual bank branch.

3.3. Calculation of Weather Normalized EUI

Weather normalized Electricity Usage Intensity for each bank branch was calculated by using Eq. (2).

$$EUI_{obs} = E \div A \qquad (2)$$

Where,

E is weather normalized annual electricity consumption, kWh and A is net internal area of the bank's building, m^2.

Table 2 shows the statistical results of observed EUI for different banks. It can be seen that UBL and NBP have higher values of mean EUI compared to other banks.

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3.4. Identification of Significant Explanatory Variables

In this research study, there are six independent explanatory variables in the MR analysis and these include:

x_1 Building area
x_2 No. of staff
x_3 No. of ATMs installed
x_4 No. of A/C units installed
x_5 No of work stations
x_6 No. of sides exposed to solar radiation

The dependent variable "Y" is EUI value.

It was found that x_1 (building area), x_3 (No. of ATMs) and x_5 (No. of work stations) are the significant independent variables based on a t-stat value greater than 1.96 whereas the

Table 2. Statistical results of EUI_{obs} for different banks

	HBL	ABL	NBP	UBL	MCB	Miscellaneous	Overall
Min	30	120	61	61	123	169	30
Max	370	278	572	631	220	285	631
Range	340	158	511	570	98	116	600
Mean	175	194	266	236	174	221	216
Median	162	184	229	211	178	210	187
Valid N	18	10	15	18	14	23	98

explanatory variables x_2 (no. of staff), x_4(no. of A/Cs) and x_6 (no. of walls exposed to solar radiation) were found insignificant and were dropped from the final regression model.

Eq. (3) presents the equation for the final regression model;

$$EUI = 168.364 - 0.264 \times building\ area\ (x_1) + 62.4 \times No.of\ ATM\ machines(x_3) + 8.369 \times No.of\ work\ stations(x_5) \quad (3)$$

3.5. Standardization of EUI_{obs} Based on MR Analysis

The standardized regression model developed by Chung et al. [14] has been applied for transforming the observed values of EUI into standardized values. This formula is shown in Eq. (4):

$$EUI_{std} = EUI_{obs} - a_1x'_1 - a_2x'_2 \dots\dots\dots - a_nx'_n = EUI_{obs} - \sum_{i=1}^{n} a_i \left(\frac{x_i - \bar{x}_i}{s_i}\right) \quad (4)$$

where EUI_{std} is the standardized EUI; EUI_{obs} is the observed EUI;a_i is the standardized regression coefficient; x_i(i=1, 2, 3, n) and $\bar{x}_i$are the observed and mean values of explanatory variables and s_i (i=1, 2, 3, n) are the values for the standard deviation for the significant explanatory variables.

Using the observed, mean and standard deviation values for three significant explanatory variables and the values of their standardized regression coefficients into Eq. (4), consequently, the standardized regression model for the EUI is presented in Eq. (5);

$$EUI_{std} = EUI_{obs} + 0.492 \times \left(\frac{x_1 - 228}{250}\right) - 0.239 \times \left(\frac{x_3 - 1}{1}\right) - 0.366 \times \left(\frac{x_5 - 7}{6}\right) \quad (5)$$

Distribution of data of EUI_{std} for 98 bank branches is shown in Fig.4

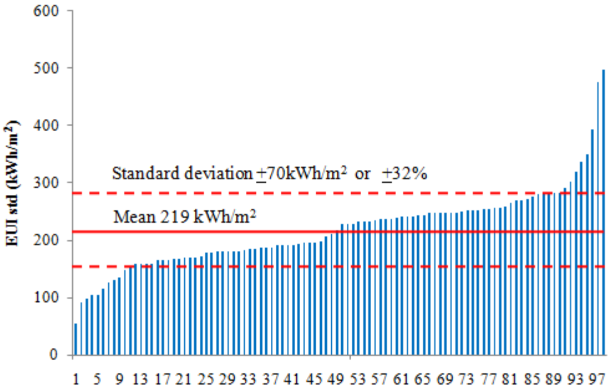

Fig. 4. Distribution of standardized EUI

3.6. Determining the Measure of Central Tendency for EUI_{std} Data Distribution

There are mainly three parameters which could be used as measures of central tendency for a data distribution. These are mean, median and mode. Before these three measures are discussed, it is important to understand the significance of the following two factors which play a significant role in the selection of an appropriate measure of central tendency.

- Normal distribution
- Skewness

3.6.1. Normal distribution of data

In a normal data distribution, the data is distributed symmetrical; and therefore, in such a case mean could be considered as a reliable measure of central tendency of the data [31]. Where the distribution is not symmetrical, it is known as skewed distribution.

3.6.2. Testing the normality of EUI_{std} data distribution

The frequency distribution of EUI_{std} of 98 bank buildings is shown in Table 3 and Fig. 5.

Table 3. Frequency distribution of EUI_{std} of 98 banks

kWh/m² Range	Frequency	Percent	Cumulative Percent
0-75	1	1	1
75-150	9	9	10
150-225	39	40	50
225-300	42	43	93
300-375	4	4	97
375-450	1	1	98
450-525	2	2	100

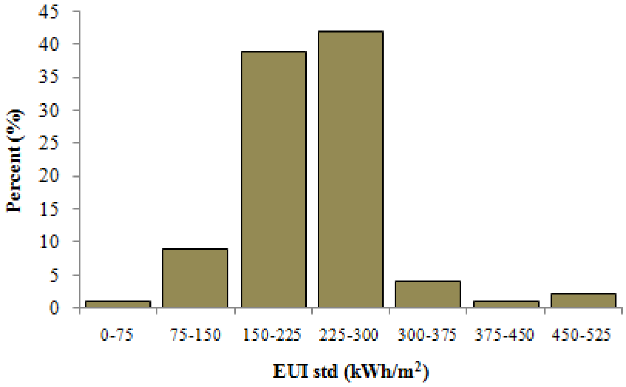

Fig.5. Frequency distribution histogram of EUI_{std} of 98 bank branches

It can be seen that 81 of 98 bank branches (i.e. 83%) have EUI_{std} values in the range of 150-300 kWh/m² whereas one building has EUI_{std} less than 75kWh/m² and 03 buildings have EUI_{std} greater than 375kWh/m². These lower and upper values of EUI_{std} could be considered as outliers. Outliers are data values that differ greatly from the majority of a set of data. This significant difference in the EUI_{std} could be due to different reasons, e.g. maybe these buildings and their respective equipment are very old and the maintenance of equipment is not being carried out regularly thus causing higher electricity consumption and lower equipment's efficiency. Other possible reasons for this variability may include incorrect meter readings, faulty electricity meters, long operational hours etc.
It is apparent from Fig.5 that the distribution is not exactly a normal distribution and is skewed right showing a long tail on right side compared to the left side. It was found that the value of skewness for EUI_{std} frequency data distribution is +1.09. Some researchers are happy to consider the data distribution as a normal distribution if the skew values are in the range +2 to -2. Others are slightly more conservative and use a range from +1 to -1 [32]. For a skewed data distribution, it is usually inappropriate to use the mean. In such cases, the preferred measures of central tendency should be median or mode, with the median usually preferred [33].

4. DISCUSSION ON RESULTS

Fig. 6 shows the values for three measures of central tendency i.e., mean, median and mode for the EUI_{std}. It is evident that mode has a higher value, i.e. 229kWh/m² compared to mean (219kWh/m²) and the median (i.e. 222kWh/m²). Keeping in mind that the EUI_{std} frequency distribution is positively skewed, the median can be used as a measure of central location [33]. Finally, the electricity consumption benchmark for the banking sector buildings in Pakistan is 222kWh/m².

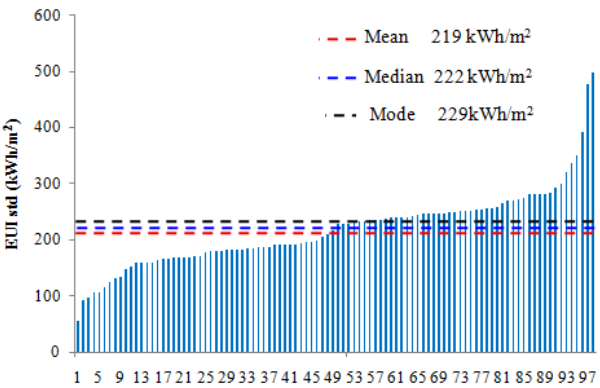

Fig. 6 Mean, median and mode of standardized EUI

Table 4 shows a comparison between the EUI of Pakistan bank branches with that of three countries, USA, Ireland and Greece. It could be seen that EUI of Pakistan's bank branches is 35% and 30% less than that of Greece and USA banks respectively. Ireland bank's EUI is 13% less than that of Pakistan.

Table 4. Comparison with EUI of bank branches of other countries

Country	Electricity consumption benchmark, kWh/m²	Reference
Greece	345	[3]
USA	319	[34]
Ireland	195	[35]
Pakistan	222	

Based on a thorough analysis from the collected data and comparative analysis of bank's EUI of other countries, the following EUI ranges for three categories of bank branches in Pakistan are suggested as shown in the Table 5.

Table 5. Suggested ranges of EUI for different categories of bank branches in Pakistan

EUI kWh/m^2/year Range	**Category**
< 150	Excellent
>150<250	Good
>250	Typical

5. CONCLUSIONS AND RECOMMENDATIONS

In this study using electricity consumption data of 98 bank buildings in Pakistan, a EUI value for the bank buildings has been established employing statistical analysis. In order to avoid over estimation or under estimation of EUI value, the electricity consumption data was normalized using cooling degree day method and it was found that a typical bank building in Pakistan consumes 222kWh/m^2/year. This consumption value is considered to be satisfactory in comparison with annual consumption of other developed countries. In addition, multiple regression method applied on this data revealed that electricity consumption in these buildings is mainly dependent on three main factors; building's area, No. of Work stations and No. of ATMs. Finally, it is recommended that more data should be collected and analysed in order to establish a robust EUI of banks.

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