END USES OF ELECTRICITY IN KARNATAKA HOUSEHOLDS

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ABSTRACT

This paper describes the results of a survey of electricity consumption in a purposive and randomly selected sample consisting of 1,200 households (825 non-AEH 5 ampere limit connections and 375 AEH 15 ampere connections) in four districts of Karnataka -- Bangalore (metropolitan region), Tumkur (southern region), Bijapur (northern region) and Uttara Kannada (coastal region). The survey has revealed the patterns of consumption of electricity in AEH and non-AEH houses, the stock of electrical appliances used by the households, the differences in the consumption of electricity in urban and rural areas, the use of other sources of energy for domestic purposes, and the degree of penetration of energy efficient appliances/devices.

The following are the main conclusions:

The engineering approach of estimating the electricity consumption based on the wattage of the appliances and a recall of the hours of usage is unsatisfactory. This is because the estimated electricity consumption when regressed on the actual consumption of electricity in both AEH and non-AEH households yields a R^2 value of only 0.37 and 0.04 respectively. Nevertheless, the approach indicates that 79.69% of the electricity consumption in an AEH house is due to lamps, immersion rods/geysers, hot plates, fans and refrigerators. In contrast, 83.38% of the electricity consumption in a non-AEH house is due to lamps, fans, television and electric iron.

The appliance stock approach of estimating electricity consumption has indicated that a unit increase in load (kW) would result in an increase of 251.4 kWh per year in the electricity consumption, assuming a coincidence factor of unity.

The step-wise regression analysis in the appliance census approach has resulted in twelve categories of appliances explaining 62% of the variation in the electricity consumption of AEH houses and 9 categories of appliances explaining 31% of the variation in the electricity consumption of non-AEH houses.

The estimated appliance elasticities show that an increment of unit percentage of appliance penetration would result in an increase of annual electricity consumption of 31.69 kWh for fans, 2.86 kWh for hot plates, 2.59 kWh for 40 watt fluorescent tubes, 2.29 kWh for 60 watt incandescent bulbs and 1.86 kWh for immersion rods in an AEH house. Similarly, for a non-AEH house, the annual increase would be 1.53 kWh for 60-watt incandescent bulbs, 0.54 kWh for fans and 0.41 kWh for televisions.

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The end use analysis of electricity consumption in AEH houses has shown that the consumption of electricity is mainly due to lighting (27.98%), air circulation (23.42%), water heating (18.13%) and cooking (14.20%). In non-AEH houses, the end uses accounting for most of the consumption of electricity are lighting (39.43%), entertainment (23.97%) and air circulation (20.76%). The end use analysis of electricity in the residential sector for the whole of Karnataka has shown that the electricity is used mainly for lighting (32.28%), air circulation (22.31%), water heating (11.09%), entertainment (9.68%) and cooking (8.69%).

The end use analysis of electricity in the residential sector has shown that electricity is used mainly for lighting, air circulation, water heating, cooking and entertainment. The survey has also yielded the appliance elasticities that show the effect of unit percentage increase of appliance penetration on the annual electricity consumption. Interventions to influence electricity consumption without decreasing the energy services provided by electricity must focus therefore on devices for lighting, air circulation, water heating, cooking and entertainment. Policy makers can take corrective actions by promoting efficiency improvements in certain end-use devices so that increases in the penetration of these devices would not affect significantly the overall electricity requirement for the domestic sector.

INTRODUCTION

If business-as-usual energy consumption patterns are not viewed as exogenous and "given", but as alterable through interventions, then the question arises regarding the nature of the interventions to influence these patterns. Obviously, the interventions must depend upon the determinants of energy consumption. In the case of residential electrical consumption, what are the main determinants? The conventional thinking is that income is the main determinant. Even if this is the case, it is politically unacceptable to think of income-reduction policies to reduce electricity consumption. Fortunately, a previous study[3] has shown that income is a weak predictor of residential electricity consumption explaining only 38% of electricity consumption. In contrast, it was shown in the same study that the appliance stock could explain as much as 93% of the dependent variable. Appliance stock, therefore, is a much better predictor of electricity consumption than income.

The formulation of plans and programmes for the power sector especially, the demand for energy and its management requires an understanding of the appliances that explain electricity consumption. With this objective, a study of household electricity consumption in the state of Karnataka was carried out in 1994-95 by the International Energy Initiative (IEI) in collaboration with the Karnataka Electricity Board (KEB) by conducting surveys in the Bangalore, Tumkur, Bijapur and Uttara Kannada districts of Karnataka.

In the year 1994-95, there were 4.898 million domestic electrical connections in Karnataka State. Of these, 0.963 million (20%) were of the AEH or 15 ampere category corresponding to a 3.5 KVA connected load, and 3.935 million (80%) were of the non-AEH or 5 ampere limit category corresponding to a 1.15 KVA load. In terms of annual electricity consumption, out of a total of 2,322 million units, AEH connections accounted for 1,296 million units or kWh (56%) and non-AEH connections for 1,026 million units (44%). The average monthly consumption per connection works out to about 112 units in AEH connections and 22 units in non-AEH connections.

In the four districts surveyed, the following were the shares of AEH and non-AEH electricity connections:

District	Number	Non-AEH	AEH
Bangalore	958,430	61%	39%
Bijapur	142,804	93%	7%
Tumkur	237,529	91%	9%
Uttara Kannada	87,740	91%	9%

There have been a number of previous studies of residential electricity consumption. Wilson and Anderson (1971, 1973) estimated the effect of household characteristics and price of electricity on the household consumption by analysing the cross-sectional data. They concluded that price is the major determinant of electricity consumption. Houthekar's (1973) study in Great Britain has resulted in the short-run income and price elasticities, i.e., the effect of income and price on electricity consumption by keeping the stock of appliances as constant. Fisher and Kayson (1962), in their analysis of residential electricity consumption in United States of America, have established that residential electricity demand is proportional to the stock of appliances. Parti and Parti (1980) used regression analysis to disaggregate the total

[3] Reddy, B.S., (1990), "The energy sector of metropoly of Bangalore" Ph.D. Thesis, Indian Institute of Science, Bangalore.

household consumption into appliance-wise consumption.

In his doctoral thesis, Reddy (1990) has used three different approaches to study the residential electricity demand in the Metropolis of Bangalore (Karnataka state, India)-- the engineering approach, the appliance stock approach and the appliance census approach. He has established that the appliance stock and appliance census approaches have explained the end-use consumption of electricity much better than the engineering approach. The present study is based on a survey of the appliance stock in selected (sample) households.

Reddy ***et al*** (1991) have shown that in the estimation of future energy demands, the shift from one source of energy to another (for example, shift from electric stoves to LPG stoves for cooking) and the use of energy efficient end-use devices (replacing incandescent bulbs with compact fluorescent lamps or CFLs) to improve energy efficiencies, are very important. Hence, the present study also focuses on studying the different sources of energy used for various end-uses in a household and the degree of penetration of energy efficient devices.

Another study jointly carried out by Integrated Rural Technology Centre (IRTC) and IEI (1996) in analysing the end-uses of various categories of appliances in the different electricity consuming sectors has shown that in the domestic sector the electricity consumption varies between the urban and rural households as the appliance stocks are significantly different. Also across different slabs of electricity usage (9 slabs were considered based on the quantum of annual usage of electricity) there exist a growth trend in the appliance stock possessed by these households. The present study has benefited from this particular study in overcoming several shortfalls and difficulties, which was encountered during pilot study and survey.

OBJECTIVES OF THE STUDY

The following objectives guided the present study:

- to disaggregate household electricity consumption by energy service and by end-use device
- to analyse differentials across consumption slabs, rural-urban regions and AEH-non-AEH connections;
- to conduct an “ABC” analysis of energy services;
- to analyse the composition of household stock of electrical appliances and inter-class differentials;
- to analyse the relative importance (in terms of number of household users) of various sources of energy in meeting household energy service needs;
- to assess the penetration of energy-efficient electrical appliances/fixtures.

METHODOLOGY AND SAMPLE SELECTION

The survey[4] research method adopted for the study used a questionnaire consisting of five sections with open-ended questions. The questionnaire was initially tested by means of a pilot study and the questionnaire was then finalised based on the comments, suggestions and responses obtained from the pilot study.

The sample opted for the survey was purposive and represented four different regions of Karnataka namely, metropolitan, coastal, northern and southern. The sample consisted of 1,200 households, of which 825 had non-AEH connections and 375 had AEH connections. These households were selected from four districts of Karnataka -- Bangalore (metropolitan region), Tumkur (southern region), Bijapur (northern region) and Uttara Kannada (coastal region). It was also decided to survey both AEH and non-AEH houses in the towns but mostly non-AEH in the rural areas. Depending on the monthly electricity consumption, the households were grouped into six slabs – Slab #1 corresponded to a monthly consumption of 0 to 100 kWh, Slab #2, 100 to 200 kWh, Slab #3, 200 to300 kWh, Slab #4, 300 to 400 kWh, Slab #5, 400 to 500 kWh, Slab #6, 500 kWh and above. The number of houses to be covered in each of the slabs was decided on the basis of the number of users in each slab as identified by the KEB. The purpose of grouping the sample into different slabs is to analyse the differences in the pattern of usage of electricity across the slabs.

For the purpose of analysis, the statistical techniques of multiple regression analysis, step-wise regression analysis, ANOVA, ratios and proportions, descriptive statistics and t and F tests were used.

In this study three different approaches are used to study the electricity consumption of end-use devices in a household, namely, the engineering approach, the appliance stock approach and the appliance census approach.

The engineering approach is based on sample surveys of variables such as number of appliances, rated power of these appliances and number of hours of usage of these appliances. An engineering estimate of electricity consumption of the end-uses will mainly depend on the number of hours of usage of the appliances possessed by the households. As this number is obtained from users, it may not be a correct estimate (as far as statistical significance is concerned) as it depends on the reliability of a person in recollecting the usage hours.

In the appliance stock approach the total electricity consumed by a household will depend on the total load (wattage of the appliances possessed by the household) accounted by a household. This could also be a poor predictor as the **coincidence factor** for usage of these appliances is not available.

The appliance census approach uses regression analysis to determine the contribution of various categories of appliances to the total electricity consumption. This could be a more reliable approach as the regression coefficients indicate the marginal change in electricity

[4] The survey was conducted by the engineering students in Tumkur, Bijapur and Uttara Kannada districts. Only in the Bangalore district the survey was conducted with the assistance of an engineering graduate. The students of Sri Siddartha Institute of Technology, Tumkur presented the survey results as project report entitled "Household Energy Consumption Survey" in partial fulfilment of their Bachelor's degree . The project was jointly financed by IEI and KSCST.

consumption per unit change in the number of appliances of that particular category. And, if the change is linear, then the regression coefficient is also the average electrical energy consumed through that category of appliances.

RESULTS

AEH and non-AEH connections

Out of the 1,200 households targeted for the survey, responses were obtained from 1,165 (97%) households. In all, the data that was used for the analysis comprised 369 (31.67%) AEH and 796 (66.33%) non-AEH households. The average family sizes in both AEH and non-AEH households are almost the same (5.60 and 5.61). The average number of rooms in AEH houses is 1.4 times that of non-AEH households (4.75 rooms/AEH house and 3.46 rooms/non-AEH house). The average electricity consumption in AEH households is 2,094 kWh/year with a standard deviation of 1,098 kWh/year which is more than 6 times that of non-AEH households with an average consumption of 324 kWh/year with a standard deviation of 261 kWh/year. The estimation of average electricity consumption per household in both the AEH and non-AEH samples is ***more*** than the actual values reported in the annual reports of Karnataka Electricity Board. This discrepancy could be attributed to the distribution of sample households -- more AEH households were considered from Bangalore district (metropolitan area) where the connected load is about 43% of the total connected load of the domestic sector of the state. In contrast, the other three districts from which the sample was chosen together account for only 7.5% of the total connected load. Secondly, the average electricity consumption in AEH households in Bangalore district is 3062 kWh/year whereas for the other three districts the average electricity consumption in AEH households is 1237 kWh/year which is much more closer to that of the state average of 1344 kWh/year for all districts.

Appliance stock

There is a difference in the number of appliances of various types owned by AEH and non-AEH households in each category of usage such as water heating, lighting, cooking, etc. Appliances such as immersion rods, geysers, hot plates, washing machines, refrigerators, kettles, vacuum cleaners, toasters and pumps (to lift water from sumps to overhead tanks) are special features of AEH households. In contrast, very few of the non-AEH households have hot plates, geysers, pumps and refrigerators. Figure 1 gives the difference in proportion of households using appliances such as television (TV), 40 watts fluorescent tube (FT40), 60-watt incandescent lamp (IL60), 40 watts incandescent lamp (IL40), mixer and electric iron, which are common to both AEH and non-AEH categories. In the AEH category, 80.2% of the households have televisions whereas in the non-AEH households, the penetration of TVs is only 47.1%. Ceiling fans are more prominent among the AEH households (93.4%) than those in non-AEH households (40 %). A larger proportion of households in the non-AEH category use 60-watt incandescent lamps but a larger proportion of AEH homes use fluorescent tubes and 40 watt incandescent lamps. The proportion of houses using mixers in the AEH category is almost double that of the non-AEH category.

The average number of appliances available in both AEH and non-AEH households in the sample are given in Table 1. The results indicate that even though incandescent lamps are a common feature in both AEH and non-AEH households, the number of bulbs per 100 households varies from 54 bulbs in AEH to 37 bulbs in the non-AEH. In the case of

fluorescent tubes, the average number per 100 households is 43 for AEH whereas it is only 10 for non-AEH. For most of the appliances, the standard deviation is quite large, which indicates that much variation exists between the households in the usage of different appliance categories in both AEH and non-AEH houses.

Engineering approach

The engineering approach is based on the number of appliances, X_{ij}, the wattage, W_{ij}, and hours of usage, h_{ij} of the appliance j reported by the sample household i during the survey. The total electricity consumption in a household i can be related thus to the appliance-wise consumption:

$$E_i = \sum_j E_{ij}$$

where E_{ij} is the electricity consumed by the jth appliance in the ith household. Also, in the ith household,

$$E_{ij} = X_{ij} * U_{ij}$$

where U_{ij} is the electricity consumption of the jth appliance category and X_{ij} is the number of electrical appliances in the jth category. U_{ij} can be written as

$$U_{ij} = W_{ij} * h_{ij}$$

where W_{ij} the wattage of the jth appliance category and h_{ij} is the number of hours per month for which the jth appliance is being used. The U_{ij}, referred to as the engineering estimate of the appliance consumption, depends upon the accuracy of determination of the hours of usage. Substituting U_{ij} in the previous equation, the following expression is obtained for the electricity consumption of the ith household:

$$E_i = \sum_j X_{ij} * W_{ij} * h_{ij}$$

Thus, from the survey data on appliance stock, wattage and hours of usage the engineering estimates of the household consumption can be obtained. These estimates were calculated for each of the appliance categories in both AEH and Non-AEH households and the results are tabulated in Tables 2 and 3. Lamps (incandescent and fluorescent), fans, fridge, geyser, immersion rod and hot plate are estimated to consume 79% of the average electricity consumption per AEH house. In contrast, lamps, fans, television and electric iron are estimated to consume 83.38% of the average electricity consumption per household in the non-AEH category. For the end-use of lighting, non-AEH households consume a high percentage (76.42%) of the average electricity consumption per household when compared to AEH households (39.28%).

The engineering estimates of the total household consumption were compared by regression with the actual values (obtained through meter readings recorded by KEB). The resulting R^2 is 0.37 for AEH and 0.04 for non-AEH, and the standard errors of estimates are 1,361 and 196, which are more than 60 per cent of their average consumption (2094 and 324 respectively). The large standard errors indicate that there are huge differences between the estimated and actual values. Hence, the engineering approach has serious limitations in estimating the actual consumption of appliances primarily because it depends largely upon

recall of the hours of usage.

Appliance stock approach

To determine electricity consumption in a household obviously its stock of electrical appliances play a major role. If X_{ij} and W_{ij} are the number and wattage of electric appliances of the jth category in the ith household, then $X_{ij} * W_{ij}$ would be the electrical load in watts due to this category of appliances. It follows that $L_i=\sum_j(X_{ij}*W_{ij})$ must be the total electrical load in watts due to this category of appliances. It is reasonable to expect the electrical energy consumption E_i (in kWh) of households is correlated with their loads L_i (in kW). When the yearly electricity consumption was regressed on the household load, the result was $E_i = 435.5 + 251.4\ L_i$ (26.61) and $R^2 = 0.32$. From this analysis, one could conclude that a unit increase in load results in an increase of 251.4 kWh per year in electricity consumption. The actual increase would be different if the coincidence factor of using the appliances at the same time is taken into account. Also, the household load due to its appliance stock explains only 32% of the variation. Even though this is low, it is much better when compared to the engineering approach and the resulting standard error (1,048) is also lower than that in the engineering approach.

Appliance census approach

In the appliance census approach the relationship used to estimate the monthly electricity consumption of the jth appliance category is given by

$$\boldsymbol{E_i}=\sum_j \boldsymbol{X_{ij}}*\boldsymbol{b_j}$$

where $\boldsymbol{b_j}$, the consumption per appliance of the jth category, can be estimated by regressing the electricity consumption $\boldsymbol{E_i}$ on the number of appliances $\boldsymbol{X_{ij}}$ of the jth category in the ith household. It must be noted that the coefficient $\boldsymbol{b_j}$ is not the consumption per appliance; it is the marginal consumption of the jth appliance category, i.e., the increase in consumption resulting from the addition of one appliance of the jth category. The marginal and the average consumption of the jth appliance category can be taken to be identical, as one expects a linear relation between the consumption and the number of appliances of a particular category.

Using the above relationship, regression analysis was carried out on the samples of AEH and non-AEH households separately. The number of appliances considered in both the sample households were large (32 categories); hence the linear multiple regression resulted in some negative and statistically insignificant coefficients that were difficult to interpret. A stepwise multiple linear regression analysis was therefore performed. In the stepwise regression analysis for the AEH sample, most of the appliance categories such as kettles, toasters, battery chargers, vacuum cleaners, inverters, washing machines, radios, VCRs, mono tape recorders and step-up transformers were eliminated because these appliances contribute only about 2% of the total electricity consumption (see Table 1). The result of the stepwise regression analysis on the AEH households is given in Table 4. The result indicates a R^2 value of 0.62, meaning that 62% of the variation in electricity consumption among the AEH houses is explained by the 12 categories of appliances included in the model. The standard error of estimate (1,070) is on the high side when compared with the mean (2,094). The reasons for the somewhat low R^2 value and the high error coefficient could be attributed to (i) the fact that

a household it may seldom use appliances that it possesses[5] and (ii) the usage of some of the appliances is taken into account because step-wise regression removes less significant appliances.

Similarly, a step-wise regression analysis was performed on the non-AEH sample households. The result (Table 5) indicates a R^2 value of 0.31 explaining 31% of the variation in the electricity consumption by the 9 categories of appliances in the non-AEH houses. This is quite low, the reason is that the 60 watt incandescent bulb which accounts for 24.60% of the total electricity consumption does not have a sufficiently high correlation to appear in the regression model. The standard error (118.59) is relatively lower than in AEH households when compared with the mean (324).

The results indicate that television sets, ceiling fans, mixers consuming 53.77, 46.48 and 39.28 kWh per year are the highest electricity consuming appliances in non-AEH households, whereas in AEH households, hot plates and water heaters (geysers and immersion rods) consume the most electricity with 1,036.15 and 960.53 kWh per year.

The implied usage hours thus obtained from the regression analysis makes much better sense when compared to the user reported hours. For example, hot plate user would use it for entire cooking (if the user does not have gas as standby), which turns out to be at least a couple of hours a day but only 1 hour of usage has been reported by the households.

End-use analysis in the residential sector

By knowing the consumption of different appliances the electricity consumption for different end-uses in the households could be estimated. Using the appliance-wise consumption figures, electrical energy used for different end-uses can be calculated using the formula

$$E_{im} = \sum_j X_{ijm} * b_{ijm}$$

where E_{im} is the quantity of electricity for the mth end-use and X_{ijm} is the number of appliances of type j in the ith household.

Using the above equation, the electrical energy for the different end-uses was obtained for both AEH and non-AEH houses. The result shows that (refer Figures 2 and 3 for AEH and non-AEH categories respectively) in the AEH houses, lighting devices (27.77%) consume most of the electricity and next is the appliances used for air circulation (23.3%). Electricity consumed by the appliances used for water heating (18.19%) and cooking (14.11%) follow them. In the non-AEH houses, it is the lighting devices (39.42%) that consume the most followed by appliances used for entertainment (23.7%) and then the appliances used for air circulation (20.75%).

Assuming that the sample represents the whole of Karnataka, that is the appliance stock in the sample is the same as that of the state, the end-use estimates for residential electricity consumption in Karnataka were obtained. The result (Figure 4) shows that in the residential sector (i.e., both AEH and non-AEH homes), lighting is the major end-use accounting for

[5] The reason for somewhat low R^2 value was discussed with Prof. N. Krishnaji, Senior Fellow, Centre for Economic and Social Studies, who indicated this as the main reason.

32.28 per cent of the total consumption, followed by air circulation with 22.31%. Water heating, entertainment and cooking account for 11.09%, 9.68% and 8.69% of the total electricity consumption respectively. The remainder is accounted for by refrigeration, grinding, water lifting, ironing and others.

Electricity consumption in the residential sector consists of heating and non-heating uses. Heating uses mainly include cooking, water heating and ironing, while non-heating uses are lighting, refrigeration, water lifting, air circulation, etc. In the total consumption of electricity, heating and non-heating uses account for 21.26 and 78.74 per cent respectively.

Appliance elasticities

X_{ij} has been defined as the number of appliances of jth category in the ith household from which it follows that $X_j = \Sigma X_{ij}$ is the number of appliances of the jth category in all the N households. Further, $X_j/N=X_j$ is the average number of appliances of the jth category per household. X_j can also be described as the penetration of jth category of appliances.

If the penetration, X_j of appliances of the jth category is increased by unity, i.e., one more appliance of this category is added to the appliance stock, then the percentage change in the penetration is $(100*1/X_j)$. In response to this change, the yearly household energy consumption is increased by b_j and the percentage increase in the average yearly household consumption is $(100*b_j/E)$ where E is the average yearly electricity consumption of households. Conventionally, elasticity is defined as the ratio of these two percentage changes. Thus, the appliance elasticity of household electricity consumption is:

$$\varepsilon = \frac{\text{Percentage change in electricity consumption}}{\text{Percentage change in appliance penetration}}$$

$$= [(100*b_j)/E]/[(100*1)/X_j)] = [(b_j*X_j)/E)]$$

Effects of increases in appliance penetration on future electricity demand can be estimated by using these elasticities. The elasticities thus calculated for various appliances in both AEH and non-AEH houses are given in Table 6.

Further, using the elasticities, an estimation of future electricity demand per increase in appliance penetration for the state of Karnataka has been calculated and listed in Tables 7 and 8 for AEH and non-AEH houses respectively. The electricity demand is calculated by using the average consumption and number of households with AEH and non-AEH connections.

Rural and Urban households

The sample consists of 46 rural and 323 urban households in the AEH category and 351 rural and 445 urban households in the non-AEH category. The average consumption of electricity per household in rural areas is 940 kWh and 240 kWh per year for the AEH and non-AEH houses respectively whereas in urban areas it is 2160 kWh and 390 kWh per year for AEH and non-AEH houses respectively. Thus, the difference in consumption of electricity between AEH rural and urban households is quite large.

District-wise analysis

The consumption of electricity in the households can also depend on the location and the socio-economic factors of the households. The average consumption of electricity for each of the slabs of usage in the AEH and non-AEH houses in Bangalore, Tumkur, Bijapur and Uttara Kannada districts was estimated. From the estimates, it is observed that the average consumption for all the slabs in metropolitan Bangalore is much higher than the values for the other three districts which do not show significant differences.

Using analysis of variance (ANOVA) test, the differences in the average consumption of electricity across the slabs and across the districts were studied. The result of the ANOVA test is given in Table 9. The result of the ANOVA test indicates that there are differences in the average electricity consumed by the households in the different districts and across different slabs of usage. This justifies the sample selection and its purpose.

Appliance stock in the districts

The district-wise analysis also revealed that there are differences in the average stock of appliances possessed by a household in each of the four districts.
Using the engineering approach, the household consumption of electricity for both AEH and non-AEH houses were estimated for the four districts. Figures 5 and 6 give the differences in proportion of consumption of electricity by various end uses in the four districts studied. The results indicate that water heating is prominent in the households of Bangalore with 29.39% of the total electricity consumption accounting for it. The least usage of water heating is in the households of Uttara Kannada district probably because of the higher ambient temperatures. For the purpose of air circulation, 36.91% and 28.61% of the total electricity are consumed by the households in Uttara Kannada and Bijapur districts respectively. Households in Bangalore district consume 12.2% of the total electricity consumption for lighting, which is very low compared to the other districts. In the non-AEH category, lighting devices consume about 65% of the total consumption of electricity in all the districts. The non-AEH households of Uttara Kannada district consume about 21% of the total electricity consumption towards air circulation, which is higher than the other districts.

In order to understand the change in electricity usage over a period of time by the households in Bangalore Metropolitan area the results of Reddy(1990) were compared with this study. The following are the major changes:

(i) The average electricity consumed by an AEH house in 1990 was 215 kWh/month whereas in the year 1995 it is 255 kWh/month.
(ii) The significant changes in appliance stock possessed by the households from 1990 to 1995 are television (70% to 92%), washing machine (0 to 24%), water pump (13% to 49%), hot plate (75% to 56%), vacuum cleaner (0 to 21%) and fans (2 fans per household to 4 fans per household).
(iii) The number of households using electric stove (hot plate) for cooking has come down by 20% due to increase in the usage of LPG for cooking. Also 90% of the houses possessing the hot plates reported to use them as standby for LPG.

Other sources of energy for domestic purposes

The survey also focused on the usage of other sources of energy for different end uses. The other sources of energy include liquefied petroleum gas (LPG), kerosene, fuel wood and biogas used for the purposes of cooking, water heating and lighting.

About 88.8% of the AEH houses and 27.6% of the non-AEH houses use LPG regularly for cooking or/and for water heating or/and for lighting (Table 10). All the households (both AEH and non-AEH) mentioning the usage of LPG, use it for cooking. Only 18% of AEH houses and 54% of the non-AEH houses use LPG for heating water.

Kerosene (75.1%), firewood (72.9%) and to a certain extent crop wastes (44%) are used extensively for cooking and water heating in the non-AEH houses. Even though AEH households could use electricity and/or LPG for cooking and water heating, a surprisingly high percentage use kerosene and firewood for cooking (31% and 16%) and water heating (19% and 26%). Hence, the proportion of households using hot plates (26.8%), geysers (30.6%) and immersion rods (35.5) are not very high in the AEH houses as seen from the earlier result (cf. Table 1). There is also some mention of the use of biogas in non-AEH houses (about 3%) for both cooking and water heating.

In the rural and urban classification (Table 11), only 17% of the households in the rural areas are using LPG whereas in the urban region it is 62%. 75% of the rural households use kerosene compared to 59% of the urban households. 87% of rural households use firewood as against 46% of the urban households.

Penetration of energy efficient devices

The energy efficient devices considered for this study are fluorescent tubes, electronic chokes, reflectors for incandescent bulbs and electronic regulators for fans. It is found that on an average 21.2% of the lamps (i.e., 1 out of 4.71 lamps) are fluorescent tube lights in a non-AEH house and 42.78% (i.e., 4.09 out of 9.56 lamps) in an AEH house. Electronic chokes (ballasts) are yet to penetrate the households – they constitute only 3.3% in AEH houses and 0.8% in non-AEH houses. The reasons for this low penetration may be (a) the higher initial cost of the electronic chokes compared to the electromagnetic ballasts and (b) the low awareness level regarding electronic chokes. A larger proportion of AEH houses (40.7%) are using reflectors for their lamps than non-AEH houses (12.7%). Also, urban households are using reflectors more than rural households. Electronic regulators for the fans are used only by the AEH houses and their penetration is nearly 8%.

CONCLUSION

The present household survey of electricity consumption in the four districts of Karnataka has revealed the pattern of consumption of electricity among the AEH and non-AEH houses, the stock of electrical appliances used by the households, the consumption of electricity in urban and rural areas, the use of non-electrical sources of energy for domestic purposes and the degree of penetration of energy efficient appliances/devices.

The end use analysis of electricity in the residential sector for the whole of Karnataka has shown that electricity is used mainly for lighting, air circulation, water heating, cooking and entertainment. The survey has also yielded the appliance elasticities that show the effect of

unit percentage increase of appliance penetration on the annual electricity consumption. Interventions to influence electricity consumption without decreasing the energy services provided by electricity must focus on devices for lighting, air circulation, water heating, cooking and entertainment. These two results help the policy makers to take some corrective actions by promoting efficiency improvements in certain end-use devices so that increases in the penetration of these devices would not affect significantly the overall electricity requirement for the domestic sector.

Apart from electricity, households use LPG, kerosene, firewood, crop waste and biogas for cooking, water heating and lighting purposes. The results indicate that usage of kerosene, firewood and crop waste (mostly used for cooking and water heating) is significant in non-AEH houses. Even AEH houses have reported the use of kerosene and fuel wood for the purpose of cooking and water heating. This result indicate a shift in the fuel source used for different applications so that it helps in forecasting the requirements of different energy sources.

Only a very small proportion of households has installed energy efficient devices such as fluorescent tubelights, electronic chokes, etc. Thus, there is tremendous scope for using energy efficient devices by the households. Steps have to be taken by the key actors such as government, manufacturers, financial institutions, and electricity utilities, to educate people and promote the usage of these devices in order to reduce unnecessary consumption.

Table 1 Appliance stock in the sample

Sl.no.	Appliance	non -AEH			
		Average	Std.dev	Average	Std.dev
1	Table Lamp	0.17	0.39	0.11	0. 31
2	Table Fan	0.21	0.41	0.17	0.38
3	Mixer	0.3	0.46	0.84	0.36
4	Refrigerator	0.02	0.13	0.58	0.49
5	Air Cooler			0.04	0.18
6	Air Conditioner			0.01	0.10
7	toaster			0.03	0.16
8	Hot plate	0.01	0.11	0.27	0.44
9	Kettle			0.04	0.19
10	Electric iron	0.31	0.46	0.66	0.48
11	Geyser			0.31	0.47
12	Immersion rod	0.01	0.09	0.36	0.48
13	Vacuum cleaner			0.12	0.32
14	Television	0.47	0.5	0.8	0.40
15	V.C.R.	0.01	0.09	0.19	0.40
16	Radio	0.42	0.49	0.24	0.43
17	Mono recorder	0.24	0.43	0.22	0.42
18	Stereo rec.	0.07	0.26	0.3	0.46
19	Electric heater			0.06	0.24
20	Battery charger			0.01	0.12
21	Inverter			0.00	0.00
22	Washing machine			0.21	0.40
23	Step up transformer			0.04	0.19
24	Water pump	0.01	0.11	0.43	0.49
25	FL20	0.01	0.18	0.02	0.15
26	FL40	1	1.25	4.03 2	0.95
27	IL15	0.25	0.67	0.22	0.73
28	IL40	1.13	1.51	2.26	0.64
29	IL60	2.12	1.57	2.61	0.76
30	IL100	0.02	0.17	0.08	0.48
31	IL25	0.18	0.54	0.23	0.71
32	Fans	0.5	0.69	2.66	0.85

Table 2 House hold consumption of electricity (AEH)

Appliance category	Wattage	Average appliance per hh	Usage hrs./Day	Usage hrs./Year	Consumption kwh/year		% of the total
					per app	per hh	
Table lamp	40	0.1	2.54	927	37.08	3.71	0.15
Table fan	60	0.17	4.76	1737	104.24	17.72	0.69
Mixer	450	0.85	0.47	172	77.20	65.62	2.57
Refrigerator	100	0.6	22.33	8150	815.05	489.03	19.17
Aircooler	170	0.03	4.8	1752	297.84	8.94	0.35
Air cond.	1500	0.01	0.81	296	443.48	4.43	0.17
Toaster	800	0.03	1.1	402	321.20	9.64	0.38
Hot plate	1000	0.28	1.37	500	500.05	140.01	5.49
Kettle	1500	0.03	1.1	402	602.25	18.07	0.71
Electric iron	750	0.67	0.48	175	131.40	88.04	3.45
Geyser	3000	0.29	1.18	431	1292.10	3 74.71	14.69
Immersion rod	1000	0.36	1.75	639	638.75	229.95	9.01
Vaccum cleaner	750	0.12	0.7	255	191.62	23.00	0.90
Television	100	0.81	3.93	1434	143.45	116.19	4.55
V.C.R.	40	0.2	2.14	781	31.24	6.25	0.24
Radio	15	0.23	2.51	916	13.74	3.16	0.12
Mono recorder	20	0.24	1.82	664	13.29	3.19	0.12
Stereo rec.	50	0.31	1.74	635	31.76	9.84	0.39
Elec. Heater	1000	0.06	1.72	628	627.80	37.67	1.48
Bat. Charger	15	0.01	3.25	1186	17.79	0.18	0.01
Washing m/c	325	0.21	0.71	259	84.22	17.69	0.69
Stepup trans.	400	0.04	0.89	325	129.94	5.20	0.20
Water pump	750	0.43	0.68	248	186.15	80.04	3.14
FL20	20	0.02	1.3	475	9.49	0.19	0.01
FL40	40	4.09	2.63	960	38.40	157.05	6.16
IL15	15	0.22	2.32	847	12.70	2.79	0.11
IL40	40	2.27	1.56	569	22.78	51.70	2.03
IL60	60	2.64	2.36	861	51.68	136.45	5.35
IL100	100	0.08	2.72	993	99.28	7.94	0.31
IL25	25	0.24	1.27	464	11.59	2.78	0.11
Fans	100	2.71	4.45	1624	162.43	440.17	17.25
						2551.34	100.00

Table 3House hold consumption of electricity (non-AEH)

Appliance category	Wattage	Average appliance per hh	Usage hrs./Day	Usage hrs./Year	Consumption kwh/year		% of the total
					per app	per hh	
Table lamp	40	0.17	2.91	1062	42.49	7.22	1.04
Table fan	60	0.21	5.78	2110	126.58	26.58	3.84
Mixer	450	0.3	0.52	190	85.41	25.62	3.70
Refrigerator	100	0.02	24	8760	876.00	17.52	2.53
Hot plate	1000	0.01	1.7	621	620.50	6.21	0.90
Electric iron	750	0.31	0.51	186	139.61	43.28	6.25
Immersion rod	1000	0.01	3.11	1135	1135.15	11.35	1.64
Television	100	0.47	3.67	1340	133.96	62.96	9.09
V.C.R.	40	0.01	2.31	843	33.73	0.34	0.05
Radio	15	0.42	2.22	810	12.15	5.10	0.74
Mono recorder	20	0.24	2.25	821	16.43	3.94	0.57
Water pump	750	0.01	1.06	1500	1125.11	11.25	1.62
FL20	20	0.01	4.11	1190	23.80	0.24	0.03
FL40	40	1	3.26	2763	110.52	110.52	15.96
IL15	15	0.25	7.57	920	13.80	3.45	0.50
IL40	40	1.13	2.52	1205	48.18	54.44	7.86
IL60	60	2.12	3.3	1340	80.37	170.39	24.60
IL100	100	0.02	3.67	398	39.79	0.80	0.11
IL25	25	0.18	1.09	2413	60.32	10.86	1.57
Fans	100	0.5	6.61	2413	241.27	120.63	17.41
						692.71	100.00

Table 4 Appliance-wise consumption (AEH)

Sl.no.	Appliance	Cons/App KWH/year	Standard deviation	T	Sig T
1.	Fans	180.94	55.40	3.26	.001
2.	Radio, tape	22.23	93.88	.23	.812
3.	IL100	102.44	119.23	.85	.390
4.	Immersion rod	516.77	142.30	3.63	.000
5.	Mixer, grinder	36.24	174.60	.20	.835
6.	Pump	133.77	124.45	1.07	.283
7.	IL40	39.32	23.63	1.66	.097
8.	Hot plate	1061.81	148.60	7.14	.000
9.	IL60	86.90	17.80	4.88	.000
10.	Fridge	265.94	144.25	1.84	.066
11.	Geyser	667.89	166.10	4.02	.000
12.	FL40	63.34	26.72	2.37	.018
(Constant)		77.62			

Multiple R .79031

R Square .62460

Adjusted R Square .61127

Standard Error 1070.89579

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	12	644932093.01549	53744341.08462
Residual	356	387624412.49449	1146817.78845

F = 46.86389 Signif F = .0000

Table 5 Appliance-wise consumption (non-AEH)

Sl.no.	Appliance	Cons/App KWH/year	Standard deviation	T	Sig T
1	Fans	107.69	13.44	8.00	.000
2	Table fan	64.13	19.45	3.29	.001
3	IL100	93.41	45.10	2.07	.038
4	Radio	66.81	16.31	4.09	.000
5	Table light	26.88	21.22	1.26	.205
6	Mono tape	36.93	18.68	1.97	.048
7	Electric iron	13.04	18.67	0.69	.485
8	FL40	18.41	7.22	2.55	.011
9	Mixer/grinder	95.87	19.55	4.90	.000
10	Television	86.68	18.52	4.68	.000

(Constant) 120.922521

Multiple R .56042
R Square .31407

Adjusted R Square .30533

Standard Error 129.37037

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	10	16983056.04918	1698305.60492
Residual	785	37091155.37796	47249.87946

F = 35.94307 Signif F = .0000

Table 6 Appliance elasticities

Sl.no.	Appliance	Appliance-wise consumption (kwh/year)		Appliance penetration		Elasticity	
		Non-AEH	AEH	Non-AEH	AEH	Non-AEH	AEH
1	Table fan	64.13		0.21		0.04	
2	Refrigerator		265.9		0.6		0.08
3	Hot plate		1061.8		0.28		0.14
4	Electric iron	13.04		0.31		0.01	
5	Geyser		667.89		0.29		0.09
6	Immersion rod		516.77		0.36		0.09
7	Television	86.68		0.47		0.13	
8	Radio	66.81		0.42		0.09	
9	Mono recorder	36.93	22.16	0.24	0.78	0.03	0.01
10	Stereo rec.						
11	Water pump		133.77		0.43		0.03
12	FL40	18.42	63.34	1	4.09	0.06	0.12
13	IL40	25.72	39.32	1.13	2.27	0.09	0.04
14	IL60	72.38	86.9	2.12	2.64	0.47	0.11
15	IL100	93.42	102.44	0.02	0.08	0.01	0.004
16	Table Lamp	26.88		0.17		0.01	
17	Fans	107.6	180.94	0.5	2.71	0.17	1.51
18	Mixer, Grinder	95.87	36.24	0.3	0.85	0.09	0.01

Sample calculation:

$$\text{Appliance elasticity} = \frac{\text{consumption of electricity by an appliance} * \text{average no. of appliances in a HH}}{\text{Average electricity consumption per HH}}$$

(for sl.no. 1) $= 64.13 * 0.21 / 324 = 0.041$

Table 7 Effect of unit percentage of application penetration on AEH electricity consumption

Sl.no.	Appliance	consumption/app (kwh/year)	Elasticity	Increase in consumption per HH kwh/year	KARNATAKA Gwh/year
1	Refrigerator	265.9	0.076	1.60	1.54
2	Hot plate	1061.8	0.142	2.97	2.86
3	Geyser	667.89	0.092	1.94	1.87
4	Immersion rod	516.77	0.089	1.86	1.79
5	Radio	-> 22.16	0.008	0.17	0.17
6	Mono recorder				
7	Stereo rec.				
8	Water pump	133.77	0.027	0.58	0.55
9	FL40	63.34	0.124	2.59	2.49
10	IL40	39.32	0.043	0.89	0.86
11	IL60	86.9	0.110	2.29	2.21
12	IL100	102.44	0.004	0.08	0.08
13	Fans	180.94	1.513	31.69	30.52
14	Mixer, Grinder	36.24	0.015	0.31	0.30
				Total	45.24

Sample calculation:

Increase in consumption per household = elasticity * average consumption of electricity in a HH
(for sl.no. 1) = 0.076% * 2094
= 1.60

Increase in consumption for Karnataka = increase in consumption per HH * no. of connections
= $1.60 * 0.963*10^6$
= 1.54 Gwh

Table 8 Effect of unit percentage of application penetration on non-AEH electricity consumption

Sl.no.	Appliance	conumn/app (kwh/year)	Elasticity	Increase in consumption per HH kwh/year	KARNATAKA Gwh/year
1	Table fan	64.13	0.042	0.13	0.53
2	Electric iron	13.04	0.012	0.04	0.16
3	Television	86.68	0.126	0.41	1.60
4	Radio	66.81	0.087	0.28	1.10
5	Mono recorder	36.93	0.027	0.09	0.35
6	FL40	18.42	0.057	0.18	0.72
7	IL40	25.72	0.090	0.29	1.14
8	IL60	72.38	0.474	1.53	6.04
9	IL100	93.42	0.006	0.02	0.07
10	Table lamp	26.88	0.014	0.05	0.18
11	Fans	107.6	0.166	0.54	2.12
12	Mixer, grinder	95.87	0.089	0.29	1.13
				Total	15.14

Sample calculation:

Increase in consumption per household = elasticity * average consumption of electricity in a HH

(for sl.no. 1) = 0.042% * 324
= 0.136

Increase in consumption for Karnataka = increase in consumption per HH * no. of connections
= 1.60 * $3.935*10^6$
= 0.53 Gwh

Table 9 Test for differences in the annual electricity consumption across districts and across slabs

* * * A N A L Y S I S O F V A R I A N C E * * *

Across four districts

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	300518248.952	3	100172749.65	46.591	.000
DIST	300518248.952	3	100172749.65	46.591	.000
Explained	300518248.952	3	100172749.65	46.591	.000
Residual	784769233.135	365	2150052.694		
Total	1085287482.09	368	2949150.767		

* * * A N A L Y S I S O F V A R I A N C E * * *

Across six slabs

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	1034156502.62	5	206831300.52	1468.381	.000
SLAB	1034156502.62	5	206831300.52	1468.381	.000
Explained	1034156502.62	5	206831300.52	1468.381	.000
Residual	51130979.470	363	140856.693		
Total	1085287482.09	368	2949150.767		

Note: From the results of analysis of variance it can be concluded that there exists a significant difference between the districts and also across the slabs in the consumption of electricity.

Table 10 Details of usage of other sources of energy in the AEH and non -AEH houses

Sl. no.	Source of energy	Usage by number of HH		Average usage per HH/month		No. of HH use for cooking		No. of HH use for water heating		No. of HH use for Lighting	
		AEH	N-AEH	AEH	N-AEH	AEH	N-AEH	AEH	N-AEH	AEH	N-AEH
1	LPG (Kgs)	328 (88.8%)	220 (27.6%)	12	3.7	328 (100%)	220 (100%)	62 (18.9%)	119 (54%)	5 (1.52%)	11 (5%)
2	Kerosene (lts)	152 (41.2%)	598 (75.1%)	2.93	6.26	116 (76%)	519 (86.7%)	71 (46.7%)	341 (57%)	50 (32.9%)	214 (35.8%)
3	Fire wood (Kgs)	120 (32.5%)	580 (72.9%)	88	130	59 (49.2%)	459 (79.1%)	96 (80%)	513 (8 8.4%)		
4	Crop waste (Kgs)	21 (5.7%)	350 (44%)	4.04	24.96	10 (47.6%)	276 (78.8%)	20 (95.2%)	273 (78%)		
5	Bio-gas (CC)	6 (1.6%)	24 (3.0%)			6 (1.6%)	24 (3.0%)	5 (1.3%)	20 (2.5%)		

Table 11 Details of usage of other sources of energy in th e rural and urban dwellings

Sl. no.	Source of energy	Usage by number of HH		Average usage per HH/month		No. of HH use for Cooking		No. of HH use for water heating		No. of HH use for Lighting	
		Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
1	LPG (Kgs)	69 (17.4%)	479 (62.4%)	2	8.5	69 (100%)	479 (100%)	12 (17.4%)	169 (35.3%)	1 (1.4%)	18 (3.8%)
2	Kerosene (lts)	298 (75%)	452 (58.9%)	4.22	5.72	250 (83.9%)	385 (85.2%)	127 (42.6%)	285 (63.1%)	108 (36.2%)	156 (34.5%)
3	Fire wood (Kgs)	346 (87.2%)	354 (46.1%)	202	72.5	293 (84.7%)	225 (63.6%)	293 (84.7%)	316 (89.3%)		
4	Crop waste (Kgs)	256 (64.5%)	115 (15%)	41.5	6.4	208 (81.3%)	78 (67.8%)	183 (71.5%)	110 (95.7%)		
5	Bio-gas (CC)	6 (1.6%)	24 (3.0%)			6 (1.6%)	24 (3.0%)	5 (1.3%)	20 (2.5%)		

Bibliography

Anderson, K.P., (1973), Residential energy use: An econometric analysis, The Rand corporation (R-1297-NSF).

Exercises for Integrated Resource Planning for Kerala – End-use Analysis – an Empirical study – IRTC & IEI joint study (draft report), 1996.

Fisher, F.M., and Kanyan, C.A., (1962), A Study of Econometrics: The demand for electricity in United states, North Holland Publishing Co., Amsterdam.

Houthekar, H.S., (1973), Some calculations on electricity consumption in Great Britain, Journal of Royal Statistics, 114, 359-371.

Parti, M., and Parti, C., (1980), The total and appliance-specific conditional demand for electricity in the household sector, Bell Journal of Economics, 11, 309-321.

Published Annual Report of Karnataka Electricity Board, 1994-95.

Reddy A.K.N., (1990), "Introduction in Energy Planning: Models, Information Systems, Research and Development, Wiley Eastern Limited, International Development Research Centre, Ottawa and United nations University, Tokyo.

Reddy, A.K.N., Sumithra, D. Gladys, Balachandra, P. and D'Sa, Antonette, (1991), "A development focused end-use oriented electricity scenario for Karnataka", Economic and Political Weekly, Vol XXVI, Nos. 14 & 15, April 6-13, 1991.

Reddy, B.S., (1990), "The energy sector of metropoly of Bangalore" Ph.D. Thesis, Indian Institute of Science, Bangalore.

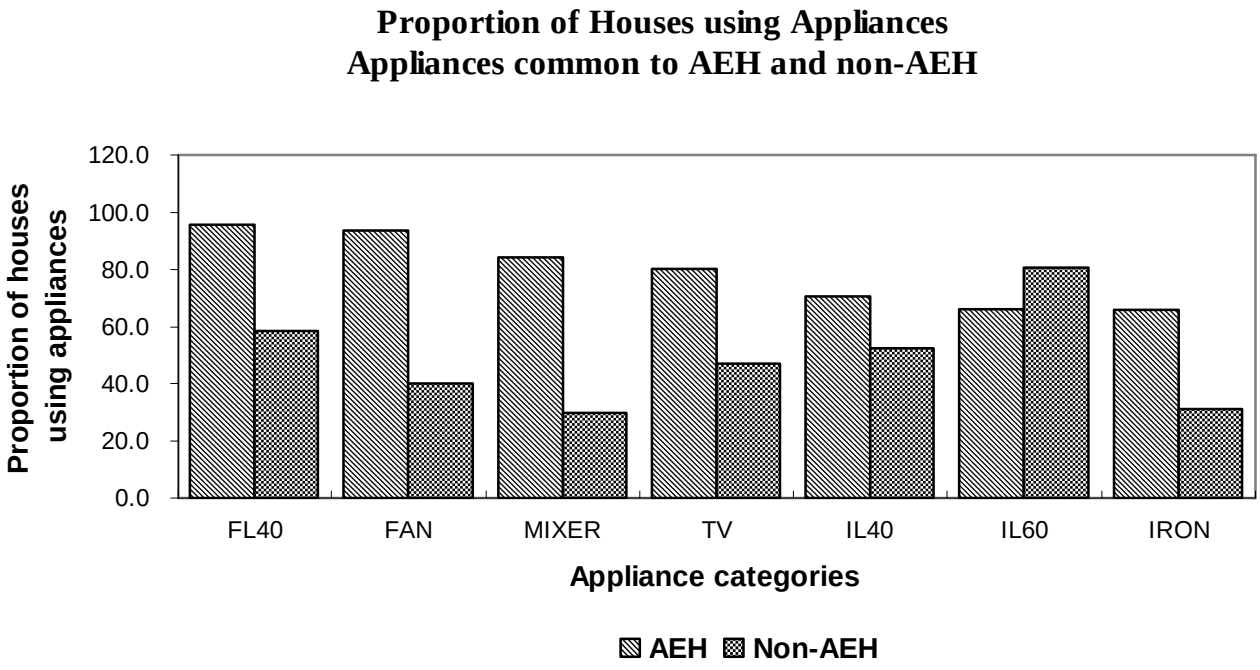
Reddy A.K.N., and Reddy B.S., (1994) “Substitution of energy carriers for cooking in the metropolis of Bangalore, Energy-the International Journal, Vol 19, 561-571.

Reddy B.S., (1995), "A Multilogit Model for Fuel Shifts in the Domestic Sector" Energy, The International Journal, Vol.20, 929-936.

Reddy, B.S., (1996),"Modelling of Competing Technologies in the Residential sector", Energy Conversion and Management, Vol. 37, No. 1, pp. 117-125.

Reddy B.S. (1998) Urban Energy Systems, Concept Publishing Company, India.

Wilson, J.W., (1971), Residential demand electricity, Review of Economic Business Vol.11, 7-19.



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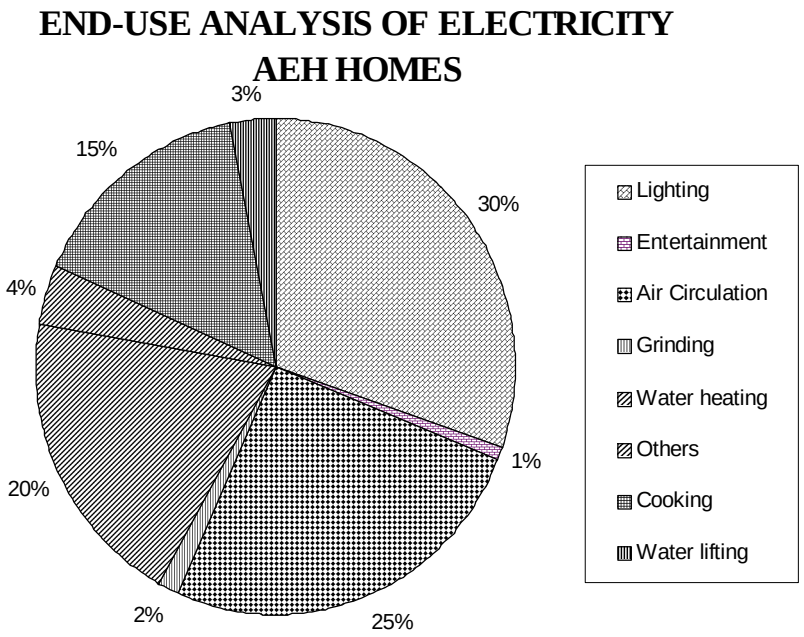
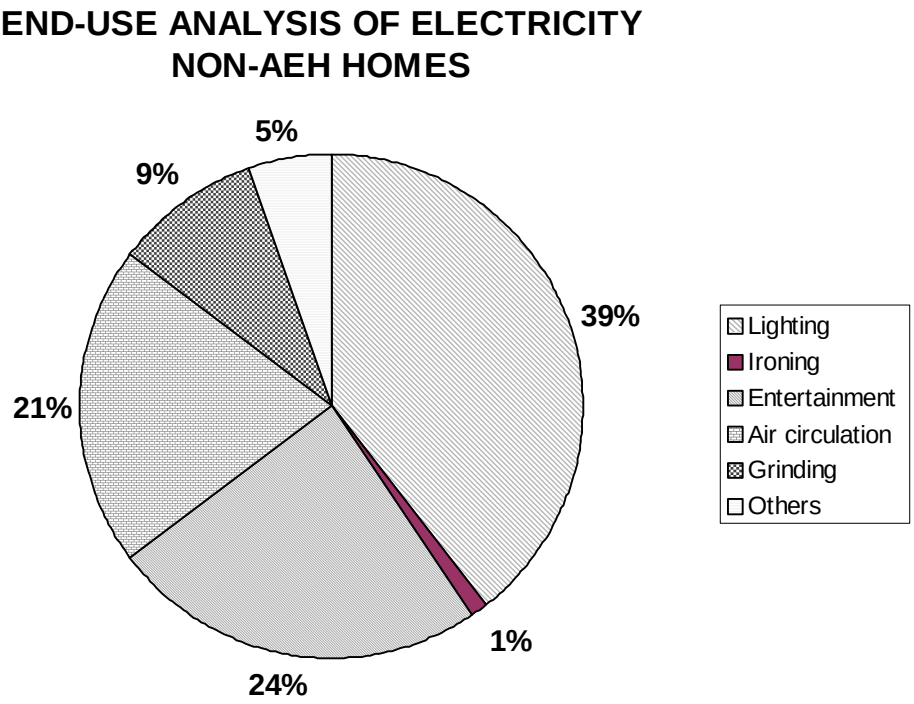


Figure 2:



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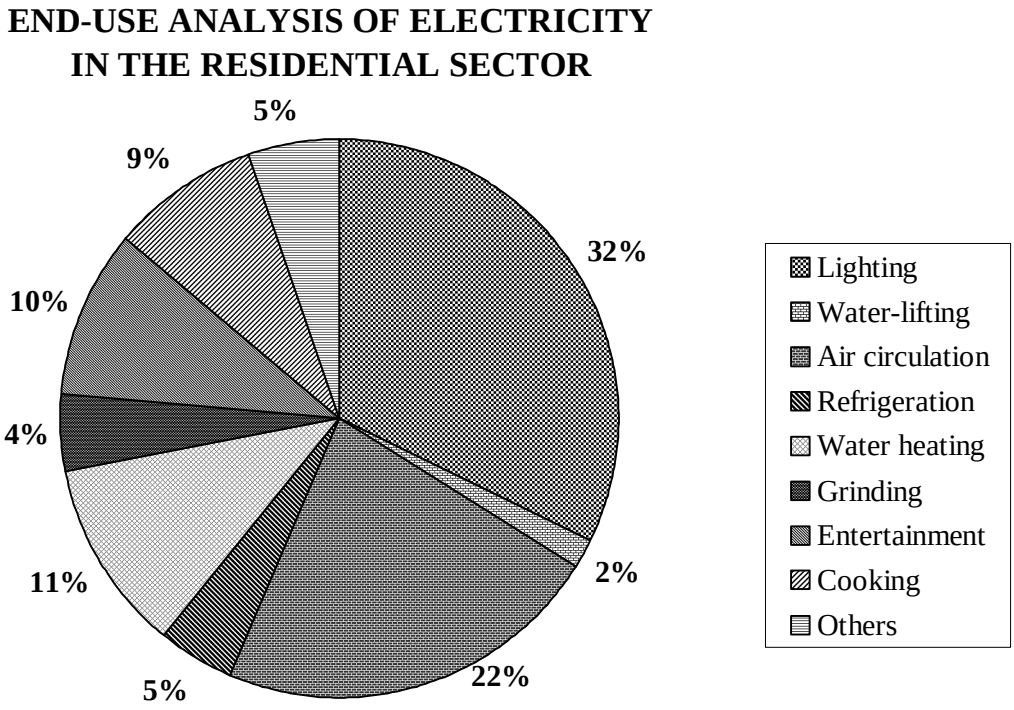

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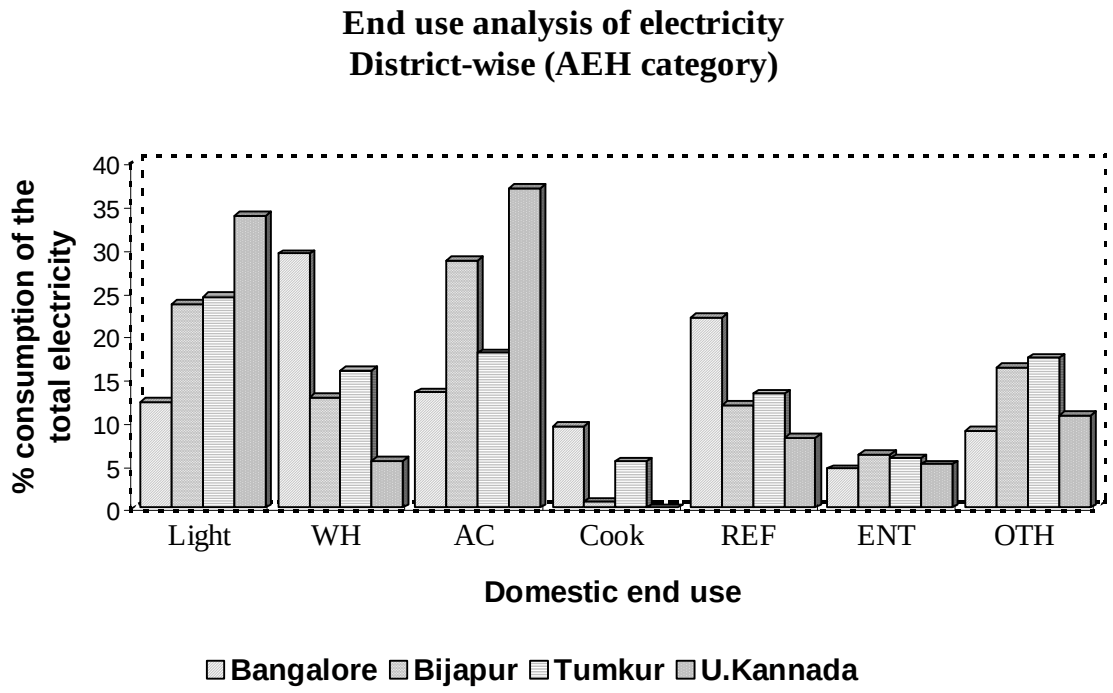

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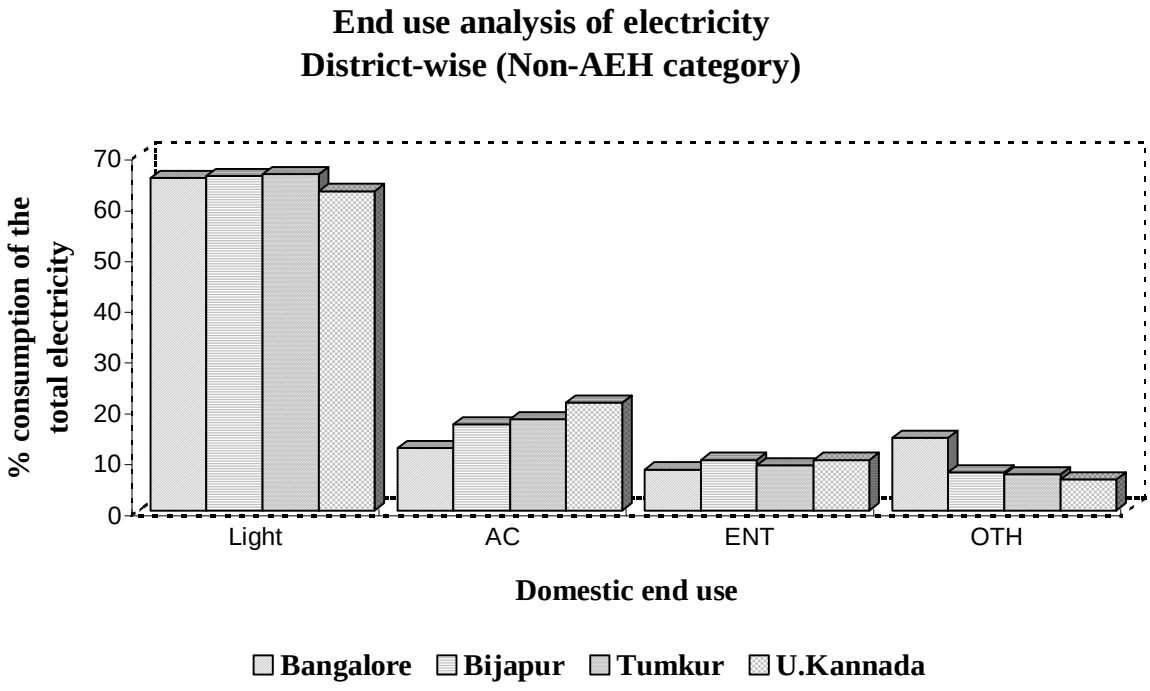

Figure 6: