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A Meta Model for Domestic Energy Consumption

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ABSTRACT: Prediction of energy consumption particularly in micro level is of vital importance in terms of energy planning and also implementation of any Clean Development Mechanism (CDM) activities that has become the order of the world today. It may be difficult to model household energy consumption using conventional methods such as time series forecasting due to many influencing factors. This paper presents a step wise regression model for forecasting domestic energy consumption based on micro level household survey data collected from Kerala, a state in southern part of India. The analysis of the data reveals significant influence of socio-economic, demographic, geographic, and family attributes upon total household energy requirements. While a wide variation in the pattern of energy requirements across the domestic sector belonging to different expenditure classes, per capita income level can be identified as the most important explanatory variable influencing variation in energy requirements. The models developed also demonstrates the influence of per capita land area, residential area among the higher income group while average age and literacy forms significant variables among the lower income group.

Keywords: Meta Model; Consumption Pattern; Domestic Energy Requirement
JEL classifications: E2; Q4

1. Introduction

Energy is crucial for the socio economic development of a country. The energy sector is a part of the economy as well as it itself consist of parts such as energy supply and energy demand interacting with each other. Energy is required for all the economic activities. The economic development is mainly dependent on the energy system of the country. In India, a variety of sources of energy are in use. Like firewood, agricultural waste, animal dung and human power are the traditional sources of energy which still continue to meet the bulk of energy requirements in rural India. These traditional fuels are gradually getting replaced by commercial fuels such as coal, petroleum, natural gas and electricity (Tiwari, 2000). Post oil crisis shifted the focus of energy planners towards renewable resources and energy conservation. However, a major cause of climatic change and air pollution in India is consumption of fossil fuels.

Micro level planning is analogous to the Gandhian concept of decentralization. However, from the beginning, Indian planners took recourse to centralized planning, and macro level policies were formulated at the center. There was no focus on local problems or situations in tiny villages which form the basic elements of any planning movement (Ramachandra, 2009). As a result, one of the primary objectives of planning, i.e., rural uplift has not been fulfilled. Locally available, scarce energy resources are not used scientifically, the existing local technologies have lost their value, and the level of dispossession and impoverishment has increased many folds since independence. Despite strong centralized efforts straddling over four decades, the countryside has experienced severe economic slump and unbridled poverty and unemployment. The disparities between the existing socioeconomic divisions have widened, leading to a dangerous degree of social split in the country (Pachauri and Spreng, 2002). The critical situation can only be circumvented by ensuring rational use of resources at the micro level, and by carefully weighing the implications of various alternative policy decisions. Micro level planning takes into account the essential needs of the local people and arrives at policies for judicious utilization of the locally available resources. A successful micro level plan relies upon several planning tools, such as system analysis, operations research, statistics, and socioeconomic evaluation (Azadeh and Faiz, 2011). For the present investigation, district-level real-life data were collected from a carefully selected representative sample of the target population. A step wise regression model was employed, and various energy-related interactions within the rural system were incorporated. Since prolific utilization of available energy resources is one of the prime aims of development, the objective of the model was to make out the optimized way of utilizing the per capita energy. The quantitative impact of several possible changes in the rural domestic system has been investigated by this approach, and forecasts of future energy scenarios for the rural domestic segment of the state were made (Malik *et al*, 1994). In order to increase the awareness and importance about the growing energy use and micro level planning in India, especially in a state like Kerala, a domestic perspective is adopted. The domestic sector perspective is adopted because it will show an insight into the complex relationships between energy use, household consumption, living style of people and overall development.

This paper attempts to present the details of the investigation and analysis undertaken in this study with section 1 highlighting the need of the study as introduction. Section 2 outlines the energy scenario in India, followed by energy scenario in Kerala, the study area. Section 3 focuses on an exploratory analysis of the data collection and validation. The step wise regression analysis methodology and the analysis are presented in Section 4. The results and inference of the analysis are discussed in section 5. The major conclusions drawn from the study are presented in the last section.

2. Energy Scenario in India and Kerala

"India experiencing a GDP growth rate of 8% per annum, putting tremendous pressure on the power sector of the country". The deficiency in the supply of energy is generally met through imports from other countries. The Indian energy scenario shows a float in the energy balance mainly due to the differed energy sources in India. The country confronts fulgurous challenges in meeting its energy needs and providing adequate energy both in terms of sufficient quality and quantity to users in a sustainable fashion and at tenable costs. If the energy production pattern is analyzed, coal and oil account for about 65% (Table 1). The rest is met by hydro power, nuclear power and natural gas. In the generation sector about 60% is from coal fired thermal power plants and 70% of coal produced every year in India is being used for thermal power generation.

Table 1. Total installed capacity in India.

FUEL	MW	PERCENTAGE
THERMAL	99861.50	64.6
HYDRO	36885.40	24.7
NUCLEAR	4120.00	2.9
RENEWABLE SOURCES	15225.35	7.8
TOTAL	**156092.25**	**100**

On the consumption side, about 55% of commercial energy consumption is by the industrial sector. Even though the per capita energy consumption in India is one of the lowest in the world, (Figure 1) the energy intensity, which is energy consumption per unit of GDP, is one of the highest in comparison to other developed and developing countries (Devadas, 1997). The energy intensity is about 4 times that of Japan, 1.6 times that of USA, 1.5 times that of Asia and about 1.55 times that of the world average, rendering a large scope for energy conservation.

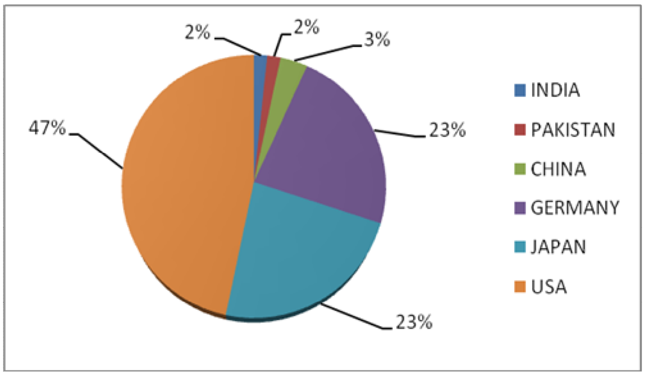

Figure 1. Per capita energy consumption (CMIE)

When the state of Kerala is considered, the major source of energy is hydro power. Majority of the hydel units in Kerala have a capacity in the range of 10 to 75MW. The existing capacity of Kerala power sector as on 2010 is given in Table 2.

Table 2. Kerala- Existing Capacity (Source: KSEB, 2010)

Sl. No.	Source	Installed Capacity (MW)
I	KSEB:- 1. HYDEL 2. THERMAL 3. WIND	 1888.60 234.60 2.03
II	PRIVATE:- 1. HYDEL 2. THERMAL	 33.00 177.44
III	NTPC-KAYAMKULAM	359.58
IV	Share from Central Grid	916.41
	Total	**3565.66**

Kerala has utilized or developed about 70% of hydel power potential as against the all India average of about 30% (Table 3). Further tapping of hydro power potential however would require settling of environmental disputes and coming up in a strategy to tap small hydro power in a big way.

Table 3. Hydel Capacity Potential and Tapped (Source: KSEB, 2010)

	Assessed Capacity (MW)	Developed Capacity (MW)	Under Develop-ment (MW)	Developed+ Under Development Assessed Capacity (%)
Kerala	3514	1837.6	606.4	69.55
All India	148701	29822	13636	29.2

In Kerala, when we consider the total energy utilization the domestic sector is a major factor which consumes about 79% of energy. Also, in the total electricity utilization too, the domestic sector is an unavoidable factor. The consumer profile and the electricity utilization in Kerala are presented in Figure 2.

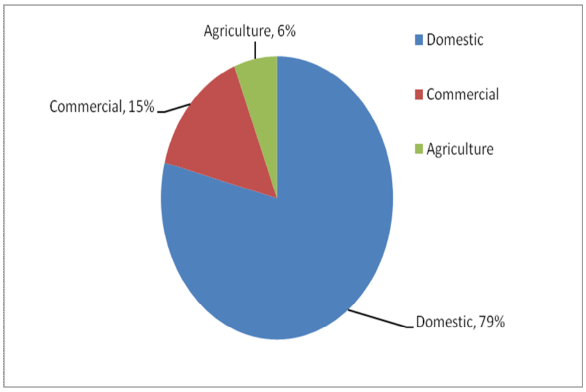

Figure 2. Consumer Profile, Electricity Distribution in Kerala (Source: KSEB, 2010)

When the distribution of total fuel utilization is considered, the major part is LPG utilization which will be around 75% of the total fuel, mainly in cooking sector. This is shown in Figure 3 as below.

The growth of power system in Kerala is shows a linear growth in generation and transmission. The installed capacity has been hiked by 2694.75MW against the 2662.24MW as on March 2010 (Source KSEB, 2010). Kerala's energy scenario is inextricably interlinked with that of India- that is dependability to fossil fuels. But still the chance of taking stock of potentials and possibilities and making necessary advance preparations is a must for Kerala. Solar, Wind energy, Biomass, Biomass gasifiers, production of alcohol fuel and bio diesel from agricultural products is very promising and form potential resources for Kerala.

The Government of India has an ambition mission of power for all by 2012. This mission would require that the installed generation capacity should be at least 200,000 MW by 2012 from the present level of 156,092 MW as on 2010. Power requirement will be double by 2020 to 4 00,000 MW.

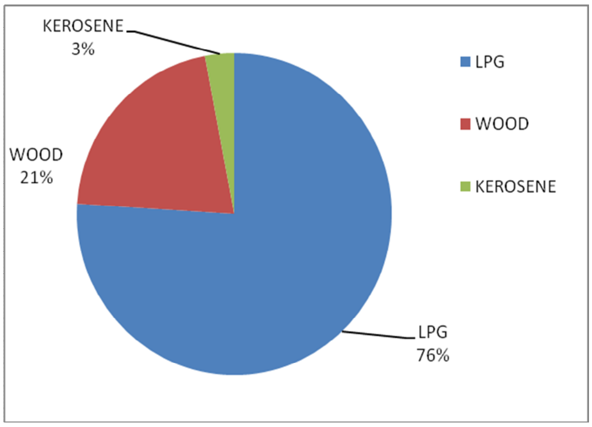

Figure 3. Distribution of Total Fuel Cost in a Month for Cooking

3. Data Collection Methodology

In this study, the state of Kerala, located in southern part of India is selected as the sample space. The region has been divided into 14 districts with a total population of 31,841,374. The survey enveloped the entire state, covering both rural and urban areas. The sampling design was based on a two stage- stratified random sampling procedure with the first stage comprising of rural areas and households forming the second stage units. The households were selected systematically with equal probability, with a random start. The Districts administratively are a collection of panchayats, each of which is further sub divided in to wards each comprising about 1200 households. Data pertaining to randomly selected 120 households was taken to be the representative sample of the District (Choi and Thomas 2009). Data collection was carried out through a questionnaire, prepared for the purpose that provides for gathering minute and precise details regarding the energy usage details. In order to verify the sufficiency of the sample size for 95% confidence interval the following equation was employed (Bernes, 1980)):

$$N' = \left(\frac{20\sqrt{N\sum X^2 - (\sum X)^2}}{\sum X} \right)^2$$, where N=1700 and X is the per capita Income of the people

The value obtained for N' was 764, as compared to the total data collected and hence the sufficiency was verified. For the purpose of data analysis, the state of Kerala was categorized into three regions namely, hilly, coastal and plain region based on geographic considerations. The data collected were also cross verified with data obtained from official statistics and other sources of information.

4. Methodology

Multiple regression is a statistical technique that allows into predicting value of one variable on the basis of combined values of several other variables. That is, the relationship between independent and dependent variables is established using this method. Stepwise regression method (SWR) was developed to economize the computational efforts, as compared with the all possible regression approach, while arriving at a reasonably good best set of independent variables. SWR is an extension of forward selection procedure, where at each stage; provision is made for inclusion and deletion of variables. The method proceeds same as for forward selection with the partial F- criterion for each variable in the regression equation is evaluated and compared with a pre selected percentage point of the appropriate F- distribution. This provides a judgment on the contribution made by each variable as though it had been the most recent variable entered, irrespective of its actual point of entry into the model. Any variable that provides a non significant contribution due to many reasons such as multi co linearity among explanatory variables is removed from the model (Al-Shehri, 2000). This process is continued until no more variables will be admitted to the equation.

In SWR, the independent variables, X_1, X_2,…X_k are entered one by one into the equation according to some pre established criterion. Once a variable is in the equation, however it may be swapped with a variable not in the equation: or it may be removed from the equation altogether. The set of criterion which helps us to determine how a variable is entered, swapped or removed is called SWR which is as follows.

1. Stepwise procedure with F-test.
2. Swapping with F-test.
3. Stepwise procedure with multiple correlation coefficients R^2.
4. Swapping with R^2 (Pasha, 2002).

From the data collected, the per capita energy cost is selected as the dependent variable 'y' and the average qualification of the people in the house (X_1), the average age of the people in the house (X_2), the per capita residential area (X_3), the per capita land area (X_4), and the per capita income (X_5) were selected as the independent variables.

In order to quantify the parameter *qualification*, the different educational levels were grouped as school, pre- collegiate, graduation, post graduation and doctoral levels. Each of these educational levels a weightage varying from 1 to 5 was assigned. For each household the weightage of the educational qualification of each member was summed up and average qualification was computed. The frequency distribution of average qualification in each class was plotted (Figure 4).

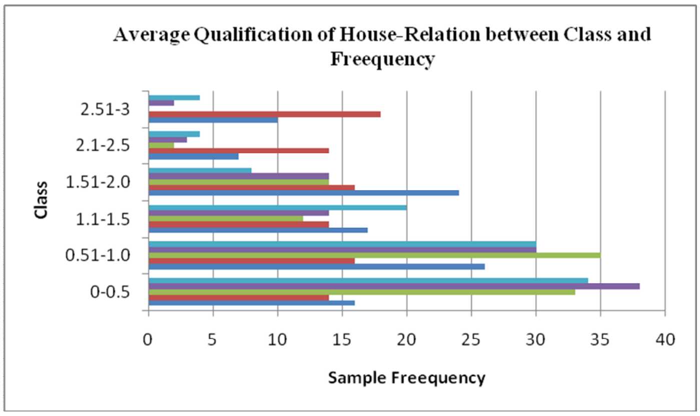

Figure 4. Class wise division of the data (AQH)

In order to quantify the parameter *age,* the different age groups were grouped as '1-10, 11-20, 21-30, 31-40, 41-50 and above'. Each of these age groups, a weight age varying from 1 to 5 was assigned. For each household the weightage of the age of each member was summed up and the average age was computed. The frequency distribution of average age in each class was plotted (Figure 5).

In order to quantify the parameters 'per capita residential area, the per capita land area, and the per capita income', nine classes were identified, for each of these parameters a weightage varying from 1 to 9 were assigned, and the frequencies of occurrence were plotted. But, in these cases the histograms were skewed since there is less variability. Hence a weightage of 2^0 to 2^8 was given to achieve a better spread of data and the frequency distribution in each class was plotted as shown in Figure 6 to Figure 8.

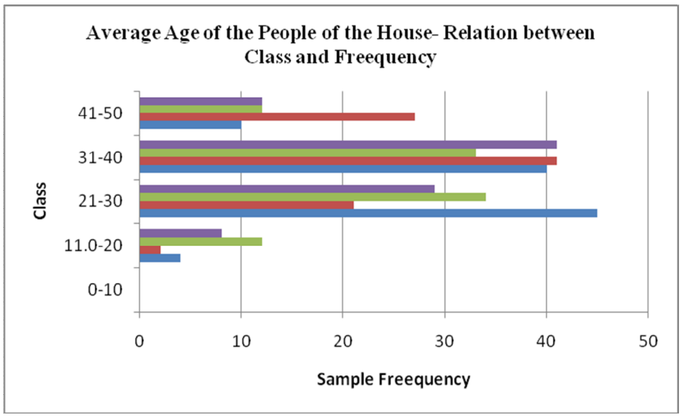

Figure 5. Class wise division of the data (AAH)

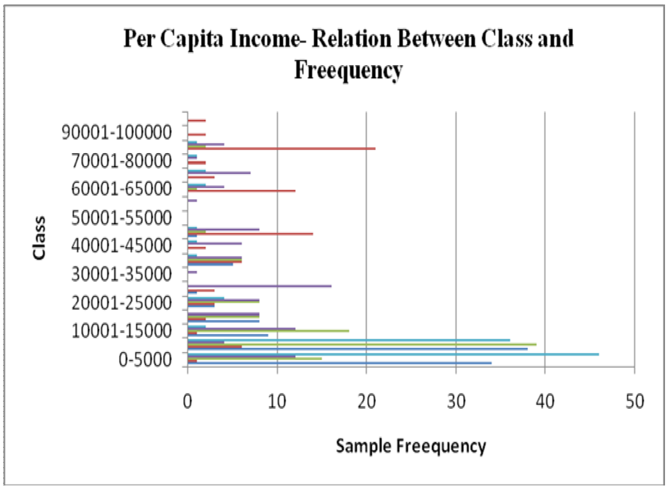

Figure 6. Class wise division of the data (PCI)

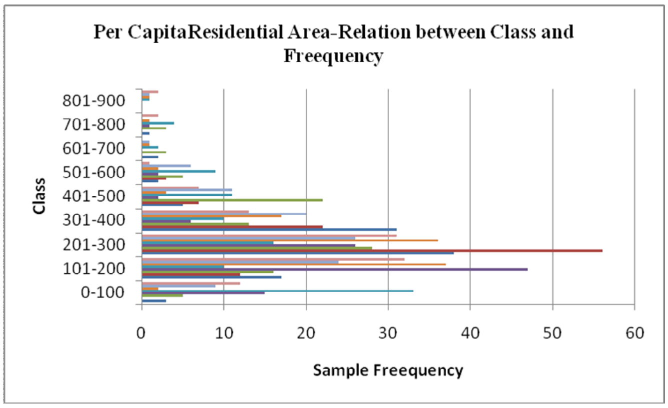

Figure 7. Class wise division of the data (PRS)

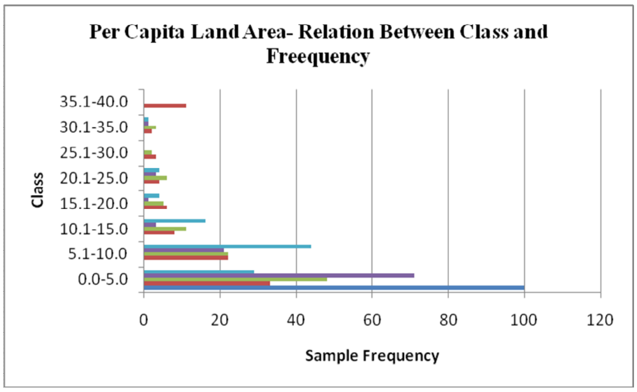

Figure 8. Class wise division of the data (PCLA)

Based on the data collected for the total energy requirement for the household- namely for, cooking, lighting, transportation and other purposes- the per capita energy requirement for each house was calculated. By using SPSS 15 version, the SWR analysis was carried out.

5. Results and inference

For each of the 17 sets of data, stepwise regression was carried out separately using SPSS. The equations obtained using SWR, after grouping the data for the three different major topological terrains as plain, hilly and coastal region is presented in Table 4. A separate Meta model was generated using the data pertaining to the entire state and was obtained as:

$$Y=67.85X_1-1.33X_2+0.36X_3+1.04X_4+0.04X_5+130.83$$

Table 4. Stepwise Regression Equations (Geographical Classification)

No	Region	Governing Variables	Regression Equation	R^2 Value	Adjusted R^2 Value
1	Plain	X_1, X_2, X_3, X_4, X_5	$75.86X_1-1.58X_2+0.21X_3+9.35X_4+0.026X_5+189.77$	0.874	0.875
2	Coastal	X_1, X_4, X_5	$42.08X_1+10.87X_4+0.05X_5$	0.893	0.890
3	Hilly	X_1, X_3, X_5	$53.85X_1+0.42X_3+0.06X_5+48.33$	0.934	0.931

Where
PCEC= Per Capita Energy Cost,
AQH= Average Qualification of the People of the House
AAH= Average Age of the People in the House,
PRS= Per Capita Residential Square Feet,
PCLA= Per Capita Land Area and
PCI= Per Capita Income.

The coefficients for the different independent variables and their associated t-values were computed using SPSS version 15, for all the three major topological terrains. It is observed that the t-values obtained for all the major parameters significantly influence the dependant parameter. The goodness-of- fit (R^2) measure varies between 0.74 and 0.90, and hence the estimator model can be considered to be reasonably accurate. Figure 9 depicts the influence of the independent parameters X_1,

X_2, X_3, X_4, and X_5 on the dependant variable in the various samples pertaining to different districts of the state. Irrespective of the geographical divisions, it can be observed that the parameter 'per capita income' has a greater influence in all the districts, while, the variable per capita residential area has significant influence in samples collected from 9 districts. The state is uniquely recognized to have very high literacy rate (nearly 90%) compared to national level. Still it can be observed that the coastal region demonstrates comparatively lesser literacy compared to plain and hilly regions and hence has lesser significance.

From this analysis, the variation of these parameters with the geographic classification is clearly understandable. The variable X_1 which corresponds to the average qualification of the people in the house is a depending factor of per capita energy consumption in five districts. All these districts are in the northern part of the state under the study. The people in that region are considerably illiterate while comparing with the other part of the state. The regression equation for this relation is given as: $Y= 0.5833X^2+1.9167X+18.75$ and the R^2 value obtained as 0.886.

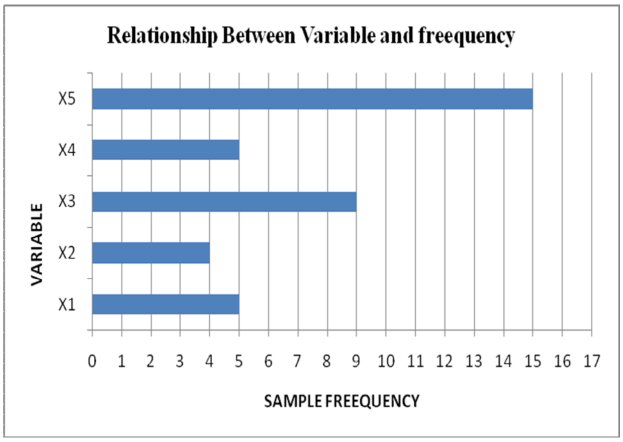

Figure 9. Frequency of occurrence of variables

The second variable X_2 which deal with the average age of the people in the house is a deciding factor of minimum energy consumption in four districts. These districts are all also belonging to the northern part of Kerala. The regression equation obtained is given as:

$Y= 2.2262X^2+17.917X-11.36$ and the R^2 value of 0.7498 is obtained. So, for these parts of the state the average age of the people in the house is also a deciding factor.

The variable per capita income, represented by X_5 is an important one as it is directly related with the energy cost. Irrespective of the geographic or demographic considerations, the energy cost directly depends on the per capita income. The majority of the income classes come under one of the lowest value which is INR 10000 to 15000.

The other two variables X_3 and X_4 which are the per capita residential square feet and the per capita land area variables are dependent on nine and five districts respectively.

In the case of per capita residential square feet, the districts which fall under this category are all in valley or plain area. The entire state which is divided into three sub areas namely plain, coastal and hilly region and this variable mainly fall under the plain area. The per capita residential square feet are one which is dependent mainly on the type of the land. The corresponding regression equation obtained is $Y= 0.1127X^2-3.3929X+24.58$ and a moderately good R^2 value of 0.8507 is obtained. The variable per capita land area (X_4) is predominant in 5 districts. All these are in the coastal area and since that is a highly dense and populated region compared with other areas in the state, the variable X_4 is much influencing in those regions.

Thus it can be observed that the variables are all having some impact or influence in certain regions of the state. The variable X_1 and X_2 are mainly influencing in the northern part of the state where as X_3 is mainly influencing the plain regions. X_4 is making a considerable impact in the coastal regions and the variable X_5 is having impact in all the regions irrespective of the geographic or demographic considerations of the state.

7. Conclusion

The study results presented herein is a pilot attempt in modeling energy consumption patterns and trends in the state of Kerala in India, identifying the various factors influencing the energy consumption pattern that could form a platform for energy planning in not only in the state but also for India as a whole. Most energy planning exercises are carried out with aggregate data at the national level. At regional level namely village, taluk or districts, there have been fewer efforts for energy planning. Energy resources and demand are spatially distributed. Aggregated analysis seldom captures the spatial variation in supply and demand. The models envisaged to be developed is expected to aid in micro level planning in the energy sector, which could go a long way in contributing to sustainable development through implementation of alternative energy potentials particularly in rural India. The paper presents only minor area concerning the domestic energy requirement patterns for rural sector. However, this study methodology can be extended to other areas of energy applications encompassing equally both rural and urban areas. In this study, a general shift towards the consumption of more energy intensive- manufactured goods is evident for higher income class. In terms of direct energy use, there is a definite shift from the use of non commercial energy to more efficient commercial forms of energy. This study shows that the change in house hold size, levels of urbanization, literacy rates and age distribution of the population have important implication for energy use. If the increased urbanization is accompanied by rising income and greater motorization, then the total domestic energy requirements can be expected to increase. The study results are a part of research work being pursued by the authors towards a wholesome solution to global sustainable development.

References

Al-Shehri, A. (2000), A simple forecasting model for industrial electric energy consumption. International Journal of Energy Research, 24, 719–726.

Azadeh, A., Faiz, Z. S. (2011), A meta-heuristic framework for forecasting household electricity consumption. Applied Soft Computing, 11(1), 614-620.

Bernes, R. M. (1980), “Motion and Time Study”. Asia publishing house, Bombay.

Centre for monitoring Indian economy (CMIE) pvt ltd, (www.cmie.com).

Choi, J., N., Thomas, Sy. (2009), Group level organizational citizenship behavior: Effects of demographic fault lines and conflict in small work groups. Journal of Organizational Behavior, 31(7), 1032-1054.

Devadas, V. (1997), Micro level Planning: Part II—Impact Analysis through Scenarios. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 19, 635-642.

http://www.mnes.nic.in.

Malik, S. B. P. S., Satsangi, S.C., Tripathy, and Balasubramanian, R. (1994), Mathematical model for energy planning of rural India. International Journal of Energy Research, 18, 469–482.

Pachauri, S., Spreng, D. (2002), Direct and indirect energy requirements of households in India. Energy Policy , 30(6), 511-523.

Pasha, G., R. (2002), Selection of variables in Multiple Regression using stepwise regression. Journal of Research (Science), 13, 119-127.

Ramachandra, T. V. (2009), RIEP: Regional integrated energy plan. Renewable and Sustainable Energy Reviews, 13(2), 285-317.

Tiwari, P. (2000), An analysis of sectoral energy intensity in India. Energy Policy, 28, 771-778.