International Journal of Energy Economics and Policy
Vol. 4, No. 3, 2014, pp.337-348
ISSN: 2146-4553
www.econjournals.com

Determinants of the Household Electricity Consumption: A Case Study of Delhi

Nidhi Tewathia
Discipline of Economics, School of Social Sciences
Indira Gandhi National Open University, Maidan Garhi,
New Delhi-110068, India. Email: tewathian@gmail.com

ABSTRACT: Electricity has attained a very important place in every household on this planet. It is a major contributor towards improvement of the standard of living of any individual, family and society at large. This paper aims to find out the monthly average household electricity consumption and seasonal variations in this consumption for the months of summer, winter and moderate weather for Delhi. The factors which influence the electricity consumption of a household have been examined by using a questionnaire based study of 395 Delhi households selected via stratified random sampling technique. Multiple regression models have been run to describe the pattern of household electricity consumption. The results from the study show that the stock of appliances in a household contributes the most to the variation in the dependent variable. An inverted U-shaped non-linear Temperature-Electricity Curve has been derived from the primary data used in the study.

Keywords: Delhi; Electricity; Electricity Consumption; Household
JEL Classifications: D11; D12; Q44

1. Introduction

The demand for electricity in a household is derived from the electricity consuming appliances used by the household. It is common knowledge that electricity is primarily used in the domestic sector for lighting and for running appliances like refrigerators, air-conditioners (ACs), water-heaters, kitchen appliances[1], television (TV), music system, etc. According to the World Bank (2008), lighting accounts for approximately 30 percent of total residential electricity use in India, followed by refrigerators, fans, electric water heaters, and TVs. Approximately 4 percent of total residential electricity used is for standby power[2]. Over the years, higher degree of urbanisation has increased the domestic sector's access to electricity. The growing disposable income has led to an increase in the usage of kitchen appliances and home electronics by a household. At the same time, increase in purchasing power of consumers has fostered lifestyle changes in the Indian household, which in turn, has increased its electricity consumption. According to McKinsey (2008)[3], rising incomes have driven, and will continue to drive, demand across consumer classes in rural and urban India. Apart from the increasing stock of electrical appliances and their usage other factors like household income, dwelling size, family size, temperature etc influence the electricity consumption of a household.

Davis & Durbach (2010), found it necessary, to make a distinction between what might be termed the amount of *electricity demanded* (or perhaps apparent electricity consumption and the amount of *electricity consumed* (or actual electricity consumption). The former measures the consumption of electricity-consuming services, rather than the consumption. The latter measures the actual amount of electricity consumed. This paper deals with electricity consumption.

[1] Juicer, Mixer/Grinder, Blender, Microwave/Oven, Induction plate, Food processor etc.
[2] The apparently small amount of power that many modern appliances consume when they are not actively turned on.
[3] The results of the study say that growing at 14 per cent over the next 10 years, India's residential power consumption will grow faster than its GDP growth at 8 per cent.

Wood and Newborough (2003) have classified the components of electricity consumption for a home in three broad terms. They named these components as ‘‘predictable’’, ‘‘moderately predictable’’ and ‘‘unpredictable’’. The former occurs when the building is unoccupied or the occupants are asleep (small cyclic loads for example from refrigeration appliances and steady loads from security lighting and items on standby such as TVs, and VCRs). The remaining consumption is affected by both occupancy and external influences (e.g. seasonal/weather variations). The ‘‘moderately predictable’’ consumption relates to the habitual behaviour patterns of the residents. For example, many people watch TV programmes at regular times each day/week and switch lights on/off each weekday morning as they rise and then leave for work. Lastly ‘‘unpredictable’’ consumption describes the majority of domestic energy use; it tends to be irregular occurring at the users discretion, for example when the occupant wants to cook food or operate the clothes- or dish-washing machine**.**

The reasons behind growth in middle class household electricity consumption in India are examined by Wilhite (2012), where household appliances are rapidly taking a place in home cooking, cleaning and cooling consumption. To know the lifestyle choices and electricity use habits of the households, socio-demographic variables prove to be very useful. Carlsson-Kanyama and Linden (2007) found that the variable ‘income’ affects the type of house bought or rented by the household. The authors believed that the type of accommodation can influence lifestyle of the family members and thus the electricity consumption patterns.

Aune et al. (2002) demonstrate the indirectness of this variable by highlighting two studies that both did not find correlations between energy use and the socio-demographic variables income or education, but McMichael (2007) determined that “the effect of income is through the size of the house”..

Labanderia et al. (2006) include place of residence, household size, age, education or labour force participation as the explanatory variables on which the electricity demand depends.

In a study by OECD (2002), it was found that demand for electricity depends on a host of exogenous factors, most importantly temperature. Insofar as the impact of demographic variables on energy consumption can be detached from the impact of income, empirics suggest that energy consumption varies over the life cycle, between ethnic groups and cultural practices. Household income actually encompasses a large number of factors that superficially seem to affect electricity demand. The study has cited an important example that while additional appliances increase electricity demand; they were bought because of rise in income. The empirical studies are yet to converge on the relationship between socio-economic variables like age and number of children.

Gupta (2011), highlights a U-shaped non-linear temperature-electricity curve, starting from low levels, rising temperatures first decrease electricity demand due to lower heating demand in cold weather, and after the level of temperature exceeds the minimum electricity demand threshold, rising temperatures increase electricity demand due to higher cooling demand in hot weather.

Spangenberg and Lorek (2002) found that the decisions of any household are hardly monocausal. But the households incorporate and react to a variety of influences and interests, all mutually influencing and modifying each other. It is mentioned that the utility from household electricity consumption is not homogenous and hence cannot be derived by aggregating single purchases. There is no direct micro-macro link, which makes it problematic to assess the total service derived from one household’s consumption, let alone from all households’ or consumers’**.**

Petersen (1982)[4] found that the demand for electricity is a function of the stock of electricity-using devices and the intensity of use of those devices**.** Halvorsen and Larsen (2001) also found that the stock of electricity appliances in a house has a relatively large impact on electricity consumption.

The model of Dubin and McFadden (1984)[5] follows a structural approach where the households consumption of electricity and choice of appliances are interrelated decisions coming from the same utility function. Thus the link between the stock of electrical equipment and electrical use is made

[4] This study was undertaken by the author for Utah. It was determined that the stock of electricity-using devices, climate, and demographic characteristics were the most important determinants of variations in household electricity consumption. This study was undertaken by the author for Utah.

[5] Dubin and McFadden (1984) analysed the demand for electricity using a cross sectional sample of U.S. households.

more explicit and allows for a thorough investigation of the bias caused by unobserved factors influencing both the choice of appliances and intensity of use.

Chambwera and Folmer (2007) find that the amount of investment in appliance positively affects both energy and electricity consumption. OECD (2002) and Rao et al. (2009) observed that the electricity powers most of the appliances that come with increasing wealth. It is no surprise that over half of electricity consumed in India in 2004-05 serves the top 20 percent of the population (refer table 1). We can say that the studies are largely inclined towards income as the factor which affects the electricity consumption of a household.

Table 1. Population Vs Electricity Demand

Population Share (%)	Electricity Demand Share (%)
Top 20	53
Middle 40	34
Bottom 40	13

Source: Rao et al. (2009)

Delhi is one of the biggest and most populous metropolitans in the world. The growth in the population, density and the number of households in Delhi over the past three decades is clearly visible from table 2.

Table 2. Population of Delhi (1981-2011)

S.No	Item	1981	1991	2001	2011
1	Total population	6220406	9420644	13850507	16753235
2	Density of Population	4194	6352	9340	11297
3	Number of households	1211784	1860748	2554149	3340538

Source: Directorate of Census operations, Delhi

Delhi is economically amongst the most advanced and fastest growing regions in India. As per the Statistical Abstract (2012), the GSDP[6] (in lakhs) for Delhi at Current price in 2009 was Rs. 22375938 which increased to Rs. 31393351 in 2011. The NSDP[7] (in lakhs) for Delhi at Current Price reached to Rs.29784326 in 2011 from Rs. 21159052 in 2009. Another important indicator of economic well being of Delhi is the per capita income, which has increased from Rs. 129746 in 2009 to Rs.175812 in 2011.

The power[8] sector in Delhi has undergone significant changes over the past few decades. Earlier, Delhi Electricity Supply Undertaking (DESU) was responsible for generation, transmission and distribution of power in Delhi apart from New Delhi Municipal Corporation (NDMC) and Military Engineering Services (Cantonment) areas, to which it supplied power in bulk for onward transmission. DESU was replaced by the Delhi Vidyut Board (DVB) in 1997; however, it proved to be merely a change in the legal status of the organisation and was not followed by any real change in its structure, functioning and work culture. The reputation of the department continued to deteriorate and its poor commercial performance[9] made it a drain on the public exchequer. It was highly incapable of raising the resources necessary to improve its services. The Government of the NCT of Delhi brought out a Strategy Paper on Power Sector Reforms in February 1999. There followed a unique, innovative yet fast track reform process that ultimately resulted in the unbundling of DVB and privatisation of distribution with effect from 1st July 2002. As a result of those reforms, private participation was introduced in distribution for the first time in Delhi. Post the notification of Delhi Electricity Reform Rules, 2001 by the Government of National Capital Territory of Delhi (GNCTD) on 20th November, 2001, the erstwhile Delhi Vidyut Board (DVB) was unbundled into two generation companies i.e. Indraprastha Power Generation Company Limited (IPGCL) and Pragati Power Corporation Limited (PPCL), one transmission company i.e. Delhi Transco Limited (DTL) and 4 distribution companies viz.

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[6] GSDP is a measure in monetary terms of the volume of all goods and services produced by an economy during a given period of time accounted without duplication.

[7] NSDP= GSDP- Consumption of fixed capital (depreciation)

[8] The words 'Power' & 'Electricity' have been used interchangeably for the purpose of the present study.

[9] The best known thing about DVB perhaps being its high Transmission and Distribution (T&D) losses.

BSES Rajdhani Power Limited (BRPL), BSES Yamuna Power Limited (BYPL), North Delhi Power Limited (NDPL) and NDMC. The distribution part of the electricity sector in Delhi was thus privatized with effect from 1st July, 2002.

Along with population and income of Delhi, the domestic electricity consumption and the number of domestic consumers has also increase steadily over the period of 2009-2013 (refer table 3).

Table 3. Domestic Consumption of Electricity in Delhi

S.No	Period	Domestic consumers	Domestic Electricity Consumption (in million units)
1	2009-10	3000383	8753
2	2010-11	3258647	9723
3	2011-12	3464611	10396
4	2012-13	3616611	10796

Source: Delhi Electricity Regulatory Commission (DERC)

Over the period of 2000-11, the share of domestic electricity consumption out of the total electricity consumption of Delhi has gone up from 23% to 25.2%[10]. Over the period of 2006 to 2012, the annual per capita electricity consumption has increased from 671.9 kWh to 879.22 kWh[11]. This indicates towards an achievement of Delhi's power sector both in terms of quantum of power supply as well as the efficiency in generation and transmission of power.

Delhi observes a weather which comprises of hot, cold and moist months. The monthly temperature of the year 2012 was taken into consideration[12] to clearly demarcate three seasons in the year. For the purpose of this study, the summer season includes the months of April, May, June and July; winter season consists of the months of November, December, January and February and the moderate weather comprises of the months of March, August, September and October. The moderate weather includes spring, autumn and rainy season.

Though, electricity has emerged as a major source of improvement of the living standard of the residents of Delhi, very few detailed quantitative estimates exist which provide information on the factors that determine the electricity consumption of a household in Delhi, particulary the factors such as stock of appliance, usage of appliance, dwelling size, family size etc.

Against this backdrop, the present paper makes an assessment of the household electricity consumption in Delhi and the factors which influence it. The paper is organized as follows: Section 2, which follows, brings out a brief review of relevant literature. Section 2 outlines the methodology adopted and database used to run the regression models for household electricity consumption. Section 3 presents empirical results and last section i.e. section 4, gives brief summary and major conclusions of the present paper.

2. Methodology and Database

The present study attempts to estimate the electricity consumption of a household and the factors which explain its consumption for a household are taken as household income (Y_H), stock of electrical appliance (S_A), use of appliances (U_A), family size (F_S), house size (H_S), time spent outside home by the family members (T_O) and household awareness (A_W), and place/location of residence (L). One or more of these variables are used in various previous studies like Petersen (1982), Dubin and McFadden (1984), Filippini and Pachauri (2004), Halvorsen and Larsen (2002), Labenderia et al. (2006) and Carlsson et al. (2007).

The education level of the head of the household is used as a proxy for household awareness. It is divided in four categories, i.e., the education level of the head of the household being nil (no formal education), up to school level, up to graduation and lastly, post-graduation or beyond. To avoid dummy trap, three dummies are used in order to capture the effect education level of the head of the household on the dependent variable. Other qualitative variable, i.e., place/location of the residence also requires the use of dummy variables. The data is collected from five strata of Delhi, i.e., East,

[10] Ministry of Power/ Central Electricity Authority
[11] August Report 2013, CEA
[12] Regional Meteorological Centre, New Delhi

West, North, South and Centre. South district is considered to be the most affluent of all residential districts of Delhi. This comparison of course, excludes the districts falling under Lutyen's Delhi, viz., New Delhi and Central Delhi. The upscale areas[13] have the highest land prices outside Lutyen's Zone in Delhi. Urban villages in South Delhi[14] have become hub for designer boutiques, restaurants and art galleries and design studios. Many renowned markets of Delhi and malls are located in South Delhi. The location of a household in South-Delhi stratum is assumed to have significant effect on the household electricity consumption and hence only one dummy is considered for location.

The consumption function for electricity is hence defined as follows:

$$E = E\ (Y_H, S_A, U_A, F_S, H_S, T_O, A_W, L)$$

where

E = Average Monthly household electricity consumption (in kwh)
Y_H = Monthly average income of the household (in Rs.)
S_A = Stock of the electrical appliances with a household
U_A = Total use of electrical appliances in a day (in hours)
F_S = Size of the family
H_S = Size of the dwelling[15] (in square yards)
T_O = Average time spent outside by a family member (in hours)
D1 = the education dummy variable which is equal to 1 if the head of the household is educated up till school level and 0 if otherwise.
D2 = the education dummy variable which is equal to 1 if the head of the household is Graduate and 0 if otherwise.
D3 = the education dummy variable which is equal to 1 if the head of the household is post-graduate and 0 if otherwise.
L1 = Dummy variable for the place of residence which is equal to 1 if the house is located in South-Delhi and 0 if otherwise.

$$\ln E = a + \beta_1 \ln Y_H + \beta_2 S_A + \beta_3 \ln U_A + \beta_4 F_S + \beta_5 H_S + \beta_6 T_O + \beta_7 D1 + \beta_8 D2 + \beta_9 D3 + \beta_{10} L1 + \mu \qquad ....(1.1)$$

The intercept term "a" in the model gives the average value of E when Y_H, S_A, U_A, H_S, T_O, F_S and the dummy variables are set equal to zero. The coefficients β_1, β_2, β_3, β_4, β_5, β_6, β_7, β_8, β_9 and β_{10} are the partial regression coefficients and μ is stochastic disturbance term. The following variables are logged in the model: household electricity consumption, household income and total use of electrical appliances. These variables are logged in order to remain consistent with the past models and for ease of interpretation. Most importantly, β_1 represents income elasticity of electricity consumption which bears an important implication for future electricity consumption.

In this model, expansion upon the previous studies is made in number of ways. Average persons per household (family size) and regional and educational dummy variables are incorporated. Family size should directly affect the amount of electricity needed to continue day to day activities which require electricity. Regional dummy is used in order to allow the social status variation in the electricity consumption.

In order to capture the seasonal variation in the electricity consumption pattern of the households, a similar model is employed for three seasons namely, summer, winter and moderate weather. Hence the dependent variable E takes three forms now, i.e., E_S, E_W and E_M where E_S is the average monthly household electricity consumption in summers (in kwh), E_W is average monthly household electricity consumption in winters (in kwh) and E_M is the average monthly household electricity consumption in moderate weather (in kwh). The independent variables remain the same.

The models are:

$$\ln E_S = a + \beta_1 \ln Y_H + \beta_2 S_A + \beta_3 \ln U_A + \beta_4 F_S + \beta_5 H_S + \beta_6 T_O + \beta_7 D1 + \beta_8 D2 + \beta_9 D3 + \beta_{10} L1 + \mu \qquad ...(1.2)$$

[13] Greater Kailash, Green Park, Chittaranjan Park, Gulmohar Park etc.
[14] Shahpur Jat, Hauz Khas Village, Lado Sarai etc.
[15] It is the accommodation availed of by a household for its residential purpose. It may be an entire structure or a part thereof or consisting of more than one structure.

$$\ln E_W = a + \beta_1 \ln Y_H + \beta_2 S_A + \beta_3 \ln U_A + \beta_4 F_S + \beta_5 H_S + \beta_6 T_O + \beta_7 D1 + \beta_8 D2 + \beta_9 D3 + \beta_{10} L1 + \mu \quad \ldots(1.3)$$

$$\ln E_M = a + \beta_1 \ln Y_H + \beta_2 S_A + \beta_3 \ln U_A + \beta_4 F_S + \beta_5 H_S + \beta_6 T_O + \beta_7 D1 + \beta_8 D2 + \beta_9 D3 + \beta_{10} L1 + \mu \quad \ldots(1.3)$$

The software SPSS 13.0 is used to estimate the models, the results of which are reported below. The data is composed from a number of sources. The respondents, i.e., the households were selected on the basis of stratified random sampling technique. The data on lifestyle choices, electricity use habits of the households and various socio-demographic variables is collected in order to draw a valid database. Both, the primary and secondary data are used for the present work. The data on dependent and independent variables is collected through primary survey. Hence, we can say that this study has adopted the approach strategy which has elements of both qualitative and quantitative research.

The basic statistics available with census reports, statistical abstracts by the government of NCT of Delhi, CMIE reports, NSS rounds, reports by various government agencies like CEA, DERC, government budgets, economic survey, reports made by NGOs and research institutions have been referred to. The secondary data on the per capita income at current prices for 2010 and 2011 and the average household size are extracted from the Delhi Statistical Handbook, 2013 in order to calculate the average monthly household income for the required time periods, i.e., 2011 and 2012.

The present study is undertaken for Delhi wherein the National Capital Region[16] has been excluded. The data on all the independent variables like income of the household, dwelling size, family size and stock of appliances is collected through primary survey of 395 households[17]. Details of the variables taken for estimation are given below.

Average Monthly Household Income: Income, in general, acts as a determinant of demand for all the commodities which are consumed by that household. The same applies to household electricity consumption. The correlation between monthly average electricity consumption in summers and income is found to be 0.587 while the correlation between monthly average electricity consumption in winters and income and moderate weather and income stands respectively at 0.557 and 0.514. Further, the relationship between different monthly household average income groups and the number of electrical appliances owned by the household is examined. For this purpose, the list of 20 electrical appliances was provided to the respondents in the questionnaire[18]. It is found that the maximum households belonging to the monthly average income group of "Rs.30,001 to 80,000" own 13 appliances while the maximum households belonging to the income group "more than Rs.1,25,000" own 17 appliances. Hence, it can be stated that as household income rises, the number of appliances owned also increase. This establishes a positive relationship between income of the consumer and number of appliances.

House size[19]: Moderate positive correlation was found between size of the dwelling and electricity consumption of a household (ranging from 0.462 to 0.612) across seasons. Hence, it can be inferred that the size of dwellings and household electricity consumption have a positive relationship. It is found that the maximum households residing in small dwellings (up to 60 sq. yards) own four appliances while the households residing in big dwellings (more than 121 sq yards) own no less than nine appliances.

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[16] Gurgaon, Faridabad and Noida.

[17] A group of persons normally living together and taking food from common kitchen constitute a household. The word 'normally' means that the temporary visitors are excluded. 'Living together' is usually given more importance than 'sharing food from a common kitchen' in drawing the boundaries of a household. (NSS 66th round)

[18] AC, Cooler, Washing Machine, TV, Music system, Water geyser, Room heater, Electric iron, Mixer, Vacuum cleaner, Inverter, pump motor, DVD player, Immersion heater, Laptop/ Desktop, Hairdryer, Shaver, Toaster, Microwave, Refrigerator.

[19] It is the accommodation availed of by a household for its residential purpose. It may be an entire structure or a part thereof or consisting of more than one structure. There may be cases of more than one household occupying a single structure such as those living in independent flats or sharing a single housing unit, in each case, there will be as many dwelling units as the number of households sharing the structure. (NSS 66th Round)

Size of the family[20]: The other factor which influences the household electricity consumption is the total members in the family, i.e., the size of the family. Common perception is that, as the size of the family increases, a family would consume more electricity. But it is found that the small families (up to four members) and big families (above four members) show similar trend in ownership of the appliances. Both types of families own as less as two appliances and as much as 20 appliances. The correlation between the size of the family and household electricity has been found positive but weak (ranging from 0.075 to 0.190) across the seasons.

Stock of appliances: Generally, it is found that the whole family holds a discussion before buying any electrical appliance and more so if the appliance is expensive. The results of the present work indicate that 70.6% households disagree that buying an appliance is not a family decision. Before purchasing any appliance, the households consider a) cost, b) quality and c) energy consumption of the appliances before buying an appliance[21] in the order mentioned. The correlation of electricity consumption and stock of appliances in a household is estimated. The correlation is found to be moderately positive for all the dependent variables (ranges from 0.445 to 0.552).

Time spent out by a family member: Most of the households' activities which require electricity happen when the family members are present in the house. Hence it is found necessary to add one more variable in the list i.e. the average time spent out by a family member. As expected, the direction of correlation is found to be negative which establishes the negative relationship between the two mentioned variables.

Education level of the Head of the Household and Place of Residence: These variables are qualitative in nature hence dummy variables are introduced to capture the effect.

3. Electricity Consumption

As per Malhotra and Negi (2009), the figures of electricity consumption in Delhi for 2000-01 indicate that the domestic sector's share in the total electricity consumption of Delhi was 44.3 per cent which was increased to 45 per cent in 2007. Further it increased to 50.5% in 2012-13[22]. The data collected from DERC in context of number of domestic consumers and the amount of electricity consumed for domestic purpose is compiled in Table 4. The period from 2007-08 to 2012-13 is covered.

Table 4. Domestic Electricity Consumption in Delhi

S.No	Period	Domestic Consumers	Domestic Electricity Consumption (in million units)	Annual Growth Rate of Electricity Consumption[23] (per cent)
1	2007-08	2627975	6945	----
2	2008-09	2755225	7481	7.7
3	2009-10	3000383	8753	17
4	2010-11	3258647	9723	11.08
5	2011-12	3464611	10396	6.9
6	2012-13	3616611	10796	3.8

Source: DERC, Delhi Statistical Handbook 2013

The electricity consumption in India has been increasing rapidly due to growing industrialization, modernization of agriculture and rising incomes. The reasons behind growth in middle class household electricity consumption in India are examined, where household appliances are rapidly taking a place in home cooking, cleaning and cooling consumption (Wilhite, 2012). Table 5 depicts the share of domestic consumption of electricity from the total electricity consumption over the period 2000-11 for India. The share of domestic electricity has increased from 23 per cent to 25.2 per cent in the mentioned period.

[20] The number of normally resident members of a household is its size. It will include temporary stay aways but exclude temporary visitors and guests. (NSS 66th round)

[21] Gaspar, R., and Antunes, D. (2011), Energy efficiency and appliance purchase in Europe: Consumer profiles and choice determinants, Energy Policy 39, 7335-7346. The consumer profiles were identified based on gender, age and whether or not the purchaser was accompanied when decisions were made.

[22] Delhi Statistical Handbook (2013)

[23] The annual growth rate of residential electricity consumption is calculated on the basis of secondary data.

Table 5. All India Domestic Electricity Consumption (%)

S.No	Year	Domestic consumption
1	2000-01	23.0
2	2001-02	24.7
3	2002-03	24.6
4	2003-04	24.9
5	2004-05	24.8
6	2005-06	24.3
7	2006-07	24.4
8	2007-08	24.0
9	2008-09	24.7
10	2009-10	24.9
11	2010-11	25.2

Source: Ministry of Power/ CEA

A gradual increase has taken place in the past years in the figures of annual per capita electricity consumption of Delhi (refer table 6). It has increased from 1417.22 kwh in 2006-07 to 1651.26kWh in 2009-10**.**

Table 6. Annual Per Capita Electricity Consumption of Delhi

S.No	Year	Per Capita Consumption (kWh)
1	2006-07	1417.22
2	2007-08	1433.36
3	2008-09	1374.16
4	2009-10	1651.26

Source: Annual Report 2011-12 on the working of State Power Utilities and Electricity Departments, Planning Commission

This could be an indicator of the development of Delhi in terms of urbanization and modernization or particularly the effect of privatisation of power sector which implies better operations. The electricity consumption of a household is influenced by the seasons of the year. Hence, the primary data is analysed in order to find out the average units of electricity consumed by a household in different seasons. In order to categorise the months of a year into different weathers/seasons, the secondary data from metrological department was referred. The average monthly temperature of the year 2012 was procured from the meteorological department for this purpose. All the months are categorized into three seasons, i.e., a) summer season b) winter season and c) moderate weather. The summer months are April, May, June and July (average maximum temperature above 35°C). The winter months are November, December, January and February (average maximum temperature below 25°C). The remaining months, i.e., March, August, September and October have been clubbed in the category of moderate weather months (average maximum temperature between 25°C to 35°C).

It is noted that number of households consuming higher levels of electricity varies depending upon the season. Figure 1 shows the electricity consumption by households under different slabs of electricity units consumed.

The number of households which consume electricity from 101 units to above 400 units per month in summer season are more vis-à-vis winter months. On the other hand, the number of households which consume up to 100 units of electricity are more in winter season vis-à-vis summer season. Hence, the average monthly consumption is found to be varying for the three seasons (Table 7). In summer season, the average monthly electricity units which are consumed by a household are 470.35 while the consumption decreases to 275.67 units for a winter month. Monthly electricity consumption of a household during the moderate weather stands at 383.43 units. The reasons for this pattern are mainly concerned with number of appliances owned by a household and their usage which is covered in Chapter 6. To recall, it was observed that the households use ACs, Coolers for a longer duration in summer season as compared to the duration for which geyser and heater are used. Also, the load of AC is much higher than geyser and heater.

Figure 1. Monthly Electricity Consumption and Households

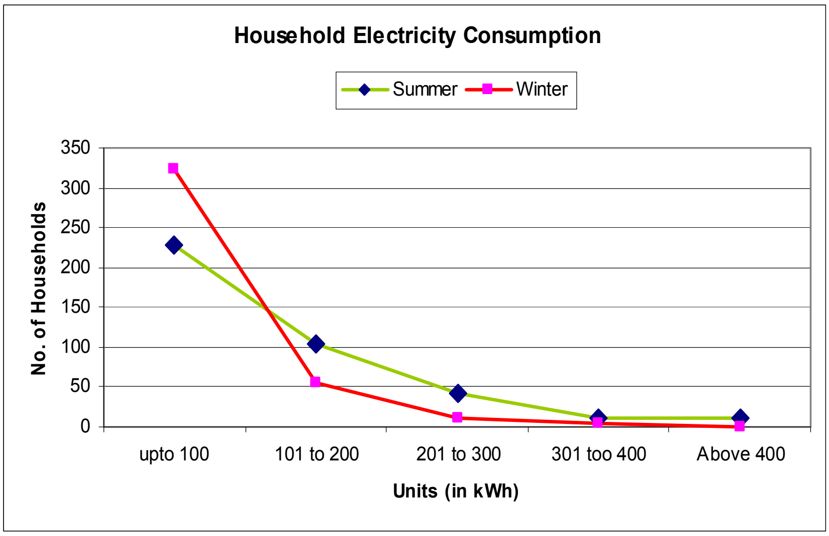
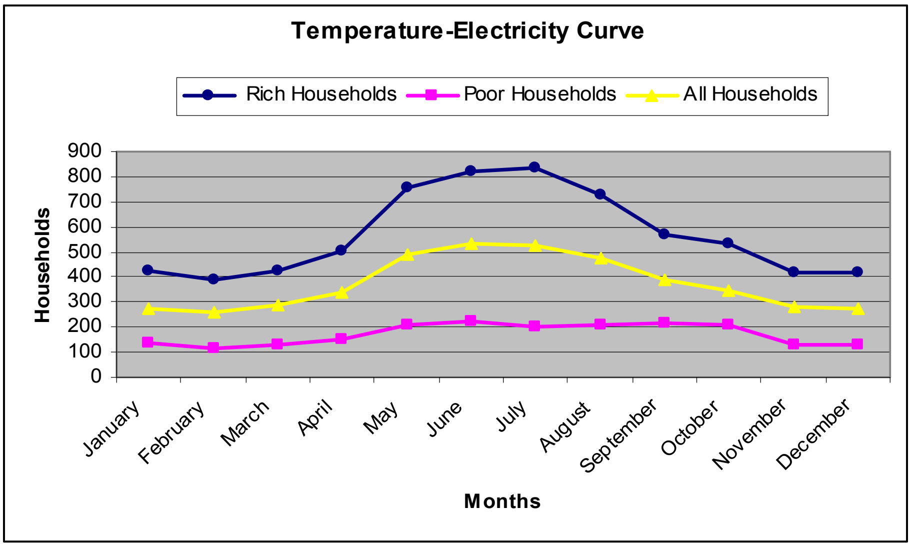


Table 7. Average Monthly Household Electricity Consumption (in kwh)

N= 395	Mean	Standard Deviation	Coefficient of Variation
Overall Monthly consumption	373.55	288.39	0.772
Summer Season	470.35	390.796	0.83
Winter Season	275.67	225.089	0.816
Moderate Weather	383.43	338.777	0.883

The TEC showing the relationship between the temperature and electricity consumption by a household follows an inverted-U like path (Figure 2). This indicates that electricity is consumed the most in the summer months and the least in the winter months. This TEC for Delhi is derived with the help of collected primary data. The average electricity consumption of the households for each of the 12 months is found and then plotted for the respective months.

Figure 2. Temperature-Electricity Curve



Geographically, Delhi is situated at an altitude where the minimum temperature rarely touches 0°C. Hence the households' requirement of heating in the winter months is not much. It was found that only 43.5% households own blowers or heaters. On average, a household uses heater for only about 8 days in a month and nearly for an hour during the day. Hence, the electricity consumption in winter season is much lower than the consumption in summer season when ACs and coolers are used for longer duration and are also owned by majority of the households.

Further, the TEC is derived for two economic classes, i.e., poor households and rich households. It is observed that the shape of TEC for both the classes remains the same albeit with an elevated peak for the rich households and a nearly flat peak for the poor households, which signifies the absence of cooling appliances in poor households.

4. Regression Analysis

In this section, multiple regression analysis is used to test models 1.1, 1.2, 1.2 and 1.4. As previously noted, there is not much variation in the variables of interest. If we look at the regression results (Table 8), we can infer that the model is a good fit. R-squared is 0.528 which also means that 52.8 per cent of the variation in dependent variable is explained by all the independent variables considered in the model. The Durbin-Watson test was undertaken to check the autocorrelation in variables. It is found that there is no autocorrelation as the value of D-W statistic is 1.648.

Table 8. Empirical Results for Model 1.1

Explanatory Variables	Coefficient	Std Error	Standardised β Coefficient	t-ratio	p-value
Constant	0.632	0.684		0.923	0.357
$\ln Y_H$	0.280	0.047	0.319	6.017	0.000
S_A	0.047	0.010	0.271	4.866	0.000
$\ln U_A$	0.335	0.135	0.106	2.479	0.000
F_S	0.058	0.026	0.084	2.222	0.027
H_S	0.003	0.000	0.236	5.685	0.000
T_O	-0.08	0.019	-0.015	-0.418	0.676
D1 (schooling)	-0.286	0.227	-0.157	-1.261	0.208
D2 (Graduation)	-0.470	0.226	-0.306	-2.082	0.038
D3 (Post-Graduation)	-0.486	.231	-0.281	-2.099	0.037
L1 (South-Delhi)	0.112	0.065	0.064	1.727	0.085
N= 395					
D-W statistic	1.648				
R-squared	0.528				
Adjusted R-squared	0.516				
Dependent Variable	lnE				

It is noticed that the independent variables, $\ln Y_H$, S_A, $\ln U_A$, F_S, and H_S and have signs consistent with a priori expectations. The coefficients of $\ln Y_H$, S_A, $\ln U_A$, and H_S are positive and they are statistically significant at 99 per cent confidence interval while the coefficient of F_S is statistically significant at 95 per cent confidence interval. The coefficient of the education dummies, i.e., D1, D2 and D3 are found to be negative and only D2 and D3 are statistically significant at 95 per cent. It indicates that higher education level has negative relation with the household electricity consumption and it significantly explains the variation in the electricity consumption of the household. Coefficients of T_O and L1 are statistically significant at 90 per cent. It can be inferred that spending more time out of home reduces the electricity consumption of the household. The regional dummy variable, L1 is positively explaining the variation in the household electricity consumption.

The coefficient of $\ln Y_H$, i.e., 0.280 represents the income elasticity of monthly household electricity consumption. It means that a 1 per cent increase in household income will increase the household electricity consumption by 28 per cent. The relative contribution of predictors can be compared by looking at the β coefficients. The variable S_A contributes the most in the variation of dependent variable as it is reflected by the strength of its coefficient (0.342). The least contributor in the variation of dependent variable is F_S with β coefficient of 0.101. The standardised β coefficients are used to compare the relative importance of predictor variables when the variables are measured in different units. It shows how many standard deviation the dependent variable will change per standard deviation change in the independent variable.

The same model is applied for the electricity consumption in different seasons. The results of model 1.2, 1.3 and 1.4 are presented in Table 9. It can be observed that the results are similar to those of model 1.1. The significant independent variables at different levels are lnY_H, S_A, lnU_A, F_S, and H_S. The dummy variables for education and place of residence are significant and not significant across seasons.

Table 9. Combined results for models 1.2, 1.3 and 1.4

Explanatory Variables	**Coefficients**		
	Summer Season	**Winter Season**	**Moderate Weather**
lnY_H	0.276(***)	0.249(***)	0.274(***)
S_A	0.052(***)	0.047(***)	0.051(***)
lnU_A	0.300(**)	0.265(*)	0.275(*)
F_S	0.049(*)	0.063(**)	0.055(*)
H_S	0.003(***)	0.003(***)	0.003(***)
T_O	0.000	-0.010	-0.013
D1 (schooling)	-0.384	-0.229	-0.297
D2 (Graduation)	-0.568(**)	-0.386	-0.527(**)
D3 (Post-Graduation)	-0.561(**)	-0.414	-0.517 (*)
L1 (South-Delhi)	0.103	0.147(*)	0.133 (*)
N= 395			
D-W statistic	1.845	1.551	1.723
R-squared	0.512	0.410	0.442
Adjusted R-squared	0.499	0.395	0.427
Dependent Variable	lnE_S	lnE_W	lnE_M

Note: (***) = Significant at 99% interval, (**) = Significant at 95% interval, (*) = Significant at 90% interval

It can be inferred that the household income, stock of electrical appliances with a household, usage of the appliances, size of the house and family size explain the variation in the dependent variable significantly through out all the seasons.

5. Conclusion

The trends in household electricity consumption clearly show that the domestic consumers, per capita electricity consumption in India, and in particular Delhi have increased over the years. The average monthly power consumption of the households varies across seasons as the requirement of electricity varies as per the prevailing temperature. The inverted-U non linear TEC shows that as temperature rises, more electricity is consumed as a result of usage of cooling appliances like AC, fridge, Cooler etc. The TEC across various income groups indicated that the cooling appliances are possessed more by the rich class vis-à-vis poor class. The independent variables; household income, stock of appliances, usage of appliances, family size, dwelling size, time spent out by the family members and higher education level were found to be significant in explaining the variation in the monthly electricity consumption of a household. The income elasticity of household electricity consumption is moderate positive at 0.28. The β coefficients of the variables indicate that there is not much of seasonal variation in the explanatory variables.

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