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A Household-based analysis of domestic energy consumption for lighting in Jaipur City

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ABSTRACT

India being the third largest economy of the world, more than two third of the total population lives in villages and started to consuming more quantity of energy in the recent years. Though the electricity consumption in the domestic sector has increased up to 22 per cent of the total electricity consumption, electricity consumption in villages is very less, since good number of villages in the rural system are not even electrified. In urban areas almost 90 percent of the household use electricity for lighting and just 10 percent use kerosene for the said purpose, whereas in the rural areas still more number of households use kerosene for lighting purposes. In this paper an attempt is made to analyze the domestic energy consumption for lighting in Jaipur city. Good amount of literature collected pertaining to domestic energy consumption for lighting purposes across the globe, analyzed thoroughly and presented. Further, a household survey was conducted among 684 households in Jaipur city by employing pre-tested schedule. The schedule has few variables including identification particulars, economic conditions, demographic pattern, domestic lighting appliances at the household level; and the energy consumption pattern. Further the collected data are analyzed and a multiple regression model was developed by considering the total electricity consumption as dependent variable 'Y' and the electrical appliances for lighting purposes, such as the number of incandescent bulbs, tube lights, CFL, and LED are considered as 'X' variables; and this study conclude with plausible findings and recommendations.

1. Introduction

India being the third largest economy of the world, more number of the population (more than two third of the total population) lives in villages, and started to consuming more quantity of energy in the recent years. The year 1999-2000, the domestic sector in India consumed 86.6 billion kWh of the total of 395 billion kWh, which is accounted for 22 per cent of the total electricity consumption (Kumar et al., 2003). Though the electricity consumption in the domestic sector has increased up to 22 per cent of the total electricity consumption, electricity consumption in villages is very less, since good number of villages in the rural system are not even electrified. In urban areas almost 90 per cent of the household use electricity for lighting and just 10 per cent use kerosene for the said purpose, whereas in the rural areas still more number of households use kerosene for lighting purposes. The per household energy consumption for lighting is 402 kWh in the urban system and it is 271 kWh in rural system (Stephane et al., 2009), whereas in kerosene consumption for lighting, it is 2151 MJ per households in the urban system and 1562 MJ per households in the rural system, which shows that the households in the urban system consume huge quantity of energy for lighting purposes compared to the households in the rural system (Stephane et al., 2009).

Though the villages do not consume more quantity of electricity in the residential sector, India has the highest per capita residential energy consumption compared to China and the US. The residential energy consumption depending on various factors including location, building size, weather, architectural design, housing unit, application of home appliances, people's attitude and behaviors, type of constructions, energy use pattern, energy consuming devices installed in building, etc. The building sector in India consumed 33 per cent of the total electricity consumption, of which the residential sector is accounted for 25 per cent, and the rest is used for the commercial sector. Energy consumption for lighting in residential sector is one of the most important parameters, which needs more attention since most of the Indian households, normally, use incandescent bulbs because of their low initial fixing cost. In India the purchasing cost of CFL is almost 50 times more than that of incandescent bulb and twice than of fluorescent tube lights (Kaya D, 2003). This incandescent bulb is absolutely inefficient compared to CFL lights since CFL light consume 4 to 5 times less amount of energy for the same lumen output compared to incandescent bulb, and it has been observed that the duration (life period) of CFL lights is increased up to 13 times compared to the standard incandescent bulb (Kumar et al., 2003).

Application of advance technology in appliances at the household's level reduces energy consumption. It is observed in Brazil that application of advanced technology in appliance reduce 27.4 per cent of electricity consumption, replacement of incandescent bulb with compact fluorescent lamp (CFL) save 14.5 per cent of energy, solar water heater save 7.7 per cent of energy, and refrigerator save 6.1 per cent of energy (Bukarica et al., 2007; Garbacz C, 1983; Mahlia et al., 2005). Similar findings were also observed in Croatia (Bukarica et al., 2007; Mahlia et al., 2005). It is also interesting to note that few more studies in different parts of world observed that application of CFL at household level reduce the energy requirement compared to the use of incandescent bulbs in lighting purposes (Anjali and Gadgil, 1996; Balachandra and Reddy, 2007; Balachandra and Shekar, 2001; Bukarica et al., 2007; Haas R, 1997; Johnson et al., 2012; Kaya D, 2003; Larsen and Nesbakken, 2004; Mahlia et al., 2005; Martinot and Borg, 1999).

An integrated planning model was developed by having the objective function of maximizing the annual return by replacing the standard device with an efficient one and observed that modern device (CFL) and the light-emitting diode (LED) are the best option compared to the traditional one, since huge quantity is conserved compared to the traditional one, further Discounted Cash Flow (DCF) technique have been employed to quantify the cost of traditional lighting devices and the modern lighting devices and observed that the modern devices are very much cost effective in long run since it gives clean energy along with conserve more quantity of energy (Balachandra and Reddy, 2007).

A study in Nigeria observed that application of CFL is the best option at household level for lighting purpose, since it saves huge amount of energy, and it is unfortunate to state that awareness of using CFL is not much observed, hence it is essential to create awareness among the masses to increase the use of CFL by imparting either demonstration methods or other plausible measures. Further, it is observed that CFL manufacturing companies are also not much available since application CFL is much lesser in this country. It is advocated to have accurate metering system, incentive to CFL manufacturing companies, setting up of a standard organization to certify the quality of the CFL and minimization of cost of CFL lamps, etc., in the system (Johnson et al., 2012). Similar observations were also observed in the study conducted in Bombay City in India (Anjali and Gadgil, 1996), and in Arizona City (Kaya D, 2003).

In Northern Ireland of UK, domestic energy use and their behavior were studied. Survey research method was employed and observed that 35 per cent of the dwellings units could improve their energy efficiency by improved tank insulation. Further, the people are very much aware of energy efficient appliances at their household level for cooking, lighting and other uses. There were 70-80 per cent of the households undertook same kind of day to day energy efficient measures at their households. Fluorescent bulbs, halogen bulbs are much popular for lighting purpose in the studied areas, and also observed that 61 per cent of the households used energy saving lighting methods. Solid fuels were much used for space heating and were greatly reduced by oil fired central heating. Oil fired central heating along with the use of natural gas has become more popular method in `space heating. Water heating provision was also increasing besides space heating in the system (Garg and Bansal, 2000).

The high dependency on traditional fuels (solid fuels) was observed is more in rural households as compared to the urban households (Reddy BS, 2004). In the rural households, on an average 21.44 kg of fuel-wood is consumed per capita per month, whereas it is 6.23 kg in the urban system; the per capita consumption of electricity 5.67 units per month in the rural system, and it is 19.96 units in the urban system, which reflects that there is a serious threat to energy security in the rural system (Jain G, 2010). Further, it has been observed that the household in the rural system shows upward movements on energy ladder starting from kerosene to electricity in lighting and solid fuel to liquid fuels for cooking purpose (Alam and Barnes, 1998; Brounen et al., 2012; Garbacz C, 1993; Gupta and Ravindranath, 1997; Heltberg R, 2003; Jain G, 2010; Link et al., 2012; Mu T et al., 2010; Rao and Reddy, 2007; Reddy et al., 2012; Reddy BS, 2004). Similar findings were also observed in Taiwan, and it is found that the residential electricity consumption had increased from 257 GWh to 26144 GWh over the period of 40 years, i.e., from 1957 to 1995. It is interesting to note that the aggregate household income is also increased from 22438 to 5003970 New Taiwanese (NT) $ million, which is equal to ten folds increase. It is also interesting to note that there is a vast scale of urbanization took place during this period, i.e., from 1957 to 1995 (Holtedahl and Joutz, 2004). The present study analyzes the lighting energy consumption in the domestic sector of Jaipur City.

2. Study Area at a Glance

Jaipur city has been chosen for conducting the present investigation. It lies at 26.92°N latitude & 75.82°E longitude and it is confined in an latitude of 431 meter (above MSL). This city is surrounded by Bharatpur and Dausa district in the East, Alwar district in the North and Sikar district in the North-West, and it has 1464 Sq. km. of geographical area under the Jaipur Development Authority region (Figure 1). As per the census 2011, it has a population of 3073350, and the Jaipur metropolitan area has a population of 3646590, which comprises of Hindu, Muslim, Jain, Christian and Sikh community representing to 77 percent, 17 percent, 4 percent, 0.5 percent and 0.5 percent respectively. It has the sex ratio of 898 female per thousand males and overall literacy rate of the district is 76.44 percent. It is the center of both traditional and modern industries, and it exports gold, diamond and stone jewelry; and is the only center for finishing blue diamond or tanzanite in the world. It is characterized by high temperature, low rain fall and mild winter, since it is located in the hot - dry region. It consumed 936 MW of electrical energy in the year 2011-12 and it's projected to increase up to 7579 MW for the year 2029-30. Residential energy consumption in the Jaipur city has increased 14.29 per cent per annum between the year 2001-2002 and 2011-2012, i.e., in the year 2001-2002 it is was 1,296,389 MWh, and in the year 2011-2012, it was 3,149,336 MWh.

3. Methodology

Survey research methodology has been employed to quantify the residential building energy consumption in the study area, Jaipur city. This city is divided into 76 wards for development administration, and of which 24 wards are selected randomly for conducting the present

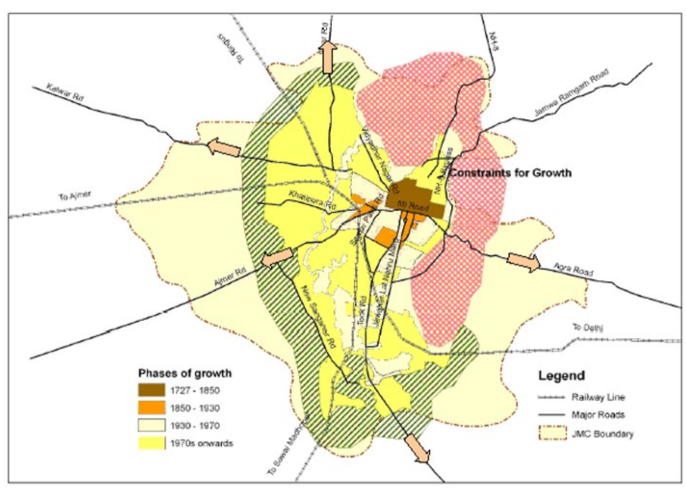

Figure 1 *Expansion of Jaipur City*

(Source: Jaipur City Development Plan, 2005)

investigation. It has been observed that the households confined in all the selected wards are varying in number and some wards are having more numbers of households, whereas few are having very less number of households. There are 684 households chosen for conducting the present investigation by employing simple random sampling technique. Subsequently, the household survey was conducted among the chosen households with the help of pre-tested household survey schedule by the investigator himself, and there after tabulation and analysis were done.

4. Tabulation Analysis

In tabulation analysis, the more important variables, which have direct association with residential lighting energy consumption are analyzed and presented in the sequel.

4.1 Income Wise Distribution of Households

Income is the most important parameter, which decides the functions of the system. The higher income households consume good amount of energy, whereas the lower income households consume lesser amount of energy in their day to day activities. Further, income more or less decides the sources of energy consumption. The higher income households consume more quantity of clean fuels, such as electricity, liquefied petroleum gas (LPG), etc., at the household level, whereas the low income households consume more quantity of traditional sources of energy for their day to day activities. Further, the income increases the households to use more quantity of modern electrical appliances at the household level, which consume huge quantity of clean energy, whereas the lower income households do not use much electrical appliances at the household level, thereby consumption of clean energy is also lesser at the lower income household level. Having this knowledge in the mind, the investigator grouped the surveyed households into six different income groups, such as monthly income of Rs. < 30,000, Rs. 30,000-60,000, Rs. 60,000-90,000, Rs. 90,000-120,000, Rs. 120,000-150,000 and above Rs. 150,000 for analysis, and the results are presented in Table 1. The table illustrates that about two-fifth of the surveyed households confined in the monthly income group of Rs. < 30,000, and it is further observed that availability of households in different income group level is decreasing along with increase in monthly income. Further, it is observed that more than two-third (69.74 percent) of the surveyed households are confined within the monthly income groups of up to Rs. 60,000, which shows that majority of population live in the city are considered to be middle income group.

Table 1 *Household Income of the Respondents*

No.	Income Group (Rs/Month)	Households	
		Nos.	Percent
1	< 30,000	263	38.45
2	30,000 - 60,000	214	31.29
3	60,000 - 90,000	100	14.61
4	90,000 - 120,000	55	8.04
5	120,000 - 150,000	30	4.39
6	> 150,000	22	3.22
	Total	684	100.00

NOTE: Indian Rupee 1000 (Rs) = US Dollar 15

4.2 Population and Household Size

Population is the one of the most important parameters, which decides the functions of the system. The considerable growth of the population in the city is more or less responsible for all kinds of socio-economic evils, which prevail in the cities including schisms, unemployment, underemployment, disguised unemployment, poverty, mall nutrition, increase in crime rate, scarcity of resources, scarcity of infrastructure services, congestion, and so on. Having this knowledge in mind, the population of the city at the household level has been considered as one of the parameters in the survey schedule, conducted the investigation among the chosen samples at the grassroots level, analyzed along with various income groups, and the results are presented in Table 2. This table reveals that more than two-fifth of the population is confined among the lowest income group of the classification, i.e. the monthly income group of Rs. < 30,000 of the total population, and the available number of population is decreasing along with increase in income groups, which is also evident from the Table 1, which states that more number of households confined among the lowest income strata. It is also observed that more than two-third (70.69 percent) of the total population of the surveyed households are confined within the monthly income range of up to Rs. 60,000, which is also almost tallying with the number of households confined in this group. Further, observe that the size of household (persons in household) is decreasing along with increase in monthly income group of up to Rs.1, 50,000, and then observe the reverse trend, which shows that the highest income category people produce more number of population compared to the rest of the income groups. The average population per household is working as 4.9, whereas the highest income category groups has the average household size of 5.8. The least income group of category, i.e., monthly income group of Rs. < 30,000 has 5.2 as average size of household, and the other monthly income groups categories have less than the average size of households, i.e., 4.9.

Table 2 *Household Income and Household Size*

No.	Income Group (Rs/Month)	Total Population		Size of House-hold
		Nos.	Percent	
1	< 30,000	1367	40.60	5.2
2	30,000 - 60,000	1013	30.09	4.7
3	60,000 - 90,000	470	13.96	4.7
4	90,000 - 120,000	260	7.72	4.7
5	120,000 - 150,000	130	3.86	4.3
6	> 150,000	127	3.77	5.8
	Total	3367	100.00	4.9

NOTE: Indian Rupee 1000 (Rs) = US Dollar 15

4.3 Domestic Lighting Appliances (Electrical)

In general, the economically well of people (higher income group people) use to fix costly electrical appliances for lighting at their household level. In fact, fixing tube lights, CFL, LED are little costlier compared to fixing incandescent bulbs. The CFL and LED consume lesser amount of energy and produce more amount of lights, whereas the incandescent bulb consume more amount of energy and produce lesser amount of output. Having this knowledge in mind, the investigator considered using different kinds of electrical appliances for lighting, which include incandescent bulbs, tube lights, CFL and LED

Table 3: Domestic Lighting Appliances

No.	Income Group (Rs/Month)	Incandescent bulb		Tube lights		CFL		LED	
		Nos.	Per-cent	Nos.	Per-cent	Nos.	Per-cent	Nos.	Per-cent
1	< 30,000	196	46.23	147	28.88	191	33.16	4	18.18
2	30,000 - 60,000	115	27.12	176	34.58	199	34.55	9	40.91
3	60,000 - 90,000	53	12.50	91	17.88	88	15.28	2	9.09
4	90,000 - 120,000	30	7.07	46	9.03	50	8.68	3	13.64
5	120,000 - 150,000	15	3.54	29	5.70	28	4.86	2	9.09
6	> 150,000	15	3.54	20	3.93	20	3.47	2	9.09
7	Total	424	100.00	509	100.00	576	100.00	22	100.00

as parameters in the household survey schedule, conducted the investigation at the grassroots level among the sampled households, analyzed it thoroughly along with income groups and the results are presented in Table 3. The per capita analysis of possessing the lighting appliances are presented in Table 4. The Table 3 illustrates that more than three-fifth of the surveyed households use incandescent bulbs. Of which, about half (46.23 percent) are confined within the lowest income group, i.e., monthly income group of Rs. < 30,000 and the number of households using incandescent bulbs is decreasing along with increase in various income groups. There are about three-fourth (74.42 per cent) of the total surveyed households using tube lights, more than four-fifth (84.21 per cent) use CFL, and a meagre of 3.22 per cent use LED. In income group analysis, the number of persons use tube light, CLF, LED are increasing along with monthly income group of up to Rs. 60,000, and then observe the reverse trend. Table 4 illustrates that the per capita availability of the lighting appliances in the system, and they reveal that the per capita number of incandescent bulbs, tube lights, CFL and LED availability at the household level is increasing along with increase in income from the monthly income group of Rs. < 30,000 to the highest income groups, i.e., above Rs. 150,000 per month. It is inferred from the table that the per capita availability of LED is very meagre (0.003) among the lowest income group, whereas it is much higher (0.016) among the higher income groups, i.e., income group of above Rs. 150,000 per month, which reflects that the higher income group people prefer costly lighting appliances at their households.

4.4 Energy Consumption for Domestic Lighting by Appliances

Various kind of electrical appliances, which include incandescent bulb, tube lights, CFL, and LED are used for lighting purposes in the system. In fact, the incandescent bulbs and tube lights are commonly used in the study area and in across the country, and uses of CFL and LED are not in much practice, since the initial cost of fixtures are higher than incandescent bulbs and tube lights. Further, awareness about the advancement in technology in CFL and LED uses are not popular among most of the population in the country, and LED is the latest technology, which is not much penetrated in the system. Having all these knowledge in mind, the investigator is interested to quantify the household energy consumption by using different types of technology for lighting purposes at their household level. In fact, the advance technology like CFL and LED consume very less quantity of energy compared to incandescent bulbs and tube lights, and provide more quantity of light. Application of these CFL and LED would reduce energy consumption at household's level. Therefore, all four types of technology like incandescent bulb, tube lights, CFL and LED are considered in the survey schedule, conducted the investigation at the grassroots level among the sampled households, analyzed them by income group wise and per capita basis, and the results are presented in Table 5. Table 5 illustrates that tube lights consume more than half (50.63 percent) of the total energy consumption for lighting purposes in the system, followed by CFL consume just above one-fourth (29.01 per cent), incandescent bulbs consume just above one-fifth (20.20 per cent) and the rest (0.16 per cent) is consumed by the LED technology. In income group analysis, it has been observed that the energy consumption by employing incandescent bulbs are decreasing along with increase in income groups, whereas energy consumption by employing tube lights and CFL's are increasing along with monthly income group of up to Rs. 60,000, and then observe the reverse trend. Energy consumption by LED is haphazardly observed, and the quantity of the consumption is very meagre. Table 6 illustrates the per capita energy consumption by employing incandescent bulbs, tube lights, CFL

Table 4: Per Capita Domestic Lighting Appliances (Electrical)

No.	Income Group (Rs/Month)	Incandescent bulb Per Capita	Tube lights Per Capita	CFL Per Capita	LED Per Capita
1	< 30,000	0.14	0.11	0.14	0.003
2	30,000 - 60,000	0.11	0.17	0.20	0.009
3	60,000 - 90,000	0.11	0.19	0.19	0.004
4	90,000 - 120,000	0.12	0.18	0.19	0.012
5	120,000 - 150,000	0.12	0.22	0.22	0.015
6	> 150,000	0.12	0.16	0.16	0.016

NOTE: Indian Rupee 1000 (Rs) = US Dollar 15

Table 5 *Energy Consumption for Domestic Lighting by Appliances*

No	Income Group (Rs/Month)	Consumption (kWh/Year)										
		Incandescent bulb		Tube lights		CFL		LED		Total		Per Capita kWh
		kWh	Per-cent	kWh	Per-cent	kWh	Per-cent	kWh	Per-cent	kWh	Per-cent	
1	< 30,000	21,433.05	34.53	26,466.48	17.01	18,815.40	21.10	136.80	27.46	6,6852	21.75	48.90
2	30,000 - 60,000	19,657.18	31.67	51,965.32	33.39	34,083.43	38.22	168.12	33.75	10,5874	34.44	104.52
3	60,000 - 90,000	8,494.79	13.68	35,888.69	23.06	14,413.27	16.16	21.74	4.36	5,8818	19.13	125.15
4	90,000 - 120,000	6,351.08	10.24	21,049.06	13.51	11,191.00	12.55	46.08	9.25	3,8637	12.57	148.60
5	120,000 - 150,000	1,970.57	3.17	13,642.56	8.77	6,129.90	6.87	43.20	8.67	2,1786	7.09	167.59
6	> 150,000	4,168.26	6.71	6,622.92	4.26	4,548.06	5.10	82.26	16.51	1,5422	5.02	121.43
	Total	62,074.93	100.00	155,635.03	100.00	89,181.06	100.00	498.2	100.00	30,7389	100.00	

and LED by income group wise. The per capita energy consumption is just 48.90 kWh/month among the income group of Rs. < 30,000, whereas it is 167.59 kWh/month for the higher income group, i.e., the monthly income group of above 150,000, which shows the higher income group is consuming huge quantity of energy for lighting purpose. It has been observed from the Table 6 that the per capita energy consumption by employing all the aforesaid types of technology, which include incandescent bulb, tube lights, CFL and LED for lighting purpose is increasing along with the increase in income group from the lowest income group to the higher income group category. It is deduced from these tables and figures that the quantity of energy consumption for lighting purpose is quite high among the higher income group category compared to the lower income group category.

5. Multiple regression analysis

A multiple regression model was developed for understanding the impact of total electricity consumption on lighting appliances in the system. In this model total electricity consumption (y) is considered as dependent variable, and the following independent variables, such as number of incandescent bulbs (x_1), number of tube lights (x_2), number of CFLs (x_3) and number of LED (x_4) are considered and are presented in equation (1) below

$$Y = f\,(x_1 + x_2 + x_3 \ldots + x_n) \qquad (1)$$

The model equation is presented in equation (2) by incorporating the values of independent variables in equation (1) and the results of the model are presented in appendix A.

$$Y= -89.357x_1+837.662x_2+364.059x_3+390.619x_4+1145.272 \qquad (2)$$

The model results show that the adjusted R square value is 0.146, which shows that 14.6 per cent variations in household income are explained by these explanatory variables included in the model. It is observed from the ANOVA table, that the $F (4,679) = 30.116$ and the p value is less than 0.001, which shows that overall model is statistically significant at 1 per cent level. Further, the variables, such as number of tube light and number of CFLs are having the respective coefficients are positive and the p value was observed as $p < 0.05$, which denotes that these variables are statistically significant in the model, For example, if all the variables except number of tube lights are constant, then the total electricity consumption per household would increase by 837.662 kwh. With similar assumption, effects of all other variables are held constant, then the total electricity consumption per household would increase as 364.059 kWh per additional unit increase in number of CFLs category. Usages of incandescent bulbs and LED are insignificant because their use in the study area is negligible. The incandescent bulb appliances share is 61.99 percent at the household level, but energy consumption share is only 20.20 percent, and the people are not using much duration. Mainly incandescent bulbs are placed in toilets, staircase lobby, car porch, verandah etc., and therefore their use is much limited and it is negative. LED appliances share is just 3.22 per cent at the household level and its share in energy consumption is just 0.16 percent. Therefore, it is insignificant.

Table 6 *Per Capita Energy Consumption for Domestic Lighting by Appliances*

No	Income Group (Rs/Month.)	Consumption (kWh/Person/Year)			
		Incan-descent bulb	Tube lights	CFL	LED
1	< 30,000	15.68	19.36	13.76	0.10
2	30,000 - 60,000	19.40	51.30	33.65	0.17
3	60,000 - 90,000	18.07	76.36	30.67	0.05
4	90,000 - 120,000	24.43	80.96	43.04	0.18
5	120,000 - 150,000	15.16	104.94	47.15	0.33
6	> 150,000	32.82	52.15	35.81	0.65

6. Results and Discussion

The residential energy consumption depends on various factors including location, building size, weather, architectural design, housing unit, application of home appliances, peoples attitude and behaviors, type of construction, energy use pattern, energy consuming devices installed in building, etc. Application of advance technology in appliances at household level reduces energy consumption. The cost of the modern advanced technology for lighting system at the residential level, such as CFL and LED are most costly items for the less income households and it becomes a dream to apply in their households. In fact the modern devices are very much cost effective in long run since it gives clean energy along with conserve more quantity of energy.

There are 684 households chosen for conducting the household surveys at the grassroots level to understand the lighting energy consumption in the study area. The surveyed households are decreasing along with increase in income, .i.e., of the total surveyed households about two-fifth (38.45 per cent) are confined in the lowest monthly income group of Rs. less than 30,000, whereas it is just 3.22 per cent of households confined among the highest income group of households having monthly income of Rs. more than 150,000.

More than two-third (70.69 per cent) of the surveyed households are confined within the monthly income range of up to Rs. 60,000, and the average household size is more than 5 among the lowest and the highest income households, whereas it is less than 5 among the other category of income groups.

Use of incandescent bulb are very much common in study area and more than three-fifth (61.99 per cent) of the surveyed households use incandescent bulb at their households, of which about half (46.26 per cent) are confined within the lowest income group.

The number of available other fixtures, such as tube light, CFL and LED are also more upto the income group of Rs. 60,000 per month, since these two groups together account for more than two-third of households among the total surveyed households, and it is quite interesting to state that the per capita availability of incandescent bulb is decreasing along with increase in income groups, whereas other fixtures such tube lights, CFL and LED are increasing along with increase in income groups, i.e., from the lowest income groups to the highest income groups, which reflects that economically weaker section use more number of incandescent bulbs since it's initially purchase cost is very less, and the higher income group use more number of energy efficient fixtures though initial fixing cost is much higher compared to the incandescent bulbs.

In energy consumption for lighting, it is understood that the per capita energy consumption for lighting are increasing along with increase in income group, i.e., just 48.90 kWh for the lowest income groups, and it is increased to 167.59 kWh for the higher income group of Rs. 120,000-150,000, which shows that income decide the quantity of energy consumption at the household level.

Income is the basic phenomenon which decides the functions of the system. The study area has more number of less income (Rs. < 30,000) households (30.60 per cent) and these less income households are more or less fixed incandescent bulb (46.23 per cent), and its cost is very less compared to the other lighting fixtures. The quantity of energy consumption for lighting incandescent bulb per hour is much higher compared to the higher cost lighting fixtures, such as tube light, CFL, LED. Even though quantity of energy consumption lighting the incandescent bulb per hour is much higher compared to other fixtures, the energy consumption made by the least income group is very less (21.75 per cent), which shows that this particular income group consume very less amount of energy compared to the higher income groups (78.25 per cent). It is evident from this study that the hypothesis can be evolved like increase in income of the households consume more quantity of energy in this particular urban system (study area). The results of the investigation proves that quantity of energy consumption is increasing (48.90 kWh to 167.59 kWh) along with increase in income (per capita basis), and thereby the hypothesis is proved. Further, it has been observed that the higher income households (per capita) fixed more number of tube light, CFL and LED lights compared to the less income households, which reflects that income decides the function of the system, i.e., increase in income leads to increase in standard of living. It is interesting to note that the regression analyzes reveal that tube light and CFL lights are having more bearing in the system in terms of electrical energy consumption at the household level, which shows that people in the study area are having more awareness pertaining to energy conservation. In fact the available number of CFL and incandescent bulb fixtures are almost same among the households confined in the income group of Rs. < 30, 000 per month, which is also reflected in Table 3 of this paper, but the usages of incandescent bulbs are much minimal. It is interesting to note that the findings of this investigation, increase in household income reflected in increase in quantity of energy consumption, which is coinciding with the energy ladder concept referred in this investigation (Cross Reference Alam and Barnes, 1998; Brounen et al., 2012; Garbacz C, 1993; Gupta and Ravindranath, 1997; Heltberg R, 2003; Jain G, 2010; Link et al., 2012; Mu T et al., 2010; Rao and Reddy, 2007; Reddy et al., 2012; Reddy BS, 2004). However, the literature review reveals about the sources and type of energy consumption is altered by increase in income, whereas in this investigation electrical lighting fixtures are altered by income, i.e., lesser income households use more number of incandescent bulbs (0.14 per capita), whereas the higher income groups use more number of CFL and tube lights (0.22 per capita) at their households.

7. Conclusion

In this study an attempt has been made to understand the domestic energy consumption for lighting purposes in Jaipur city. Survey research method was employed to collect the necessary amount of data at the grassroots level to understand the domestic energy consumption for lighting purposes in the study area. The data are analysed thoroughly and multiple regression model was developed and employed in this investigation to understand the functions among few variables, such as incandescent bulb, tube light, CFL and LED and the total electricity consumption for lighting purposes.

It is observed that tube light (74.42 per cent) and CFL (84.21 per cent) getting more importance among the electrical lighting appliances used in the system, invariably among all income groups including the least income group, whose is monthly income is less than Rs. 30,000. The available number of incandescent bulb and CFL lights are almost same in this least income group and their representation is 46.23 per cent and 33.16 per cent respectively which shows that the available number of incandescent bulbs are very less among the higher income households. The following recommendations are made, (a) Government may bring policies to provide CFL and LED lights at cheaper rate or free of cost to the least income households, (b) Awareness programs may be organized among the population to employ advanced technology for appliances at the households level, which intern results into reduction in energy consumption, (c) Awareness programs may be organized among the population regarding attitude and behavior change for switching off the lights, while it is not required, (d) Government may promote energy efficient buildings by giving special benefits in FAR or subsidy in approval fee. This may enforced through building byelaws giving more emphasis to natural lighting, cooling etc., (e) Government may promote advanced lighting technology manufacturing fixtures industries to reduce the cost of lighting appliances by giving special incentives, (f) Government may start programs of energy management at residential level such as retrofitting of incandescent bulb with CFL and LED, (g) The purchasing power of households (income) may be considered while evolving policies pertaining to energy related action since more than four-fifth of the surveyed households (85.35 per cent) confined within the less than Rs. 100,000 per month income, therefore, plausible policies may be evolved pertaining to energy related activities since energy is the basic phenomenon for any development in the system.

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Appendix A

Total electricity consumption with lighting appliances model summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.388[a]	.151	.146	993.99999

a. Predictors: (Constant), LED (Nos.), Incandescent bulb (Nos.), Tube lights (Nos.), CFL (Nos.)

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	119021900.667	4	29755475.167	30.116	.000[b]
	Residual	670876432.262	679	988035.983		
	Total	789898332.929	683			

a. Dependent Variable: Total Electricity consumption for Domestic Appliances (kWh/year
b. Predictors: (Constant), LED (Nos.), Incandescent bulb (Nos.), Tube lights (Nos.), CFL (Nos.)

Regression Coefficient

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
	(Constant)	1145.272	135.631		8.444	.000
	Incandescent Bulb (Nos.)	-89.357	80.472	-.040	-1.110	.267
	Tube lights (Nos.)	837.662	87.845	.340	9.536	.000
	CFL (Nos.)	364.059	107.089	.124	3.400	.001
	LED (Nos.)	390.619	216.881	.064	1.801	.072

a. Dependent Variable: Total Electricity consumption for Domestic Appliances (kWh/year)