

Study of Energy Consumption Pattern in Residential Neighborhood: Case Study Lucknow

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Abstract:

Energy systems in India are available in form of fossil fuel and renewable fossil fuels. Oil, natural gas, coal gas, renewable energy is available in form of solar PV, hydroelectricity, bio energy and wind. Energy is transported in form of electricity wherein uses of energy is in transport, industry and buildings, whereas buildings constitute the major part of energy. Buildings consume energy in form of space cooling, lighting, building envelopes, heating, district heating, appliances and equipment. How we can manage the energy demand is by providing energy efficiency technique, policy guide as per the demand. As per the latest global electricity demand growth in 2022 reported by IEA International energy agency, there is a slight growth in electricity demand in India while Covid restrictions affected China's growth. Having a look through social economic characteristics of the site, electricity consumption relationship between household income and occupation. This article also focuses light on per capita electricity consumption. Factors responsible for energy consumption or also required to emphasise on in the study area. Therefore, in residential sectors, electricity depends upon different variables such as household, income appliances, family size, dwelling size, major hours of lighting, cooling heating, and the reduction can be attained with the implementation of energy policies and planning interventions

Key words, Energy sources, socio economic characteristics, Typology of building, electrical consumption analysis

1. Introduction

Energy is a key element in the overall efforts to achieve sustainable development. The increased population and economic development have raised the energy consumption in the past few decades. (Verma et al., 2012). It has been observed that energy use in the residential sector, which account for about 15% of the world delivered energy consumption in 2006, is defined as the energy consumed by households, excluding transportation uses (Verma et al., 2012). globally energy is being used in residential sector as per European countries data is it has been found that Lowering households' energy demand is a key factor to achieve carbon dioxide emission reductions as it has an important energy-saving potential. Households in the European Union (EU28) countries have a significant weight (25%) in the total final energy consumption. (Gouveia, 2017). As per 2020 GLOBAL STATUS REPORT findings for buildings

and construction, the total final energy consumption of the global buildings sector remained at the same level in 2019 compared to the previous year. Electricity consumption in building operations represents nearly 55% of global electricity consumption. Effort has been made towards energy efficiency improvements, the energy demand of buildings is still growing driven by increased demand for floorspace and thermal comfort (IEA 2019b).

2. Sources of Energy

Energy is one of the most important indicators of socio-economic development, and per capita energy consumption is often viewed as a key index of development. (Gyawali et al., n.d.). Building sector (residential and commercial) constitutes 33% of total electricity consumption in India as discussed by energy benchmarking guidelines for climate proofing buildings in u.t. of Puducherry. As per Energy benchmark report

high urbanization levels, increasing in the average per capita income levels, improved electricity access and electrification and increased economic activities impacting these demand sectors have been some of the contributing factors for progression in the power demand. According to author building energy use accounts for as much as 30–40% of the global energy requirements. In many studies, especially in the northern countries, but elsewhere as well, residential energy consumption has also been found to constitute the largest or at least one of the largest sources of energy demand and GHG emissions of a household. ((Heinonen & Junnila, 2014). Nuclear energy, fossil energy (such as oil, coal, and natural gas), and renewable energy (such as wind, solar, geothermal, and hydropower) are examples of primary energy sources. Electricity, a secondary energy source that travels to your house and place of business via power lines and other transmission infrastructure, is created from these main sources as described by department of energy.

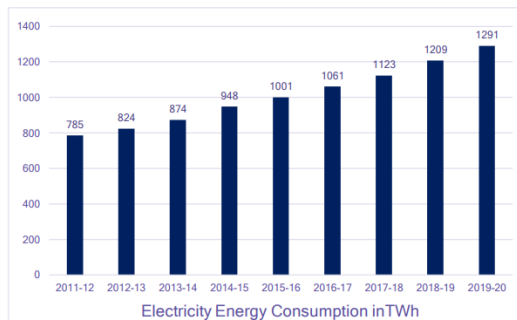


Figure 1: Electricity Energy Consumption in India (Source: Energy Benchmark Report 2022)

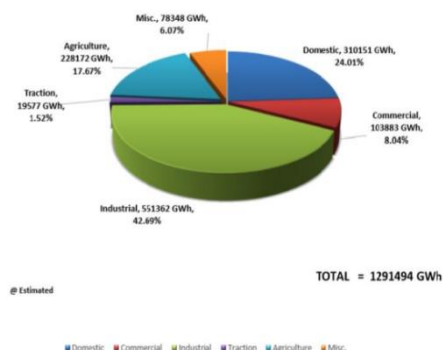


Figure 2: Sector Wise Electricity Consumption in India (Source: Energy Benchmark Report 2022)

Electricity consumption in India has increased three times since 2000. Households holding electricity has been increased to more than 80% in 2017 from 55% in 2001.

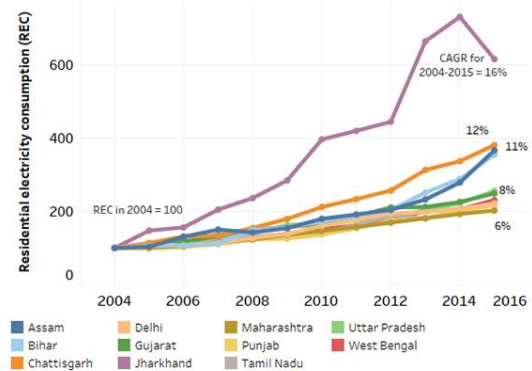


Figure 3: Residential Electricity Consumption Growth in Selected States (2004-2015) Source: Annual General Reviews for Individual Years (CEA)

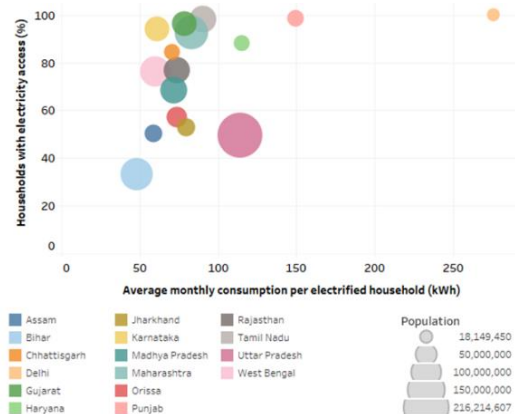


Figure 4: Average Monthly Electricity Consumption of an Electrified Household in Different States Source: Center for Policy Research

Household in Delhi consumes about 250-270 units or kWh of electricity per month on average, households in larger states like Maharashtra, Gujarat, and Tamil Nadu, with higher rates of electrification, consume on an average a lower amount of about 80-90 units per month. Karnataka is on the lower end with about 60 units. States like Uttar Pradesh (UP), Jharkhand, and Chhattisgarh show high monthly household electricity consumption. It is unlikely that states with a high share of newly electrified

households and low reliability of power supply consume as high as an average household in Chandigarh or Mumbai.

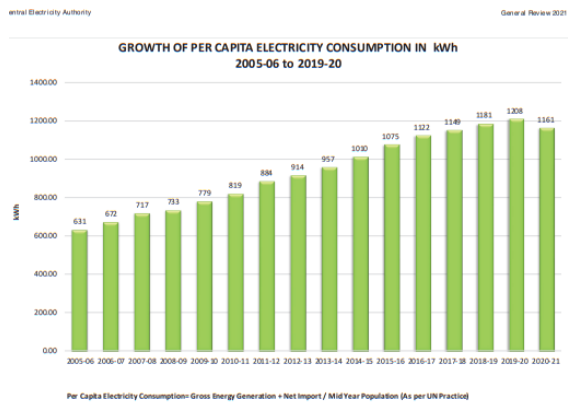


Figure 5: Per Capita Electricity Consumption= Gross Energy Generation + Net Import / Mid Year Population (As per UN Practice)

According to All India Electricity Statistics 2022 the per capita consumption of electricity on All India basis works out to 1161 kWh for the year 2020-21 against 1208 kWh in the year 2019-20. Per Capita Electricity Consumption is worked out as the total gross electrical energy consumed divided by Mid-Year Population during the year.(Global Alliance for Buildings and Construction 2020

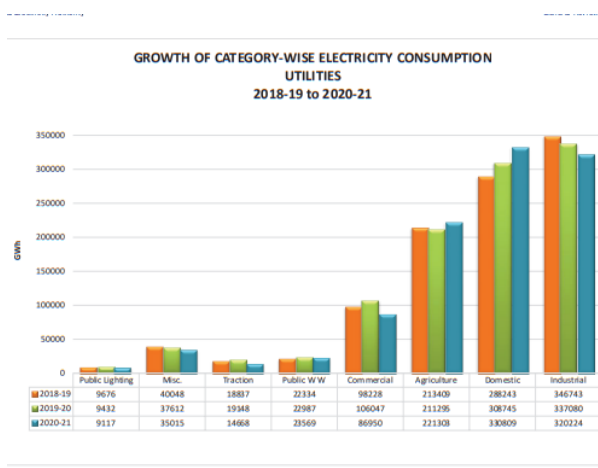


Figure 6: Growth of Electricity in Lucknow

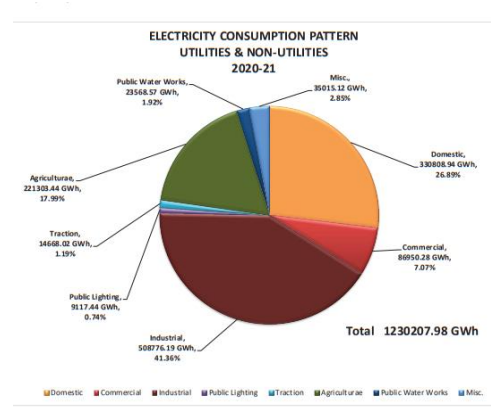


Figure 7: Electricity Consumption Patterns

There are several factors that affect electricity demand. The key factors are electricity price, number of electricity appliances, income, temperature, and consumer load pattern that differ by regions and consumer groups (Bansal, 2005; Yee, 2011)(Bhardwaj et al., 2011). Author has analyzed the requirement of electricity with respect to the future population for the major forms of energy in the Lucknow city in Uttar Pradesh state of India.(Mastrucci et al., 2021) It has been observed that electric power demand forecast in 2023 corresponding to the city temperature with respect to the population in the Lucknow City which is the capital of “Uttar Pradesh” state of India(Bhardwaj et al., 2011)

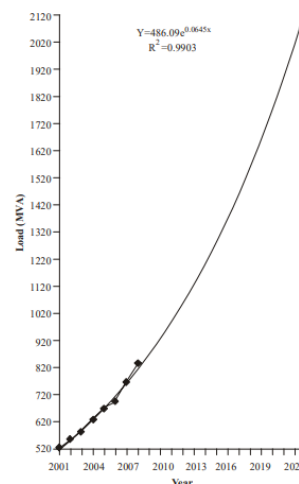


Figure 8: Lucknow Forecast Trend for 2023

3. Factors Responsible for Energy Consumption

To reduce the end-use energy consumption and Greenhouse gas (GHG) emissions from the residential sector, a large number of options need to be considered. These include improving the energy efficiency of houses through improving envelope characteristics; replacing existing heating equipment, household appliances and lighting with higher efficiency ones; and switching to less carbon-intensive fuels for space and domestic hot water heating.(Gyawali et al., n.d.). factors potentially affecting energy consumption and energy saving in the urban residential areas. the factors which are responsible for energy consumption in total are categorized broadly in four groups ,first is house type which accounts for typology of house neighbourhood characteristics, location, number of household members, appliances. Second: social and cultural factors such as level of education and income/household. Third: Economic factors such as household expenditure. Fourth: communication and information factors such as industry source, government source, professional, interpersonal, law and regularity, government support, and public information, andlast: psychological factors such as attitudes, knowledge, beliefs, and motives.(Gyawali et al., n.d.).As per the 2001 Indian Census, (Census of India, 2001) Lucknow had a population of 22,66,933; and in 1991 it was 19,13,166. The percentage level of the city with respect to the total population of U.P. was 2.22 in 2001 and 2.09 in 1991 and also having 10th position rank wise in 1991. The maximum temperature during summer season is between 40 and 45°C (District Profile, 2009; Central Electricity Authority of India, 2008).(Bhardwaj et al., 2011).Energy is placed in the middle of triangle among the nature, society and economy; it is treated as an essential element of global progress(Vf[KyHkkjrh; Fo|q r Lka [f;Dh, n.d.)

Demand of energy is increasing every year as a result of growth in population and socio economic condition of society. (Tewathia, 2018)The usage of electricity in households is affected by two different trends, i.e., an increased efficiency of household appliances which causes

the reduction of consumption and the increasing number of appliances per household which negatively affects the efficiency trends. Lin et al. stated that a population growth, residential energy use per capita and GDP per capita as an indicator of household income influence household energy consumption(Vf[KyHkkjrh; Fo|q r Lka [f;Dh, n.d.)

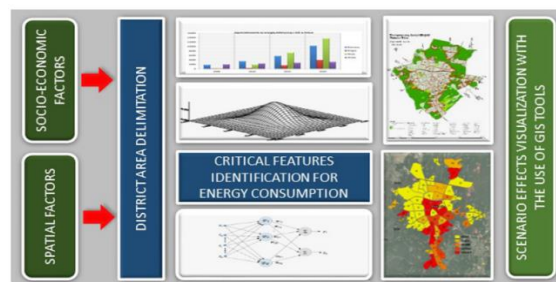


Figure 9: Source:(Mrówczyńska et al., 2020)

The inner-city approach is rarely presented, as described in a review by Chevez.(Mrówczyńska et al., 2020)There is a gap in the research literature regarding the demand for energy at the level of urban settlements and regions.(Vojtovic et al., 2018)

4. Study Area

4.1. Introduction

The energy consumptions pattern and its sustainability influence the urban agglomerations and population growth in cities (Dar-Mousa & Makhmreh, 2019).



Source: District census handbook Lucknow 2011 The largest populated state of India between 26° 30'N and 27° 10'N latitude and 80° 30'E and 81° 31'E longitude, of Gangetic Plain on the banks of

river Gomati.(Final-Report-of-Lucknow TCPO, n.d.)



Figure 8: Location Map of Site

Over the decades cities are been expanding rapidly in size and structure due to urbanization and parallel economic development. As a result urban structure is becoming more complex, irregular in shape and heterogenous in character.(Final-Report-of-Lucknow TCPO, n.d.).'Proximity to the city' is not the only criteria to define peri-urban area but rural-urban continuum, uncontrolled urbanization, prevailing socio-cultural and political environment, etc. have direct impact on the formation of such areas. The greater demand for space forces the city to expand spatially with increase in population. The aspirations of dwellers further leads to buy additional lands for their housing needs in a location where land price is cheap, mainly in the peri-urban areas.(Final-Report-of-Lucknow TCPO, n.d.).Climate of lucknow is composite where summers lasts having extreme hot months ,rainy months along with winter months ,rainfall is about 896.2mm.Foret is 4.66% of total area of city.

4.2 Demographic Profile

As per Census 2011, Lucknow city's total population is 28.17 lakh. The population in the last six decades has risen tremendously by almost six times (from 5 lakh to 28 lakh in 2011). Lucknow city is expected to have population of 4.5 million in 2021. The temporal and spatial dimensions of the land use have changed significantly. The city has experienced a steady increase in population arising from natural growth, large-scale migration and addition of peri-urban areas.

Table 1: Population growth in Lucknow Urban Agglomeration (1901-2011)

Year	Lucknow UA		Lucknow MC	
	Population	Growth Rate %	Population	Growth Rate%
1901	256238	-	256239	-
1911	252114	-1.61	252114	-1.61
1921	240566	-4.58	240566	-4.58
1931	274659	14.17	251057	4.38
1941	387177	40.97	361294	43.89
1951	496861	28.33	459484	27.18
1961	655673	31.96	615523	33.96
1971	813982	24.14	774644	25.85
1981	1007604	23.79	947990	22.38
1991	1669204	65.66	1619116	70.79
2001	2245509	34.53	2185927	35.00
2011	2880108	28.26	2817105	28.87

Source : Census Handbook

Figure 9

Table 24: Existing Land Use of LDA 2010-11 (Area in Ha)

S. No.	Land use	LDA	LDA	%
		excluding LIDA	Area (Urban Area)	
1.	Residential	10271.68	10278.68	41.99
2.	Commercial	623.14	623.14	2.55
3.	Industrial	940.57	940.57	3.84
4.	Institutional	888.76	888.76	3.63
5.	Community Facilities/Amenities/Utilities	2137.26	2137.26	8.72
6.	Recreational (Parks/Play grounds)	14672.75	997.71	4.08
7.	Transport	7842.74	7842.74	32.04
8.	River/Tanks/Drains	2255.32	578.64	2.36
9.	Others	194.07	194.07	0.79
10	Agriculture/Orchids/Shrubs	76379.06	-	-
11	Undefined land	2595.09	-	-
Total		105125.40	24481.57	100

Source: Lucknow Development Authority, Lucknow Master Plan -2031

Figure 9: Land Use Data, Source-LDA Master Plan 2021

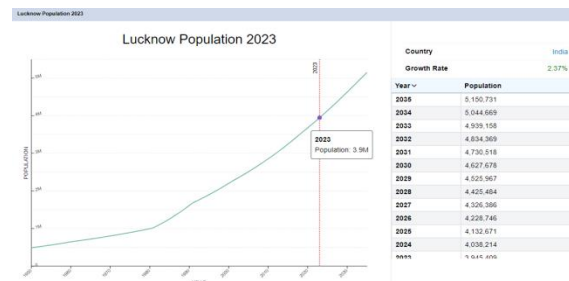


Figure 10: Population graph

Lucknow is having 349 sqmts of total surface area, the density is 8100 residents per square kilometer with increase in population.

4.3 Households

PRIMARY CENSUS ABSTRACT
FIGURES AT A GLANCE

DISTRICT	Lucknow			
	DISTRICT			
	2001	2011	Variation	
No. of Sub-Districts	4	4	0	
No. of Towns	9	12	3	
No. of Statutory Towns	9	10	1	
No. of Census Towns	0	2	2	
No. of Villages	835	807	-28	
No. of Households	Normal	637,816	846,450	208,634
	Institutional	2,445	8,516	6,071
	Houseless	4,008	5,737	1,729

Figure 11: Image Depicting Increase in Number of Households as per Census 2011.

There are 806,703 households in the district accounting for 2.6 per cent of the total households in the state. The average size of household in the district is 5.3 persons.

DISTRICT CENSUS HANDBOOK - LUCKNOW										
DISTRICT PRIMARY										
Location code number	District/ CD Block/ Town	Total/ Area in Rural/ Square Kilometre	Area in Urban/ Square Kilometre	Number of households	Total population (including institutional and houseless population)			Population in the age-group 0-6		
					Persons	Males	Females	Persons	Males	Females
1	2	3	4	5	6	7	8	9	10	11
157	Lucknow - District	Total	2,528.00	8,60,703	45,89,838	23,94,476	21,95,362	5,43,641	2,83,952	2,59,689
		Rural	2,057.29	2,83,193	15,50,942	8,13,752	7,37,090	2,22,592	1,15,432	1,07,160
		Urban	470.71	5,77,510	30,38,996	15,80,724	14,58,272	3,21,049	1,68,520	1,52,529
0294	Mai	Total	246.86	31,429	1,70,962	89,553	81,409	25,340	13,306	12,034
		Rural	246.86	31,429	1,70,962	89,553	81,409	25,340	13,306	12,034
		Urban	0.00							

Figure 12: Presenting Number of Households of Study Area as per District Census Handbook :Lucknow

A household energy survey is done to statistically gather the data on energy demand and hence formulate the appropriate design strategies. A structured survey designed sample including questionnaires fieldwork and data analysis, the exercise is done for yield of information culminating in policy guidelines. The objective of this household survey is to find out residential energy consumption assessing the relationship between consumption and household socio economic characteristics, identifying the existing problems. To achieve these objectives, the survey can obtain detailed information on: (a) the price, quantity, end-uses and availability of marketed fuels; (b) the quantities, end-uses, collection times and availability of gathered fuels; (c) cultural factors such as diet, cooking habits and rituals which may affect energy demand; (d) the cost, efficiencies and lifetimes of energy-using devices, e.g. cookstoves; (e) expenditure claswes and the relative importance of energy m the family budget; (f) household size and its impact on per capita fuel use; and (g) changes in fuel use with geographical/ecological zone.(Leitmann, 1989)

DISTRICT CENSUS HANDBOOK - LUCKNOW										
URBAN PRIMARY										
Location code number	Name of Town/ Ward	Area in Square Kilometre	Number of households	Total population (including institutional and houseless population)			Population in the age-group 0-6			
				Persons	Males	Females	Persons	Males	Females	
1	2	3	4	5	6	7	8	9	10	
0106	Ward No. 106	3.218	19,082	8,929	9,253	1,922	996	966		
0107	Ward No. 107	4.208	23,720	12,239	11,481	2,731	1,374	1,357		
0108	Ward No. 108	2.079	12,195	6,143	6,052	1,377	702	675		
0109	Ward No. 109	4.004	23,179	11,945	11,234	2,675	1,408	1,267		
0110	Ward No. 110	3.325	18,404	9,296	9,108	1,869	942	927		
800952	Lucknow (CB)	27.56	11,559	63,003	36,586	26,417	6,195	3,284	2,911	
0001	Ward No. 1	1.339	14,590	12,044	2,946	596	310	278		
0002	Ward No. 2	3.007	12,273	6,214	6,059	1,892	1,032	860		
0003	Ward No. 3	830	3,455	1,771	1,684	408	220	188		
0004	Ward No. 4	1,207	5,358	2,722	2,636	540	289	251		
0005	Ward No. 5	851	4,193	2,172	2,021	359	185	174		
0006	Ward No. 6	1,390	7,218	3,665	3,553	770	386	384		
0007	Ward No. 7	1,270	7,173	3,705	3,468	717	383	334		
0008	Ward No. 8	1,665	8,343	4,293	4,050	921	479	442		
143558	Kaali Pashchim (CT)	11.73	2,307	12,157	6,347	5,810	1,714	910	804	

Table - 2 : Percentage distribution of Households living in Permanent.					
Sl. No.	Name of Sub - District	Total			
		Permanent	Semi permanent	Temporary	Permanent
1	2	3	4	5	6
1	Sub-District - Maitiabad (0915700819)	27,822 (42.78%)	5,438 (8.36%)	30,846 (47.43%)	25,454 (41.02%)
2	Sub-District - Bakshi Ka Talab (0915700820)	40,936 (67.85%)	3,804 (6.3%)	13,579 (22.51%)	32,797 (66.25%)
3	Sub-District - Lucknow (0915700821)	524,118 (86.19%)	28,450 (4.68%)	30,032 (4.94%)	50,822 (64.23%)
4	Sub-District - Mohanlalgarh (0915700822)	54,584 (61.26%)	9,444 (10.6%)	19,969 (22.41%)	51,203 (61.3%)
District - Lucknow (09157)		647,460 (78.71%)	47,136 (5.73%)	94,426 (11.48%)	160,276 (58.45%)

1. Data Source - Census of India, 2011, HH- series Tables on Houses, Household amenities and assets.

Figure 13: Source (MASTER PLAN FOR NOTIFIED AREA OF LIDA-2031, n.d.)

Type of dwelling unit One Storied 70.38 Two storied 3.45 Multi Storied 0.78 Flat 0.11 Slum/Hut 24.61 Source: Socio Economic Survey by TMIPL From the above table it is noticed that About 70% of the households reside in one storied houses in the area, while 3.45% dwelling units are two storied. A significant number of households (24.61%) live in slum/hut type of dwelling units in this area.

In order to cater to the projected population of 22 lakhs direct population, an area of 6165 hectares has been reserved for residential purpose. The existing town and village abadi falling within the Proposed Residential areas are also accommodating the part of projected populations. The residential areas proposed in the Master plan shall be developed on neighborhood concept by making provision of all community facilities and services within the sectors on average gross residential density of 300 persons per hectare. The minimum width of the roads in a residential colony/sector shall not be less than 9meters. And the minimum area for parks/open spaces in a residential colony/sector shall be planned in such a manner that it shall meet the minimum norm of 2.5 square meters per persons. (MASTER PLAN FOR NOTIFIED AREA OF LIDA-2031, n.d.).Residential land use: The Land use category in a development of layout plan devoted to residential activity which may be further subdivided into zones/ Cluster By nature, intensity, type, ownership, income(Jain, 2016)

5. Electricity Consumption

In this study, a questionnaire was designed for the collection and compilation of responses regarding energy consumption patterns for major end-uses. The items within the

questionnaire are summarized in the appendix and include; household characteristics, size of household, income, vocation or occupation of the head of the household, dwelling characteristics and access to solar radiation. The questionnaire was first tested with a few respondents to identify those questions which could not result in the desired information. Based on this exercise a modified questionnaire was used to conduct the survey by personally interviewing the families. (Bhat et al., 2011)

Table-4 : Number and Percentage of Households

Sl. No.	Name of Sub-District	Total Rural/Urban	Total number of households	Number and Percentage of households		
				Electricity	Kerosene	Solar
1	Sub-District - Malhabad (0915700819)	Total	65,033	14,421 (22.17%)	49,251 (75.73%)	238 (0.37%)
		Rural	62,046	12,217 (19.69%)	48,566 (78.27%)	233 (0.38%)
		Urban	2,987	2,204 (73.79%)	685 (22.93%)	5 (0.17%)
2	Sub-District - Bakshi Ka Talab (0915700820)	Total	60,336	25,621 (42.46%)	33,818 (56.05%)	68 (0.11%)
		Rural	49,505	18,858 (38.09%)	29,940 (60.48%)	56 (0.11%)
		Urban	10,831	6,763 (62.44%)	3,878 (35.8%)	12 (0.11%)
3	Sub-District - Lucknow (0915700821)	Total	608,120	519,259 (85.39%)	81,917 (13.47%)	1,148 (0.19%)
		Rural	79,128	30,612 (38.69%)	47,070 (59.49%)	319 (0.4%)
		Urban	528,992	488,647 (92.37%)	34,847 (6.59%)	829 (0.16%)
4	Sub-District - Mohantalgaonj (0915700822)	Total	89,102	23,468 (26.34%)	64,008 (71.84%)	369 (0.41%)
		Rural	83,533	21,122 (25.29%)	60,986 (73.01%)	352 (0.42%)
		Urban	5,569	2,346 (42.13%)	3,022 (54.26%)	17 (0.31%)
District - Lucknow (09157)		Total	822,591	582,769 (70.85%)	228,994 (27.84%)	1,823 (0.22%)
		Rural	274,212	82,809 (30.2%)	196,562 (68.04%)	960 (0.35%)
		Urban	548,379	499,960 (91.17%)	42,432 (7.74%)	863 (0.16%)

Note: Percentage is given in brackets after the number of households.

6. Conclusion

Household electricity consumption explains that per capita electricity consumption is been increased over the years. The average monthly power consumption of households varies across seasons as the requirement of electricity varies as per the prevailing temperature. Previous studies show 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 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. (Tewathia, 2014)

In the residential sectors, the usage of electricity is majorly for the purpose of lighting, cooling, heating, cooking and entertainment. The reduction can be attained with the implementation of planning interventions.

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