DETERMINANTS OF URBAN HOUSEHOLD COOLING ELECTRICITY CONSUMPTION- EVIDENCE FROM INDIA

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Overview

The residential sector is the second largest consumer of electricity in India, accounting for 30% of the total energy consumption (IEA, 2020). Moreover, the energy sector is the largest contributor towards greenhouse gas emissions (37%) in India ("India: GHG emissions", 2019). The estimates provided by the IEA (2020) indicate that India's energy demand is expected to increase by 35% between 2019 and 2030. The electricity consumption in urban households includes the use of electrical appliances for cooking (induction-stove), space heating (electric heaters), water heating (electric geysers), cooling (air conditioners, air coolers, and fans), and lighting (tubelights). Compared to other end-uses of energy, the energy used for space-cooling is growing faster and has more than tripled between 1990 and 2016, globally (IEA, 2018). India is one of those countries that is characterized by tropical climate conditions where the number of households owning air conditioners is expected to rise 15-fold by 2040 (IEA, 2020). However, this pattern of residential electricity use varies across states and countries due to their climate attributes, economic factors such as income and electricity price, and household characteristics such as household age, household size, dwelling type, and dwelling size. Household size and household income are the two most common household-specific socio-economic indicators used in the studies carried out in other country contexts (Wangpattarapong et al. 2008; Huebner et al. 2015). Moreover, household income is observed to be a more significant variable in the majority of studies explaining residential electricity demand (Wangpattarapong et al. 2008; Eskeland & Mideksa, 2009) as compared to household size. However, it is crucial to understand that occupant behavior plays an equally important role in determining the electricity consumption within a household. This behavior is governed by the ownership pattern of different appliances and their use based on the climatic conditions prevalent in a region at a particular time-period (Wallis et al. 2016). However, the complex nature of consumer behavior makes it complicated for researchers to capture its influence on energy usage (Chen et al. 2013). Few studies have attempted to analyze these consumer behavioral factors and their linkage with residential electricity demand (Sanquist et al. 2012; Chen et al. 2013; Wallis et al. 2016). To our knowledge, Singh et al. (2018) is the only study in the Indian context that has included the behavioral component in terms of the ownership pattern of different electrical appliances. Their results showed that household electricity consumption is influenced more by the ownership pattern of the air-conditioners than by demographic variables like electricity prices. To fill this gap in the literature, this study aims to address two research objectives: 1) to investigate the changing pattern of household electricity use during summers in Indian states characterized by different climate attributes; and 2) to analyze the role of socio-economic, demographic, and behavioral factors in influencing the urban household cooling electricity consumption within Indian states.

Methodology

Household survey was carried out within the selected districts of four states, i.e., Rajasthan, Uttar Pradesh, Punjab, and Maharashtra. Five districts (given in the Table below) were chosen as representative of these four states based on two sets of criteria: a) they should belong to different climate zones within each state; and b) they should represent a higher percentage of total state population as well as urban population. In order to examine the importance of socio-economic, behavioral, and demographic factors within a household, a multiple log-linear regression technique was deployed to determine their significance behind the change in residential monthly cooling electricity consumption. A cluster sampling technique was used to select 1053 households for the survey within the five districts of the four mentioned states. A closed-ended questionnaire survey was used to perform the survey during 2019–2020 (summers).

Table : Districts selected for carrying out the survey

DISTRICT	STATE NAME	CLIMATE ZONE
Amritsar	Punjab	Composite
Lucknow	Uttar Pradesh	Composite
Bikaner	Rajasthan	Hot and dry
Aurangabad	Maharashtra	Hot and dry
Nagpur	Maharashtra	Composite

A multiple-linear regression (MLR) model was formed, with monthly household electricity consumption (log-transformed) during summers (KWh) as the dependent variable, and demographic factors (number of members in a household, family compostition, and dwelling size), behavioral factors such as usage of electrical appliances (air-conditioners, air-coolers, refrigerators, and fans) during the morning (5:00–9:00), afternoon (13:00–18:00), evening and late-evening (18:00–24:00), and late-night (0:00–5:00), different appliance attributes such as the brand, type, star-rating, and capacity, and socio-economic (family income) factors as exogenous inputs. Due to the presence of a high degree of multicollinearity between family size and other variables, it was dropped from the model. Both standardized and unstandardized coefficients were obtained for all the variables.

Results

The statistical results of the household survey show that, on average, a household consumes 593 KWh of electricity during the summer, with the highest consumption in Amritsar and the lowest in Lucknow. This can be attributed to the lower household income, smaller dwelling size, usage of all three electrical appliances such as air conditioners, air coolers, and fans in the latter. The daily average number of operating hours of air coolers was observed to be higher than that of air-conditioners (ACs) and fans. Similarly, the average hourly usage of air-coolers on weekdays was higher than that of fans and ACs, whereas on weekends, both air coolers and fans were found to be used for an equal number of hours. As expected, the pair-wise correlation matrix shows that household income, behavioral variables, and demographic variables were positively correlated with residential electricity consumption. In contrast to this, a negative correlation was observed between the number of children in a household and residential electricity consumption. This can be due to the greater engagement and awareness of children in following energy conservation practices at home when compared to adults. The empirical model findings show that both household characteristics and behavioral factors alone account for 32% of the variability in household electricity consumption, leaving aside household income. In contrast to the earlier literature, household income turned out to be insignificant. However, behavioral factors such as the use of air-conditioners during the evening and late-evening, and the usage of fans during the afternoon turn out to be the most significant determining factors behind cooling electricity consumption in urbanized households across the Indian states. This was followed by the number of adults and children within a household.

Conclusions

In this study, we aim to investigate the major factors that influence the household electricity consumption during the summer season in five districts from two different climate zones. This was based on a household survey conducted within 1053 households. A multiple log-linear regression technique was deployed to determine the significance of the various demographic, socio-economic, and behavioral factors. The factors related to appliance usage time during the day turned out to be most significant in our study. This was specifically true for air conditioners and fans. Hence, behavioral factors related to the usage of appliances should be considered when effectively designing policies in India. The increased consumer awareness on how the inefficient use of electricity contributes to higher emissions and global warming is pertinent. Hence, switching to more energy-efficient practices by households is required in the long run to reduce the carbon footprint of the residential sector. Some of the factors which are not considered in the study such as, the age of household head, electricity price, household type, dwelling age, and behavioral patterns related to other household appliances, can be considered in future research studies. This can add a different dimension to exploring their linkage with electricity consumption. Similar household surveys should be extended to other districts and states within India. Additionally, heating electricity consumption can also be studied in the states where the winter season is prominent.