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# Empirical assessment of sociotechnical factors that influence residential electricity use in India

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## 1. Introduction

Residential energy (electricity) use in India is projected to increase four-fold by 2030 yet there is limited data and understanding of how electricity is used in Indian households. This paper empirically investigates *how* and *why* electricity is used in Indian dwellings with and without air-conditioning (AC), using an interview-based survey approach applied in 41 dwellings located across two cities (Hyderabad and Jaipur) representing the composite climate of India. Statistical analysis (multi-variate regression) is used to analyse co-relations between physical characteristics of dwellings (such as built form), income group, occupancy patterns, socio-demographics and appliance usage in AC and non-AC dwellings that influence household electricity using behaviours. The study is part of a wider Indo-UK research programme called RESIDE – Residential Building Energy Demand Reduction.

## 2. Background and methodology

Residential electricity consumption (REC) in India has nearly tripled in the past two decades and accounted for 24.2% of the overall electricity consumption in 2019 [1, 2]. This increase was due to an increased use of space cooling and other electrical appliances driven by higher access to electricity, improved socio-economic status and thermal comfort expectations ADDIN EN.CITE [1, 3-5]. In order to develop residential energy policy or programme, a deeper understanding of REC and end-use energy behaviours is necessary [6]. Internationally various studies have examined the determinants of residential energy use that include physical characteristics, socio-demographics, occupant behaviour and electricity tariff subsidies ADDIN EN.CITE [7-9], however such studies are lacking in the Indian context. In 2013, a review of data quality related to building performance for residential and commercial buildings in four regions (India, China, United States and EU) found that building performance data for

residential (and commercial buildings) sector was weakest in India. Accessibility to such data, be it national, regional or local is very limited due to the lack of substantial funding, general lack of interest and absence of technology to do so ADDIN EN.CITE [10, 11]. Recently the India residential energy survey (IRES) investigated the level of energy access in rural and urban dwellings, with limited focus on sociotechnical factors that shape urban residential electricity use[3].

This study was designed to gather bottom-up sociotechnical data for 41 dwellings (having 41 households) using an interview-based questionare survey implemented online on Google form. Data were gathered about physical and household characteristics, socio-demographics, occupancy and appliance usage. Historic electricity bills were collected for one year (2018-2019). Initially 47 dwellings were recruited using purposive sampling, however complete set of data were available for 41 dwellings, out of which 22 were located in Hyderabad and 19 in Jaipur. Low-income (LIG), middle-income (MIG) and high-income groups (HIG) were defined using the income slabs recommended by the Government of India (Pradhan Mantari Awas Yojana). The empirical data was prepared for regression analysis through checking for collinearity, normality, removing highly-correlated variables and transformation of variables where necessary for an unbiased result [12]. Multi-variate regression analysis was conducted to establish the strength of the relationship between different variables and annual residential electricity use.

## 3. Results

The 41 dwelling sample was split as 16 LIG, 16 MIG and 9 HIG households occupying 12 apartments and 29 stand-alone houses. While 28 dwellings had one or more ACs each, 13 had no ACs especially in LIG dwellings. As expected mean annual REC was observed to be highest in HIG dwellings (5618 kWh), followed by MIG dwellings (3870 kWh) and lowest in LIG dwellings (2169 kWh). The difference in electricity use across seasons was evident since the average monthly electricity use and electricity cost across 41 dwellings were found to be 375.23 kWh and US$29 in summer/monsoon, while these were less than half in the winter equating to 182.12 kWh and US$11.

Electricity consumption with respect to the income group and AC/no-AC dwellings is represented in the figure below.

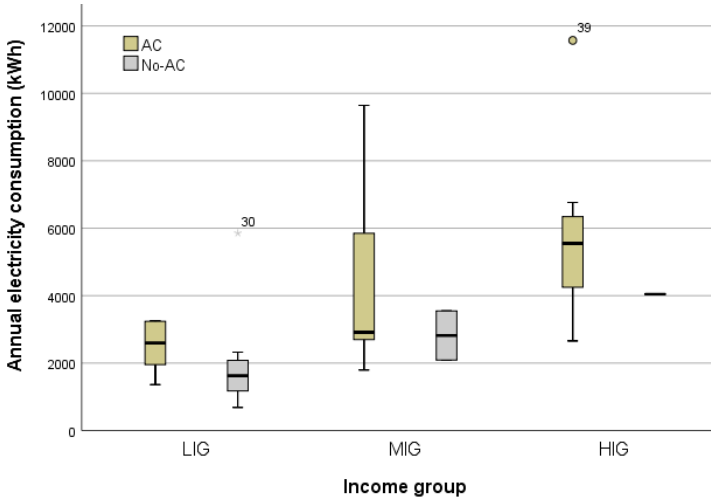


Figure 1. Distribution of annual electricity use across different income groups with and without ACs

Appliance ownership data showed 98% of households owned a refrigerator and television, while 68% owned an air conditioner. The mean annual REC for AC dwellings was found to be 4,208 kWh, nearly double that of dwellings without ACs (2,260 kWh). Although HIG dwellings reported higher use of AC in the summer than LIG and MIG, about 7% of AC dwellings reported non-usage of AC implying that having an AC does not mean it is also being used regularly.. Analysis of the annual usage hours for appliances (excluding ACs) by different income groups revealed that LIG dwellings despite owning a smaller number of appliances had higher annual usage hours.

A regression model was developed to examine the variation in electricity use across the dwelling sample as shown in Table 1. The number of occupants, presence of AC, total appliance hours, number of rooms (dwelling size), and income group were found to explain 81% of the variation in REC, with 76% of the variation explained through presence of AC and income group.

Table 1. Regression model

| *(Dependentvariable)- Annual electricity consumption (kWh)* | *Unstandardized Coefficients* | | *Standardized Coefficients* | *t* |
|---|---|---|---|---|
| | B | Std. Error | Beta | |
| *(Constant)* | 6.09 | 0.19 | | 31.29 |
| *Number of rooms* | 0.05 | 0.02 | 0.29 | 2.95 |
| *Presence of ACs* | 0.48 | 0.11 | 0.37 | 4.44 |
| *Numberof occupants* | 0.09 | 0.02 | 0.39 | 4.9 |
| *Appliance hours* | 0.0001 | 0 | 0.31 | 3.41 |
| *Incomegroup* | 0.28 | 0.12 | 0.19 | 2.27 |
| *R Square* | **0.808** | | | |
| *Durbin-Watson* | 1.758 | | | |

## 4. Discussion and conclusion

Statistical analysis of the empirical data by income group, ownership of ACs and appliance usage hours, has helped to gain deeper understanding of the causes of variation in electricity use across 41 dwellings. It is evident that dwellings with AC and higher incomes have at two to three times more electricity use than those on lower incomes and with no ACs. These findings have implications for designing energy efficiency programmes in India. It will be worthwhile focussing on HIG and MIG dwellings - 80% of which are found to own ACs.

This study also provides important process lessons for scaling-up survey based techniques in India and the challenges that need to be addressed in terms of time taken to do the survey, internet connectivity when using online survey forms and cross-relating survey findings with measured electricity data.

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