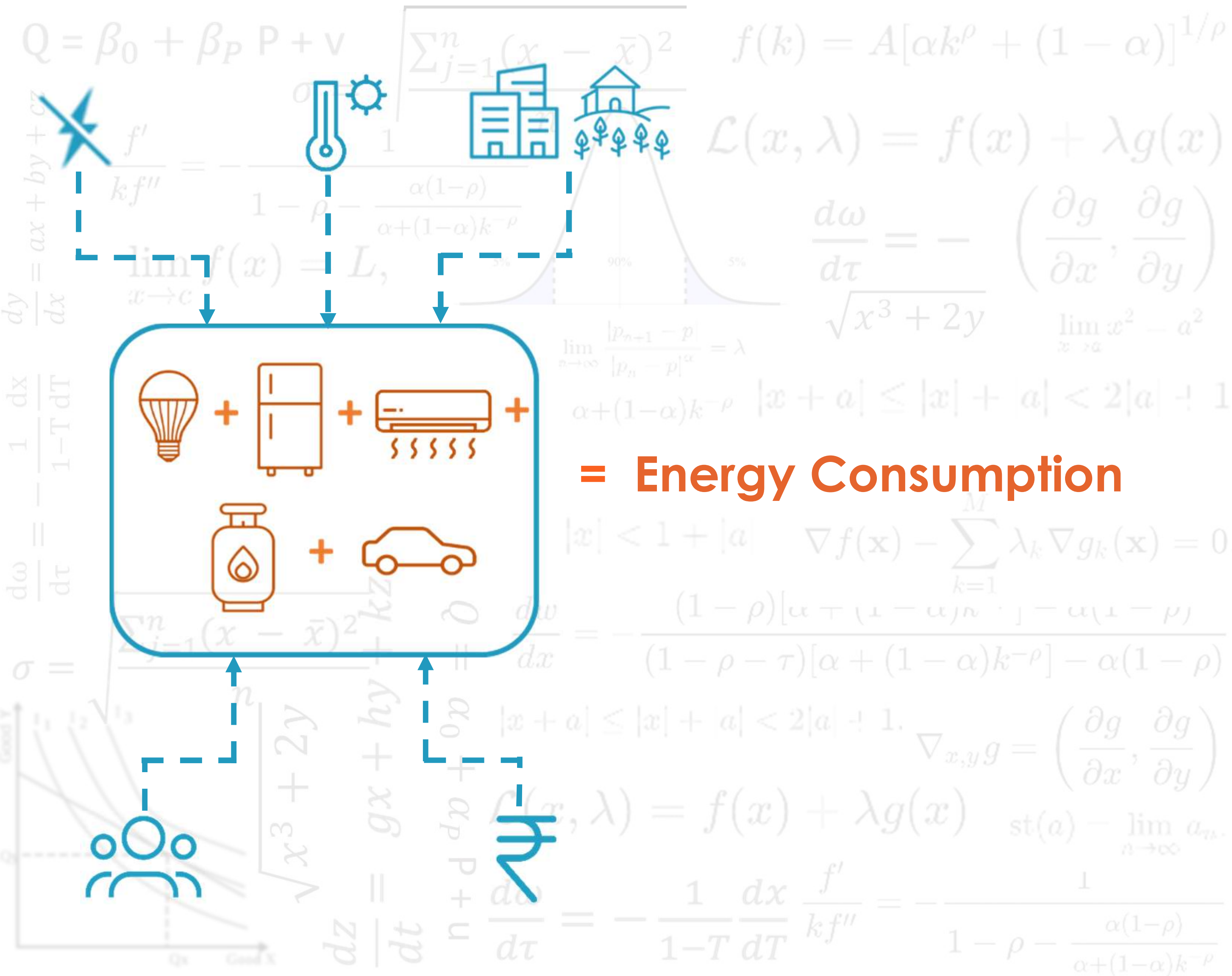
Energy Consumption Patterns in Indian Households

Insights from Uttar Pradesh and Maharashtra



Prayas (Energy Group)

About Prayas

Prayas (Initiatives in Health, Energy, Learning and Parenthood) is a non Governmental, non-profit organization based in Pune, India. Members of Prayas are professionals working to protect and promote the public interest in general, and interests of the disadvantaged sections of the society, in particular. Prayas (Energy Group) works on theoretical, conceptual regulatory and policy issues in the energy and electricity sectors. Our activities cover research and intervention in policy and regulatory areas, as well as training, awareness, and support to civil society groups. Prayas (Energy Group) has contributed in the energy sector policy development as part of several official committees constituted by Ministries and Planning Commission. Prayas is registered as SIRO (Scientific and Industrial Research Organization) with Department of Scientific and Industrial Research, Ministry of Science and Technology, Government of India.

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Acknowledgements

We would like to thank Good Energies Foundation for its financial support to this work. Dr. Shonali Pachuari from IIASA and Dr. Ashok Sreenivas from Prayas reviewed the report and provided valuable comments. We would also like to thank all our colleagues particularly Nimita Kulkarni, Sanjana Mulay, Mrudula Kelkar, Rajat Kulkarni, Maria Chirayil and Shilpa Kelkar for assisting on different aspects of the study. Morsel Research and Development Pvt. Ltd. conducted the survey in Uttar Pradesh and Market Xcel Data Matrix Pvt. Ltd. conducted the survey in Maharashtra. All icons used in this report have been sourced from thenounproject.com.

Suggested citation: Prayas (Energy Group). (2020,February). Energy Consumption Patterns in Indian Households: Insights from Uttar Pradesh and Maharashtra

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February, 2020
For private circulation only

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Executive Summary

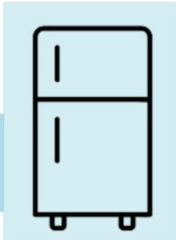
India's household energy consumption patterns are changing rapidly. Increase in household incomes, urbanization, and rapid technology development along with government policies/programmes to push for adoption of modern energy sources and efficient end-use technologies are driving these changes. It is crucial to study these emerging patterns and trends to meet the future demand in sustainable and affordable manner. These insights can inform both, policies aimed at influencing demand and planning of resources required to meet the demand. India does not conduct periodic residential energy consumption surveys as conducted in many countries. There is limited data and understanding of the ownership and usage patterns of different appliances and fuels for various end-uses at household level in India captured through census and surveys with multiple objectives.

In an attempt to add to the limited knowledge base on India's residential energy consumption, we conducted two detailed residential energy consumption surveys in: (a) 3,000 semi-urban and rural households in Uttar Pradesh (UP) and Maharashtra (MH); (b) 1,200 households in the cities of Pune, Talegaon, and Ahmednagar in Maharashtra.

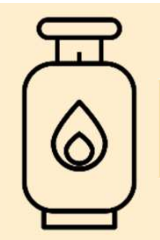
In this executive summary we present key findings and observations gathered from the survey in 2 states. This survey was conducted in February-March 2019. We hope that these insights make a strong case for conducting periodic residential energy consumption surveys at both national and sub-national level in India.

Key Insights

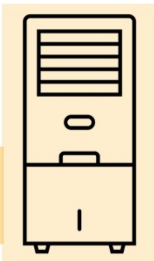
83% of the total lighting stock in UP and 54% in MH is LED lighting



~ 50% of households in both states own refrigerators



67% of households in UP and 95% in MH use LPG for most of the cooking

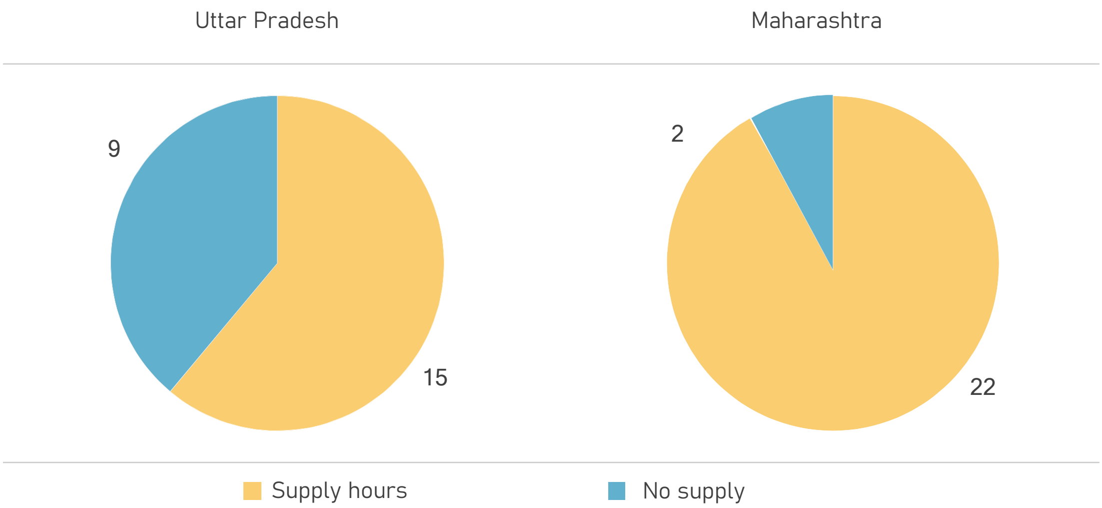


In medium and high income households, 40% in UP and 30% in MH own air-coolers

65% of households in UP and 98% in MH own smart phones

Quality of Supply

Supply hours, the primary measure of Quality of Supply (QoS), reported by the surveyed households are observed to be higher in MH than UP. The average daily supply hours are about 22 hours in MH and 15 hours in UP with a significant variation within the sample. Occurrence of frequent and unpredictable power-cuts added with voltage fluctuations can make meaningful use of appliances difficult. Poor quality supply puts additional burden on households to invest in options like alternative lighting, voltage stabilizers, and power backup.

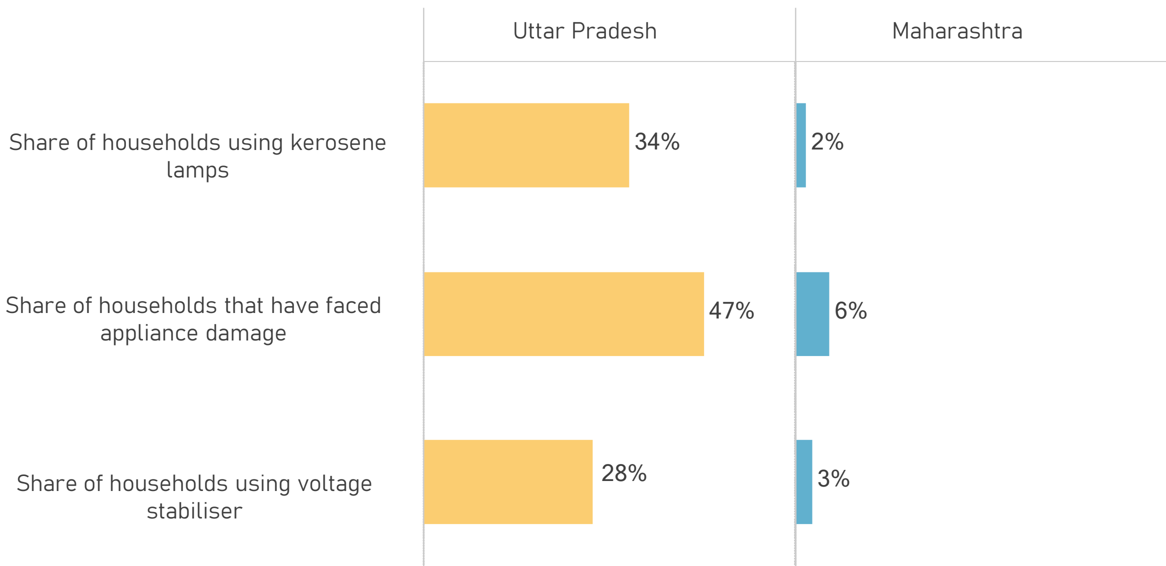


57% households in Uttar Pradesh

25% households in Maharashtra

Experience voltage fluctuations

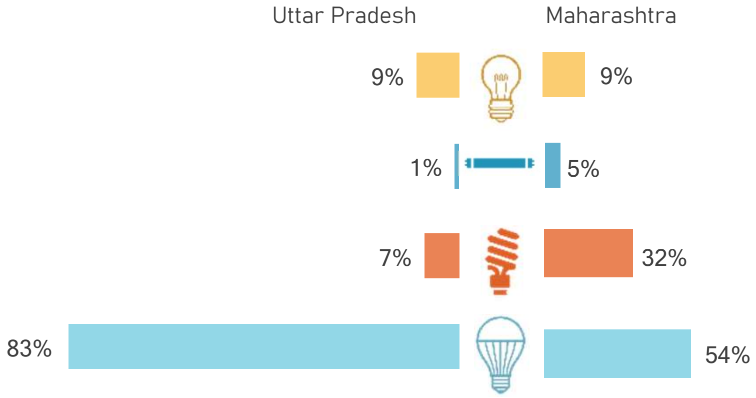
Although MH compares better than UP, the survey shows that QoS issues exist in both states. Measures to improve QoS are necessary to enable households make more meaningful use of electricity.



Lighting

Households in UP seem to have leap-frogged from either no-lights or incandescent bulbs to Light Emitting Diode (LED) bulbs, while those in MH are gradually moving from Compact fluorescent lamps (CFLs) to LED bulbs. We see a fairly high adoption of LED lighting in both UP and MH in our survey. More than 80% of all the lighting devices used in the surveyed households from UP are LED bulbs or tube-lights. This is observed across all the income categories.

Lighting stock



Unnat Jyoti by Affordable LEDs for All (UJALA) has facilitated a market transformation to LED lighting. It is crucial for the government and other actors to focus on ensuring the availability of good quality LED bulbs in order to sustain the on-going LED market transformation.

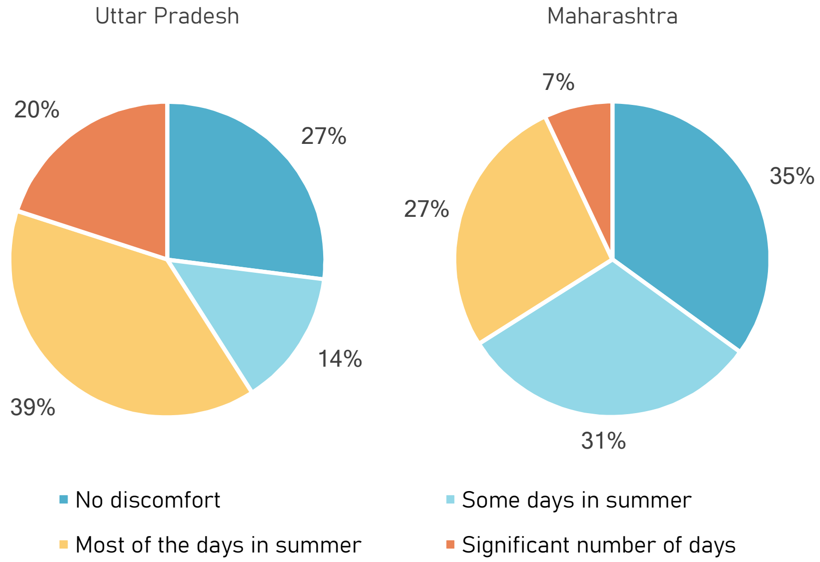
Space Conditioning

Fans are the most commonly used appliances in both states with more than 90% share across all households. Ownership of air-coolers is higher in UP. A number of households report buying local-make fans and air-coolers. Some of these appliances may be cheap, non-standard or highly inefficient models. Only a few high income households own air-conditioners.

Quite a few households face discomfort from heat in both states which decreases with the ownership of air-coolers and air-conditioners.

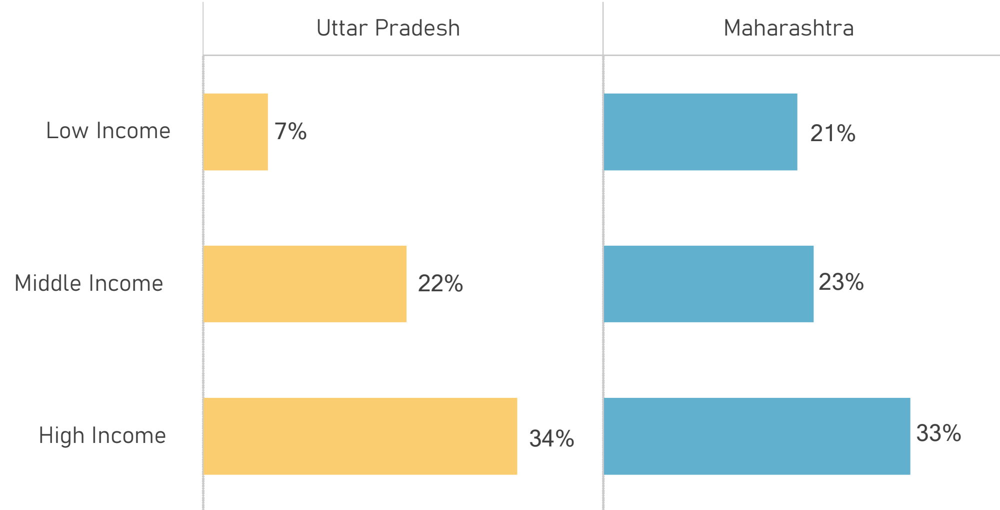
Higher levels of discomfort in households coupled with the trend of increasing temperatures suggest a potential demand for all space-conditioning appliances. Interventions like Standards and Labelling (S&L) for air-coolers and programmes similar to UJALA supported by the Super-Efficient Equipment Programme (SEEP) will be required to efficiently support this demand.

Breakup of surveyed households according to type of discomfort experienced



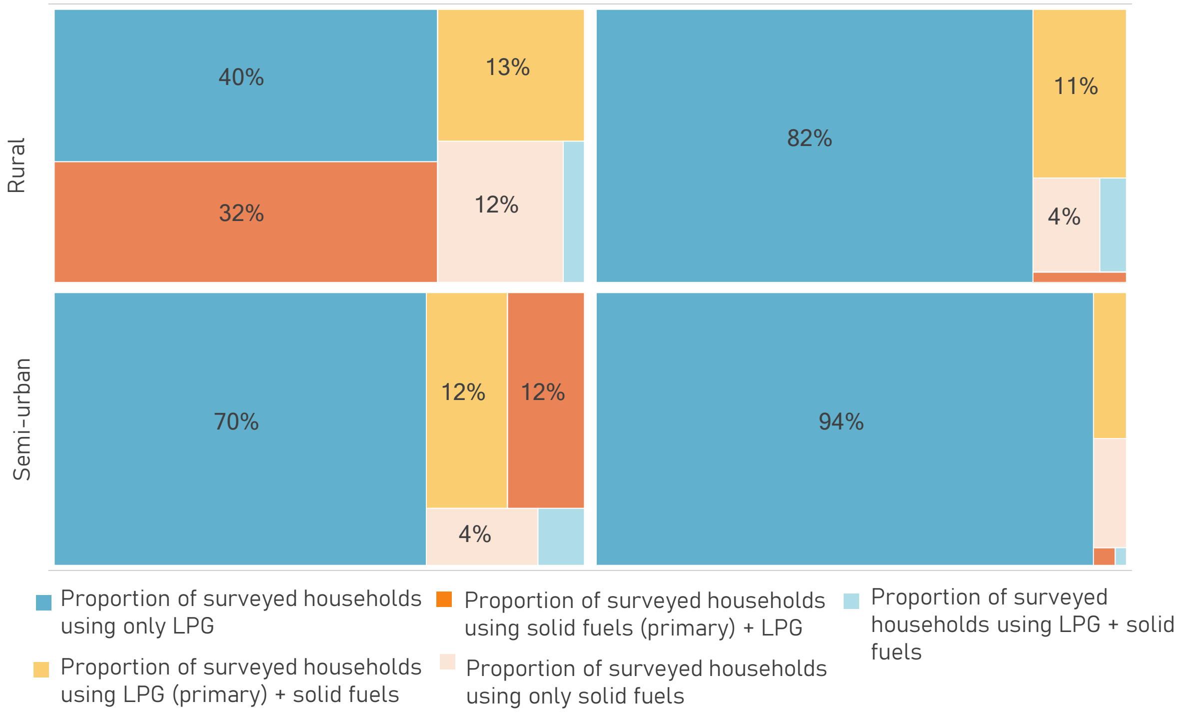
Awareness about Star Rating

Awareness about star rated appliances is very low in both states and decreases as incomes decrease.



Cooking

Liquefied Petroleum Gas (LPG) ownership is high in both states however quite a few households still use solid fuels for cooking particularly in UP. Majority of these households find LPG to be expensive to use for all of their cooking. A sizeable proportion also quote preference for food cooked on chulha. Interventions, both economic and behavioural, are needed to push for sustained and exclusive use of LPG as well as other clean alternatives to eliminate the use of solid fuels for cooking.



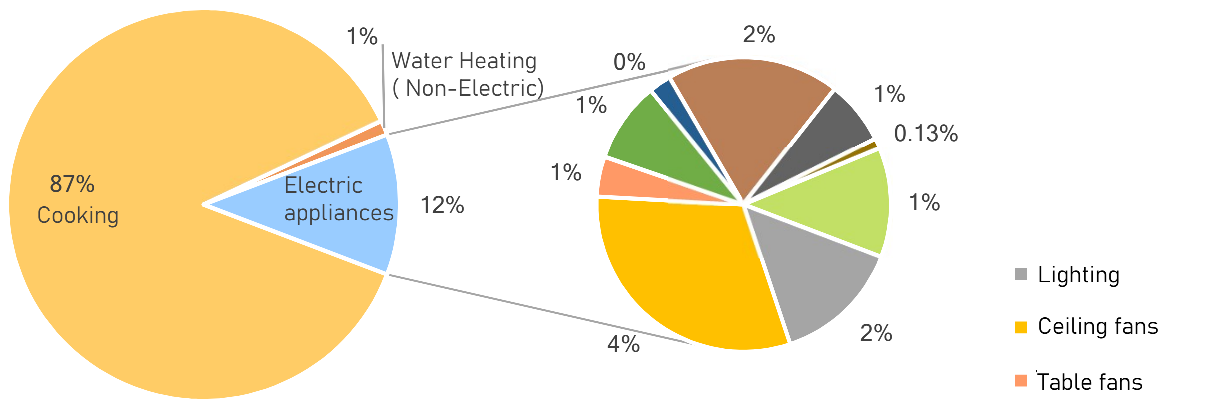
Water Heating

Only about 34% of households in UP heat water for bathing compared to 92% in MH. Solid fuels are commonly used across the income categories, regions, and states and even by those households which use LPG for all their cooking. As the incomes increase, households use LPG and in some cases electricity to heat water. Ownership of solar water heaters is negligible. Specific interventions focused on water heating after careful evaluation of alternatives are required.

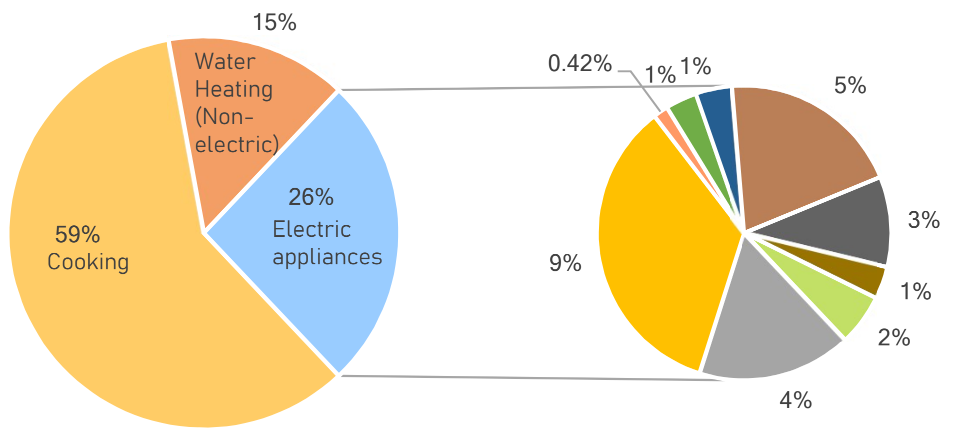
Energy End-Use

An end-use model was developed from the survey data to estimate the share of individual end-uses and fuels in the household's total energy consumption.

End-use wise share of total energy consumption in Uttar Pradesh



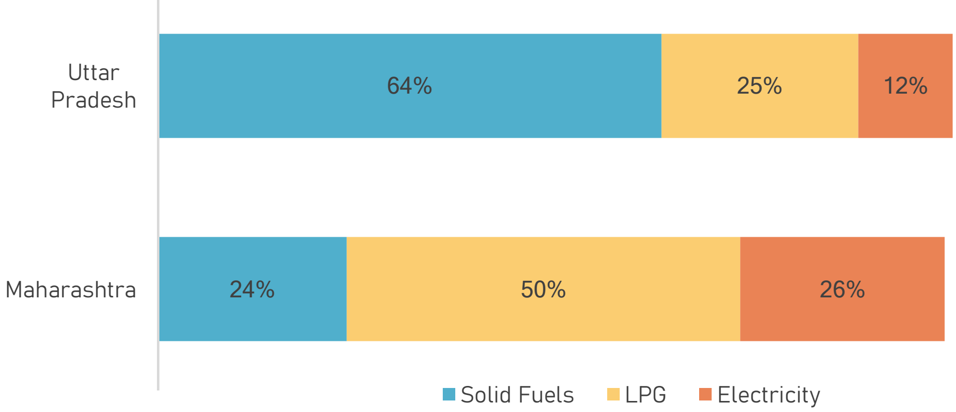
End-use wise share of total energy consumption in Maharashtra



Cooking contributes to the largest use of energy in both UP and MH followed by water heating in MH. Fans and air-coolers are the largest uses of electricity in both the states.

LPG contributes to half of the total energy used in the surveyed households in MH and about a quarter in UP. Households in UP continue to use solid fuels for part or most of their cooking whereas in MH most of the solid fuels are used for water heating.

Fuel-wise share of total energy consumed



1 Introduction

India’s annual per capita energy consumption is 0.6 tonnes of oil equivalent, about a third of the world average according to the Economic Survey of 2018-19 (MoF, 2019). The Survey states that India’s energy consumption needs to increase to achieve a higher level of economic development and prosperity. More specifically, the energy consumption needs to increase by four times if India has to achieve a Human Development Index (HDI) of 0.8, which is considered to be ‘very high’. The per capita annual residential electricity consumption in India is also low at 182 kWh. In comparison, China’s per capita electricity consumption is about three times greater (NSBC, 2018), while the United States is about 24 times (EIA, 2018).

India’s challenge is to meet this future demand in a sustainable and affordable manner. There is already a major policy push for adoption of modern energy sources and efficient end-use technologies at household level. Pradhan Mantri Sahaj Bijli Har Ghar Yojana (SAUBHAGYA programme) (MoP, 2019c) has provided 26 million last-mile electricity connections and has helped India achieve near-universal household access to electricity. UJJWALA programme (MoPNG, 2019) has provided 75 million LPG connections to households helping them to move away from the use of solid fuels which causes indoor pollution and leads to major health issues. . Unnat Jeevan by Affordable LEDs and Appliances for All (UJALA) programme (MoP, 2019b) has sold more than 360 million Light Emitting Diode (LED) bulbs at low prices to the households leading to a widespread shift from less efficient options like Compact Fluorescent Lamps (CFLs) and incandescent bulbs. Standards and Labeling programme (BEE, 2019) has been facilitating a shift to energy efficient appliances since 2006 by prescribing minimum standards for efficiency and by providing informative labels to help consumers choose energy efficient appliances. Furthermore, FAME scheme (MoHI&PE, 2019) is facilitating the shift to electric vehicles and there are various central and state level programmes to promote the adoption of rooftop solar (MNRE, 2019). These policies/programmes along with factors such as increase in incomes, urbanization, and rapid technology development are expected to change the household energy consumption patterns substantially. It is crucial to study these emerging patterns and trends. This can inform the policies aimed at influencing demand as well as aid the planning of resources required to meet the demand.

India does not conduct periodic national level Residential Energy Consumption Surveys (RECS) as done by many other countries like the United States, United Kingdom, several EU countries, China, Indonesia, Thailand and others. RECS can help in capturing data across a wide cross-section of households on characteristic of their homes and their energy consumption patterns and trends. The available data on ownership of different appliances and use of fuels is captured in the census and various surveys conducted by the government, academia, and research organisations. Office of the Registrar General and Census Commissioner conducts a nation-wide census every ten years. Census questionnaire includes the primary source of energy used for lighting and cooking along with ownership of few appliances like radio, television, computer and mobile phone (Census of India, 2011a). National Sample Survey Office (NSSO) (NSSO, 2014) conducts a nationally representative survey every five years on household consumption of goods and services[1]. The survey provides data on ownership of most of the appliances used in a household along with primary source of energy used for lighting and cooking. It also provides data on expenditure on different fuels. University of Maryland and the National Council for Applied Economic Research (NCAER) have conducted two rounds of a nationally representative household survey called the India Human Development Survey (IHDS) in 2004–05 (Desai, Vanneman, & NCAER, 2005) and 2011–12 (Desai, Vanneman, & NCAER, 2011). This survey provides some additional data over the NSSO survey in form of electricity supply hours, more number of appliances, and metro-city level data. However, none of these surveys collect information on usage and appliance efficiency. More recently a couple of large-scale surveys were conducted with an objective to assess the status of access to modern energy in rural areas in states which were subject to the recent electrification and LPG connection drives. Council on Energy, Environment, and Water (CEEW) (CEEW, 2018) in collaboration with Columbia University conducted panel surveys in 2015 and 2018 in 9,000 households across six states. Smart Power India (SPI & ISEP, 2019) conducted a

[1] Ministry of Statistics and Programme Implementation (MOSPI), NSSO's parent ministry, has decided not to release the data from the latest round due to data discrepancies.

survey of 10,000 households and 2,000 rural enterprises across four states in 2018. These surveys include questions on electricity supply hours, appliance ownership & usage patterns, and fuels used for cooking but the focus was on states where households have recently acquired access to electricity and LPG. CLASP in partnership with the Bureau of Energy Efficiency (BEE) (EDS, 2019) has conducted a detailed residential electricity consumption survey in about 5000 households in 20 cities across India representing various socio-economic classes and climatic zones. Their focus is on urban areas. This brief review of primary data sources shows that there is limited understanding on how Indian households use appliances and consume energy.

In an attempt to add to the limited knowledge base on India's residential energy consumption, we conducted two detailed residential energy consumption surveys in: (a) 3,000 semi-urban and rural households in Uttar Pradesh and Maharashtra; (b) 1,200 households in the cities of Pune, Talegaon, and Ahmednagar in Maharashtra. In this report we discuss the insights gathered from the survey in 2 states. A separate report[2] published simultaneously, discusses the insights from the survey in 3 cities. Uttar Pradesh and Maharashtra are at different levels of development. Maharashtra is one of the richer states in India with a per capita GDP of ₹ 1,41,152 about three times that of Uttar Pradesh (MOSPI, 2019). Maharashtra has been early in providing near-universal household access to electricity while Uttar Pradesh joined the ranks only recently. As per the 2011 Census, about 84% of households in Maharashtra used electricity as a primary source of lighting while this share was only about 37% in Uttar Pradesh. Further, 19% of households in Uttar Pradesh used LPG as a primary fuel for cooking compared to 43% in Maharashtra in 2011 (Census of India, 2011d). Although Uttar Pradesh is smaller in size than Maharashtra, its population is 1.8 times that of Maharashtra as it is denser with 829 persons per square km compared to Maharashtra's 365 (Census of India, 2011e). We chose semi-urban and rural households as they have been the primary beneficiaries of the recent government initiatives on providing access to electricity, improving electricity supply quality, providing access to LPG and others. Hence, their energy consumption patterns are expected to change substantially. Our

[2] tinyurl.com/ECH3cities

objective of this study is twofold: First, to gather insights on energy consumption patterns in the two states to inform relevant policy decisions; and second, to make a strong case and provide a template to conduct a national level residential energy consumption survey in India.

In the next section, we discuss the methodology which includes the sampling plan, questionnaire design, and the asset index computation. We then discuss our key observations and their policy implications. We also discuss the results of the end-use model that estimates the total household energy consumption and the share of individual end-use and fuel source. Assumptions of the end-use model and the questionnaire are provided in the Appendices. The survey data along with the codebook is available on our website.[3]

[3] http://prayaspune.org/peg/publications/item/445

2 Methodology

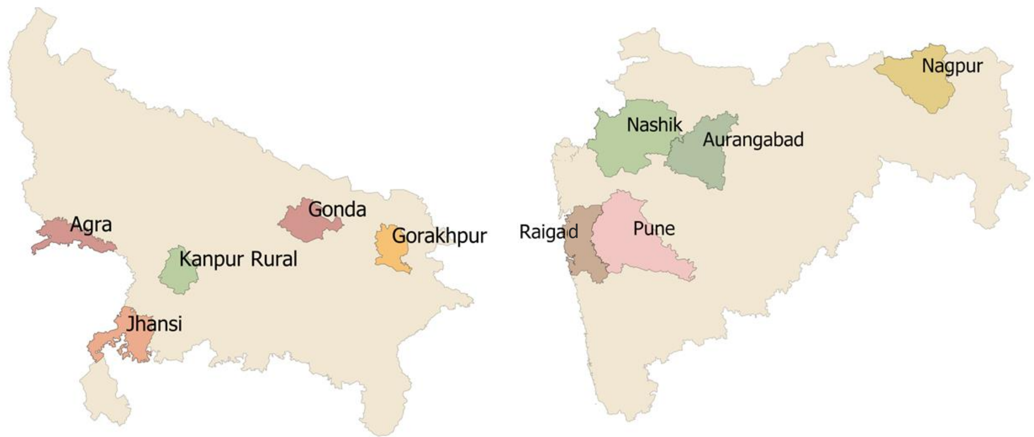
2.1 Sampling

The survey was conducted in February-March 2019 on 1,500 semi-urban and rural households each from Uttar Pradesh and Maharashtra. Each state has five different regions with fairly distinct climates, geographies, and cultures. These regions are also reflected in administrative divisions of each state.

Table 1: Regions and districts in sample

	Maharashtra	Uttar Pradesh
1	Konkan	Braj (Western UP)
2	Paschim Maharashtra	Awadh (Central)
3	Khandesh	Maharashtra
4	Marathwada	Purvanchal (Eastern UP)
5	Vidarbha	Baghelkhand

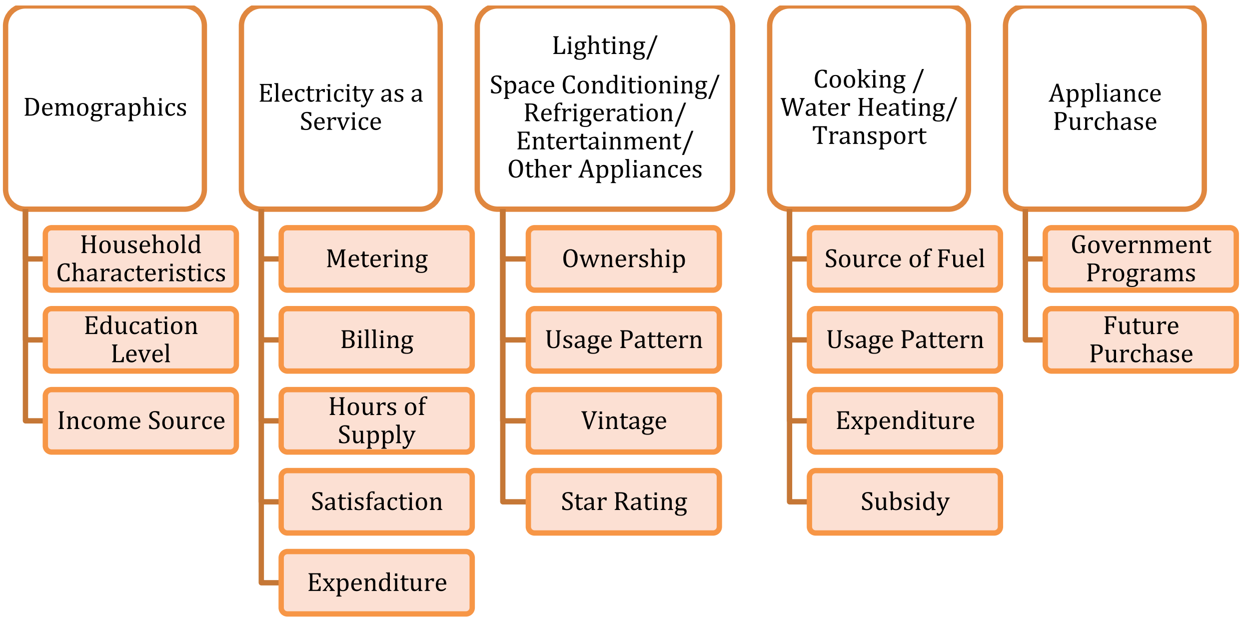
Figure 1: Regions and districts in sample



We chose one district from each of the regions and sampled 300 households within that district. These 300 households were equally distributed in three tehsils geographically spread across the district. In each tehsil, 50 households were chosen in a semi-urban area, 25 households in large village, and 25 households in small village. As per the Reserve Bank of India (RBI)'s classification (RBI, 2013), semi-urban is a town with a population between 10,000 and 1,00,000 while population of rural areas is less than 10,000. We further identified a village with a population between 7,000 and 10,000 as a large village and a village with a population between 3,000 and 7,000 as a small village. Hence, the sample in each state has equal number of semi-urban and rural households distributed across 15 towns and 30 villages in 5 districts. In each town or village, surveyors used a pre-identified set of visual indicators to ensure households from different income levels are chosen. These visual indicators included size of the house, structure (kaccha/pucca), ownership of vehicles among others.

2.2 Questionnaire design

Figure 2: Survey questionnaire framework



The survey questionnaire focuses on major end-uses like lighting, space conditioning, refrigeration, cooking, water-heating, entertainment, and transport. It also includes questions on factors that can influence consumption patterns such as demographics, electricity supply quality, awareness about government programmes and perceptions related to appliance purchase. Framework of the questionnaire is shown in Figure 2. The full questionnaire is available in Appendix C.

2.3 Asset index

As mentioned earlier, pre-identified visual indicators were used by the surveyors to choose households across different income categories. For the purpose of analysis, we use the asset index method to re-categorize the households to account for the surveyor's bias, if any, in selecting the households.

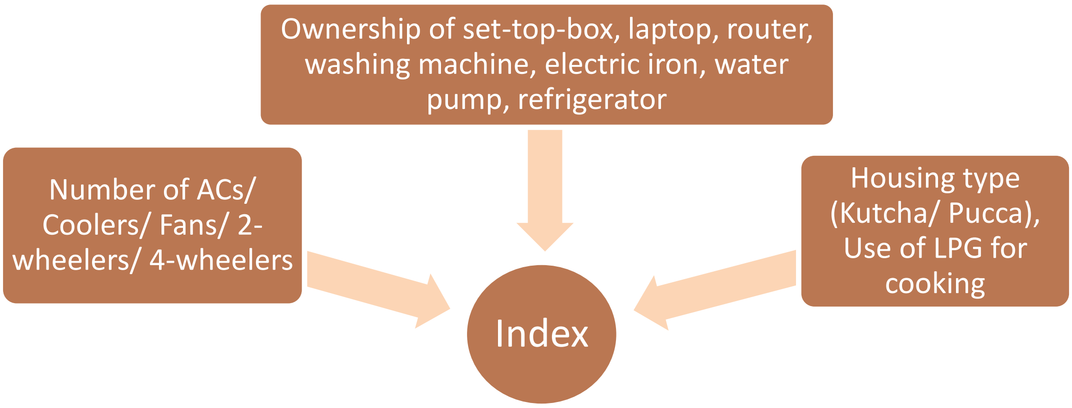
Asset Index is computed based on ownership of certain appliances and certain household characteristics (see Figure 3). The underlying assumption is that these appliances and characteristics can explain a household's long-term wealth better than the income stated by households in the survey. Effectively, differing levels of a household's long term wealth, manifest in the form of variability in asset ownership (Filmer & Pritchett, 2001). A combination of these variables serves as a proxy for wealth. Hence, different levels of wealth will lead to have different index values which will thus belong to low, middle or high levels of income.

A typical household in a higher income group would be living in a pucca house, have an air-conditioner, a 2-wheeler or a 4-wheeler vehicle and use LPG for cooking. On the other hand, a household in the lower income group is more likely to not own an Air Conditioner (AC) or a motor vehicle but will own a bicycle, an incandescent bulb and use solid fuel for cooking.

Principal Component Analysis (PCA) (Jaadi, 2019) is used to compute asset index for each household. PCA is a multivariate statistical technique which converts a set of possibly correlated variables into a set of uncorrelated variables called principal components. PCA works by generating a number of components which capture variance in the data set. Each component is a linear combination of all the predictor variables. This technique assigns weights to each of the asset variables (predictor variables). The first component (Z1) captures maximum information from the original data set and each additional component records lesser information than the previous one.

For instance, Z1 will have loadings for each predictor variable, i.e. a weight for number of ACs, ownership of set-top box, housing type etc. For each household the number of ACs will be multiplied by the loading for number of ACs and so forth for every predictor variable. A sum of these products will add up to form the score corresponding to Z1. This process of score calculation is done for all the households, such that each household has a score derived from Z1. For each component then, this procedure of determining scores is repeated across all households. We then select significantly relevant components based on certain statistical tests and compute an Asset Index using the scores from these selected components.

Figure 3: Asset Index Computation



Asset Index is computed separately for each state. The index is then used to divide each state sample into tertiles which correspond to low, medium, and high-income levels. Table 2 shows the distribution of demographic characteristics across these tertiles for the two states.

Table 2: Demographic features of households in different tertiles

	Average Number of Rooms		Average Carpet Area (in square feet)		Average Household Size	
Income	UP	MH	UP	MH	UP	MH
Low	2.9	2.2	856	460	6	4
Middle	3.6	2.7	1080	597	7	5
High	4.9	3.4	1436	696	7	5

3 Observations & policy implications

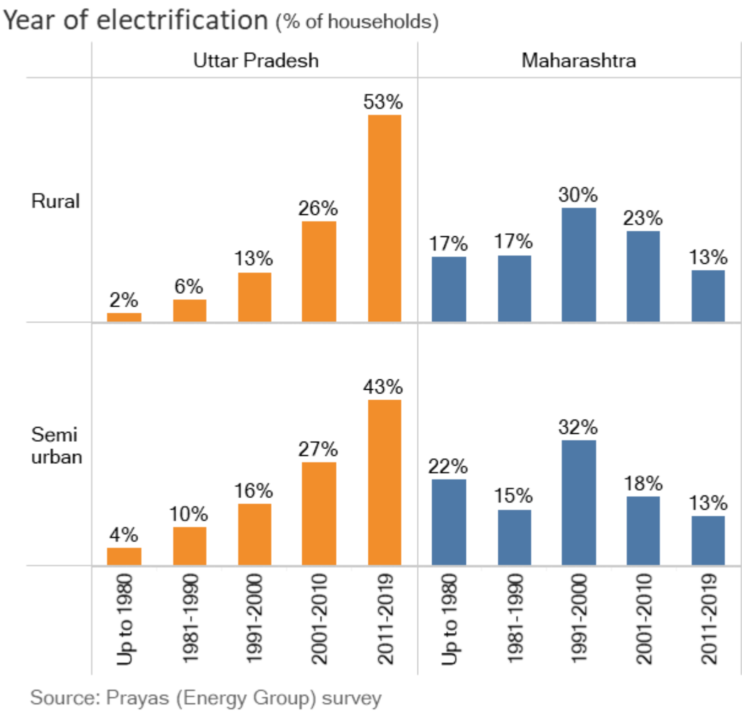
In this section we discuss key observations from the survey and its policy implications. We begin with quality of supply of electricity, an important factor driving the ownership and use of appliances. We then discuss the ownership and usage patterns of appliances and fuels for individual end-uses in the surveyed households. We also briefly discuss the factors that affected the recent purchases of appliances by the surveyed households. We finally discuss the results of our end-use model developed to estimate the energy consumption of each end-use.

3.1 Electricity as supply

Quality of Supply and Service (QoS) of electricity by the distribution companies (DISCOMs) has significant influence on a household’s decision to buy and use appliances that can improve its standard of living. Inadequate electricity supply can limit the duration of use of appliances. Poor quality of electricity supply like frequent outages and voltage fluctuations can damage appliances or reduce their life. Some households invest in options like solar lamps, inverters, or voltage stabilisers. Others either restrict the use of appliances or avoid buying them altogether. Rural electrification programmes in India till date have succeeded in providing near-universal household access to electricity (PEG, 2018c). The discourse is now shifting to providing reliable and quality supply as reflected in the Ministry of Power’s (MoP) forthcoming draft distribution perspective plan (PTI, 2019b) to ensure round the clock power to all.

Maharashtra has been early in providing near-universal household access to electricity while Uttar Pradesh joined the ranks only recently. As per the 2011 Census (Census of India, 2011b), about 84% of households in Maharashtra used electricity as a primary source of lighting while this share was only about 37% in Uttar Pradesh. The same is also reflected in the survey sample. The average year of electrification of our sample in Maharashtra is 1994 while that of Uttar Pradesh is about 2006. About 45% of the surveyed households in Uttar Pradesh have been electrified after 2011 (see Figure 4).

Figure 4: Year of electrification for surveyed households



Supply hours, the primary measure of QoS, reported by the surveyed households are observed to be higher in Maharashtra than Uttar Pradesh. The average daily supply hours are about 22 hours in Maharashtra and 15 hours in Uttar Pradesh (see Figure 5). On average, households in semi-urban areas in Maharashtra get about 40 more minutes of electricity supply than their rural counterparts while the number is about 2 hours in Uttar Pradesh. However, there is significant variation across the locations as indicated by a high value of standard deviation in the sample.

The nature of power outages is as important as the total duration of power supply. Frequent interruptions can damage typical residential loads (Kundu, 2016) such as lighting and motors with electronic components. About 42-47% of households in Uttar Pradesh reported power outages to be frequent and unpredictable while the number is lower in Maharashtra at about 26-28% (see Figure 6). The unpredictable nature of power outages makes it difficult for households to confidently plan the use of appliances.

Figure 5: Average daily supply hours reported by surveyed households

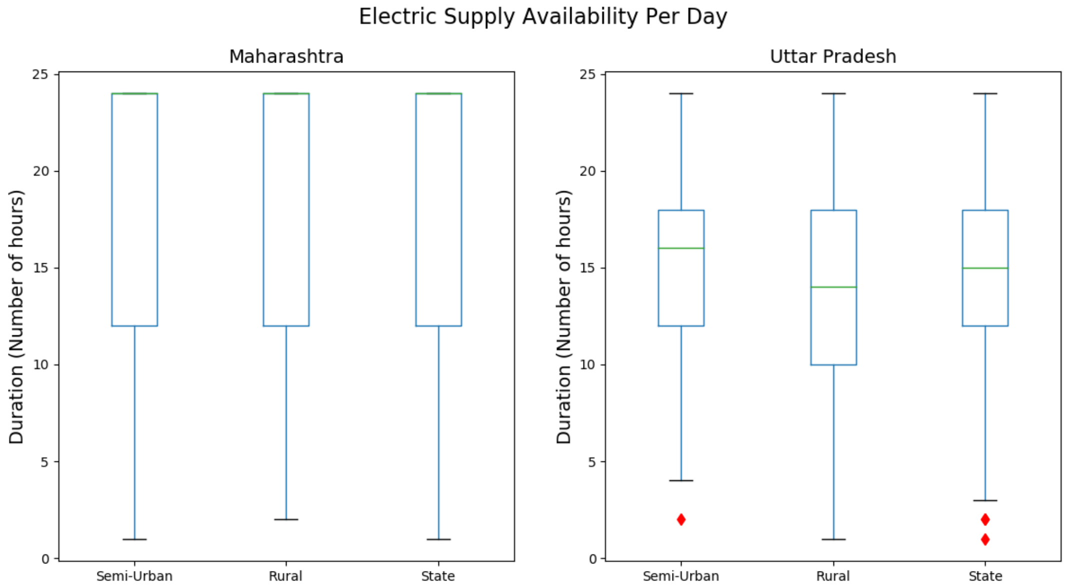
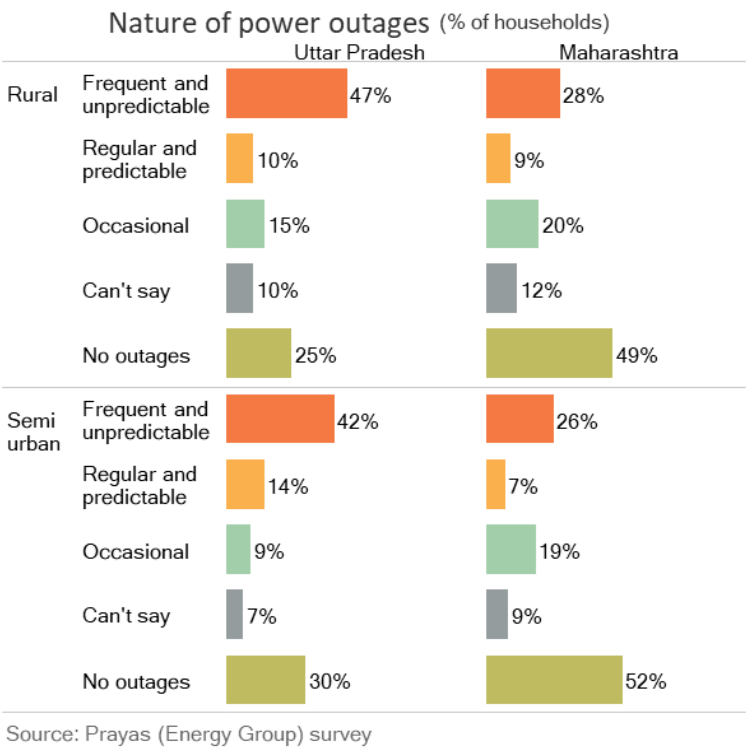


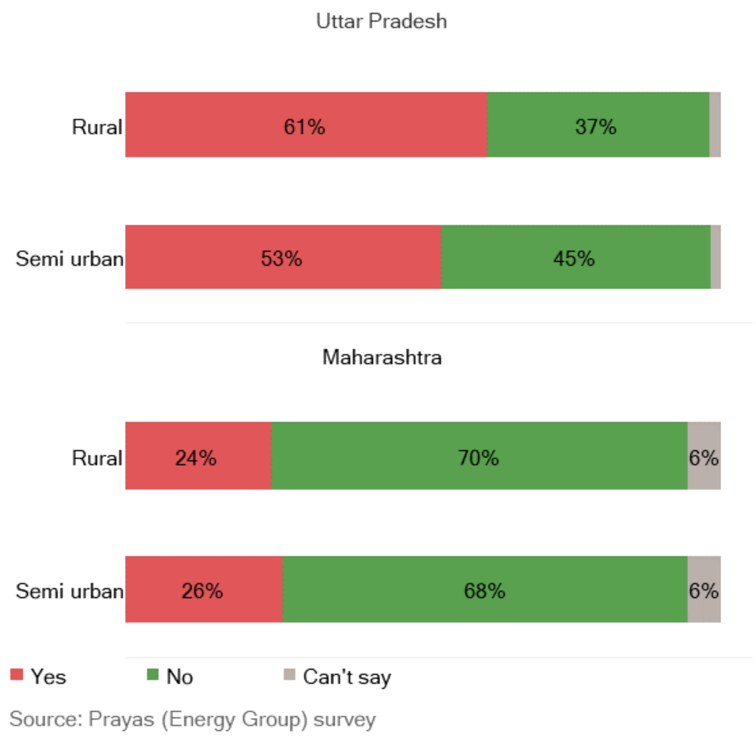
Figure 6: Nature of outages as perceived by surveyed households



Poor supply voltage is another aspect of electricity supply quality which can include number of issues like voltage fluctuation, imbalance, sag and swell. Consumers perceive poor supply voltage mostly as voltage fluctuations. These can damage appliances severely. About 50-60% of the households in UP experienced voltage fluctuations while the number is lower in

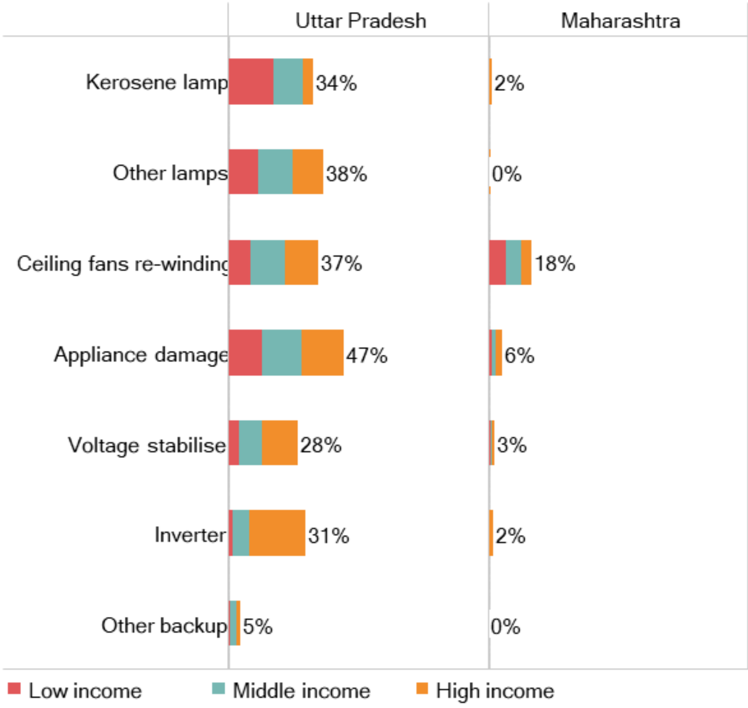
Maharashtra at about 24-26% (see Figure 7). Both semi-urban and rural households in both the states seem to experience voltage fluctuations.

Figure 7: Voltage fluctuations as perceived by surveyed households



QoS issues force households to spend money on buying power-backup options and other alternatives as well as repairing damaged appliances. Poor supply quality in Uttar Pradesh is reflected in higher ownership of alternative lighting options as well as higher instances of appliance damage (see Figure 8). About 34% of all households, including a significant share of low-income category households, still use kerosene lamps as a back-up option. These lamps can cause indoor pollution and accidents. Further, 38% use other emergency lamps such as solar lamps or LED bulbs with integrated batteries. About 47% of the households report some kind of appliance damage from poor supply quality. Some households (28%), mostly from middle income and high income, have bought voltage stabilisers to protect their appliance while about 31% have bought inverters to address the power-cut issue. In Maharashtra, on the other hand, ownership of inverters and stabilisers in surveyed households is less than 5%. Only about 6% of the households report damage to appliances from poor supply quality.

Figure 8: Poor electricity supply effects



Source: Prayas (Energy Group) survey

One of the factors that contribute to the DISCOM's ability to provide reliable and good quality supply is the recovery of revenues from consumers which can be used to strengthen the distribution network and for its periodic maintenance. Accurate and prompt metering & billing (FOR, 2009) can help build consumer trust while also help in detecting theft and tampering thereby improving the billing revenues. In rural Uttar Pradesh about 24% of the surveyed households do not have meters while another 12% report having non-functional meters. The situation is better in semi-urban areas where about 95% of the surveyed households have functional meters. On the billing front, about 82% of the semi-urban households receive a regular electricity bill while that number is only 42% for rural households. In Maharashtra on the other hand about 98% of both semi-urban and rural households are metered and receive regular bills.

QoS issues are reflected in the households' satisfaction levels. Only 54% of the surveyed rural households and 61% of the semi-urban households in Uttar Pradesh are satisfied with their quality of supply while the number is higher in Maharashtra at about 80%. We conducted a logistic regression analysis to examine the relative impact of different indicators of QoS on the households' dissatisfaction levels. In Uttar Pradesh, increase in supply hours and voltage fluctuations are observed to be most statistically significant indicators compared to others. Frequent and unpredictable power cuts are also observed to be significant. In Maharashtra, frequent and unpredictable power cuts are most likely to increase household's dissatisfaction levels. The other statistically significant factor observed in Maharashtra is the number of years since electrification. It is observed that households with more recent connections are more likely to be satisfied with the quality of supply. Detailed analysis in Appendix B.

Although Maharashtra compares better than Uttar Pradesh, the survey shows that QoS issues exist in both states. Measures to improve QoS are necessary to enable households make more meaningful use of electricity. In the survey, we have focused on the household's perception on electricity supply quality since this affects its decision on purchase and use of appliances. We have also been monitoring the actual electricity supply quality at about 400 locations across India since 2015 under the Electricity Supply Monitoring Initiative (ESMI)[4]. Our upcoming report will present a comprehensive analysis on the data collected from the same.

[4] The minute-wise data and analysis reports from all the locations is available publicly on www.watchyourpower.org.

3.2 Lighting

Lighting is the most basic use of electricity in a house. In many low-income and newly electrified households it may be the major or the only use of electricity. Lighting also coincides with the evening peak time use of electricity. Several government/utility programmes in the past have targeted replacement of incandescent bulbs with highly efficient CFLs and LED bulbs. The most recent and also the most successful is the on UJALA programme. Under UJALA, LED bulbs are being made available at a discounted price to consumers by procuring bulbs in bulk quantity and selling them through contracted vendors (PEG, 2017). More than 350 million LED bulbs (MoP, 2019b) have been sold so far under the programme. About 1.4 billion bulbs and tube-lights (ELCOMA, 2019) were manufactured in India in 2018. About 46% of these were LED lighting and 43% were incandescent bulbs with rest being CFLs and fluorescent tube-lights. LED lighting has seen a burgeoning demand while CFL sales have plummeted in recent years. Sales of incandescent bulbs are also dropping but at a much lower rate than that of CFLs.

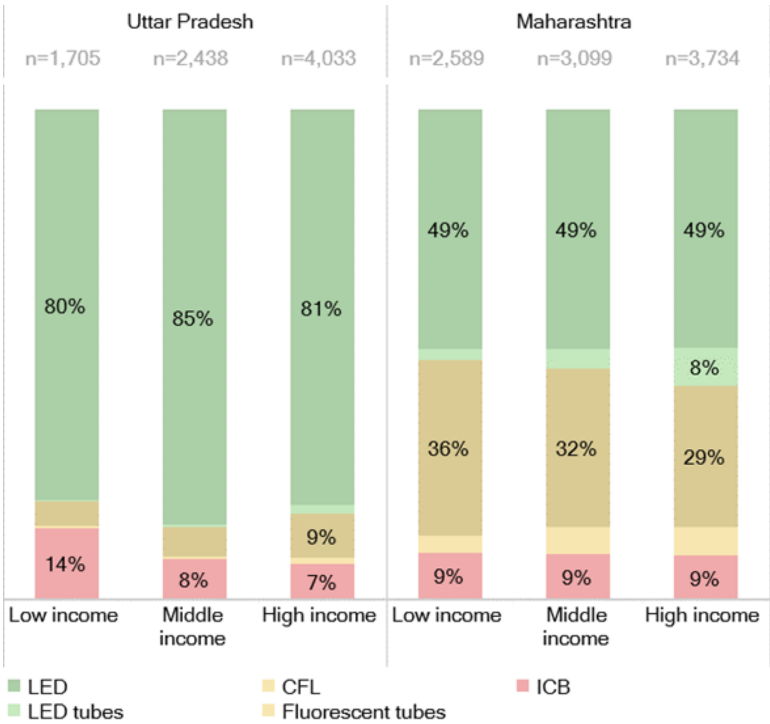
Households in Maharashtra own more bulbs and tube-lights compared to those in Uttar Pradesh (see Table 3). Majority of the households opt for bulbs. Only 5% of the surveyed households in Uttar Pradesh and 40% in Maharashtra use tube-lights and they are mostly high income households in semi-urban areas. As income increases in Maharashtra, a household is more likely to own a tube-light than a bulb as against UP where penetration of tube-lights is not as high.

Table 3: Average number of bulbs and tube-lights in surveyed households

	Average number of bulbs		Average number of tubes	
Income	UP	MH	UP	MH
Low	3.4	4.9	2.3	1.4
Middle	4.8	5.6	1.6	1.5
High	7.7	6.4	2.1	1.8

A fairly high adoption of LED lighting is observed in both Uttar Pradesh and Maharashtra (see Figure 9) in our survey. More than 80% of all the bulbs and tube-lights used in the surveyed households from Uttar Pradesh are LED based. This is observed across all the income categories. About 68% of the surveyed households use only LED bulbs for lighting and these are evenly distributed across all three income categories. Most of the households responded that they are satisfied with the performance of LED lights and will continue using them. In Maharashtra, about 54% of all the bulbs and tube-lights used in the surveyed households are LED lights with some variation across income categories. CFLs form the second most used lighting option (about 27-28%). One possible reason for the lower adoption of LED bulbs in Maharashtra households is due to their early adoption of CFLs, partly due to the government's previous programmes to promote CFLs like Bachat Lamp Yojana (BLY) (MoP, 2010). CFLs last longer than incandescent bulbs and hence households will probably shift to LED bulbs after their in-use CFLs stop working. Most of the surveyed households in Maharashtra responded that they will buy LED bulbs in future. Households in Uttar Pradesh, on the other hand, seem to have leap-frogged from either incandescent bulbs or no-light to LED lights.

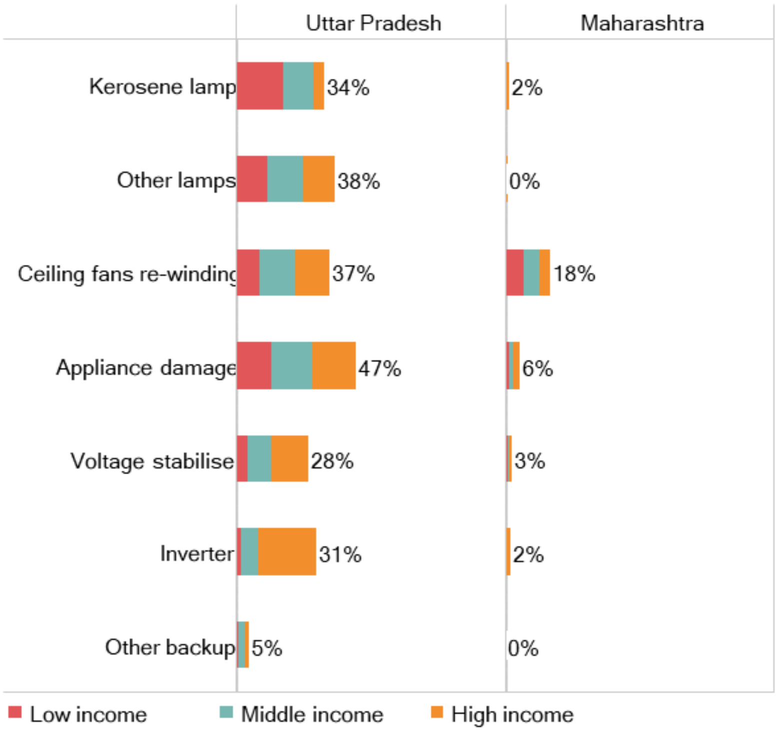
Figure 9: Lighting stock of surveyed households



Source: Prayas (Energy Group) survey

Interestingly, only 12% of the surveyed households in Uttar Pradesh and 17% in Maharashtra reported buying LED bulbs under the UJALA programme. However, the widespread adoption can still be attributed to the programme due to its broader impacts on the lighting industry. Economies of scale enabled by UJALA have drastically reduced the price of LED bulbs sold outside the programme as well. Moreover, the demand for LED bulbs has also spawned a large small-scale industry. There are about 250 registered LED bulbs manufacturing units (Bureau of Indian Standards (BIS)-a) in India, up from a small number in 2014. Hence, there is an abundance of cheap LED bulbs in markets. However, this has also raised concerns about their quality. Bureau of Indian Standards (BIS) mandates all the LED lights sold in India to conform to certain safety and performance standards (BIS). BEE's standards and labeling programme is mandatory for LED lamps. However, compliance with these regulations is lax. A recent survey (Dutta, 2019) of 400 retailers across 8 cities finds that half of the LED bulb brands available in the market do not conform with the BIS standards for safety and performance. In our survey, only 2-3% of the households in both Uttar Pradesh and Maharashtra knew about the star ratings for LED bulbs. Further, majority of the households in both states cited performance as the reason for the purchase of LED bulbs. Only a few households mentioned low price of LED bulbs and reduction in electricity bills due to use of LED bulbs as a reason for their purchase. Hence, it is crucial to ensure the availability of good quality LED bulbs to sustain the on-going market transformation to LED lighting. This will require increased consumer awareness about the star-rating programme for LED bulbs and stricter compliance with the regulations.

Figure 10: Alternative lighting options used by surveyed households



Source: Prayas (Energy Group) survey

The survey also highlights the impact of electricity supply quality on the household behaviour. About 45% of the rural households in Uttar Pradesh still use kerosene lamps as a backup option for lighting which can cause indoor pollution and accidents (see Figure 10). Ownership of LED bulbs integrated with battery and solar lamps is also in the range of 11-14% in both semi-urban and rural households. These options are more expensive than regular LED bulbs but even low income households seem to opt for it. In Maharashtra on the other hand very few households use alternate lighting options possibly because the quality of supply is better than that in Uttar Pradesh.

3.3 Space-Conditioning

India's climate varies substantially across regions and seasons. However, most of the country experiences hot summers which are getting hotter (Ross, Krishnamurti, Pattnaik, & Pai, 2018). About 50 million fans (PTI, 2018), 8 million air-coolers (ET Now, 2018), and 4.5 million air-conditioners (PTI, 2019a) are bought annually. Their sales have grown steadily over the last few years and are expected to increase. However, the household ownership of air-coolers and air-conditioners is still low in India (PEG, 2016). India is one of the few countries to have developed a cooling action plan (PIB, 2019) with a goal to provide sustainable cooling and thermal comfort for all while securing environmental and socio-economic benefits for the society.

Uttar Pradesh is usually hotter than Maharashtra. In 2018, the number of days where the maximum temperature exceeded 40 degrees Celsius was significantly more in the surveyed districts of Uttar Pradesh than in Maharashtra (see Table 4). Although the winters are cold, particularly in Uttar Pradesh, the ownership of electric room heaters is found to be negligible in the surveyed households of both states. Hence, we focus only on the use of electricity by households to seek relief from the heat.

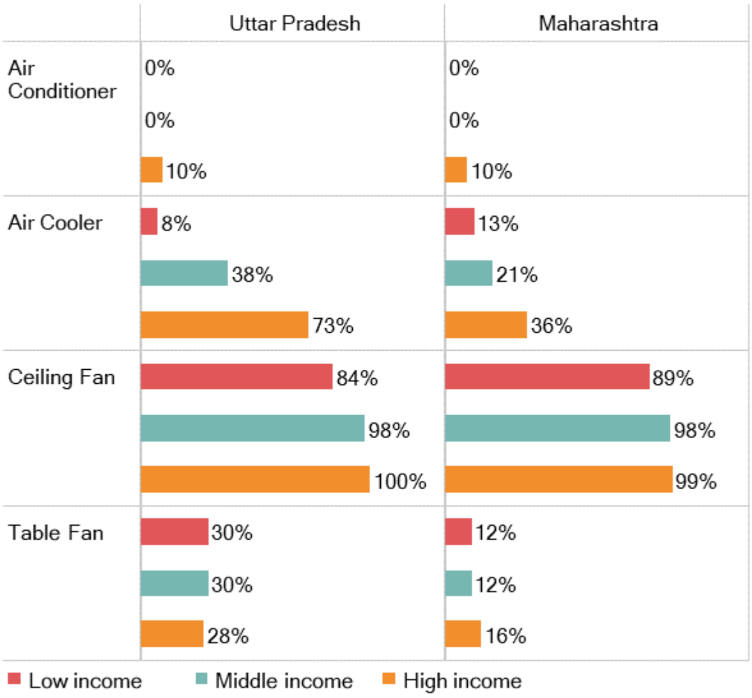
Table 4: Number of days in 2018 with maximum temperature exceeding 40 degrees Celsius

Uttar Pradesh		Maharashtra	
District	Days	District	Days
Gorakhpur	39	Aurangabad	32
Gonda	15	Nagpur	59
Agra	51	Nashik	0
Jhansi	39	Pune	0
Kanpur Dehat	53	Raigad	1

Source: https://openweathermap.org/

Ceiling fans are the most commonly used space-conditioning appliance with more than 90% of the surveyed households in both the states owning them (see Figure 11). There are about 2.6 ceiling fans per household in Uttar Pradesh and 1.7 in Maharashtra.

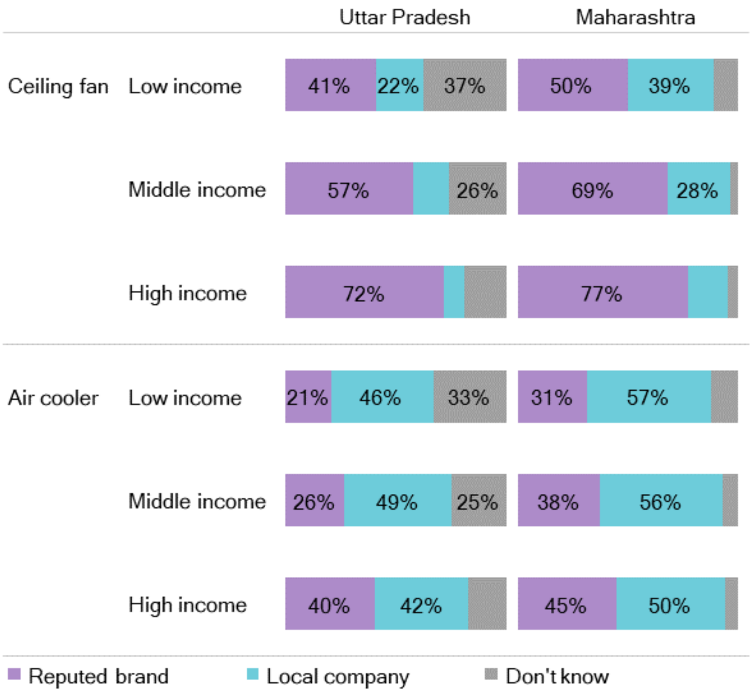
Figure 11: Ownership of space-conditioning appliances in surveyed households



Source: Prayas (Energy Group) survey

The next popular appliance is air-cooler with 40% ownership in Uttar Pradesh and 23% in Maharashtra. Although the ownership is higher in high income households some low- and medium-income households also own air-coolers. Ownership of air-conditioners on the other hand is very low in both states at about 3.5% and mostly in the higher income category. Majority of the air-conditioners are split-type; 84% in Uttar Pradesh and 70% in Maharashtra with the rest being window air-conditioners. The average age of the most used appliance in each category was reported to be 7 years for ceiling fans, 4 for air-coolers, and 2.5 for air-conditioners in Uttar Pradesh and 7, 5, 3 in Maharashtra respectively.

Figure 12: Make of ceiling fans and air-coolers



Source: Prayas (Energy Group) survey

BEE's standards and labelling programme is voluntary for ceiling fans. More than 95% (PEG, 2018a) of the ceiling fans produced in India are not star-rated. About 6% of the surveyed households in Uttar Pradesh and 18% of households in Maharashtra reported having star-rated ceiling fans. BEE recently revised the standards (BEE, 2016) and the new 5-star ceiling fan consumes half as much electricity as compared to a non-star-rated fan. Awareness, affordability, and availability of star-rated ceiling fans must increase to facilitate their wide-scale adoption. BEE can conduct national level campaigns to increase awareness about star-rated fans. BEE can also make the S&L programme mandatory for all the ceiling fans so that inefficient non-star rated fans cannot be sold in India. Energy Efficiency Services Ltd. (EESL)'s UJALA programme (MoP, 2019a) sells 5-star fans at discounted price. EESL can upgrade the programme to sell new 5-star fans which are 30% more efficient than the old 5-star fans. BEE can support the UJALA programme with its own Super-Efficient Equipment Programme (SEEP) (BEE, 2014b) under which time-bound financial incentives were to be provided to manufacturers to cover incremental cost of producing super-efficient fans (the new 5-star fans) over normal fans. This can further bring down the price of these fans and increase their uptake. A similar approach can be taken for air-coolers. Unlike ceiling fans, BEE's standards and labeling programme does not cover air-coolers. The first step would be to include air-coolers in the star-rating programme, and then launch an UJALA kind of programme.

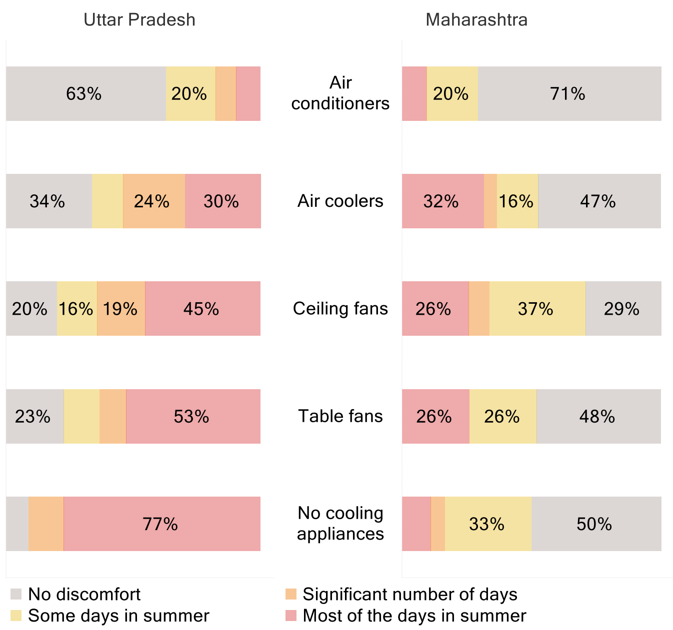
One challenge for the standards and labeling programme for ceiling fans and air-coolers can be the presence of local manufacturers. Some of them may sell cheap, non-standard, and highly inefficient models. BEE can find it difficult to monitor the compliance of these products with the standards. This problem is more pronounced in the case of air-coolers. The share of surveyed households owning local-make air-coolers is much higher than that of ceiling fans (see Figure 12) in both the states. Addressing this issue will be crucial to the success of the star-rating programme for both air-coolers and fans. Another challenge is the re-winding of the motors of the ceiling fans. Re-winding of motor reduces its efficiency thereby increasing the electricity consumption of ceiling fans. About 37% of the households in Uttar Pradesh and 18% in Maharashtra reported re-winding the motors of ceiling fans. We did not ask the reason for re-winding but it can be either due to poor quality of the ceiling fans or poor quality of electricity supply. We did observe that both local and reputed fans have similar shares of re-wound fans.

The ownership of air-conditioners in the surveyed households is low in both the states (see Figure 11). About 6% of air conditioner owning households in Maharashtra and 10% in Uttar Pradesh, own more than one air conditioner. However, some observations can be made about their usage from the survey. BEE'S standards and labeling programme is mandatory for air-conditioners. About 34% of households with air-conditioners in both the states reported owning efficient 4 and 5-star rated models. About 49% of households in Uttar Pradesh and 32% in Maharashtra either did not know about the star-labels or reported owning a non-star rated model indicating a lower awareness about the programme even for the air-conditioners. Households report an average temperature setting of 21 degrees Celsius (σ [5]=

[5]Standard deviation is represented using σ

3.3) in Uttar Pradesh and 22 degrees Celsius (σ = 2.9) in Maharashtra. This indicates that making default setting to 24 degrees Celsius as recommended by BEE recently (BEE, 2018) can nudge consumers to set the temperatures higher and save electricity. On the other hand, the usage of air-conditioners is quite low. In both Maharashtra and Uttar Pradesh, air conditioners are used mostly in the night time, followed by afternoons. The average usage of air-conditioner on a typical summer day is 3.8 hours (σ = 3.0) in Uttar Pradesh and 4.5 hours (σ = 2.6) in Maharashtra. It is quite possible that people set lower temperature in the air-conditioners and then switch it off after the room has been cooled. This also suggests a higher possibility of rebound effect (Irfan & ClimateWire, 2013) where consumers can end up using air-conditioners for longer duration if they become more efficient. However, this needs to be investigated further.

Figure 13 Discomfort in Summer



Source: Prayas (Energy Group) survey

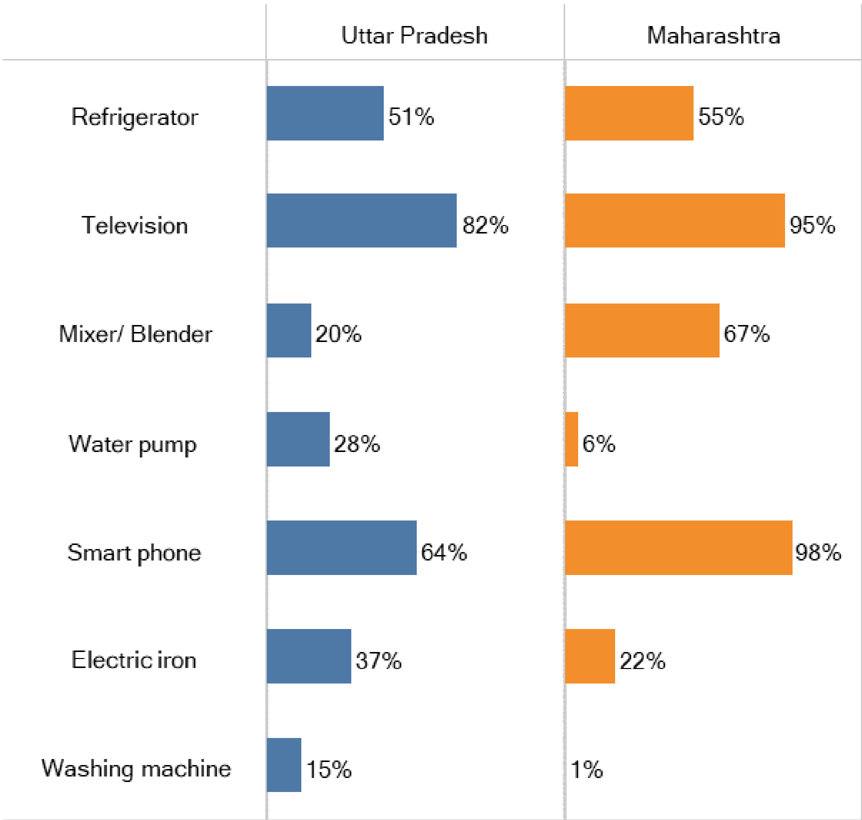
We also asked the households whether they faced any discomfort in summer even after using the appliances they own. About 59% of the surveyed households in Uttar Pradesh and 34% in Maharashtra reported facing discomfort for significant or most of the days in summer. We further segregated the households based on their ownership of space-conditioning appliances and compared their discomfort levels as shown in Figure 13. In the figure, households owning one category of appliances may own all the appliances listed below it which means households owning an air-conditioner may either own air-cooler, ceiling fan and table fan or one of the three and so on. In Uttar Pradesh, the share of households facing discomfort reduces as people move from table fans to air-conditioners. However, the trend is not so clear in Maharashtra. One possible reason maybe the higher intensity of summers in the surveyed districts of Uttar Pradesh.

Interestingly, there are about 10% of households in both states who own an air-conditioner but still face discomfort for most of the days in summer. This may be because of the incorrect sizing of the air-conditioners, limited use of the air-conditioners either because of high electricity bills or frequent power outages or both. We conducted a logistical regression analysis to examine whether discomfort is related to the poor quality of electricity supply. It was found that occurrence of voltage fluctuations is a statistically significant variable in both states that increases the likelihood of feeling discomfort. Interestingly, the number of supply hours is not found to be a statistically significant factor in either of the states. Detailed analysis in Appendix B.

3.4 Other Appliances

Beyond the basic uses of lighting and space-conditioning, people use electricity for a host of appliances which reduce drudgery and improve the quality of life. Appliances such as refrigerators, mixer-blenders, washing machines, electric irons, water pumps and atta chakkis fall into the category of appliances which reduce the toil associated with daily chores. Televisions, smartphones and other entertainment devices also contribute to enhancing a person's living conditions. As the household's income increases, the use of these appliances increases significantly adding to its electricity consumption.

Figure 14: Ownership of kitchen, entertainment, and other appliances



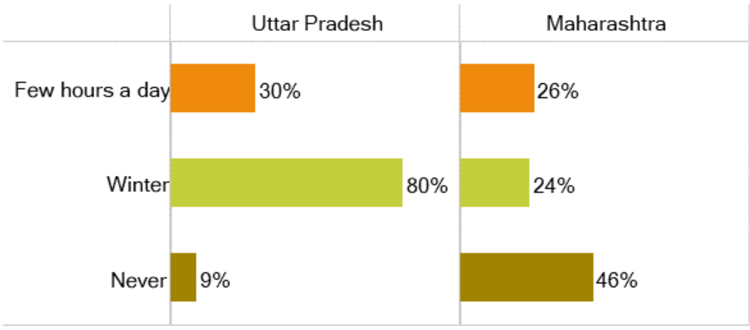
Source: Prayas (Energy Group) survey

3.4.1 Refrigerator

Refrigerator is the most commonly used kitchen appliance. There are two types of refrigerators: frost-free and direct-cool. Frost-free refrigerators are generally larger in size, cost more, consume more electricity, and do not require manual defrosting as compared to direct-cool refrigerators. More than 10 million refrigerators (PEG, 2018a) are sold annually with a significant share of direct-cool refrigerators. BEE's standards and labeling programme is mandatory for both types of refrigerators meaning no refrigerator can be sold in the market without a star label.

About 51% of the surveyed households in Uttar Pradesh and 55% in Maharashtra own a refrigerator (see Figure 14). The ownership is more than 90% in the high income households and about 10% in the low income households in both the states. About 96% of these households in Uttar Pradesh and 89% in Maharashtra own a direct-cool type of refrigerator. This suggests that the ownership of the frost-free refrigerators is limited to the urban and large metro cities. About 50% of the households with a refrigerator either do not know about star-ratings or report owning a non-star-rated refrigerator. The S&L programme was made mandatory for direct-cool refrigerators four years ago, in 2015. The average age of refrigerators in the sample is about 7 years in both states which probably explains the higher share of non-star rated appliances. BEE has periodically revised the star-ratings upward since its launch but the companies have been slow in introducing new 4-star and 5-star models (PEG, 2018a). This is reflected in the survey with only about 31% of surveyed households in Uttar Pradesh and 37% in Maharashtra owning the energy efficient 4 and 5-star models.

Figure 15: Refrigerator switching off behaviour



Source: Prayas (Energy Group) survey

We also observed that about 80% of the surveyed households across all income categories in Uttar Pradesh switch off their refrigerators in winters. The number is low at 24% in Maharashtra. Furthermore, about 30% of the surveyed households in Uttar Pradesh and 26% in Maharashtra switch off their refrigerators every day for a few hours. Households may be trying to reduce their electricity bills by limiting the use of refrigerator. One other reason may also be the social practices around cooking like buying fresh food and cooking just before meal-time which makes the use of refrigerator redundant. Anecdotal evidence from Uttar Pradesh suggests that people in semi-urban and rural areas use refrigerator only for cooling water/beverages in summers. Models on India's residential electricity consumption as well as the calculations to estimate savings from the standard and labeling programme should account for this behavior to avoid over-estimation.

3.4.2 Televisions

India has a large television market with reported sales of about 10 million in 2018 with a large share of LCD/LED TVs (Jinoy Jose, 2018). This is reflected in the high ownership in the surveyed households in both the states: about 82% in Uttar Pradesh and 95% in Maharashtra (see Figure 14). Interestingly, about 65% of the televisions in both the states are the Cathode Ray Tube (CRT) type. This suggests that either the TVs are old and were bought before the fall in the prices of LED TVs or there is a large second-hand market where CRT TVs are sold at prices much lower than that of LED TVs. This can have an impact on the overall efficiency as LED TVs are much more efficient than a CRT TV. The standards and labeling programme is mandatory for TVs. However, about 86% of the households in Uttar Pradesh and 81% in Maharashtra did not know about star-rating programme for TVs. According to BEE, a 5-star TV with screen size 29 inches can consume 30% less than a 1-star TV based on the assumption of 6 hours of daily watching. The surveyed households in Uttar Pradesh reported watching 5 hours of TV a day while the number was 4 hours in Maharashtra.

3.4.3 Mixer/Blender

Mixer-blender is another kitchen appliance whose ownership is high, particularly in Maharashtra. About 60% of households use mixer-blender at least once a week in Maharashtra compared to 20% in Uttar Pradesh. Although its contribution to the household's total electricity consumption is less as it is used for only a few minutes per day, it drastically reduces the drudgery of manual grinding. The ownership and use of mixer-blender may also depend on cooking practices similar to refrigerator. BEE's standards and labeling programme does not cover mixer-blender.

3.4.4 Water pumps

Individual house-level water pump is another most-used appliance, particularly in Uttar Pradesh. About 28% of households in Uttar Pradesh use water pump at least once a week while the number being only 6% in Maharashtra. These water pumps are used from half an hour to one hour per day on average. Normally these pumps consume about 1 horsepower (746 Watts). Daily usage of water-pumps can significantly add to the household's electricity consumption. BEE's standards and labeling programme does not cover water pumps.

3.4.5 Smart phones

Smart-phone ownership is high in both states, about 64% in Uttar Pradesh and 98% in Maharashtra. There are about 2 smart-phones per smart-phone owning household in both the states. Interestingly, about 47% of the households in Uttar Pradesh reported watching any sort of media like TV, news, or movies on mobile while the number was only 2% in Maharashtra. Although the direct impact of smart-phones on household's electricity consumption is small the high ownership of smart-phones may impact the use of electricity and energy in different ways. Increased use of smart-phones for media may impact the use of TVs in the future. High ownership of smart-phones can enable provision of various value-added services from distribution utilities, appliance manufacturers and other technology providers which can change the way how households use energy.

3.5 Appliance purchase behaviour

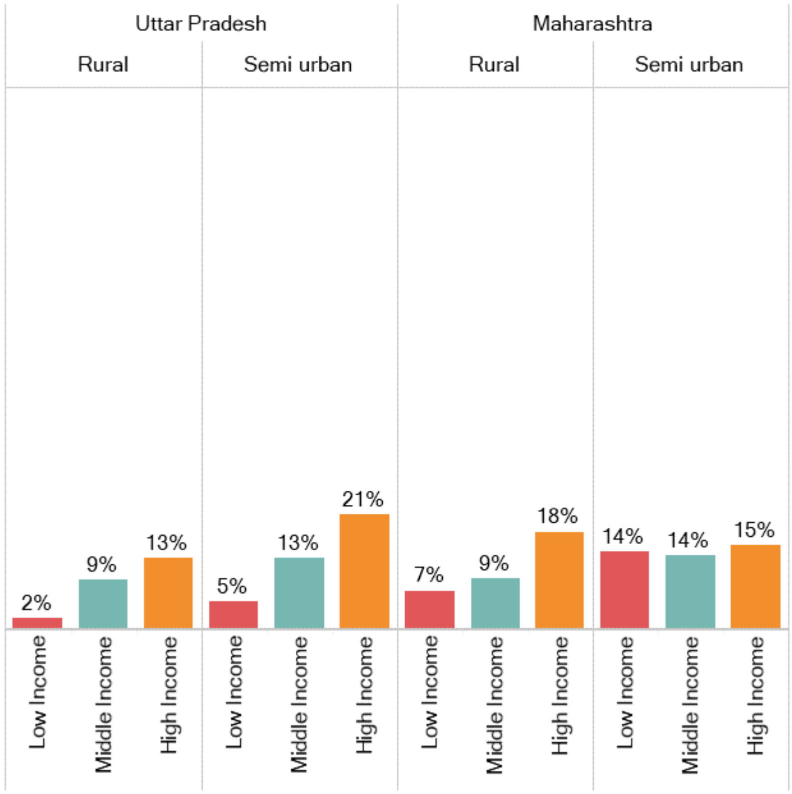
We asked a few questions on the recent purchase/acquisition of appliances made by the surveyed households. Ceiling fan was the most commonly purchased appliance followed by television, refrigerator, and washing machine. Most of the appliances were bought new with a very small share of second-hand appliances. In Uttar Pradesh about 50% of all the newly acquired TVs, refrigerators, and washing machines were 'gifts'. We did not ask the source of the gifts. We can presume that the actual buyer of the gifts may not have necessarily considered energy efficiency as a factor for purchase. This 'gift' behaviour is not observed in Maharashtra.

Table 5: Average price (rounded-off) of ceiling fans, televisions, refrigerator, and washing machine

	MH	UP
Ceiling fan	₹1,570	₹1,470
Television	₹18,520	₹14,350
Refrigerator	₹14,950	₹13,450
Washing machine	₹14,580	₹9,560

The average price paid by the households who bought new appliances is shown for selected appliances in Table 5. Awareness about BEE's standards and labeling programmes is generally low in both the states and across the income categories (see Figure 16). Higher income households are comparatively more aware about the programme.

Figure 16: Awareness about standards and labeling



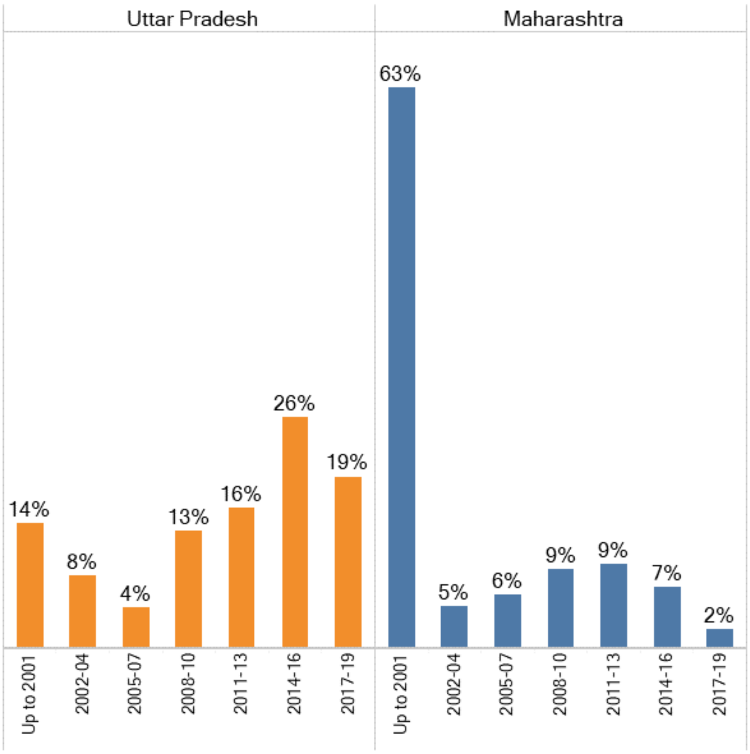
We also asked about the appliances people wished to buy in the near future. Overall, few households expressed the desire to buy one or more new appliances, about 35% in Uttar Pradesh and 17% in Maharashtra. In both states, as incomes increase, more surveyed households express the desire to buy one or more new appliances. 22% of high-income households in Maharashtra and 39% of high-income households in Uttar Pradesh wish to buy one or more new appliance as against only 11% of low-income households in Maharashtra and 33% of low income households in Uttar Pradesh. Refrigerators seem to be the most sought-after appliance with about 17% of households in Uttar Pradesh and 7% in Maharashtra wishing to buy one. This is followed by washing machine, 15% in Uttar Pradesh and 6% in Maharashtra. Only 3-4% households expressed desire of buying an air-conditioner.

3.6 Cooking

Cooking is one of the most basic energy needs in a household. In 2011 (Census of India, 2011c), about 70% of the households in India used solid fuels for cooking. In 2015, indoor air pollution from the use of solid fuels for cooking was estimated to have caused over 1 lakh premature deaths, mostly women and children (Pandey, 2018). Interventions to eliminate the use of solid fuels have ranged from subsidized smokeless chulhas (Hanbar & Karve, 2002) to subsidized LPG connections. The most recent programme Pradhan Mantri UJJWALA Yojana (PMUY) (MoPNG, 2019) has provided about 8 crore free LPG connections to poor households between 2016 and 2019.

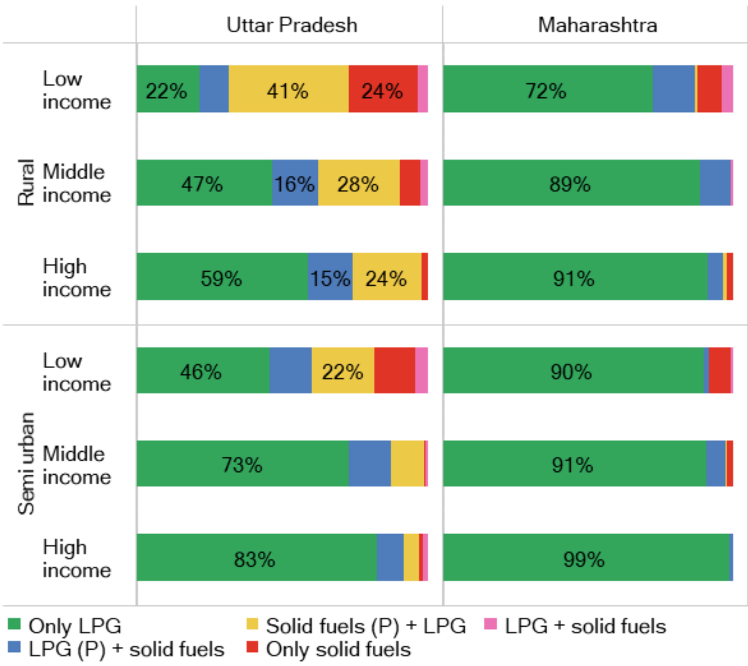
About 91% of the surveyed households in Uttar Pradesh and 96% in Maharashtra have LPG connections. Households in Maharashtra have been using LPG for much longer than those in Uttar Pradesh (see Figure 17). About 19% of the surveyed households in Uttar Pradesh and just about 2% in Maharashtra got LPG connections after 2016 when PMUY was launched. Hence, the share of PMUY beneficiaries in the survey sample is small.

Figure 17: Year of LPG connection for surveyed households



The actual use of LPG connections for cooking is also observed to be high in both states. About 67% of the households in Uttar Pradesh and 95% in Maharashtra use LPG for most of their cooking. However, the use of solid fuels has not completely stopped. Many studies (PEG, 2018b) have reported use of multiple fuels by households mostly constrained by affordability and availability of LPG cylinders. This is also observed in our survey. About 45% of all the surveyed households in Uttar Pradesh and 12% in Maharashtra still use solid fuels for part or all of their cooking. In Uttar Pradesh, about 82% of the households that are using solid fuels already have an LPG connection. In low income rural households, about 41% of the surveyed households use solid fuels for most of their cooking in spite of having an LPG connection (see Figure 18). Another 24% only use solid fuels for cooking. Households in other income categories of Uttar Pradesh have shifted to higher use of LPG. In medium and high income households of semi-urban areas, about 80-90% of households use LPG for most of their cooking. This is comparable to Maharashtra where more than 90% of all the households in all income categories and semi-urban/rural areas use LPG for all or most of their cooking.

Figure 18: Fuels used for cooking in surveyed households



(P): Primary fuel, i.e. used for most cooking
Source: Prayas (Energy Group) survey

Number of LPG cylinder refills is another indicator for the use of LPG for cooking. In Uttar Pradesh, the number varies significantly depending on the stacking of the fuels and whether the household is rural or semi-urban (see Table 6). The average annual refills for households using only LPG for cooking is about 9, twice the number of refills done by households that have LPG connections but still use solid fuels for most of the cooking. Households in semi-urban areas use about a cylinder more than their rural counterparts. These numbers are comparable to those in Maharashtra, where households in both rural and semi-urban areas refill the cylinder about 9 times each year on average, the range being 7 to 9.5. Two points should be noted here. First, households in Uttar Pradesh are larger (6.9 people per household) than those in Maharashtra (4.7 people per household). Second, about 31% of the households in Maharashtra use LPG to heat water for bathing as compared to about 13% in Uttar Pradesh.

We will discuss our findings on water-heating in the following section but the exact attribution of these factors to the actual requirement of LPG in a household, and its use for cooking has been examined using regression analysis which is detailed subsequently.

Table 6: Average cylinder refills per household in Uttar Pradesh in a year[6]

	Rural	Semi-urban
Only LPG	8.9	9.7
LPG (P) + solid fuels	7.8	8.9
Solid fuels (P) + LPG	4.5	5.9

We also asked the households their reasons for the continued use of solid fuels. Households without LPG connections are less than 10% in both the states and are primarily in rural low income category. Half of these households reported LPG being expensive as a reason for not getting a LPG connection while the other half reported non-availability of LPG. About 70% of the households without LPG connection in Uttar Pradesh and 67% in Maharashtra have heard about the PMUY programme. In case of households with LPG connections but not using it for all their cooking, the reasons are somewhat different. Most of these households are in Uttar Pradesh. Around 55% of these households find LPG too expensive to use for all the cooking. About 60% of the households who find LPG too expensive report getting subsidy sometimes or never. Overall about 54% of the surveyed households with LPG connections in Uttar

[6] (P): Primary fuel, i.e. used for most cooking

Pradesh and 85% in Maharashtra report getting regular subsidy payment. Furthermore, about 60% of the households who find LPG too expensive get their solid fuels for free. This further adds to their perception of LPG being expensive. Finally, about 20% of the households with LPG connections but using solid fuels quote reasons other than affordability and availability. The most common other reason is the preference for the taste of food cooked over the chulha.

High ownership of LPG connections in both the states has the potential of eliminating the use of solid fuels for cooking and consequently the adverse health impacts associated with it. It is encouraging to notice that even though more than 60% of surveyed households in Uttar Pradesh got an LPG connection only after 2010, LPG usage in these households is significant except for rural low-income households. At the same time, interventions are needed to push for sustained and exclusive use of LPG in these households. Subsidy quantum and its disbursal can be made more effective as a majority of the households not using LPG for all their cooking still find it expensive. Interventions to address gender, behavioural, and cultural barriers for adoption of LPG are also required. There are other cleaner fuels like electricity, biogas, and piped natural gas that can be used, as LPG may not be preferred or appropriate choice for all the households. We find almost negligible adoption of these in the surveyed households but interventions to facilitate their adoption can be designed and implemented. In Maharashtra, although most of the households have adopted the exclusive use of LPG for cooking, they still use solid fuels for water heating, contributing to the local air pollution.

The average time spent daily on cooking in the surveyed households is 2.5 hours in Uttar Pradesh and 2 hours in Maharashtra. The cooking time does not include the time spent on collecting fuel. In Maharashtra, the average cooking time in rural areas is 12 minutes lesser than that in semi urban. However, in Uttar Pradesh the opposite is true with the average cooking time in rural areas being 6 minutes more than semi urban areas. The average cooking time increases as income increases for both states.

Figure 19: Average daily cooking time in the surveyed households

Cooking time may be affected by a number of factors including the use of fuel, use of different appliances like refrigerator and mixer-blender, number of people in the household and the type of food being cooking. We did a regression analysis to examine this relationship. We find that that use of LPG, use of mixer-blender, and household size to be statistically significant in both the states. However, the direction of co-relation is different for different variables and needs to be examined further. For example, use of LPG as an exclusive fuel reduces the cooking time in Uttar Pradesh whereas it increases in Maharashtra. This may be because use of the solid fuels for cooking in Maharashtra is limited to only few low income households where more time is spent on income generating labour than on cooking. On the other hand, the use of mixer-grinder is observed to be linked with increase in cooking time in both the states contrary to the expectation that mixer grinder should reduce the cooking time. As expected the cooking time increases with increase in household size in both states. (Detailed analysis in Appendix B).

We also examined the relationship between the use of cylinders and various factors using regression analysis. We find age, asset index, and use of LPG for water heating to be statistically significant in both the states. In both the states the number of cylinders increases with the age of the LPG connection and stabilizes around 8-9. A household that uses LPG for water heating uses more LPG cylinders as expected. In Uttar Pradesh, region is also statistically significant with the number of cylinders decreasing with the move from semi-urban areas to rural areas. (Detailed analysis in Appendix B).

3.7 Water heating

Water heating for bathing is an overlooked end-use in India in the current policy context. Interventions (MoPNG, 2019) aimed at eliminating the use of solid fuels have focused primarily on its use for cooking. Solar water heaters received significant policy attention in past but a national programme (MNRE, 2014) subsidizing solar water heaters was discontinued in 2014. Bureau of Energy Efficiency (BEE), on the other hand, does have a mandatory standards and labeling (S&L) programme (BEE, 2014a) for storage type electric water heaters.

Winters are usually colder in Uttar Pradesh than in Maharashtra. However, only 34% of the surveyed households in Uttar Pradesh use hot water for bathing compared to 92% in Maharashtra. Furthermore, households in Uttar Pradesh which use hot water for bathing do so only for 2 months on average as compared to 6 months in Maharashtra. Several factors may be behind the low use of hot water for bathing in Uttar Pradesh. Income is possibly one of the reasons, with the share of households using hot water for bathing increasing from about 25% in low income households to about 50% in high income households. Social practices may also play a part. Anecdotal evidence suggests that people use warm groundwater for bathing in winters. However, there is a possibility that as incomes rise and social practices change, there is a rise in use of energy for heating water. This needs to be examined further.

Figure 20: Fuels used for water heating in surveyed households

Source: Prayas (Energy Group) survey

Households that already use hot water for bathing use different fuels. Use of solid fuels is quite common in both states (see Figure 20). About 35% of the surveyed households using hot water in Uttar Pradesh and 52% in Maharashtra use solid fuels. Interestingly, about 37% of these households in Uttar Pradesh and 91% in Maharashtra using solid fuels for heating water use LPG for most of their cooking. This suggests the need for carefully designed interventions to move people away from using solid fuels for water heating. Use of solid fuel boilers or open air chulhas placed in courtyards is quite common in households in Maharashtra. This may not result in indoor household pollution but can contribute to the local air-pollution. LPG is the next commonly used fuel for water heating, particularly in semi-urban areas. About 39% of the surveyed households using hot water in Uttar Pradesh and 33% in Maharashtra use LPG for heating water. Households using LPG for water heating typically use 2 cylinders more than those who do not in Uttar Pradesh and 0.7 in Maharashtra. Only about 19% in Uttar Pradesh and 7% in Maharashtra use an LPG instant water-heater. Others use an LPG stove which most probably is the same on which the food is cooked.

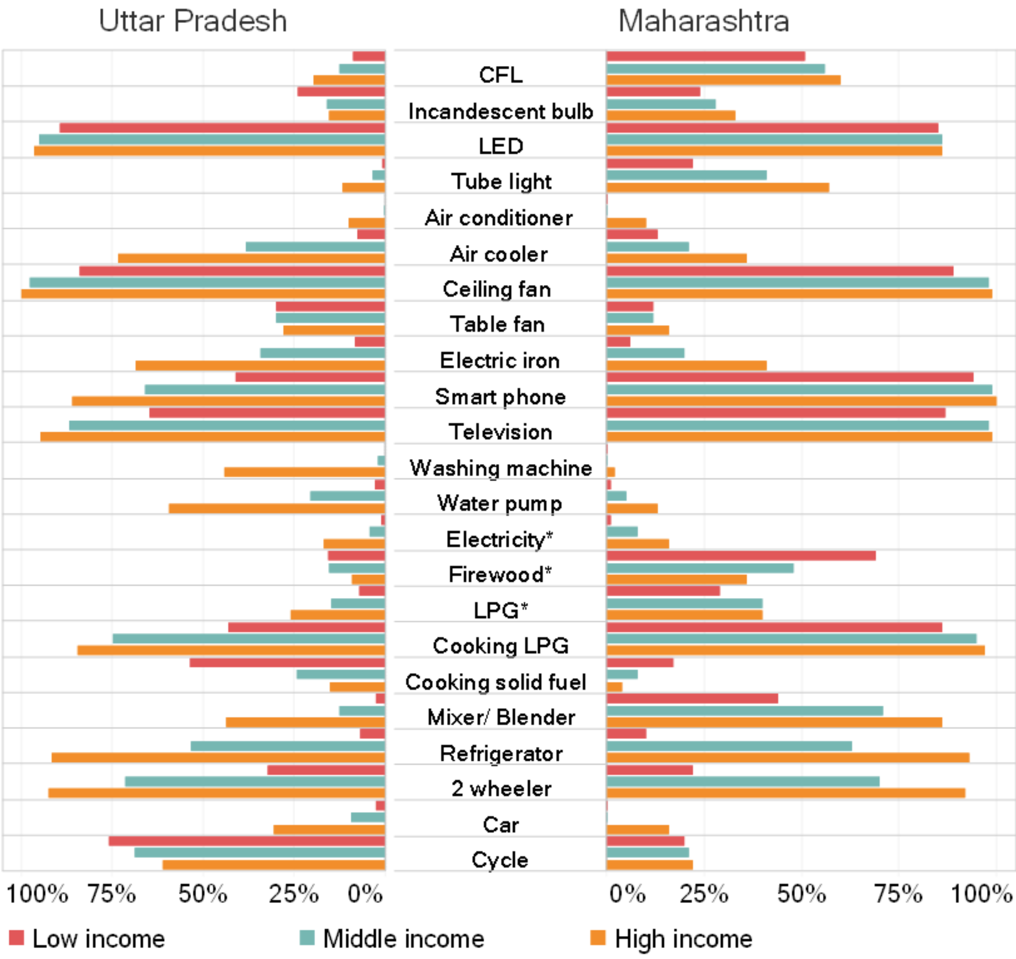
Few households use electricity for water heating, about 19% of the households using hot water in Uttar Pradesh and 8% in Maharashtra. About 92% of the households in Uttar Pradesh and 82% in Maharashtra using electricity for water heating use an immersion rod which is prone to electric shocks and fire accidents. Use of solar water heaters is almost negligible in both states. Households do not switch between fuels for water heating like they do for cooking.

Water heating, if used, contributes significantly to the total household energy consumption. The common use of solid fuels can result in indoor as well as local air-pollution with consequent adverse health impacts. Interventions focused on eliminating the use of solid fuels for cooking may not work for water heating. A careful evaluation of alternatives like electricity, LPG, or solar water heaters is needed before designing interventions to push for their adoption.

3.8 End-use model

An end-use model is useful to estimate the share of individual end-uses in the household's total energy consumption. In this section we describe the results of such an end-use model which we developed to estimate the energy consumption of the surveyed households. In this model, we first estimate the energy consumption of individual end-uses at the household level based on the survey responses on appliance ownership, efficiency levels, and usage patterns from that household. These responses are combined with appropriate assumptions wherever necessary. (see Figure 21) summarize the different appliances and fuels used by the surveyed households in both the states according to income categories.

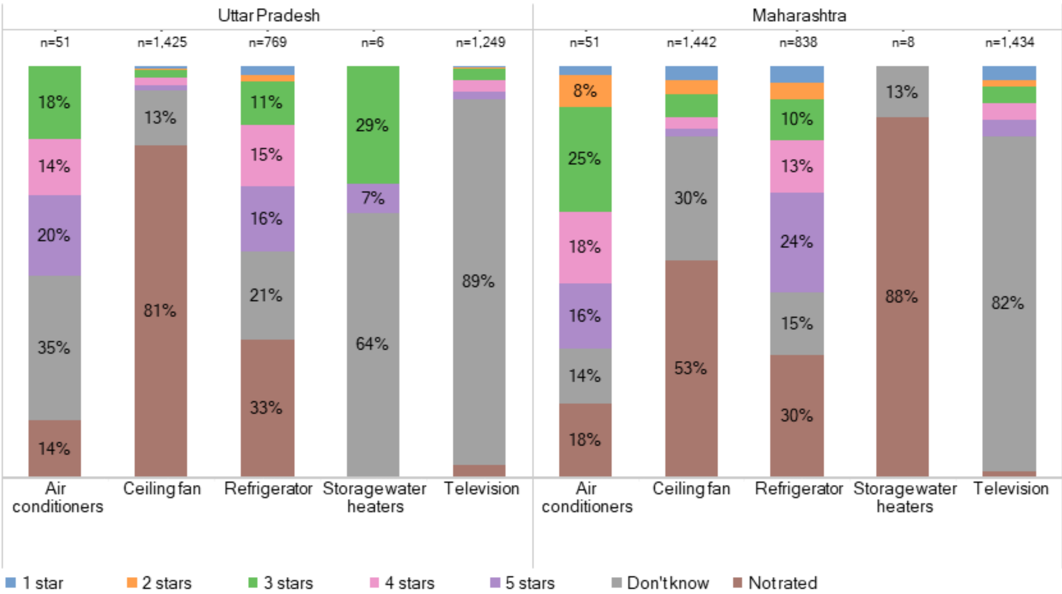
Figure 21: Appliance ownership and fuel use in surveyed households across income levels



Source: Prayas (Energy Group) survey * used for heating water for bathing

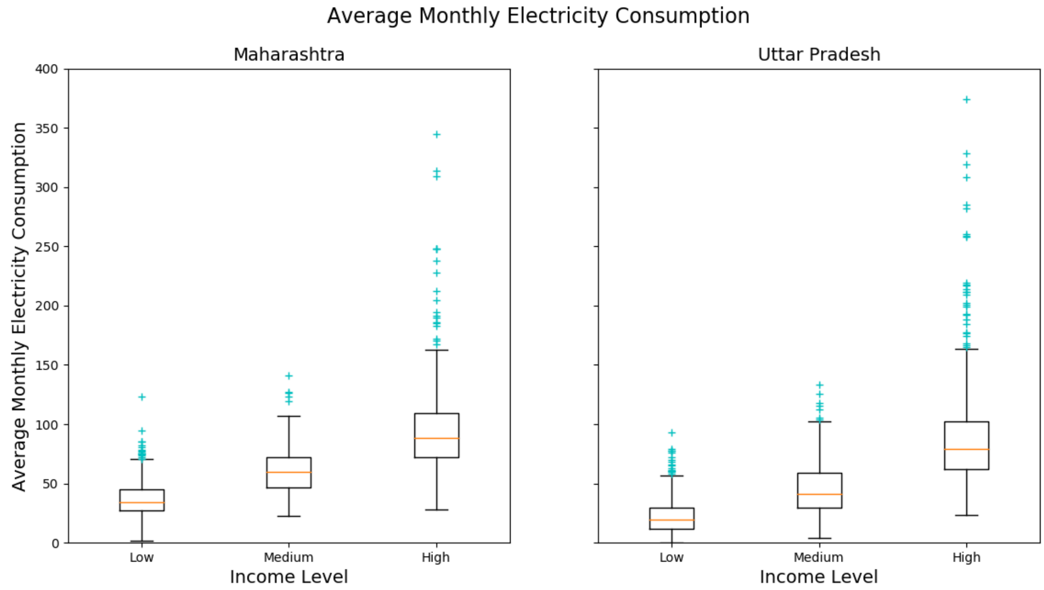
The individual end-use consumption estimates are aggregated to arrive at the total energy consumption at the household level. Finally, the individual end-use level energy consumption and the total energy consumption of all the households are summed up to calculate the total energy consumption of all the households and the share of each end-use in the total energy consumption. Furthermore, we also calculate these values for different income categories and semi-urban/rural regions to examine its variation. Figure 22 summarizes the share of different star-rated appliances owned by the households. All the assumptions used for the end-use model are mentioned in Appendix A.

Figure 22: Share of star-rated appliances in surveyed households



The average monthly electricity consumption of the surveyed households is estimated to be about 52 kWh in Uttar Pradesh and about 66 kWh in Maharashtra according to the end-use model. This varies with income as can be seen in Figure 23. In each income category, semi-urban households consume slightly higher than the rural households. Low income households in rural Uttar Pradesh consume about 22 kWh per month on average compared to about 36 kWh by their counterparts in Maharashtra. On the higher end, the difference between the two states is marginally less with high income semi-urban households consuming about 89 kWh in Uttar Pradesh and about 102 kWh in Maharashtra on average. The consumption varies significantly within an income category as shown by the range bands. However, overall, the electricity consumption remains low with only about 12% of the total 3000 households surveyed in both states consuming more than 100 kWh per month on average. It has to be noted that the monthly consumption has been averaged over a year. Households consume more than average in the summer months due to increased use of space-conditioning appliances in summer.

Figure 23: Average monthly household electricity consumption of surveyed households

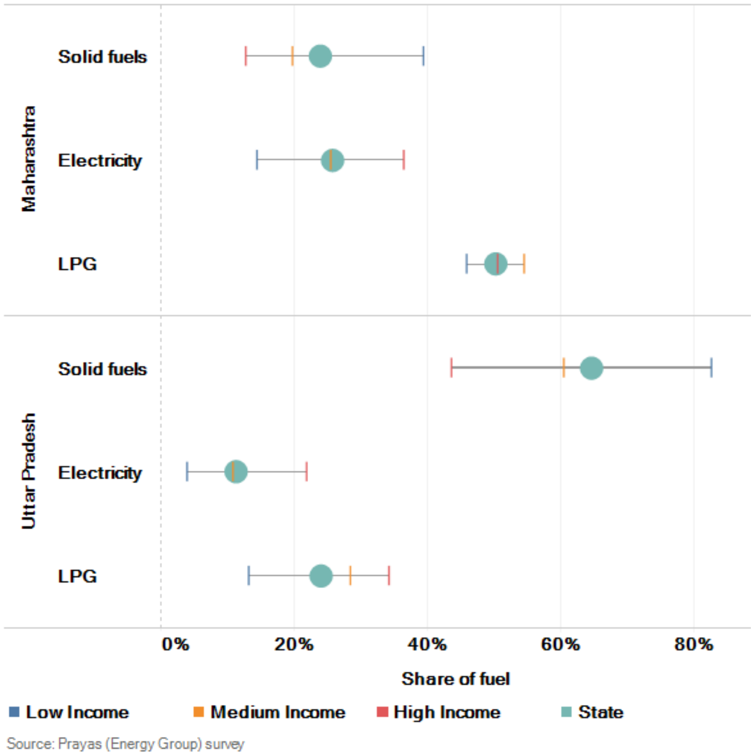


Share of individual end-uses in the total annual electricity consumption of all the surveyed households is shown in Figure 24. Space conditioning appliances contribute the most, about 47% in Uttar Pradesh and 44% in Maharashtra. Ceiling fan is the highest contributing appliance in both the states, 31% in Uttar Pradesh and 35% in Maharashtra. Air-coolers take up about 9% of the total in Uttar Pradesh where its ownership is higher. Air-conditioners have a small share of the total electricity consumption of the surveyed households due to their low ownership. However, in households owning air-conditioners, their share is about 30-36% of the total electricity consumption. Refrigeration is the next highest electricity consuming end-use with its share of about 20% of the total in both states. In households owning refrigerators, they contribute to about 26-28% of the total electricity consumption. Lighting contributes to 14% of the total in Uttar Pradesh and 17% in Maharashtra. Higher adoption of LED bulbs in Uttar Pradesh has resulted in lower share of lighting in the total electricity consumption. Electric water heaters, similar to air-conditioners, contribute just 1-3% to the total electricity consumption. However, in households owning them, their share is about 24% in Maharashtra and 9% in Uttar Pradesh. Households in Maharashtra use water heaters for more months than those in Uttar Pradesh resulting in their higher share.

Figure 24: Share of end-uses in total annual electricity consumption of surveyed households

A household's total energy consumption includes the use of electricity as well as use of LPG and solid fuels for cooking and water heating. Solid fuels mostly include firewood, agricultural residue, and cow-dung cakes. The use of other fuels like coal, charcoal, and kerosene is negligible in the surveyed households. Fuel-wise share of the total energy consumption is shown in Figure 25. As seen, electricity is about 11% of the total energy consumption of the surveyed households in Uttar Pradesh and about 25% in Maharashtra. The share is higher in semi-urban and higher income households. Higher adoption of LPG is reflected in its higher share in both the states. Solid fuels still have a higher share in the energy use due to their continued use for part-cooking in Uttar Pradesh and for water-heating in Maharashtra. Chulhas have an abysmal efficiency of 14% in converting the energy of solid fuels to useful energy thus leading to the disproportionate higher share of solid fuels in the final energy mix, especially in Uttar Pradesh.

Figure 25: Fuel-wise share of total annual energy consumption in surveyed households



The relative share of end-uses in the total household energy consumption is useful to assess the adoption of different technologies and fuels for the use of energy in households. It is also useful to identify end-uses which can be prioritized for energy efficiency interventions. However, it has to be noted that these estimates are based on the reported usage patterns of the households which may not accurately capture the actual consumption. Our forthcoming study is examining the actual usage patterns of electricity in a smaller sample of households measured using advanced IoT based metering systems. Summary monthly observations from the study are being updated on eMARC website.[7]

[7] http://emarc.watchyourpower.org/

4 Conclusion

The residential energy consumption survey of 3000 semi-urban and rural households of Uttar Pradesh and Maharashtra gives several insights that can inform policy decisions. Energy consumption patterns of households are observed to vary significantly with income and location. It is also observed that energy consumption in households is restricted by reliability in electricity supply, affordability of appliances, and affordability and accessibility to clean cooking fuels. Quality of electricity supply and service needs improvement in both the states but more so in Uttar Pradesh. Quite a few households in Uttar Pradesh spend money on voltage stabilisers, inverters, and back-up lighting options compared to Maharashtra.

Households in Uttar Pradesh seemed to have leap-frogged to LED lighting while those in Maharashtra seem to be gradually transitioning from CFLs to LED lighting. The focus now needs to be on ensuring the availability of good quality LED bulbs to sustain this on-going market transformation. Space conditioning is the largest contributor to the total electricity consumption of all the households. Ceiling fans and air-coolers are the most commonly used followed by a much smaller share of air-conditioners. Higher levels of discomfort in the households coupled with the trend of increasing temperatures suggest a potential demand for all the space-conditioning appliances. Interventions are required to ensure that these appliances are energy efficient to meet the cooling needs in a sustainable and affordable manner. A sizeable share of local-make companies for ceiling fans and air-coolers can pose a challenge for these interventions.

Beyond the basic appliances, significant variation is observed between Maharashtra and Uttar Pradesh. Ownership of television, refrigerators, mixer-blenders, and smart-phones is higher in Maharashtra. People in Uttar Pradesh also tend to switch off their refrigerators in winter suggesting a much lower use than that in Maharashtra. Awareness of the standards and labeling programme is generally low among all the households in both the states across income categories. It is particularly low for appliances like ceiling fans, televisions, and LED lamps.

Energy for cooking remains one of the most important requirements of households and its demand continues to be met using multiple sources of fuels. Majority of the households have LPG connections in both the states. However, quite a few households still use solid fuels for part or most of their cooking, particularly in Uttar Pradesh. Majority of these households find LPG to be expensive while some prefer the taste of food cooked over fire to shift to LPG for all of their cooking. Furthermore, it is observed, particularly in Maharashtra, that people who have shifted to LPG for cooking still use solid fuels for water heating causing local area air-pollution. Interventions, both economic and behavioural, are needed to push for sustained and exclusive use of LPG or other clean alternatives to eliminate the use of solid fuels for cooking and water heating.

These insights highlight the value of a detailed residential energy consumption survey (RECS). Periodically collecting such information which is representative at both national and sub-national level is crucial for informing and evaluating policies aimed at managing the rapidly changing household energy demand in India. A number of countries like the United States, United Kingdom, several EU countries, China, Indonesia, Thailand and others conduct such surveys on periodic basis. This is also one of the key recommendations of the sub-group on building sector for demand side energy data constituted by NITI Aayog. The newly formed National Statistical Office (NSO) which includes the National Sample Survey Organization (NSSO) can periodically conduct this survey similar to its other large scale surveys on household expenditure, housing conditions, health and other aspects at household level.

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6 Appendices

Appendix A : End-use model method & assumptions

As mentioned earlier, we estimate the energy consumption for individual end-uses at the household level. The individual end-use consumption estimates are aggregated to arrive at the total energy consumption at the household level. Finally, the individual end-use level energy consumption and the total energy consumption of all the households are summed up to calculate the total energy consumption of all the households and the share of each end-use in the total energy consumption. In this Annexure, we describe the method and assumptions used to estimate the energy consumption of key end uses at the household level.

A. 1 Lighting

$$\mathbf{E\_lighting_i = NR_i * NL * WL_i * HL_i * DL}$$

Where

- E_lighting_i = Annual electricity consumed in kWh by lighting in household i
- NR_i - number of rooms in the household i. Input from survey
- NL = average number of lights and bulbs per room from survey. This number is 1.5 for Uttar Pradesh and 2 for Maharashtra
- WL_i = Weighted input power (kW) of all the lighting options in the household i. This is estimated using the number of each lighting option with the household i from the survey and wattage assumed for each lighting option as follows. 1kW = 1/1000 W.

Lighting Source	Power (W)
Incandescent bulb	60
CFL	15
LED bulb	9
Fluorescent tube-light	36
LED tube-light	20

- HL_i = Hours of usage per day for household i from the survey. We asked the number of hours lights are used during day time (6 am to 6 pm) and night time (6 pm to 6 am). HL_i is the sum of both. Missing values have been populated with the average values for the state.
- DL = Average number of days in a year the lights are used in house i to discount for travel and other reasons of non-use. This number is assumed to be 335 for both Uttar Pradesh and Maharashtra.

A. 2 Ceiling fans & Table fans

$$\mathbf{E\_ceiling\text{-}fans_i =}$$

$$\mathbf{WCF_i * NM\_summ_i *(NCF\_summ\_1_i * NH\_summ\_1_i + NCF\_summ\_2_i * NH\_summr\_2_i)}$$

$$\mathbf{+ WCF_i * NM\_nonsumm_i *(NCF\_nonsumm\_1_i * NH\_nonsumm\_1_i + NCF\_nonsumm\_2_i * NH\_nonsumm\_2_i)}$$

Where

- E_ceiling-fans_i = Annual electricity consumed in kWh by ceiling-fans in household i
- WCF_i = Input power (kW) of ceiling fans in the household i. For non star rated fans, this value is assumed to be 75W and for star-rated fans this value is assumed to be 60W. 1kW = 1/1000 W.
- NM_… = Number of months for which ceiling fans are used in summer (summ) and non-summer (nonsumm) by household i. Input from survey.
- NCF_… = Number of ceiling fans used in summer (summ) and non-summer (non-summ) by household i. Category 1 denotes ceiling fans used for more than 8 hours and category 2 denotes ceiling fans used for less than 8 hours. Input from survey.

- NH_… = Number of hours the ceiling fans are used in summer (summ) and non-summer (non-summ) by household i. Following assumptions are made

	Summer (hours/day)	Non-summer (hours/day)
Fans used for more than 8 hours	15	8
Fans used for less than 8 hours	4	2

Similar approach is adopted to estimate annual electricity consumption of table fans. Input power of table fans is assumed to be 55 W

A. 3 Air-coolers

$$\mathbf{E\_air\text{-}coolers_i = WA_i * NA_i * (NM\_summ_i * NH\_summ_i + NM\_nonsumm_i * NH\_nonsumm_i)}$$

Where

- E_air-coolers_i = Annual electricity consumed in kWh by air-coolers in household i
- WA_i = Input power (kW) for air-coolers. Air-coolers are usually customized. We take 170 W as input power, average of standard air-coolers available in the market for 30 litres. 1kW = 1/1000 W
- NA_i = number of air-coolers used by household i. Input from survey
- NM_.. = Number of months air-cooler(s) are used by household i in summer (summ) and non-summer (nonsumm). Input from survey.
- NH_.. = Number of hours for which air-cooler(s) are used by household i. Input from survey

A. 4 Air-conditioners

$$\mathbf{E\_air\text{-}conditioners_i = WAC_i * NAC_i * (NM\_summ_i * NH\_summ_i + NM\_nonsumm_i * NH\_nonsumm_i)}$$

Where

- E_air-conditioners_i = Annual electricity consumed in kWh by air-conditioners in household i
- WA_i = Input power (kW) for air-conditioners. This value is estimated based on three parameters: type of AC (window/split), year of purchase, and star rating. BEE's schedule for star-ratings for different years since 2010 is used for the purpose. All the three parameters are inputs from the survey.
- NA_i = number of air-conditioners used by household i. Input from survey
- NM_.. = Number of months air-conditioner (s) are used by household i in summer (summ) and non-summer (nonsumm). Input from survey.
- NH_.. = Number of hours for which air-conditioner(s) are used by household i. Input from survey

A. 5 Refrigerators

$$\mathbf{E\_refrigerators_i = NR_i \ * (Adj\_Sto\_Vol_i * Constant\_1_i + Constant\_2_i) * Correction\ factor_i}$$

Where

- E_refrigerators_i = Annual electricity consumed in kWh by refrigerators in household i
- NR_i = Number of refrigerators in the household i. Input from survey
- Adj_Sto_Vol_i = Adjusted storage volume of the refrigerator in the household i. This is as per the formula prescribed by the BEE in its schedule for star rating.
    - Adj_Sto_vol = Fresh_food_storage_vol + Constant * Freezer_storage_vol. Constant is 1.31 for Direct-cool refrigerator and 1.62 for Frost-free refrigerator.
    - Storage volume is assumed to be about 85% of the gross volume. Further the total storage volume is assumed to be distributed into 80% for fresh-food and 20% for freezer. These values are based on average of the most popular models available.
    - Gross volume is assumed based on the input from the survey. Households were asked to mention whether the refrigerator was small, medium, or large. Following assumptions are made about gross volume based from inputs.

Option	Gross Volume (litres)
Small	180
Medium	260
Large	500
Don’t know	190

- Constant_1_i and Constant_2_i for the refrigerator owned by the household i are taken from the BEE schedule of star-rating from the schedule since 2010. Constants are based on three parameters: type of refrigerator (direct-cool/frost-free), year of purchase, and star rating. All the three parameters are inputs from the survey.
- Correction factor: The final estimated electricity consumption of refrigerators is corrected for the switching-off behavior. Following values are used corresponding to the input from the survey.

Switching-off behaviour from survey	Correction factor
Daily	90% (assuming 2.5 hours switch off daily)
Winter	67% (assuming 4 months switch-off)
Both	60% (combining above two)

A. 6 Televisions

$$\mathbf{E\_televisions_i = Constant\_1_i * Area\_screen_i + Constant\_2_i}$$

Where

- E_televisions_i = Annual electricity consumed in kWh by televisions in household i
- Area_screen_i = Area of the screen in sq.inches. This is estimated based on the input from the survey on the screen size of the TV which is the diagonal of the screen and commonly used parameter. This is given in table below. An aspect ratio of 16:9 is assumed for LCD-LED backlit TVs and 4:3 for CRT TVs

Size from survey	Assumed Size
Upto 30 inches	21
31 to 40 inches	32
41 to 49 inches	46

50 and above	55
Don’t know	21

.

- Constant_1_i and Constant_2_i are constants taken from BEE schedules for Televisions. Constant_1_i is originally estimated in the schedule assuming usage hours of 6 per day. We revise it for each household depending on the actual reported usage hours. Constants depend on three parameters: type of TV (CRT/LCD-LED), year of purchase, and star rating. Type and star-rating is input from the survey. Year of purchase was not asked in the survey. We have assumed 2016 for all the televisions. This makes the estimates conservative as BEE has upgraded schedules periodically.

A. 7 Cooking

Three methods are used to estimate the annual energy consumption for cooking by the households depending on the type of fuel used.

A.7.1 *Households using only LPG*

$$\mathbf{E\_cooking_i = (NC_i * EC * Eff\_stove - NUH) / Eff\_stove}$$

Where

- E_cooking_i = Annual energy consumed in kWh for cooking by household i. The choice of units is to enable a comparison with electrical energy consumed by a household.
- NC_i = number of cylinders used in a year by household i. Input from survey
- EC = Energy content of a cylinder in kWh = 179 kWh. This is estimated assuming 14.2 kg cylinder and Calorific value of LPG as 45 MJ/kg. 1 MJ = 0.27778 kWh.
- Eff_stove = 55%, average value of most commonly used LPG stoves
- NUH = Normative useful heat required for water-heating per capita per day in kWh. Explained in the next section on water heating.

A.7.2 *Households using only solid-fuels for cooking*

$$\textbf{E\_cooking}_i = \textbf{NP}_i * \textbf{NUH} * \textbf{NDY} / \textbf{Eff\_chulha}$$

Where

- E_cooking_i = Annual energy consumed in kWh for cooking by household i
- NP_i = Number of persons in household i. Input from the survey.
- NUH = Normative useful heat required for cooking per capita per day in kWh. This is assumed to be 2.2 MJ/day based on literature survey[8]. 1 MJ = 0.27778 kWh
- NDY = Number of days in a year cooking is done at home. Assumed to be 365.
- Eff_chulha = Efficiency of chulha. Assumed to be 14%

A.7.3 *Households using both solid-fuels and LPG for cooking*

- Normative useful heat required for cooking in the households is estimated from the number of persons in a household, normative useful heat per capita and number of days.
- Useful heat from the LPG cylinders used for cooking is computed as NC_i * EC * Eff_stove. Details of variable are above.
- If the calculated useful heat from LPG cylinders is less than the normative useful heat then the balance is assumed to be drawn from the solid fuels.

A. 8 Water heating

Two methods are used to estimate the annual energy consumption for water-heating by the households depending on the type of fuel used.

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[8] van Ruijven, Bas J. & van Vuuren, Detlef P. & de Vries, Bert J.M. & Isaac, Morna & van der Sluijs, Jeroen P. & Lucas, Paul L. & Balachandra, P., 2011. "Model projections for household energy use in India," Energy Policy, Elsevier, vol. 39(12), pages 7747-7761.

A.8.1 *Household using electricity*

$$E\_water\text{-}heating_i = WW_i * NM_i * 30 * NH_i$$

Where

- $E\_water\text{-}heating_i$ = Annual electricity consumption in kWh by household i for water heating
- WW_i = Input power of the electrical equipment used for water heating (kW). Following assumptions are made based on input from the survey. 1kW = 1/1000 W

Water-heating equipment	Input Power (W)
Immersion rod	1250
Storage water heaters	2000
Instant water heaters	3000

- NM_i = Number of months water heaters are used by the household i. Input from the survey
- NH_i = Number of hours for which the electrical equipment is used. This is assumed to be 1 hour per day in the absence of reliable inputs from the survey.

A.8.2 *Households using LPG or Solid-fuel*

$$E\_cooking_i = NP_i * NUH * NM * NDM / Eff\_fuel$$

Where

- E_water-heating_i = Annual electricity consumption in kWh by household i for water heating
- NP_i = Number of persons in household i. Input from the survey. It is assumed that all the members of household use hot water.
- NUH = Normative useful heat required for water-heating per capita per day in kWh. This is estimated as follows

- Energy required to heat 1 kg of water from 25 degree celsius to 60 degree Celsius is calculated using m * c_p * delta_T. Here m is 1 kg, c_p is specific heat of water 4.186 kJ/°C/Kg and and delta_T is the temperature difference. 1 MJ = 0.27778 kWh
- It is assumed about 3 litres of hot water is required per person per day. This is about a fifth of a standard 15 litre bucket.
- NUH is estimated at 0.122 kWh/day/capita

- NM = Number of months hot water is used by the household i. This is assumed to be 6 months in Maharashtra and 2 months in Uttar Pradesh based on survey inputs.
- NDM = Number of days in a month = 30
- Eff_fuel = Efficiency of the LPG stove (55%) or Chulha (14%) for solid fuels

Appendix B : Regression Analysis

B. 1 Decoding consumer dissatisfaction with QoS

Table 7: Odds ratios predicted for dissatisfaction with electricity supply[9]

Dissatisfaction with electricity supply - Odds Ratio		
	UP	MH
Voltage fluctuation	2.333***	0.159*
Power cuts experienced or not	3.674**	57505123
Frequency of billing: regular	1.15	3630653
Frequency of billing: irregular	1.435	
Appliance damaged due to poor supply	1.602*	0.248
Power cut: regular and predictable	1.839.	2.179
Power cut: frequent and unpredictable	2.486**	11.375*
Power cut: occasional	0.353**	0.093*
Number of hours of electricity supply	0.778***	1.036
Years since electrification	1	1.041.
McFadden's R square	0.37	0.38

Results from the regression analysis show that the surveyed households in Uttar Pradesh are more likely to be dissatisfied with the quality of supply if they experience voltage fluctuations, power cuts and appliance damage. More specifically, a household that moves from having no voltage fluctuations to having voltage fluctuations, is 2.3 times more likely to experience dissatisfaction. Experiencing power cuts would cause a household to be 3.7 times more likely to be dissatisfied with the quality of electricity supply. A household that has had an appliance that was damaged due to poor quality of electricity supply is 1.6 times more likely to experience dissatisfaction with electricity supply. Regular and predictable power cuts will lead to dissatisfaction such that experiencing power cuts of this particular nature will make a household 1.8 times more likely to be dissatisfied. However, experiencing frequent and unpredictable power

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[9] *** representing significant at 99.99% level, ** representing significant at 99.9% level, *representing significant at 95% level, representing significant at 90% level

cuts will lead to a house to being 2.5 times more likely to be dissatisfied. Occasional power cuts will make a household more likely to be satisfied. The probability of being a dissatisfied household increases by 0.35 if a household experiences occasional power cuts. A unit increase in supply hours will cause a household to be more satisfied i.e. the probability of being dissatisfied will increase by a factor less than 1 (0.7). It is important to mention here that any factor less than 1 will cause the probability to reduce and not increase which is why factors less than 1 will lead the household to be less likely to be dissatisfied i.e. more likely to be satisfied.

In Maharashtra, the relationship between dissatisfaction and frequent, unpredictable power cuts and with occasional power cuts in Maharashtra is similar to that observed in Uttar Pradesh. Households that experience frequent and unpredictable power cuts are 11.4 times more likely to be dissatisfied as against households that do not experience power cuts of such a nature. A household experiencing occasional power cuts will be more likely to be satisfied with the quality of supply. Thus, experiencing occasional power cuts will lead a household to be 0.1 times more likely to be dissatisfied. This relationship between dissatisfaction and occasional power cuts, in both MH and UP, is different from that of other types of power cuts. One possible explanation for this could be that a household that currently experiences occasional power cuts was experiencing regular/frequent power cuts earlier thus making the current nature of power cuts more acceptable than the what was being previously experienced. In the case of Maharashtra, another important variable is years since electrification. For a unit increase in this variable, a household is 1.04 times more likely to be dissatisfied. This implies that a household that has been more recently electrified, is more likely to be satisfied with the quality of electricity supply. This could be because households that have been recently electrified view access to electricity as an upgrade from their earlier situation of no access and hence do see any reason to complain. However, the relationship between dissatisfaction and experiencing voltage fluctuations seems anomalous. Households seem to be more satisfied with the quality of supply with increase in voltage fluctuations. This needs to be investigated further.

B. 2 Summer discomfort and quality of electricity supply

Table 8: Odds ratios predicted for discomfort experienced despite owning cooling devices[10]

Discomfort experienced despite owning cooling devices – Odds Ratio		
	UP	MH
Voltage fluctuations	1.887*	4.220***
Gonda/ Aurangabad	2.138.	0.356.
Gorakhpur/ Nashik	0.656	0.497
Jhansi/ Nagpur	1.123	0.691
Kanpur/ Raigad	1.094	0.182*
Region	0.883	0.865
Asset index	0.622***	0.790.
Supply hours	0.980	0.979
Age of house	0.996	1.859
Mc Fadden's R square	0.06	0.07

In Uttar Pradesh, the surveyed households 1.9 times more likely to experience discomfort if they experience voltage fluctuations. Furthermore, households in Gonda district are expected 2.1 times more likely to experience discomfort as compared to Agra district although the number of days exceeding 40 degrees Celsius in Agra are more than three times that in Gonda. A higher asset index, i.e. a richer household, would be less likely to experience discomfort. A unit increase in the asset index will make a household 0.6 times more likely to experience discomfort.

In Maharashtra a household experiencing voltage fluctuations is 4.2 times more likely to experience discomfort. Households in Aurangabad and Raigad districts are more likely to

[10] *** representing significant at 99.99% level, ** representing significant at 99.9% level, *representing significant at 95% level, representing significant at 90% level

experience discomfort as compared to this in Pune district. Aurangabad has more number of days with temperature exceeding 40 degrees Celsius than Pune and Raigad. Quality of electricity supply is better in Pune as compared to both the districts would make one less likely to experience discomfort. As is the case with Uttar Pradesh, a richer household is less likely to experience discomfort. A unit increase in the asset index will make a household 0.8 times more likely to experience discomfort.

For both states, lower supply hours should lead to greater discomfort however number of supply hours are not a statistically significant variable in this regression. This could be specific to the sample that has been considered and might not hold in a larger sample. Therefore, this needs further investigation.

B. 3 Factors driving cooking time

Table 9: Coefficients from regression on cooking hours and related variables[11]

Cooking hours and related variables - coefficients		
	UP	MH
Fuel used: only solid fuel	0.023	-0.211
Fuel used: only LPG	-0.332***	0.205**
Refrigerator	0.003	-0.128
Mixer-Blender	0.141*	0.516***
Region (1 - Semiurban, 2-Rural)	-0.016	-0.089*
Number of people in the family	0.096***	0.113***
Constant	2.001***	1.043***

[11] *** representing significant at 99.99% level, ** representing significant at 99.9% level, *representing significant at 95% level, representing significant at 90% level

In Uttar Pradesh, a household that uses LPG is likely to spend less time cooking (~20 minutes less) than a household that does not use LPG. Using a mixer-blender will lead to more time being spent in cooking. One possible reason maybe that owning a mixer-blender encourages people to prepare more elaborate meals thus requiring more cooking time (~9 minutes more). Ownership of refrigerator is not observed to be significant variable affecting the cooking time. This maybe because the use of refrigerators is still not prominent in Uttar Pradesh with majority of them switching off daily or for longer periods in winter. The cooking time also increases with the size of the households. It is likely to increase by 5 minutes for an increase of one person in the household.

In Maharashtra, households using LPG are more likely to spend more time cooking than households that do not use LPG. One possible reason maybe that only very low-income households use solid fuels for cooking. Hence, only basic meals are cooked every day requiring less time. Furthermore, there is higher probability of women taking up paid jobs outside due to economic necessity thereby reducing working time. However, this need more investigation. Unlike Uttar Pradesh, use of refrigerator is a significant variable and reduces the cooking time by approximately 8 minutes. However, similar to Uttar Pradesh, the cooking time is higher in households with mixer blender compared to those without (about half an hour more). The location also seems to play a significant role in cooking time with a household in rural region spending 5 minutes less than a household in urban Maharashtra. Finally, as the number of people in the family increases by a unit, the cooking time also increase by 7 minutes.

B.3.1 *Factors driving the use of LPG cylinders:*

Table 10: Coefficients from regression on number of cylinders and related variables[12]

Number of LPG cylinders used and related variables - coefficients		
	UP	MH
Age of LPG connection	0.052***	0.018***
Region (1 - Semiurban, 2-Rural)	-0.757***	-0.096
Asset Index	0.633***	0.23***
Use of LPG for water heating	0.301***	0.567***
Constant	8.656***	8.433***

In Uttar Pradesh, older the connection, the greater the number of cylinders a household uses. A household in a rural area will own less cylinders (~0.76 units lesser) than a household in an urban area. As income increases, the number of cylinders that a household owns will also increase.

In Maharashtra, cylinder ownership shows a positive relationship with the age of a connection and the asset index Similar to Uttar Pradesh, a richer house owns more cylinders, as is indicated by the direction of the relationship between the asset index and number of cylinders. Finally, in the case of Maharashtra since more people use hot water for bathing, there are greater number households which use LPG to heat their water. This could possibly explain why using LPG for heating water is a significant factor in influencing the number of LPG cylinders used by a household in Maharashtra but not in UP. A household that uses LPG for hating water effectively uses half a cylinder more than a house that does not, thus validating the hypothesis that using LPG to heat water leads to more cylinders being used.

[12] *** representing significant at 99.99% level, ** representing significant at 99.9% level, *representing significant at 95% level, representing significant at 90% level

Appendix C : Questionnaire

Residential Energy Consumption Survey

For semi-urban and rural areas

Instructions to interviewers are given in italics.

All questions are compulsory unless otherwise stated.

The questionnaire will be programmed with inbuilt skip-logic so that only those questions which are relevant appear on the screen. Interviewer will ask the questions on tabs.

Introduction

Hello, I am __________________ from __________________. I am conducting a survey on behalf of Prayas (Energy Group), a Pune based non-governmental organization working for public interest in India's energy sector. The objective of the survey is to understand how people use energy in their houses. This information about how people consume energy and what devices they use can inform policy and resource planning. In this regard, I would like to conduct this survey which will take 30-45 minutes. Information gathered from this survey will be used only for research purposes. Personal data collected will not be shared with anyone. A representative from Prayas (Energy Group) may call you for verification purposes.

<The respondent should be an adult with knowledge about the appliances and their usage patterns in the house.>

1. Do you agree to participate in the survey?
    a. Yes
    b. No ----> Abort the survey
2. Does your household have an electricity connection?
    a. Yes

b. No ------> Abort the survey

Basic Information

Questions in this section will be filled in by the surveyor without any input from the respondent

3. Interview start Time: *(Automatic)*
4. Date of interview: *(Automatic)*
5. Interviewer ID: *(leave it to survey organization for providing unique IDs)*
6. State Name:
7. District Name: *(Can provide a drop-down from the list of 5/10 pre-determined districts)*
8. Block/Tehsil Name:
9. Village/Town Name:
10. Region
    a. Semi-urban
    b. Rural
11. What is the income category of the household *<As assigned by the surveyor>*
    a. Low Income
    b. Middle Income
    c. High Income
12. What is the type of the house?
    a. Pucca House
    b. Kuccha House
13. *<If response to Q12 is a>* What is the structure of the house?
    a. Independent house
    b. Apartment/Building

Household Information

I will start by asking some questions about your household.

14. What is your surname? __
15. What is your name? ___
16. What is your age? ___
17. What is your gender *<Surveyor selects. Do not ask>*
    a. Male
    b. Female
    c. Other
18. What is your relation to the head of the household?
    a. Self
    b. Spouse

c. Child
d. Parent
e. Other

19. What is your level of education?
    a. No formal schooling
    b. Upto 12th Class
    c. Graduate
    d. Post Graduate
20. What is the postal address of the house? __
21. What is the nearby landmark? __
22. Can you give us your phone number? __ *<If asked, please mention that the number will not be shared and is only collected for verification purposes. If the respondent still does not want to give phone number move to next question>*
23. Can you give us your email id? __ *<recommended but not mandatory>*
24. How many rooms are there in the house? (excluding rented rooms, bathrooms and toilets) __
25. Do you pay rent for this house?
    a. Yes
    b. No
26. What is the carpet area of the house? __ square feet. *<This should exclude open area outside the built house such as lawn or garden>*
27. Is any part of your house used for commercial activity? *<If people have rented out one of the rooms, it is not considered as a commercial activity>*
28. If yes to above question, please specify the activity ____
29. When was the house built?
    a. __ *<Year in YYYY>*
    b. Don't know
30. Since when do you/your family live in this house? ___ *<Year in YYYY>*
31. How many windows does your house have excluding ones in bathroom and toilets? __
32. How many people usually live in this house? __
33. Please mention the number of people staying in this house according to their age-groups:
    a. 0 to 15 __
    b. 16to 30 __
    c. 31 to 45 __
    d. 46 to 60 __
    e. More than 61 __
34. What type of ration card does your household have?

a. None
b. APL
c. BPL
d. Antyodaya
e. Patragrahasti

35. What is the primary source of income in your household?
    a. Agriculture and/or Livestock farming
    b. Salaried Job
    c. Business
    d. Daily wages
    e. Other *<Specify>*

Lighting

I will now ask some questions regarding lighting in your house.

36. How many light bulbs do you have in your house and veranda? __
37. *<Ask if answer to Q36 is non-zero>*How many of each type of light bulbs are used? *<Show images of each type>*
    a. Incandescent Bulbs __
    b. CFL __
    c. LED bulbs __
    d. Don't know
38. How many tube-lights do you have in your house and veranda? __
39. *<Ask if answer to Q*38 *is non-zero>* How many of each type of tube-lights are used? *<Show images of each type>*
    a. Fluorescent tube-lights __
    b. LED tube-lights __
    c. Don't know
40. How many hours do you use bulbs/tube-lights between 6 am and 6 pm (day)?
    a. __
    b. Whenever electricity is available
    c. Can't say
41. How many hours do you use bulbs/tube-lights between 6 pm and 6 am (night)?
    a. __
    b. Whenever electricity is available
    c. Can't say

Ask Q42 to Q46 if response to Q37.c and Q39.b is non-zero

42. Why did you purchase LED bulbs and/or tube-lights? *<Select all that apply>*

    a. Work better in poor electricity supply
    b. Better light quality than other lighting options
    c. Longer life
    d. Available for low cost/free under government programme
    e. Can't Say

43. Are you satisfied with the LED lighting in your house?
    a. Yes
    b. No

44. <Ask if response to Q43 is b> Why are you not satisfied with LED lighting in your house? *<Select all that apply>*
    a. Causes Strain to the eye
    b. Light is insufficient
    c. Stopped working sooner than expected
    d. Has dimmed over time
    e. Other

45. Did you buy any LED bulbs/tube-lights under the government's UJALA programme? *<If they don't recollect UJALA programme, tell them they were required to submit aadhar card and electricity bills to get LED bulbs>*
    a. Yes
    b. No
    c. Don't know about the programme

46. *<Ask if response to Q45 is a>*What can you say about most of the LED bulbs/tube-lights you bought under the UJALA programme?
    a. Working and satisfied with their quality
    b. Working but not satisfied with their quality
    c. Stopped working
    d. Never used
    e. Don't know

47. Will you buy LED bulbs or LED tube-lights in future?
    a. LED bulb
    b. LED tube-light
    c. Both
    d. Neither
    e. Don't know

48. Do you use any other source of lighting?
    a. Solar lamps
    b. Kerosene lamps

c. LED bulb + Battery
d. Other
e. None

49. Can you rank the light bulbs as per their longevity? *<1 indicates longest life and 3 indicates shortest life>*
    a. CFL: (1,2,3)
    b. LED: (1,2,3)
    c. Incandescent bulb:(1,2,3)

Space Conditioning

I will now ask you about appliances you use for cooling or heating your rooms.

<u>Fans</u>

50. Do you use ceiling fans?
    a. Yes
    b. No

<Ask Q 51 to Q 57 if answer to Q50 is a>

51. How many ceiling fans are used in your house? __
52. How many months in a year do you use ceiling fans? __
53. In summer, how many ceiling fans are used for more than 8 hours a day?
54. What is the star rating of your most used ceiling fan? *<Show image of a star label>*
    a. Not rated
    b. 1 star
    c. 2 stars
    d. 3 stars
    e. 4 stars
    f. 5 stars
    g. Don't know
55. How old is your most used ceiling fan? __ (years) *<round off to the nearest integer. Less than 1 year should be put as 1> <If there are more than one fans being used the most then choose the fan which is the oldest>*
56. What is the make of your most used ceiling fan?
    a. Reputed brand
    b. Local company
    c. Don't know
57. Have you re-wound/repaired any of your ceiling fans in last year?

    a. Yes
    b. No
    c. Don’t know
58. How many table/pedestal/wall mounted fans are used in your house? __
59. *<Ask if response to Q58 is non-zero>*How many of these table/pedestal/wall mounted fans are used for more than 5 hours a day in summer? __

<u>Air Coolers</u>

60. Do you use any air-coolers?
    a. Yes
    b. No

<Ask Q61 to Q67 if answer to Q60 is non-zero>

61. How many air-coolers are used in your house? __
62. Do you use ceiling fan with the air-cooler in a room?
    a. Yes
    b. No
63. What is the make of your most used cooler?
    a. Reputed brand
    b. Local company
    c. Don’t know
64. How old is your most used air-cooler? __ (years) *<round off to the nearest integer. Less than 1 year should be put as 1>*
65. How many months in a year is the most used air-cooler used? __ months *<round off to the nearest integer. Less than 1 month should be put as 1. A cross check so that this number is only between 1 to 12 both 1 and 12 included>*
66. When do you use your most used air-cooler on a typical summer day? *<select all that apply>*
    a. Morning
    b. Afternoon
    c. Evening
    d. Night
67. How many hours is the most used air-cooler used on a typical summer day? __ hours *<round off to the nearest integer. Less than 1 hour should be put as 1>*

Air-conditioners

68. Do you use any air-conditioners?

   a. Yes
   b. No

Ask Q69 to Q81 only if answer to Q68 is a>

69. How many air-conditioners are used in your house? __
70. How many of each type of air-conditioners are used in your house? *<Show images> <If respondent does not know about inverter technology consider the AC as option a>*
    a. Split (non-inverter) __
    b. Split (inverter) __
    c. Window
71. Do you use ceiling fan with the air-conditioner in a room?
    a. Yes
    b. No
72. How frequently do you service your air-conditioners?
    a. Once in a year
    b. Once in two years
    c. Once in three years
    d. Have not serviced air-conditioners in last 3 years
    e. Don't know
73. What is the type of your most used air-conditioner? *<If the difference between inverter and non-inverter is not known, put it as non-inverter>*
    a. Split (non-inverter)
    b. Split (inverter)
    c. Window
74. What is the capacity of your most used air-conditioner?
    a. __ tons
    b. Don't know
75. What is the star-rating of your most used air-conditioner? *<Show image of the star-rating on AC>*
    a. Not rated
    b. 1 star
    c. 2 stars
    d. 3 stars
    e. 4 stars
    f. 5 stars
    g. Don't know

76. What is the age of your most-used air-conditioner? __
77. How many months in a year is the most used air-conditioner used? __ months *<round off to the nearest integer. Less than 1 month should be put as 1. A cross check so that this number is only between 1 to 12 both 1and 12 included>*
78. When do you use your most used air-conditioner on a typical summer day? *<select all that apply>*
    a. Morning
    b. Afternoon
    c. Evening
    d. Night
79. How many hours is the most used air-conditioner used on a typical summer day? __ hours *<round off to the nearest integer. Less than 1 hour should be put as 1>*
80. How many hours is the most used air-conditioner used on a typical non-summer day? __ hours *<round off to the nearest integer. Less than 1 hour should be put as 1>*
81. What is the average temperature setting for the most used air-conditioner on a typical summer day? __ degree Celsius

<Ask Q82 to Q88 only if answer to Q69 is more than 1 >

82. What is the type of your second most used air-conditioner? *<If the difference between inverter and non-inverter is not known, put it as non-inverter>*
    a. Split (non-inverter)
    b. Split (inverter)
    c. Window
83. What is the capacity of your second most used air-conditioner?
    a. __ tons
    b. Don't know
84. What is the star-rating of your second most used air-conditioner?
    a. Not rated
    b. 1 star
    c. 2 stars
    d. 3 stars
    e. 4 stars
    f. 5 stars
    g. Don't know
85. How many months in a year is the second most used air-conditioner used? __ months *<round off to the nearest integer. Less than 1 month should be put as 1>*

86. When do you use your second most used air-conditioner on a typical summer day? *<select all that apply>*
    a. Morning
    b. Afternoon
    c. Evening
    d. Night
87. How many hours is the second most used air-conditioner used on a typical summer day? __ hours *<round off to the nearest integer. Less than 1 hour should be put as 1>*
88. What is the average temperature setting for the second most used air-conditioner on a typical summer day? __ degree Celsius

<u>General questions regarding space-conditioning</u>

I will now ask a few general questions related to the household's thermal comfort.

89. Even after using available fan/air-cooler/air-conditioner do the household members experience discomfort in house from heat in summer?
    a. Some days in summer
    b. Lot of days but still less than half of the total days in summer
    c. Most of the days in summer
    d. No discomfort

Ask Q90 and Q91 if answer to Q89 is among the first three options.

90. Do you wish to buy an air-conditioner in next two years?
    a. Yes
    b. No
    c. Can't say
91. In addition to using fans/air-coolers/air-conditioners, what else do you do to get relief from heat in summer? ___ *<subjective. Note down whatever the respondent says in short meaningful sentences>*

Water Heating

I will now ask a few questions on energy used in your house to heat water for bathing.

92. Does your household use hot water for bathing?
    a. Yes
    b. No

Ask Q93 to Q105 if response to Q92 is a

93. Which of the following is used for heating water in your house? *<select all that apply. Pictures should be shown for immersion rod, instant electric water heater, storage electric water heater>*
    a. Firewood/crop residue/dung cake stove
    b. Kerosene stove
    c. Immersion rod
    d. Electric Geyser
    e. LPG gas based water-heater
    f. Solar water heater
    g. Electric coil stove
    h. LPG Stove

Ask Q94 to Q97 if the option c is checked in Q93

94. How many months in a year is the most used immersion rod used in your house? __ *<round off to the nearest integer. Less than 1 month should be put as 1. A cross check so that this number is only between 1 to 12 both 1 and 12 included>*
95. When do you use the most used immersion rod on a typical winter day? *<select all that apply>*
    a. Morning
    b. Afternoon
    c. Evening
    d. Night
96. How many buckets of water do you heat each day with the immersion rod used on a typical winter day? __
97. Did any of the household members experience an electric shock due to the use of immersion rod in last two years?
    a. Yes
    b. No

<Ask Q98 to Q103 if the option d is checked in Q93>

98. How many electric water heaters of each type are used in your house? *<Show images of Instant water heater and storage water heater>*
    a. Instant water heater __
    b. Storage water heater __
    c. Don't know
99. What is the type of your most used electric water heater?
    a. Instant water heater

   b. Storage water heater
   c. Don’t know

100. How many months in a year is the most used electric water heater used in your house? __ *<round off to the nearest integer. Less than 1 month should be put as 1. A cross check so that this number is only between 1 to 12 both 1 and 12 included>*
101. How old is your most used water heater?
102. When do you use the most used electric water heater on a typical winter day? *<select all that apply>*
   a. Morning
   b. Afternoon
   c. Evening
   d. Night
103. How many hours of a day is the most used most used electric water heater used on a typical winter day? __

<Ask Q104 and Q105 if response to Q98.b is non-zero>

104. To your knowledge, do storage electric water heaters come with star labels? *<show the picture of star labels>*
   a. Yes
   b. No
   c. Don’t know
105. *<Ask if response to Q104 is a>* What is the star-rating of your most used storage electric water heater?
   a. Not rated
   b. 1 star
   c. 2 stars
   d. 3 stars
   e. 4 stars
   f. 5 stars
   g. Don’t know

Cooking

I will now move to questions related to energy used for cooking in your house.

Please try to ask these questions related to cooking to person who actually does cooking in the house.

106. How many hours of the day are typically spent in cooking for people living in this house? __
107. Which fuel do you use for cooking? *<Select all that apply>*
    a. Solid fuel (Firewood/agricultural residue/cow-dung cake/Coal/lignite/charcoal)
    b. Kerosene
    c. LPG
    d. Electricity (induction stove/electric cooking coil)
    e. Bio-gas

Ask Q108 to Q112 if response to Q107 is a.

108. What can you say about the use of solid fuel for cooking?
    a. It is used for most of the cooking every day
    b. It is used for some of the cooking every day
    c. It is used occasionally for some special cooking
    d. It is used when alternate fuel options are not available
109. Which of the following solid fuels do you use for cooking? *<Select all that apply>*
    a. Fire-wood
    b. Cow-dung cake
    c. Agriculture residue
    d. Coal/lignite
    e. Charcoal
110. What type of chulha do you use? *<Improved chulha is one with less or no smoke. Normal is one with lot of smoke>*
    a. Normal
    b. Improved
111. Do you purchase any of the solid fuels you use?
    a. Always
    b. Sometimes
    c. Never
112. *<Ask if response to Q111 is a or b >* How much do you approximately spend on solid fuels each month?
    a. ___ Rs
    b. Don't know

Ask Q113 and Q114 if response to Q107 is b

113. What can you say about the use of kerosene for cooking?
    a. It is used for most of the cooking every day

   b. It is used for some of the cooking every day
   c. It is used occasionally for some special cooking
   d. It is used when alternate fuel options are not available

114. How much kerosene is used for cooking every month?
   a. _____ litres
   b. Don’t know

Ask Q115 to Q118 if response to Q107 is c

115. What can you say about the use of LPG for cooking?
   a. It is used for most of the cooking every day
   b. It is used for some of the cooking every day
   c. It is used occasionally for some special cooking
   d. It is used when alternate fuel options are not available
116. *<Ask if response to Q115 is other than a>* Why do you not use LPG for all your cooking?
   a. LPG cylinder is expensive
   b. LPG cylinder is not available
   c. Difficult to use
   d. Others
117. How many cylinders do you buy in a year?
   a. __
   b. Don’t know
118. Do you receive subsidy for LPG cylinder in your bank account?
   a. Always
   b. Sometimes
   c. Never
119. Since when do you use LPG for cooking?
   a. Year :<>
   b. Don’t Know

Ask Q120 and Q121 if response to Q107 is d

120. What can you say about the use of electricity for cooking?
   a. It is used for most of the cooking every day
   b. It is used for some of the cooking every day
   c. It is used occasionally for some special cooking
   d. It is used when alternate fuel options are not available
121. Which of the appliances do you use for cooking?
   a. Induction cook-stove

b. Electric coil
c. Micro-wave
d. Rice-cooker

Ask Q122 to Q124 if response to Q107 is e

122. What can you say about the use of biogas for cooking?
    a. It is used for most of the cooking every day
    b. It is used for some of the cooking every day
    c. It is used occasionally for some special cooking
    d. It is used when alternate fuel options are not available
123. What kind of bio-gas plant is used?
    a. Household level
    b. Community level
124. What is the feed for your bio-gas plant?
    a. Vegetable waste?
    b. Cow dung/agricultural waste
    c. Food waste
    d. Toilet/sewage

Ask Q125 to Q126 if response to Q107 is <u>not</u> c

125. Why do you not use LPG?
    a. LPG cylinder is expensive
    b. LPG cylinder is not available
    c. Difficult to use
    d. Others <Specify>
126. Have you heard about UJWALA programme?
    a. Yes
    b. No

Refrigeration & Other Kitchen Appliances

I will now ask some questions related to your refrigerator.

127. Do you have refrigerator in your house?
    a. Yes
    b. No

<Ask Q128 to Q136 if answer to Q127 is a>

128. How many refrigerators do you use in your house? __
129. How old is your most used refrigerator? __ years
130. What best describes your most used refrigerator?
    a. One door
    b. Two doors
    c. Three doors or more
131. What is the size of your most used refrigerator?
    a. Small (less than 200 litres)
    b. Medium (200 to 400 litres)
    c. Large (More than 400 litres)
    d. Don't know
132. What is the star rating of your most used refrigerator? *<Show the image of the star label>*
    a. Not rated
    b. 1 star
    c. 2 stars
    d. 3 stars
    e. 4 stars
    f. 5 stars
    g. Don't know
133. Is there a sticker of star-rating on your refrigerator? . *The values for the following questions will be on the star-rating sticker on the refrigerator. Show an image of the sticker with both values circled.*
    a. Yes
    b. No

Ask Q134 and Q135 if response to Q133 is a

134. What is the estimated annual consumption? __ kWh
135. What is the gross volume of the refrigerator? __ litres
136. Do you switch off the refrigerator? *<select all that apply>*
    a. For a few hours in a day
    b. When going on a vacation
    c. In winter
    d. When there are voltage fluctuations
    e. Never
137. Which of the following appliances are used at least once in a week while cooking in your house? *<Select all that apply>*

a. Microwave oven
b. Toaster/Griller
c. Electric rice cooker
d. Mixer/blender
e. Food processor
f. Atta Chakki
g. None

Entertainment and other appliances

Next few questions will be related to appliances used for entertainment.

138. Do you watch television (TV) in your house?
    a. Yes
    b. No

<Ask Q139 to Q144 if response to Q138 is a>

139. How many televisions (TV) are used in your house? __
140. What is the type of your most used TV? *<Show images>*
    a. CRT
    b. LED/LCD
    c. Plasma
141. What is the screen size of your most used TV?
    a. Upto 30 inches
    b. 31 to 40 inches
    c. 41 to 49 inches
    d. 50 and above
    e. Don't know
142. To your knowledge, do TVs come with star-rating labels? *<show picture of a star rating label>*
    a. Yes
    b. No
143. *<Ask if response to Q142 is a>* What is the star rating of your most used TV?
    a. Not rated
    b. 1 star
    c. 2 stars
    d. 3 stars
    e. 4 stars
    f. 5 stars

g. Don’t know

144. How many hours in a day is your most-used TV typically used? __ hours
145. Please select all the appliances that are used atleast once a week
    a. Set-top box
    b. Laptop/Desktop/Tablets/iPad/smart-phone
    c. Internet modem/router
    d. Washing Machine
    e. Electric Iron
    f. Water pump (individual for house)
    g. None of the above
146. *<Ask if option b in Q145 is checked>* How frequently do you watch news/shows/movies on mobile devices such as laptop, tablet or smart phone?
    a. Every day
    b. Few times a week
    c. Once a week
    d. Never
147. *<Ask if option f of Q145 is checked>* How many hours in a day is water pump used? __
148. How many smart-phones are used in your household? __
149. Do you have a room heater in your house?
    a. Yes
    b. No

Ask Q150 to Q155 if response to Q149 is a

150. How many room heaters are used in your house? __
151. What is the type of your most-used room-heater?
    a. Electric heater with fan
    b. Electric heater without fan
    c. Electric coil heater
    d. Gas heater
    e. Other
152. What is the make of your most used room-heater?
    a. Reputed brand
    b. Local company
    c. Don’t know
153. How old is your most used room-heater? __ (years) <*round off to the nearest integer. Less than 1 year should be put as 1*>

154. How many months in a year is the most used room-heater used? __ months *<round off to the nearest integer. Less than 1 month should be put as 1. A cross check so that this number is only between 1 to 12 both 1 and 12 included>*
155. How many hours is the most used room-heater used on a typical winter day? __ hours *<round off to the nearest integer. Less than 1 hour should be put as 1>*

Appliance purchase behaviour

I will now ask you a few questions on recently purchased appliances by your household.

156. Which electric appliances did your household acquire in last year? *<There should be a list of all the appliances and only those should be checked which respondents mention>*
    a. Ceiling fan
    b. Television
    c. Refrigerator
    d. Washing Machine
    e. Water heater
    f. Air-conditioner
    g. Other

For each appliance bought there should be following set of questions. We can id these questions based on the question number and options. For example 156.a.1

157. How did your household acquire the appliance?
    a. Bought it new
    b. Bought it second hand
    c. Got it as a gift

<Ask Q158 to Q159 if response to Q157 is a or b>

158. How much did you pay for the appliance?
    a. __ Rs
    b. Don't know
159. What was the mode of payment?
    a. Paid upfront
    b. Took loan
    c. Don't know
160. Which appliances would you like to buy in the future? *<Ask respondent to give 3 responses and check those three from below>*
    a. Ceiling fan

b. Television
c. Refrigerator
d. Washing Machine
e. Water heater
f. Air-conditioner
g. Room heater
h. Other

161. Do you know about the Star rating programme? *<Show image of a star label>*
    a. Yes
    b. No

<Ask Q162 and Q163 if response to Q161 is a>

162. What does a 5-star appliance mean to you? *<Select all that apply>*
    a. It has better performance
    b. It is expensive
    c. It consumes less electricity
    d. It is just a marketing gimmick
    e. It does not mean anything
163. Which appliances do you think are covered under star rating programme? *<Read out the list and check if the respondent says yes>*
    a. LED bulb and tube-light
    b. Ceiling fan
    c. Television
    d. Refrigerator
    e. Washing Machine
    f. Water heater
    g. Air-conditioner

Electricity as a service

I will now ask some questions related to the supply of electricity to your house.

164. What year was your house electrified?
    a. ____ (YYYY)
    b. Don’t know
165. Do you have an electricity meter?
    a. Yes
    b. No
166. *<Ask if response to Q165 is a>* Is the electricity meter functional?

a. Yes
b. No
c. Don’t know

167. Do you receive an electricity bill?
    a. Yes
    b. No

Ask Q168 to Q171 if response to Q167 is a>

168. How frequently do you receive/collect the electricity bill?
    a. Once a month
    b. Once every two months
    c. Once a year
    d. Irregularly
169. Can we see a copy of your electricity bill?
    a. Yes
    b. No
170. *<Ask if response to Q169 is a >*Can we note down the consumer number and substation number? This will be used only for research purposes
    a. Yes
    b. No
171. *<Fill in if response to Q170 is a>* Bill details
    a. Consumer number
    b. Substation number
172. How do you pay for electricity?
    a. Pay to the electricity company according to the bill
    b. Pay a fixed charge to the electricity company
    c. Pay to neighbour/landlord/others or as a part of rent
    d. Pay according to pre-paid meter
    e. Do not pay for electricity
173. How many hours in a day do you generally receive electricity supply? __
174. Do you experience power-cuts in your home?
    a. Yes
    b. No

Ask Q175 to Q180 if option a is selected for Q174. If the respondent has recently moved, the questions apply to the duration of time the household has lived in the home.

175. Which season(s) did you experience most of the power-cuts in the last year? *<Select all that apply.>*
    a. Summer
    b. Monsoon
    c. Winter
    d. Can’t say
176. What was the nature of most of the power-cuts experienced in the last month? *<Select all that apply.>*
    a. Regular and predictable (e.g. every Thursday or everyday 2pm to 3pm)
    b. Frequent and unpredictable (e.g. on any day and at any time of the day)
    c. Occasional (e.g. due to heavy rains or lightning)
    d. Can’t say
177. How long were most of the power-cuts experienced in the last month? *<Select all that apply.>*
    a. Less than 15 minutes
    b. More than 15 minutes up to an hour
    c. More than an hour to 6 hours
    d. More than 6 hours
    e. Can’t say
178. What time of the day most of the power-cuts were experienced in the last month? *<Select all that apply.>*
    a. Morning
    b. Afternoon
    c. Evening
    d. Night
    e. No specific pattern
179. How does the electricity supply resume in most cases after there a power cut? *<Select all that apply>*
    a. Automatically
    b. Pay a certain amount to the electricity company
    c. Pay a certain amount to the lineman
    d. Call/Phone the electricity company
    e. Can’t Say
180. Are you satisfied with the quality of electricity supply?
    a. Yes
    b. Somewhat
    c. No
    d. Can’t say

181. What kind of power back-up does your home have?
   a. None
   b. Inverter/UPS
   c. Self-owned diesel generator
   d. Society owned diesel generator
   e. Solar panel + Battery

Ask Q182 if response to Q181 is other than a.

182. Which appliances can be run on power back-up? *<Select all that apply>*
   a. Lights
   b. Fans
   c. Mobile Charging
   d. Television
   e. Refrigerator
   f. Other appliances __ *<mention which appliances>*
183. Do you experience voltage fluctuations in your home?
   a. Yes
   b. No
   c. Don’t know
184. In your home, a voltage stabilizer has been installed on:
   a. None
   b. Refrigerator
   c. Air-conditioner
   d. Other appliance
   e. Entire home
185. Were any of your appliances damaged due to poor electricity supply in last year?
   a. Yes
   b. No
186. Which of the following safety features does your home have? *<show pictures of MCB and fuse>*
   a. MCB
   b. Fuse
   c. None
   d. Don’t know
187. Did anyone experience an electric shock in your home last year?
   a. Yes
   b. No

Transport

Our final set of questions will be regarding energy consumed for local transport.

188. How much does your household spend on public transport/autorickshaw/taxi per month?
    a. __ Rs
    b. Don't know
189. How many vehicles do you own of each of the following category? *<Check none if no vehicles>*
    a. None
    b. Bicycle __
    c. Motorbike/Scooter __
    d. Car __
    e. Electric bike __
    f. Electric car __
190. *<Ask if response to option c or d of Q189 is non-zero>* How much does your household spend on petrol/diesel per month?
    a. __ Rs,
    b. Don't know

<Ask Q191 if response to option e Q189 is non-zero>

191. How frequently do you charge the electric bike?
    a. Every day
    b. Few times a week
    c. Once a week
    d. More than a week

<Ask Q192 if response to option f of Q189 >

192. How frequently do you charge the electric car?
    a. Every day
    b. Few times a week
    c. Once a week
    d. More than a week

We would like to ask one last question

193. Considering income from all sources, under which monthly income category does your household fall?

a. Upto Rs. 10,000
b. Rs. 11,000 to 20,000
c. Rs, 21,000 to 40,000
d. Rs. 41,000 to 80,000
e. More than 80,0000
f. Would not like to reveal

Related Publications

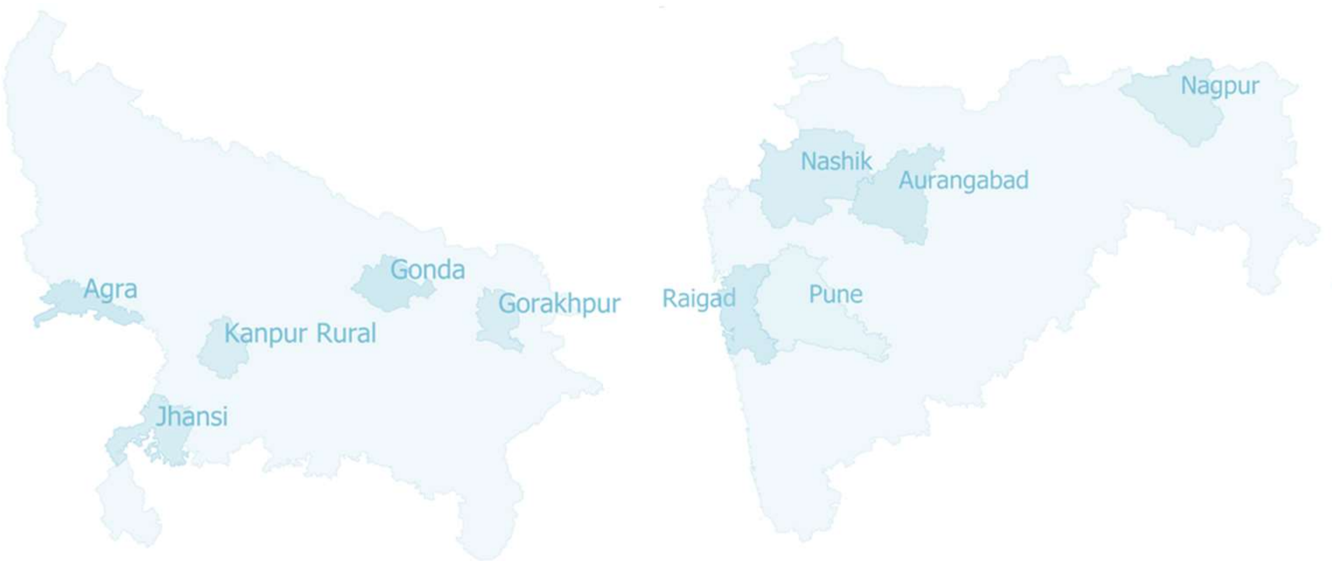
1. **Energy Consumption Patterns in Indian Households: Insights from Uttar Pradesh and Maharashtra**
   The following can be downloaded from: tinyurl.com/ECH2states
   - Detailed report
   - Survey data
   - Codebook for the survey data

   Blog series capturing insights from the survey can be found at: bit.ly/ECHOblog

2. **Energy Consumption Patterns in Indian Households: Insights from three cities:**
   The following can be downloaded from: tinyurl.com/ECH3cities
   - Detailed report
   - Survey data
   - Codebook for the survey data

3. **Under eMARC - Monitoring and Analysis of Electricity Consumption**, we are collecting data on residential electricity consumption in Indian homes from a selected sample of households and appliances This data is recorded by advanced IoT metering systems. Summary analysis of this data can be found at: emarc.watchyourpower.org

India's household energy consumption patterns are changing rapidly. Increase in household incomes, urbanization, and rapid technology development along with government policies/programmes to push for adoption of modern energy sources and efficient end-use technologies are driving these changes. However, there is limited data and understanding of the ownership and usage patterns of different appliances and fuels for various end-uses at household level in India. This report describes the findings of a detailed residential energy consumption survey on 3,000 semi-urban and rural households in Uttar Pradesh and Maharashtra. We hope that these insights make a strong case for conducting periodic residential energy consumption surveys at both national and sub-national level in India.



Prayas (Energy Group)