

ACCESS TO CLEAN COOKING ENERGY AND ELECTRICITY

Survey of States

ABHISHEK JAIN, SUDATTA RAY, KARTHIK GANESAN, MICHAËL AKLIN, CHAO-YO CHENG, AND JOHANNES URPELAINEN





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A report on ‘Access to Clean Cooking Energy and Electricity – Survey of States’.

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Shakti Sustainable Energy Foundation works to strengthen the energy security of India by aiding the design and implementation of policies that support energy efficiency and renewable energy.

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Executive Summary

The role of energy access in socioeconomic development of individuals and communities has been well established. Internationally, governments have understood the linkage and are endeavouring to improve the status of energy access. Currently available metrics suggest that globally, close to 1.1 billion people lack access to electricity and 300 million of this deprived lot live in India, by far the highest share of any single country. Similarly, on the cooking energy side, globally, more than 2.9 billion people rely on traditional biomass for cooking. Once again, India tops the chart with close to 800 million continuing to use firewood, dung cakes, charcoal or crop residue to meet their cooking energy needs. Although these metrics are rudimentary, they suggest that India has a long way to go before addressing the energy needs of its population. In development discourse in India, household energy access is measured by household's primary source of lighting and cooking, or through electrification status of household. These are unidimensional measures with binary states and do not provide a sense of the true deprivation experienced by households.

Measures such as village electrification rate (which currently stands at 96.7 per cent) or the number of active LPG connections (~150 million, enough to cover 60 per cent of all the households) hold limited value in bringing tangible improvements to the energy access situation of households. In reality, energy access is a multi-dimensional phenomenon which is much more than the presence of a connection and the same must be reflected in the way it is measured. As far as electricity is concerned, focus must be on the quality and availability of supply, along with the affordability and even legality of access. Moreover, access in some dimensions cannot be classified using a binary measure, as the 'level of access' varies significantly (e.g. in terms of capacity to support various energy services or in the number of hours supply is available for), and has concomitant socioeconomic impacts. Capturing these nuances is important to effectively plan for and achieve universal energy access in the country.

In order to bridge this gap in understanding of energy access, as well as to capture the detailed data on the state of energy access in India, we conducted this study with two main objectives. The first was to develop a multi-dimensional, multi-tier energy access measurement framework. The second was to evaluate this framework by using primary data collected specifically for the purpose of ascertaining state of energy access. To achieve our objective and fill the current gap in understanding and data, we carried out the largest primary data collection exercise dedicated to energy access, in the history of India. We surveyed some of the most energy deprived states of the country, i.e. Bihar, Jharkhand, Madhya Pradesh, Uttar Pradesh, Odisha, and West Bengal. The survey was conducted over a period of 80 days and covering all the 48 administrative divisions in each of the states, reaching out to 714 villages in 51 districts. A comprehensive questionnaire comprising 155 questions was administered by a team of 60 enumerators, to the 8,566 households that constitute this statistically representative sample. Given the particularly poor situation of energy access in rural India, we specifically focused on energy access in rural areas in this study.

Framework to measure energy access

Energy access pertains to access and consumption of modern forms of energy for household use, community use and productive use. However, the current study focuses only on household energy access. The decision to limit the evaluation to household energy access is corroborated even in the survey response where respondents indicate that energy for use within the household is of top-priority.

The study develops two separate multi-dimensional, multi-tier frameworks to evaluate access to electricity and clean cooking energy in households. There are six dimensions in the electricity access framework and five dimensions in the cooking energy access framework. Under the proposed framework, a tier is assigned to each household for each of the dimensions. The tiers, ranging from Tier 0 (lowest) to Tier 3 (highest), represent increasing endowments and a progression in the path to energy access. The outcome metric for every household, for electricity access and cooking energy access, is an overall tier associated with each. This overall tier (for electricity and cooking energy) corresponds to the minimum tier achieved across all the dimensions within each of the frameworks. While this does make for a conservative estimation of the overall tier, such an approach effectively highlights the priority area of action, making the framework highly valuable for decision-makers and key stakeholders. Aggregating the results at household level, an index (one each for electricity and cooking) is created at district, division, and state level. The index is a weighted average estimation based on the proportion of households in each tier. Such an index is useful for comparisons across regions, but the need of understanding energy access tiers and the distribution of households across them cannot be avoided for concrete policy actions.

Electricity Access Framework

Tier	Tier 0	Tier 1	Tier 2	Tier 3
Dimension				
Capacity	No electricity	Lighting + Basic entertainment / communication (Radio/ Mobile) (~1-50W)	Lighting + Air circulation + entertainment / communication (TV/ Computer) (~50-500W)	Tier 2 services + Medium to Heavy loads (>500W)
Duration	<4hrs	>=4hrs and <8hrs	>=8hrs and <20hrs	>=20hrs
Reliability (Black-out Days)	5 or more days	2-4 days	1 day	0
Quality*	$N_H > 3$; $N_L > 6$	$N_H = 0-3$; $N_L = 0-6$	$N_H = 0-1$; $N_L = 0-3$	$N_H + N_L = 0$
Affordability	Unaffordable		Affordable	
Legality	Illegal		Legal	

* N_H is number of high voltage days in a month causing appliance damage; N_L is number of low voltage days in a month limiting appliance usage.

NOTE: For dimensions where the categories span multiple tiers, only the higher tier values apply. For example, affordability can only be categorised as Tier 1 or Tier 3. The same is the case for legality.

Clean Cooking Energy Access Framework

Tier	Tier 0	Tier 1	Tier 2	Tier 3
Dimension				
Health & Safety	Only traditional fuel used (firewood, dung-cakes, agricultural residue)	A mix of traditional fuel and BLEN (Bio-gas, LPG, Electricity, Natural Gas) is used		Only source of cooking fuel includes BLEN
Availability	Cooking less because of availability	Unsatisfied with availability	Neutral to availability	Satisfied with availability
Quality	Quality of cooking is not adequate		Quality of cooking is adequate	
Affordability	Not affordable		Affordable	
Convenience	Both difficult to use and time consuming		Either difficult to use or time consuming	Neither difficult, nor time consuming

NOTE: For dimensions where the categories span multiple tiers, only the higher tier values apply. For example quality and affordability dimensions can only take on Tier 1 or Tier 3. Health and safety can take on Tier 0, Tier 2 and Tier 3.

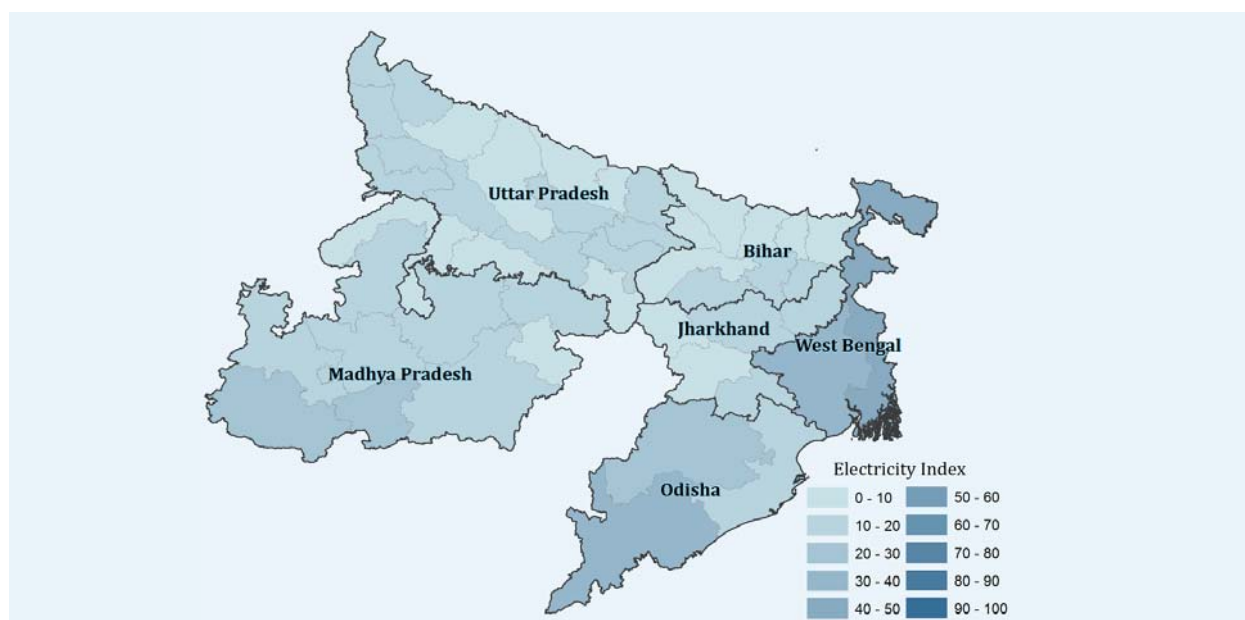
The basic structure of the proposed framework and many of the dimensions overlap with that of the Global Tracking Framework (developed by the World Bank, ESMAP and International Energy Agency). However, differences arise in the definition of some of the dimensions, setting of thresholds for various tiers and in some cases, the nature of responses (use of subjective responses in lieu of objective thresholds) which are used to populate the framework. One major modification that our framework has in comparison to the GTF is the choice of overall number of tiers to measure energy access. The proposed framework has only four tiers as compared to the six used in the GTF. Being a global framework, the number of tiers defined in the GTF might be more relevant in the context of other countries where a finer differentiation may be possible or necessitated. However, for India, our survey results suggest that the results are not sensitive enough to justify the need for six tiers.

What is the state of play?

Electricity access

The evaluation of electricity access, using the multi-tier framework, paints a grim picture of the rural areas in the six states. On a scale of 0 to 100, the electricity index across the six states ranges from as low as 8.1 for Bihar to 41.8 for West Bengal. A map, highlighting the electricity access situation of each division across these six states, is shown in figure below. Darker shades represent a better electricity access situation. Majority of areas are in lightest shades, especially in Bihar Jharkhand and Uttar Pradesh, and points to the poor electricity access situation in these areas. It is also important to note that no division across these states achieves an electricity index score beyond the 60-70 band (the highest possible score being 100).

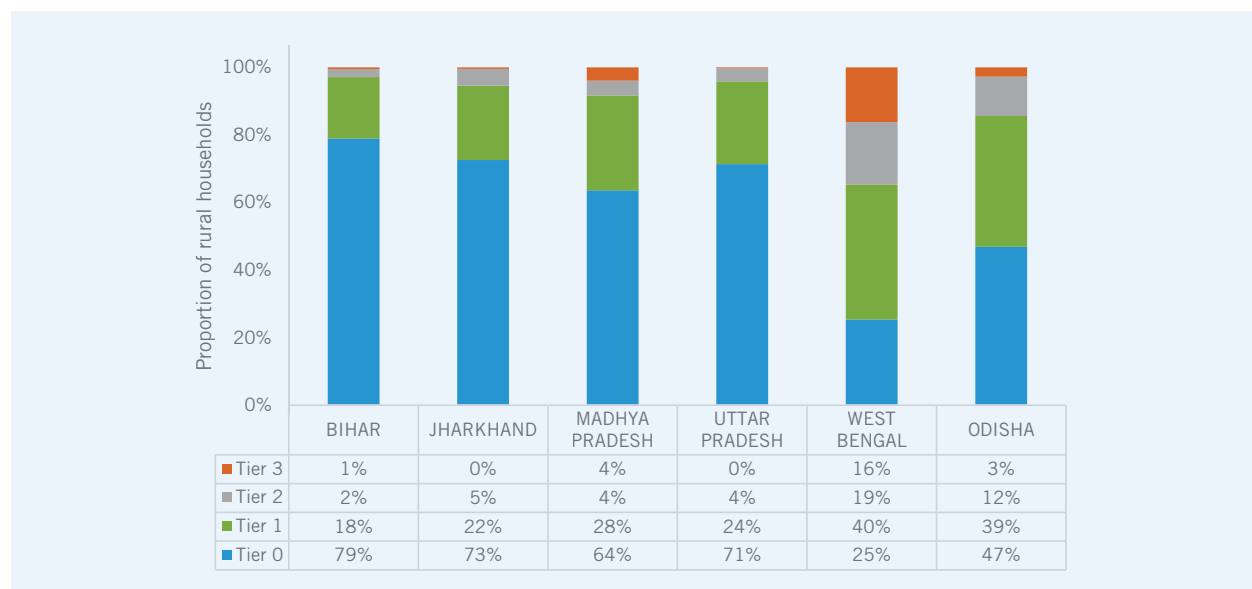
Electricity access index for six states



Beyond the geographical representation, the proportion of households spread across the four tiers is shown in the figure below. West Bengal is the best performer on electricity access with the greatest proportion of households in Tier 3 and the lowest proportion in Tier 0, when compared to other states in the study. In the remaining states (barring Odisha) more than half of the households were categorised in Tier 0. It is useful to contrast this metric against the reported electrification rates of villages in these

states which range from 92 per cent (Orissa) to 99.99 per cent (West Bengal). Bihar, where 79 per cent of rural households were classified in Tier 0, has a village electrification rate of 95.5 per cent. Also, there is a significant lag between the time when electricity was first brought to the villages and the households in these villages actually getting electrified. The median lag ranges from two years (in the case of Jharkhand and Bihar, which saw a recent wave of electrification) to more than 25 years in Odisha and about 15 years in the case Madhya Pradesh and Uttar Pradesh.

Distribution of households across electricity access tiers



The Rajeev Gandhi Grameen Vidyutikaran Yojana (RGGVY) (now, Deendayal Upadhyaya Gram Jyoti Yojana), the flagship rural electrification programme of Indian government, has been under implementation for over a decade now. In villages which did see RGGVY, the household electrification rates vary from 47 per cent in Bihar to 92 per cent in West Bengal. In villages that witnessed RGGVY, in the states of Bihar, Jharkhand and Uttar Pradesh, more than 60 per cent of the households that had an electricity connection (at the time of the survey) got one only after the program commenced in the villages. Intensive electrification under RGGVY does seem to have impacted villages in these three states in a positive manner.

A startling finding across six states is that, *of the households that are classified in Tier 0* (lowest level of energy access), *nearly 50 per cent are there despite having an electricity connection*. This highlights the need to look beyond metrics such as ‘possessing an electricity connection’ to meaningfully describe the energy access situation. *Households face severe challenges of quality, reliability and duration of supply* which then drive their classification in the lower tiers.

Among the other 50 per cent of the households (those without an electricity connection), *two third of them did not take an electricity connection, despite having the electricity grid in the vicinity*. Households cited main reasons as affordability of the connection charges and monthly charges, and unreliable supply. An analysis of *affordability indicates* that among houses which have opted out of having an electric connection citing high monthly charges; *only a small fraction of the unconnected population would truly find the prevailing prices to be high*. This is based on the normative limit of four per cent of total expenditure going towards threshold electricity consumption. This indicates a gap in perception or misinformation regarding electricity use expenditure and this must be addressed by the service providers or utilities.

For those that made it to the next tier (Tier 1), *affordability* was the key bottleneck in *West Bengal and Madhya Pradesh* for being trapped at that level. In the *other states*, *reliability of supply* (black-out days) turned-out as the major roadblock and was responsible for a large portion of the households not progressing to higher tiers.

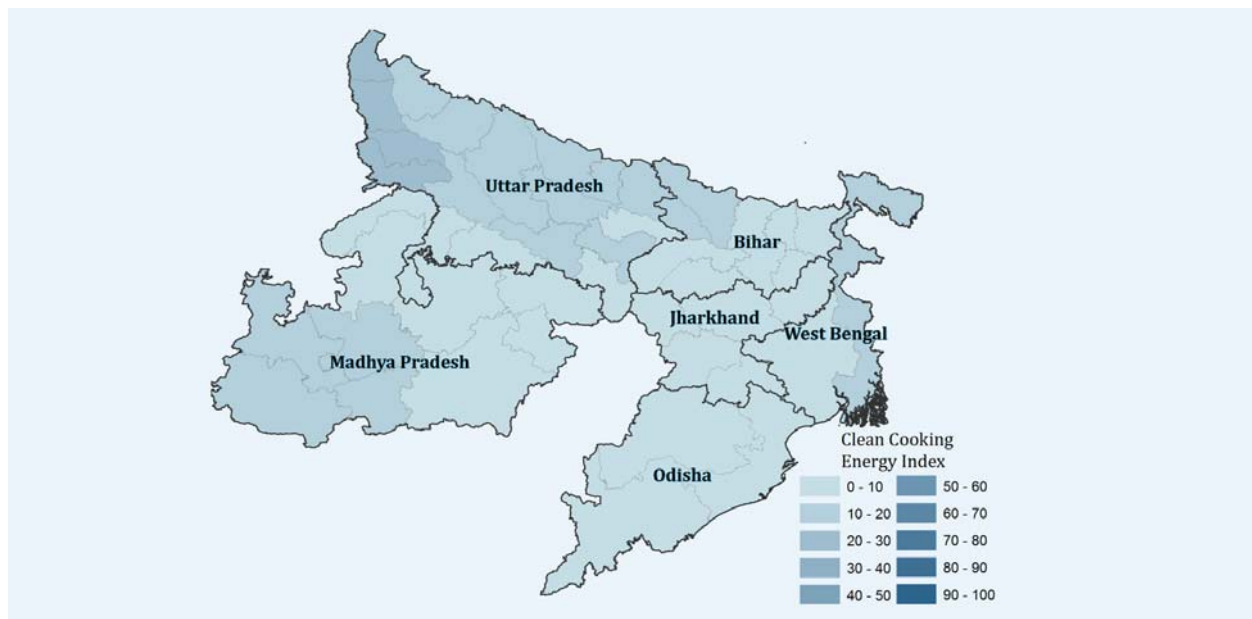
Only a small proportion of households made it to Tier 2 and Tier 3. In the case of *Odisha*, *duration of supply* was a major issue for those not progressing beyond *Tier 2*. It was found that very few households across the states receive round-the-clock supply of electricity and is definitely a factor that hinders movement to higher tiers. Since evening hours of supply are particularly important for the purposes of lighting, we also analysed this dimension across states. Jharkhand and Uttar Pradesh were the poorest performing states with an average of two hours of supply and were closely followed by Bihar at three hours. This effectively also precludes these households from achieving even Tier 2. In the case of *Tier 2* households in *West Bengal*, it was the *reliability and quality* of supply that prevented a significant share of households from graduating to the top tier.

Clean cooking energy access

The state of clean cooking energy access shows lot less variation across the six states. Although there are perceptible variations in the use and mix of traditional biomass fuels across states, the unifying feature is the limited access to modern cooking fuels in all the states. Even aggregated figures from the Census (2011) suggest that access to clean cooking energy in rural India is lower than access to electricity. This is exemplified in the results from the six states surveyed for this study. This excessive dependence on traditional fuels has significant adverse health impacts as a result of poor indoor air quality. As per the survey, *only 14 per cent households in rural areas across the six states have stated BLEN* (Biogas/ LPG/ Electricity/ Natural Gas) as their primary source of cooking. In sharp contrast, the *total fraction of households in these states that are reported* (by oil marketing companies) *to have LPG connections ranges from 26 per cent in Jharkhand and Odisha to more than 50 per cent in Uttar Pradesh*. Even though the number of connections is at the state level and represents all households (rural as well as urban), the large disparity between the number of connections and the actual use of LPG already illustrates the need for better metrics.

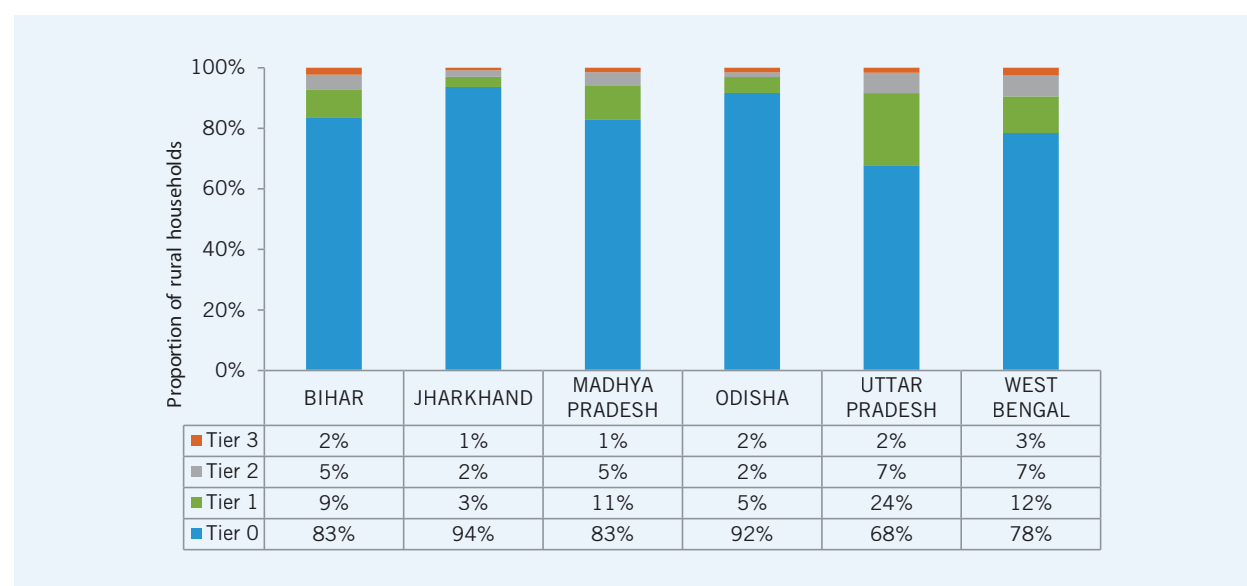
In terms of the clean cooking energy access index, all states are concentrated towards the very low end of the spectrum ranging from 3.4 to 14, on a scale of 0-100. Except some parts of Uttar Pradesh, Madhya Pradesh and West Bengal, which have marginally better access, most of the rural areas in these six states have very poor access to clean cooking energy, as shown by the light colours in the map.

Clean cooking energy access index across six states



When aggregated across the states, more than *three quarters of the households* are *categorised in Tier 0* for cooking energy access (see figure below). A household falls in Tier 0 only in two cases – either on account of *total reliance on traditional biomass* for cooking or *if it reports insufficient cooking as a result of unavailability of sufficient fuel* (of any form). More than *99 per cent of the households* categorised in Tier 0 are there as a result of the *total reliance on traditional fuels*. Thus, it is vital to understand the bottlenecks that households face in using cleaner cooking energy options. We found that penetration and inclination to adopt improved biomass cookstoves or biogas as very low. *Only 0.74 per cent and 0.21 per cent rural households were using improved cookstoves and biogas for cooking, respectively*. Virtually, all the adoption and use of clean cooking energy in rural areas could be attributed to LPG. Thus, we focused on understanding the reasons for households to not opt for an LPG connection and continue relying on traditional biomass entirely. The *high upfront cost to secure an LPG connection* is cited as the *biggest hurdle* (for 95 per cent of households) to adopting LPG. Furthermore, the *high recurring monthly expenditure* (88 per cent), and *lack of distributors for the fuel in the local area* (72 per cent) were also stated to be significant impediments to LPG adoption. Moreover, there is poor awareness about adverse health impacts of the use of traditional *chulhas*. Nearly 45 per cent of households without an LPG connection are unaware of the positive health benefits of using LPG over traditional *chulha*. Such poor levels of awareness of the impact of cooking fuels on health, could also be a reason for the low demand and adoption of the clean fuel.

Distribution of households across clean cooking energy access tiers



For households that are categorised in *Tier 1*, the *most significant impediment* to graduate to higher tier is the *affordability* of cooking energy. Nearly *83 per cent of the households* in Tier 1 spend more *than six per cent* of their total monthly expenditure on procuring cooking energy. *More than a quarter of the households* face challenges associated with *convenience of cooking*, citing that cooking using their primary cooking arrangement is both time consuming and difficult.

Across tiers, an analysis of the outlay for households that incur some (non-zero) expenditure on procuring cooking energy reveals some interesting results. In all states, *households that rely exclusively on biomass, and pay for some or all of it, end up spending more money* on cooking energy than *those who exclusively use LPG*.

In Uttar Pradesh only a third of the households rely entirely on free of cost biomass. In Madhya Pradesh the figure is also low, at 38 per cent. *In West Bengal, Jharkhand and Orissa a lot more households rely entirely on free of cost biomass (~ 60 per cent).* This assumes significance when investigating the economic rationale for transitioning to use LPG.

Analysis of responses in *UP indicate that though the distribution infrastructure for LPG* is poor, they *show higher subscription rate for LPG*. This could partially be explained by the fact that a significant proportion of population rely on market procured firewood (as opposed to collecting it for free), and hence subsidised LPG (at the prevailing prices) becomes an economically becomes an economically competitive option.

Only five per cent of the households are classified in *Tier 2* for cooking energy. The *mixed use of traditional fuels and LPG* is the *main barrier* that *prevents households from achieving the highest tier, Tier 3*. This mixed use (referred to as fuel stacking) is a result of availability of free-of-cost biomass and its use alongside LPG, since it does allow for some cost savings. However, the impacts associated with emissions from the use of traditional fuels are not accounted for by the decision makers of these households. Another significant impediment to their progression is the convenience dimension associated with traditional cooking practices. More than 50 per cent of households stated that cooking on a traditional *chulha* is both time consuming and difficult. Households reporting such issues with LPG based cooking were far lesser (about four per cent). *Less than three per cent* of the rural households across the states *are categorised in the highest tier*.

Understanding policy preferences of people

Apart from understanding the current state of energy access, we also explored peoples' preferences about energy sources, its use, related decision making and its associated policies. We first explored how people prioritise energy access over other necessities? After education, which was accorded highest priority, clean drinking water and electricity were the next in line. But LPG or clean cooking energy were not given the same importance, as compared to these other necessities.

We also asked households about the priority areas for electrification. Household electrification emerged as the most important need, cited by 66 per cent of households as their top priority. This was followed by street lighting, community use and productive (income generating) use, in that order.

When asked about who should look after their energy supply, people overwhelmingly believe that the government should continue overseeing energy supply. However, across the states, there is a divergence in opinion about the appropriate level of government (in particular state vs. central government).

In terms of technology choices, we gauged the interest of the population for micro-grids and solar lanterns. More than two-thirds of the population preferred grid supply over micro-grid. However, close to **78 per cent of the households supported the idea of providing capital support on solar lanterns in lieu of reducing kerosene subsidy**. On the cooking energy front, LPG garnered the highest support, in all states and across all tiers. Improved biomass cookstoves received a cold response, whereas biogas for cooking was not preferred at all. This reflects a loss of confidence in these technologies, stemming from the very limited successful experiences with these technologies, despite three decades of dedicated programme implementation.

Need for continuing assessments

Energy access is multi-dimensional with disparate needs, preferences, technology choices and outcomes. The multi-tier framework provides numerous novel insights on energy access in India, which would be of use to policymakers to refine existing schemes and their implementation. While this is a static evaluation at one point in time, the state of access is likely to change rapidly as a result of the increased focus on providing universal energy access. Continuing this exercise as an annual or biennial basis will provide further information on the progress and changing facets of energy access. As penetration increases with each passing year, the bottlenecks of energy access will change over time. The multi-tier, multi-dimensional framework developed and evaluated here is ideally suited to track such developments and could be the authoritative basis for decision makers to evaluate the impact of their programmes and take stock of persisting challenges.

1. Introduction

India is home to around 1.2 billion people (Census 2011) and it is estimated that more than 21 per cent of them live below the poverty line (Planning Commission, 2013). Economic definitions of poverty capture the multiple dimensions associated and are easily communicated in monetary terms. Most development oriented schemes also tend to address economic inequality through interventions that are directed at health improvements, nutritional intake and improvements in literacy. The quantum and quality of energy consumption and the impacts thereof, on the pace of development, were hitherto not in the reckoning of policymakers.

Notwithstanding the variations in estimations of income poverty, there is a need to distinguish it from energy poverty. The former refers to the “*lack of financial resources to live a tolerable life*”, while the latter “*is a lack of access to modern energy services*” (Bhide & Monroy, 2011). Modern energy services primarily concern household access to electricity and clean cooking energy (IEA, 2013). Equating income and energy poverty would be erroneous, as some ‘non-poor’ households, based on the income/expenditure poverty measures, may still be energy poor (Khandker, Barnes, & Samad, 2010).

The lack of access to modern energy services is a well-recognised issue in India (Bhattacharyya, 2006; Pachauri & Jiang, 2008; Ekholm, Krey, Pachauri, & Riahi, 2010; Balachandra, 2011). Census of India (2011) indicates that more than 80 million households rely primarily on sources other than electricity for their lighting needs. It is very likely then, that these households lack other electricity based energy services. As a result, appliance penetration rates are low and there are limited options for pumping clean water, refrigerating food and drugs as well as using modern communication technologies like the Internet.

Furthermore, nearly 160 million households in the country primarily rely on fuels such as firewood, dung-cake, charcoal and agricultural residue for their cooking energy needs (Census, 2011b). These fuels (often referred to as non-commercial fuels) do not form part of the formal energy accounting process, despite catering to a large proportion of household energy demand. We estimated the total non-commercial energy consumption in India to be more than 150 MTOE, nearly 20 per cent-25 per cent of the total purchased energy consumption.¹ More importantly, traditional fuels, when combusted in a *chulha* have significant impact on indoor air quality and remain a significant contributor to mortality and morbidity among women and children (WHO, 2014).

There is a great deal of uncertainty when one attempts to convey and comprehend the magnitude of energy poverty in India. Official government statistics that suggest 96.7 per cent of villages are electrified, bear little weight (CEA, 2015), when the actual per capita consumption of energy is measured. India’s per capita energy consumption stands at 0.58 toe/ person² – well short of the world average of 1.8 toe/ person and even less than the African average of 0.67 toe/ person (WDI, 2011). Though such comparisons of aggregate per capita energy consumption hide underlying inefficiencies and structural differences across economies, they clearly indicate that energy access and consumption is still a challenge in India.

1 CEEW estimates based on national communication on energy consumption and NSSO data

2 CEEW estimates based on population figures from Census 2011 and provisional energy consumption data for 2011-12 in Twelfth Five Year Plan draft document

Unlike developed countries, where energy demand has reached or is close to a saturation stage, the latent demand for energy is significant in India where the majority of energy demand still remains unmet. Numerous programmes have been rolled out by the government, in pursuit of the elusive goal of universal energy access. It would be a fair assessment to say that energy access has been accorded greater importance than measures that ensure ‘energy security’ at the national level (Ahn & Graczyk, 2012). While most schemes, particularly on electricity access, pertain to rural areas, provision of subsidised LPG and kerosene (through the public distribution system) also cover urban dwellers.

The Rural Electrification Corporation and the subsequent flagship program for rural electrification, Rajeev Gandhi Grameen Vidyutikaran Yojana (2005), have enabled the roll out of modern energy to several rural areas. The National Program on Biogas Development (1982) and National Program on Improved Chulhas (1983) for cooking energy in rural areas had aimed to decrease reliance on imported fossil fuels like LPG. After more than two decades of operations, these programs were reviewed and launched in a revamped form, with a bid to increase the penetration of decentralised clean cooking solutions. A comprehensive list of energy access schemes and programmes that have been rolled out in the country (post-Independence) are highlighted in Annexure I³.

Energy consumption at a household level is dictated by three key factors - affordability, availability and household characteristics (*inter alia* education levels, awareness, income, whether urban or rural). However, most schemes have focused mainly on making energy commodities affordable via subsidies, without necessarily paying attention to other factors. Therefore, despite the large subsidy outlay on an annual basis, the complete transition towards sustained use of modern forms of energy is still not achieved. This suggests that understanding energy access requires the adoption of a nuanced approach. More importantly, before defining an effective course of action to improve energy access, we need to be able to measure it in a manner that allows for specific strategies for different groups found wanting on different aspects of energy consumption.

1.1 Organisation of the report

The rest of the report is organised as follows. Section 2 delves into the motivation for the researchers to carry out this study. It discusses the literature that has been reviewed in the process of understanding the gaps in existing metrics for energy access. The section concludes by highlighting the main objectives of the study.

Section 3 provides details about the methodological approach taken. It elaborates the framework used, and its suitability in the Indian context. Further it details the survey techniques used in empirical testing of the framework across six Indian states.

Section 4 provides a detailed view of the results from the analysis of the survey data using the framework developed. It is divided into two sections – the first focusing on electricity access and the second on cooking energy. The overall picture at a state level and detailed discussions of the performance of each state along each dimension is presented in this section. Each of the two sub-sections concludes with key insights that would be of use to policymakers.

Section 5 expands on the results from one part of the survey which elicited priorities and policy preferences of households towards interventions that would improve energy access. These provide useful inputs

³ Appendices are only available in the e-version of the report. The report can be downloaded from following: <http://ceew.in>

on what needs to be prioritised, who should oversee energy provisions, what technologies and their scale do people prefer, and how they view energy access among other necessities.

Section 6 provides concluding remarks which captures the key takeaway points and highlights the need for this work to be carried out on periodical basis in order to develop a profile of the changing state of energy access within the country.

2. Motivation and Objectives

The existing body of works in the area of energy poverty and energy access in India is immense and the issue of is receiving more attention than ever before. However, there is a vast chasm between policymakers advocating for the eradication of energy poverty and their ability to provide for universal energy access. This exists, in part, because of the way energy poverty is understood and measured. The development of robust metric(s) for measuring the state of energy access is a first step in bridging the gap between policy and action.

There are many existing metrics that drive home the point of poor levels of energy access in developing countries such as India. The first of these is an “energy poverty line” or “fuel poverty line” from a conventional income or expenditure poverty measure. This can be computed by determining energy use as a function of income (or expenditure), and by calculating the average level of energy use corresponding to an amount of income or expenditure specified by the official income or expenditure poverty line (i.e. the level specified as the minimum amount needed to meet basic needs) (Pachauri & Spreng, 2003). While this approach is computationally fairly simple, it only provides a single energy or fuel poverty line, i.e. a number that is basically a transformation of the monetary poverty line, and does not, by itself, add any new insight by way of suggesting the factors that have resulted in the low spend or low consumption. It is certainly useful in getting a head count for energy poverty on the basis of the metric it uses.

Another approach to measuring energy poverty uses estimates for determining the direct energy required to satisfy basic needs (Goldemberg, Johansson, Reddy, & Williams, 1985; Pachauri & Spreng, 2003; Practical Action, 2010). Modi, McDade, Lallement, & Saghir, (2005) and propose an alternative, less data-intensive way to approximate useful energy. They require that two poverty cut-offs have to be exceeded: First, a minimum amount of final energy used in the form of modern fuels (gaseous or liquid fuels or otherwise electricity) and technologies (such as improved biomass cookstoves) for cooking and, second, a minimum amount of electricity for all other services, excluding heating and mobility.

Both of the above discussed metrics are in some sense normative and are unidimensional. One important drawback in setting the normative thresholds is the difficulty in pinning down the exact minimum level of energy required for basic needs, owing to the significant inter-country and regional differences in cooking practices and heating requirements. Energy consumption is often location-specific due to the differences in climatic conditions and cultural practices. The minimum needs for physical quantities of energy (for specific tasks) are chosen somewhat arbitrarily (Khandker, Barnes, & Samad, 2010). Furthermore, modern energy service uses less primary energy and is more affordable. Modern energy services have a higher service quality in terms of light, heat etc., and reduce household expenditure and increase resource efficiency simultaneously allowing the target population to enter a sustainable technological path of development (Bazilian et.al, 2010). Further, these metrics (and thresholds) require to be updated constantly and often lose their utility over time.

To overcome some of these drawbacks Khandker, Barnes, & Samad (2010) empirically determine an energy poverty threshold based on estimations of final and end-use energy consumption. The threshold is

defined as the income decile where energy consumption is significantly different from the consumption in the first decile. Given this construction, the threshold is supposed to represent the point until which energy demand is insensitive to income changes, as households below the point can only consume a bare minimum level of energy. This is a useful metric that provides for an understanding of the difference between income poverty and energy poverty. However, this approach does not help in understanding the factors that keep households from meeting threshold level of consumption (energy deprivation). Though the study controls for a variety of household characteristics, it is hard for a policymaker to gauge the factors that have resulted in the current state of energy poverty and to increase the levels of energy consumption in households which are seen to be 'energy-poor'. Further, it fails to highlight (contrary to assumptions made in the study) that energy consumption is elastic even among the poor (Bensch 2013).

The notion of poverty as a multidimensional phenomenon coincided with the increased availability of datasets that provide the necessary data even for developing countries (Deaton, 2010). The Multidimensional Energy Poverty Index (MEPI), presented in Nussbaumer, Bazilian, & Modi (2012), is an adaptation of the general Multidimensional Poverty Index (MPI). Instead of a single poverty cut-off, the underlying dual cut-off method requires to define thresholds in two steps: dimensional cut-offs for each sub-dimension, whereas the poverty cut-off determines in how many sub-dimensions an individual household has to be deprived for being classified as poor. In addition, a weight is attributed to each sub-dimension so that the final headcount of poverty that is defined incorporates the importance attached to each dimension. According to the authors, attainments in all the six sub-dimensions are deemed to be relevant, which are all expressed as dummies equalling one, if the household has overcome deprivation in each dimension. Modern cooking fuel usage (this is electricity, LPG, kerosene, natural gas, or biogas), modern cooking stove usage (including modern cooking fuel stoves except kerosene stoves as well as stoves equipped with a hood or chimney) and electricity access, ownership of a radio or television, phone and fridge ownership form the six dimensions of the MEPI.

The drawback with the MEPI is that the proxies it uses to define the quality of energy access (the assets, presumably) are not robust enough. Merely possessing these assets and consuming some small quantum of modern energy cannot qualify households as having access. A very simple case in point is that there are quite a few households in rural India where the houses do have appliances such as refrigerators (given as dowry during the wedding) which lie unused or underused for want of reliable supply of electricity. Fuel stacking⁴, a very common phenomenon is also not accounted for or penalised, since many households tend to use LPG only for a select set of cooking activities but use their traditional stoves for the rest.

An alternative multi-dimensional index, the Total Energy Access Standard, was developed by Practical Action, UK (Practical Action, 2012). This was developed in cooperation with entities such the International Energy Agency (IEA), World Bank, the Global Alliance for Clean Cookstoves and national development cooperation agencies. The TEA corresponds to the headcount ratio of energy poverty. In a significant departure from the MEPI, it considers the intensity of deprivation as irrelevant so that any person deprived in any of the six sub-dimensions (also along the lines of those used in the MEPI) enters the metric with a value of 1, representing (complete) energy poverty. Despite the number of dimensions captured in TEA standard, there are some areas where the field data collection becomes intractable and some areas where the definition is merely to define the absolute bear minimum thresholds of energy consumption. Identifying the intensity of lighting provided by a device is not easily captured without on-field measurements and mapping existing devices to the level of lighting they provide is also a tough task given the other variables that control the final intensity (as perceived by the user). More importantly, it is important to be able to classify people on a spectrum (discrete, nonetheless) of energy access and not just be able to define who is not in the lowest tier

4 Refers to the use of multiple fuels, especially for cooking purposes, in a household

of energy access. The TEA, despite being dimensionally extensive, still has a binary view of energy access. A multi-tier view must form the basis for robust energy access indicator.

It is clear that existing metrics fail on several grounds to provide a nuanced view of energy access. More importantly they do not dwell on the factors preclude access. The key point is that energy access is not only multi – dimensional, but also multi-tiered. In other words, **households are distributed on an energy consumption spectrum, rather than a binary classification of having and not having access to energy and the services thereof.**

More recent global efforts to understand these nuances include the Global Tracking Framework (GTF)⁵. The GTF approach looks at developing a multi-dimensional energy access measurement approach. They then combine this information to assign multiple tiers to households based on their level of energy access. However, being a global tool, **there remains the need to adapt and empirically test the GTF for understanding energy access in a country specific context.**

We propose a novel framework that addresses some of these shortcomings. In addition, this framework enabled a better analysis of the choices faced by households in accessing their preferred sources of energy. Our study has four main objectives:

1. To propose a framework of multi-dimensional and multi-tier indicators that help capture the state of access to electricity and modern cooking energy suited to the Indian context
2. To empirically test the framework by design of a robust questionnaire and extensive field survey
3. To categorise the reasons for deprivation and identify the bottlenecks which limit the transition of households from lower to higher tiers
4. To understand policy preferences for energy access provision and aspiration levels of the rural population

⁵ GTF is a collaborative effort between more than 26 entities, coming together to develop a unified methodology to measure and track the progress of SE4ALL goals.

3. Methodology

3.1 Framework to measure energy access

We developed a measurement framework that would capture the multi-dimensional nature of energy access while also categorising the level of access (under each dimension) in a tiered manner. This approach helps to clearly identify bottlenecks and target policy interventions. For this study, we used a modified version of GTF, which contextualises and effectively captures the energy access scenario in rural India. We referred to the version of the GTF, presented (on 19 February, 2014) by the World Bank and the Energy Sector Management Assistance Programme (ESMAP, 2014). However, we also included the changes in our framework based on the most recent GTF version, as appropriate.

Two separate multi-dimensional, multi-tier frameworks were used to analyse electricity access and cooking energy access. Multi-dimensionality of the framework pertains to the different dimensions across which we analyse the energy access situation. These include dimensions such as affordability, availability, health & safety, duration of supply, quality of supply. The multi-tier approach refers to the notion of that there are multiple levels of energy access and not just the binary states of having and not having access. Under the proposed framework, a tier is assigned to each household for each of the dimensions. Finally, we assigned an overall tier to the household which corresponded to the minimum tier achieved across all the dimensions. Apart from being conservative in the estimation, such an approach effectively highlights the priority area of action, making the framework valuable for decision-makers and key stakeholders.

While the basic approach of our framework and even some of the dimensions are similar to the GTF, differences arise in the definition of the indicators and formulation of the tiers. One major difference is in the number of tiers to measure energy access. Unlike the six tiers used in GTF, our proposed framework has only four tiers. Being a global framework, the number of tiers defined in the GTF might be more relevant in the context of other countries, where a finer differentiation may be possible or necessitated. Further details on our choice of number of tiers are provided in Box 1.

For both electricity and cooking energy access, we describe in detail the construction of dimensions and tiers, the points of departure (and reasons) from the GTF in the subsequent portions of this section.

3.1.1 Electricity access

For electricity access, we captured the entire information across six dimensions and four tiers. The six dimensions are capacity, duration, reliability, quality, affordability, and legality. *Health and safety*, one of the indicators included in the GTF, was excluded from our analysis. This was because health and safety information could not be captured comprehensively in the current survey. Table 1 provides a snapshot view of the framework that was used to measure electricity access.

Table 1: Multi-dimensional, multi-tier framework to assess electricity access

Tier	Tier 0	Tier 1	Tier 2	Tier 3
Dimension				
Capacity	No electricity	Lighting + Basic entertainment / communication (Radio/ Mobile) (~1-50W)	Lighting + Air circulation + entertainment / communication (TV/ Computer) (~50-500W)	Tier 2 services + Medium to Heavy loads (>500W)
Duration	<4hrs	>=4hrs and <8hrs	>=8hrs and <20hrs	>=20hrs
Reliability (Black-out Days)	5 or more days	2-4 days	1 day	0
Quality*	$N_H > 3$; $N_L > 6$	$N_H = 0-3$; $N_L = 0-6$	$N_H = 0-1$; $N_L = 0-3$	$N_H + N_L = 0$
Affordability	Unaffordable		Affordable	
Legality	Illegal		Legal	

* N_H is number of high voltage days in a month causing appliance damage; N_L is number of low voltage days in a month limiting appliance usage.

NOTE: For dimensions where the categories span multiple tiers, only the higher tier values apply. For example, affordability can only be categorised as Tier 1 or Tier 3. The same is the case for legality.

1. **Capacity:** The capacity indicator is defined as the peak power that could be drawn from a given electricity connection. The capacity of supply is the primary dimension that determines the level of services a household can use, provided it can afford the corresponding appliances to derive those services. The capacity tiers are designed to correspond to a set of incremental energy services for each tier. The watt ratings were determined by aggregating the load of devices or appliances that would be used in providing these services.
 - a. Tier 0: households without a grid connection or any off-grid solution (micro-grids, solar home systems and solar lanterns) fall in this tier and are referred to as un-electrified households.
 - b. Tier 1: pertains to services of general lighting, basic communication and entertainment (mobile/radio). This tier reflects houses that have only lighting and mobile charging services, either through a solar lantern, solar home system or a micro-grid. Given the efficiency of prevalent appliances in the country, rudimentary calculation suggests that the power requirements corresponding to this service level are 0-50 W.
 - c. Tier 2 includes capacity that allows for air circulation (fans), advanced communication and entertainment (TV/ Computer). Households connected to micro-grids having capacity to support at least a fan or a TV, and households with solar home systems, having a fan or a TV or both, are captured within this tier. The power requirements corresponding to this service level ~ 50 - 500 W.
 - d. Tier 3 – (> 500 W) includes power requirements that support medium to heavy loads like refrigerator, iron, air conditioner, etc. All grid-connected households are assumed to be in this Tier.⁶
2. **Duration** is defined as the average number of hours for which electricity is available in a day. The way the tier boundaries are defined for the duration (measured in hours) dimension directly reflects the level of limitation on the consumption of electricity service. Households with less than four hours of supply in a day were assigned to Tier 0. This is equivalent to almost not having any electricity. The subsequent tiers are defined as 4 to 8 hours (Tier 1), 8 to 20 hours (Tier 2) and beyond 20 hours of supply (Tier 3) in a day.

⁶ The actual appliance ownership data of the household is not used to determine the capacity tier, because appliance ownership is strongly influenced by affordability of appliance. Moreover quality and reliability of service could also influence the appliance ownership rate. In this multidimensional framework, where we are trying to dis-aggregate the issues, appliance ownership to determine capacity would not truly reflect the system's capacity which is providing electricity to the household.

Another aspect of supply duration could be to specifically look into the number of evening hours of supply. We have captured this data in the survey, but are not including it in the framework to retain the simplicity of the tiers, rather analysing it in conjunction with the framework.

3. **Reliability** is another important factor that directly impacts electricity consumption as well as influences the need for an alternative provision. GTF defines reliability as a binary measure by looking at the occurrence or absence of unscheduled outages. As unscheduled outages are a common phenomenon in rural India (as in urban India), this approach would overestimate lack of electricity access. Short-term power outages are often used as a demand control or grid balancing measure in India. In addition, momentary interruptions (less than 5 minutes) do not even figure in the reliability measurements used by utilities in India.⁷ Therefore, we estimated the reliability of the electricity supply by looking at the number of days in a month with no power supply (i.e. complete blackout), which is usually due to reasons other than intentional demand management by load dispatch centres. The lowest tier includes households that experience five or more number of blackout days in a month resulting in 'extremely unreliable supply'. Tier 1 captures those households that witness two to four blackout days in a month. Households experiencing one blackout day in a month were assigned to Tier 2, and those without any blackout days were in Tier 3.
4. **Quality (Voltage)** – The quality level associated with electricity supply could be assessed through multiple attributes, depending upon the context and end-use. For the purpose of household access, we used voltage fluctuations - power surges and low voltages, as the key indicators for quality. Two measures are used - the number of days witnessing voltage surge causing appliance damage (N_H) and number of days in a month, witnessing low voltage instances limiting appliance use (N_L). The threshold for these across tier levels were defined as below:
 - a. Tier 3: $N_H = 0$ & $N_L = 0$
 - b. Tier 2: $N_H = 0 - 1$ or $N_L = 0 - 3$
 - c. Tier 1: $N_H = 0-3$ or $N_L = 0 - 6$
 - d. Tier 0: $N_H > 3$ or $N_L > 6$
5. **Affordability:** Affordability is measured using a binary tier structure (Tier 1 - unaffordable and Tier 3 - affordable). Households are categorised as having 'affordable' electricity supply if less than 4 per cent of its monthly expenditure is spent on a *threshold level* of electricity consumption. **The *threshold level* was defined as consumption of 1kWh per household per day. The definition of *threshold level* emerges from an energy service perspective, and takes into account typical usage of basic energy services (lighting, fan, television and mobile charging) in a day.**⁸ Incidentally, this threshold level also matches targets specified in the National Electricity Policy of 2005 for minimum household consumption.

In a discussion on affordability, it is difficult to define a normative threshold for the affordability ratio, below which the energy could be termed as affordable. However, there exists a precedent in literature where governments or international agencies have tried to establish such normative limits on different energy expenditures to design policies to safeguard vulnerable or low income groups (Bartl, 2010; Chester, 2014; Frankhauser & Tepic, 2007). Meta-analysis of these cases indicates that such a limit is about 10 per cent for the overall energy expenditure.

7 Based on grid reliability numbers, even in states such as Karnataka which exhibit higher levels of development, the average rural areas experience more than 8 outages a week with total outages of more than 300 minutes a week (CEA, 2014)

8 1kWh of electricity would be equivalent to 6-8 hours of lighting (2-3 units), 8-10 hours of fan (1 unit), 2-3 hours of TV (1 unit), and mobile/radio charging. Essentially, the expenditure against such energy service should be within the affordability limit. Over 90% of the households in our survey elicited lighting, fan and TV (in that order) + mobile charging – as the first three services they would consume if connected to electricity. This also formed the basis of our assumption on minimum set of energy services to be considered for determining affordability thresholds.

The limit of four per cent of monthly expenditure is arrived at through a combination of two empirical observations from household expenditure patterns. The first is the affordability ratio as defined above. The second is the share of expenditure on electricity in the total energy expenditure (~40 per cent) from consumer expenditure data of the National Sample Survey (Jain, Agrawal, & Ganesan, 2014). The combination of these, results in the 4 per cent limit that is imposed on expenditure towards electricity consumption.

GTF defines affordability based on a proportion of the monthly income, rather than a proportion of monthly expenditure. Given the lack of data, and difficulty in estimation of incomes for India, it is easier and more reliable to use monthly expenditure numbers.

The recurring monthly expenditure (no capital expenditure) was estimated for various households, based on the type of connection, as follows:

- a. **Grid Connected:** Information about the connection status (metered or un-metered) from our survey, along with the published tariff structures (corresponding to metered and unmetered connections, and applicable slab rates for 30kWh/month), were used to calculate expenditure towards electricity and determine the affordability tier.
 - b. **Off-grid households:**
 - i. Households that did not have a regular monthly outlay, such as those that owned solar home systems or solar lanterns were categorised into ‘affordable’ tier.
 - ii. For households using off-grid electricity services (i.e. either connected to a micro-grid, or rented or pay-as-you-go SHS/lantern), their reported monthly outlay is used to estimate their electricity affordability level.
- 6. Legality** pertains to whether payment for electricity consumption is made to the legal entity that supplies electricity (directly or indirectly). In this dimension, household connections are classified as being legal or illegal (binary). This is done on the basis of their response to a specific question which identifies who the periodic payments (if at all) are made to, against the metered/ unmetered consumption. An illegal connection could refer to the unauthorised tapping of electricity from the mains as well as non-payment of bills for a legal connection. While legality might not affect the electricity consumption of an individual household directly, but due to the shared nature of electricity grid, it does indirectly influence the system reliability, quality and affordability of electricity. Hence it is important to capture this dimension while measuring energy access.

Box 1: How many tiers to capture the nuances of energy access?

Our analysis of the GTF suggests that the finer gradation in the duration and capacity dimensions drive the need for the total number of tiers in its overall framework (in the case of electricity access). A closer inspection of the GTF's capacity dimension suggests that the choice of thresholds in that framework does not very well correspond to existing commercial offerings in India. Households connected to the grid would automatically be in a position to connect significant loads that would take them into tier 4 and 5 (as proposed in the GTF). The capacity differentiation for households relying on off-grid or micro-grid solutions could be done by differentiating between the services that this capacity enables them to use. Similarly, one could argue that the finer gradations used in defining the duration tiers could be combined to have a lower number of tiers.

A sensitivity analysis (refer Annexure III) carried out for the different tier thresholds in the duration dimension, suggests that there is not a significant variation in the split of households across the tiers for different threshold values. The other dimensions effectively are binary in nature and do not rely on the extensive tier structure. In cooking energy too, there is a possibility to collapse the number of tiers. Indoor air quality and cook-stove efficiency influence the total number of tiers in the framework. However the definition of tiers for the dimension on cook-stove efficiency is not yet clearly defined. Furthermore, the translation of ambient fine particulate matter exposure to ultimate health impacts is not linear (Burnett, et al., 2014). Creating thresholds which do not show significant difference in ultimate impact would result in redundant tiers. The measurement of on-field efficiencies (of cook stoves) is also cumbersome and the efficacy of such a dimension itself could be called into question.

3.1.2 Cooking energy access

The body of work focussing on access to cooking energy is significantly limited⁹. However, based on our past work on clean cooking energy (Jain, Choudhary, & Ganesan, 2015) as well as expert interactions and discussions with multiple stakeholders, we identified five pertinent dimensions to capture access to cooking energy. These included health and safety, availability, quality, affordability, and convenience.

A summary of the cooking energy framework, provided in Table 2, captures the information across each dimension in four tiers.

Table 2: Multi-dimensional, multi-tier framework to assess cooking energy access

Tier	Tier 0	Tier 1	Tier 2	Tier 3
Dimension				
Health & Safety	Only traditional fuel used (firewood, dung-cakes, agricultural residue)	A mix of traditional fuel and BLEN (Bio-gas, LPG, Electricity, Natural Gas) is used		Only source of cooking fuel includes BLEN
Availability	Cooking less because of availability	Unsatisfied with availability	Neutral to availability	Satisfied with availability
Quality	Quality of cooking is not adequate		Quality of cooking is adequate	
Affordability	Not affordable		Affordable	
Convenience	Both difficult to use and time consuming		Either difficult to use or time consuming	Neither difficult, nor time consuming

NOTE: For dimensions where the categories span multiple tiers, only the higher tier values apply. For example quality and affordability dimensions can only take on Tier 1 or Tier 3. Health and safety can take on Tier 0, Tier 2 and Tier 3.

1. **Health & Safety** pertains to the health impacts of indoor air pollution resulting from the use of a particular cooking arrangement. It is one of the most important dimensions, as indoor air pollution together with the drudgery and lack of convenience associated with the use of traditional fuels, is one of the major drivers for households to transition to modern forms of cooking energy. There are two main determinants, cook-stove and fuel, which determine the level of indoor air pollution emission. Apart from this, the surrounding condition, i.e. open or close space, size of the room in which cooking is taking place, provision or absence of ventilation, proximity to the cook-stove, etc. determine the exposure of the emissions to affected individuals. This continued exposure over time determines the health impact on exposed population. Ideally, to determine the exact levels of exposure and to categorise into tiers based on this exposure one would need a multi-seasonal emission exposure profile for each household. However, such an exercise is well beyond the scope of this work. Instead, conservative estimates were made about the performance of households on this dimension using the following approach.
 - a. For all the households who use only traditional fuels, we assign them the bottom-most tier, irrespective of the type of cooking device and surrounding environment. We are taking this conservative approach because of three main reasons. First, in India the most common device to burn traditional biomass is still the traditional chulha. Of the surveyed households, 96 per cent report ownership of at least one traditional chulha. Second, the penetration and use of improved cookstoves is limited; only two per cent of the household report ownership of an improved cook-stove. Further, only 0.74 per cent households report that they still use their improved cookstove.

⁹ A search on Google Scholar with key words: 'Cooking energy access', 'access to clean cooking energy', 'access to cooking energy', and 'access to cooking fuels', collectively yield less than 200 results, as opposed to single search of 'electricity access', which yielded more than 2600 results.

Third, there is a significant divergence of the on-field performance as compared to the theoretical performance of improved cookstoves. All of these together lend support to the conservative estimation of the tier.

- b. Households which stack traditional fuels with cleaner fuel (Biogas, LPG, electricity) are categorised in Tier 2. The impact of transitioning towards cleaner fuels varies based on the extent of replacement of traditional fuels. Those, who are cooking mostly using cleaner fuels, are likely to reap greater health benefits as compared to others who use it to a lesser extent. However, since the exposure to emissions also depend on other factors such as ventilation of cooking area, proximity to cookstove and type and quality of biomass, we categorise all households using any amount of traditional fuel along with cleaner fuels into Tier 2. Moreover, the bottleneck of all these households is the same – stacking, so we put them in a common tier, for the health and safety dimension.
- c. Households using only clean fuel for cooking are ranked in the top tier, i.e. Tier 3.

This is a significant departure from the criteria used in the GTF for assessing households on the health and safety dimension. The GTF uses information on the type of cook-stoves owned by households for this indicator, but as discussed in the preceding paragraphs, just the type of cookstove alone cannot effectively determine the health impacts associated with the cooking arrangements in a household.

2. **Availability** dimension provides information on the availability of the primary cooking fuel for a household. Reduced availability of primary fuel could either lead to stacking using other (often inferior) fuel types, or worse, to curtailment of cooking itself. It is assessed on the basis of satisfaction of the household about the availability of their primary cooking fuel.¹⁰ Households that face availability issues, to the extent that it limits their cooking, are assigned to Tier 0. Those who are unsatisfied with their fuel availability were assigned Tier 1. Tier 2 captured the households who were neutral about their cooking energy availability. Finally, those who were satisfied with the availability of their cooking fuel were assigned Tier 3.
3. **Quality** primarily covers the quality of cooking associated with the primary cooking arrangement. This binary dimension is assessed by analysing the household's view on whether its primary cooking energy arrangement cooks food adequately or not. Quality could be an issue due to reasons including inappropriate cookstove unsuitable for particular utensils or cooking needs (local dishes), or fuel adulteration leading to improper combustion resulting in poor quality of cooking.
4. **Affordability** was measured by calculating total expenditure on procuring all types of fuel by a household to meet its cooking energy needs. If the total amount is less than six per cent of its total monthly expenditure, then the household is classified in the affordable tier. We used six per cent as the threshold spend on procuring cooking energy based on analysis carried out by Jain, Agrawal, & Ganesan (2014). The GTF considers only the affordability of the primary fuel used for cooking. In a significant departure from this assumption, this study considers overall expenditure on all cooking fuels; in order to effectively capture fuel stacking that is prevalent in many rural Indian households. To estimate the expenditure, we use market price of the fuel as stated by the respondents and use this in conjunction with the total quantity of fuel that is procured (from a vendor/ local market). For the purposes of the affordability analysis, no monetary value was assigned to biomass that is collected free-of-cost.
5. **Convenience** of cooking could be attributed to multiple factors like time taken for cooking, ease or difficulty associated in handling cooking appliances, ease of flame control or heat intensity, quick start-stop operation etc. Some of these could be desirable and others could be the necessary attri-

10 Due to the lumped nature of cooking fuel (except in case of piped gas supply or electricity – both of which are virtually non-existent in rural India), the availability of fuel in itself captures the reliability of fuel supply as well. Unreliable supply would lead to lower levels of satisfaction with fuel availability.

butes, each having a different weightage or importance depending upon individual household priorities. For the purpose of energy access determination, we use two basic criteria – an ordinal estimate of time consumed in cooking and the ease of cooking with the primary cooking arrangement. For households that report their primary cooking arrangement as both time consuming and difficult to use, are assigned Tier 1. Those who report any one of the two criteria as a problem with their primary cooking arrangement are classified into Tier 2. Tier 3 is assigned to those who report neither of these issues, as a challenge.

We used the same approach, as that adopted for electricity access, to determine the overall cooking energy access tier for a household (minimum across all dimensions). To address the subjectivity in defining the thresholds for various tiers, we undertook a sensitivity analysis by studying two alternative scenarios each with varying cut-off points for each dimension. We find that the current tier structures and their cut-off points are fairly robust, across the six states surveyed. The details of the same are provided in the Annexure III.

3.1.3 Aggregation of households results

Once the overall tiers for each household was determined (separately for both electricity and cooking energy), we aggregated results to create two respective indices (electricity and cooking) at state and division levels through the population adjusted weighted average approach. In mathematical form it can be understood as:

$$E = k \sum_{i=0}^3 f_i \cdot i$$

where E is the electricity index at state/division level, k is a constant with value $100/3$, used to normalise the index to a scale of 100. f_i is the fraction of households in i^{th} tier for electricity access, and i is the tier level. For example, at a state level, if proportion of households falling into Tier 1 and Tier 3 is 40 per cent and 60 per cent respectively, then the overall access index for the state would be $(0.4 \times 1 + 0.6 \times 3) \times 100/3 = 73.33$. As a result of this formulation, the aggregated index value can take values 0 to 100 (100 being the best possible index that can be achieved). The same approach as described above is used to calculate cooking energy access index (C) as well.

3.2 Survey and data gathering

Given the level of details and data points required to assess the energy access situation as per proposed framework, none of the existing datasets such as Census, NSS or IHDS could be used. In order to understand the true state of energy access, its barrier and drivers, and to empirically test our proposed energy access measurement framework, we conducted a large scale primary survey exercise. We surveyed 8,568 households across six states, Bihar, Jharkhand, Madhya Pradesh, Odisha, Uttar Pradesh, and West Bengal. Together, these states house approximately 500 million people (almost 40 per cent of the Indian population) and have some of the lowest levels of energy access in the country.

The technical details of the survey – starting from the questionnaire design to implementation are provided in a separate document which is available online¹¹. A brief summary of the process including various stages is provided below.

¹¹ Technical report on survey design and implementation is available at: <http://ceew.in>

3.2.1 Questionnaire design

This stage required defining the substantive goals of the survey, identifying the information to be collected, and drafting a questionnaire that enabled the survey team to collect the data. It evolved through several rounds of revisions, with critical inputs coming from two pilot surveys that were conducted to ascertain the ease of administration and the nature of responses received from respondents. The questionnaire was also reviewed by some of the external subject experts. The final questionnaire (designed to be completed within 45 minutes) consisted of 155 questions and encompassed the following broad sub-sections.¹²

1. Socioeconomic information of the household
2. State of electricity access
3. Electricity access related satisfaction
4. State of cooking energy access
5. Cooking energy related satisfaction
6. Policy preferences of the household

3.2.2 Sampling

A critical step in the survey design process was to create a robust sampling strategy that would capture an accurate picture of the state of energy access using a representative sample.

We used a random sampling approach with multiple levels of stratification. States in India are geographically divided into administrative divisions. Given the logistical and resource constraints, we sampled one district from each division, while ensuring a geographically representative sample. In West Bengal alone, where there are only three large administrative divisions, each with significant population, two districts were chosen from each division to get better representation.

Using 2011 Census data, we first split each district into two groups: small and large villages, based on their population size. Each group consisted of 50 per cent of all rural households in the district. Next, 7 villages from each group were chosen at random in every district. This split of large and small villages was necessitated to ensure that the specific challenges faced by small and big villages would be captured adequately. Finally 12 households were randomly selected from each village, to cumulatively form a sample of 8,568 respondents. Even within the villages, we tried to ensure a representative sample across different habitations/hamlets within the village.

The number of districts, villages and households surveyed in each state are shown in Table 3.

¹² The complete survey instrument, both household and village level, is available at <http://ceew.in>

Table 3: Sampling strategy for the six states

State	Divisions	Districts	Villages	Responses
Bihar	9	9	126	1,512
Jharkhand	5	5	70	840
Madhya Pradesh	10	10	140	1,680
Odisha	3	3	42	504
Uttar Pradesh	18	18	252	3,024
West Bengal	3	6	84	1,008
Total	48	51	714	8,568

3.2.3 Data collection and cleaning

For the data collection exercise, we selected enumerators through role-playing exercises. For all teams of enumerators, we conducted in-person training sessions. Further, to the extent possible, we tried to design a self-contained questionnaire, which included all the instructions to avoid any confusion. Two pilot surveys were carried out to check the reliability and validity of the questionnaire. We made modifications to the questionnaire based on the pilot survey results. We carried out a thorough quality check of the data for incorrect recording of observations, missing values as well as outliers, prior to the analyses.

3.3 Limitations

While the framework has been developed keeping in view the nuances associated with the state of energy access and representative of the ground realities of energy delivery in India, it does have certain limitations. Listed below are points that must be noted while using this framework.

1. First and foremost, evaluation of the framework is based on stated responses in a face to face survey. A number of the questions on energy consumption levels rely on the respondents to recall consumption in the past month (or an average level over a longer period). To this end, all the information may not be entirely accurate. But given the lack of a better alternative to gather such levels of details across households, this limitation appears as a necessary evil.
2. Further, there were few questions for which the responses were not forthcoming from all households. For some of these questions that were not perception based, we imputed values for the missing data points. These include data points for questions such as “what is the market price at which LPG cylinders are sold near you?” This was done from responses from other respondents who were in close proximity (in geographic terms) to the household. Imputed values could represent responses from others in the hamlet, and if data-points were still found missing then it would move progressively up the aggregation chain to village-level and the district-level.
3. The questionnaire was carefully designed, and trainings were rigorously conducted to minimise the enumerator bias and keep them from leading the respondents. Wherever discrepancies were observed (in the data), the survey company was asked to either cross-verify the information or redo the survey. In fact, the entire survey exercise was re-conducted in Odisha, as significant enumerator bias was observed. Despite all these efforts, it is likely that some responses to reflect the enumerators bias and responses to a more ad-hoc framing of the question that was posed.
4. Assumptions had to be made in places where specific questions to elicit the required response were not in place or were difficult to administer. For instance, we assumed all houses connected to the grid to be connected at a capacity of more than 500W. Establishing the connected load in each household

is a tedious task and was beyond the scope of the survey itself. Further, tariff orders for Jharkhand, Odisha and West Bengal could not be found for 2014-15. An earlier tariff order from 2013-14 was used to in estimating the affordability metrics.

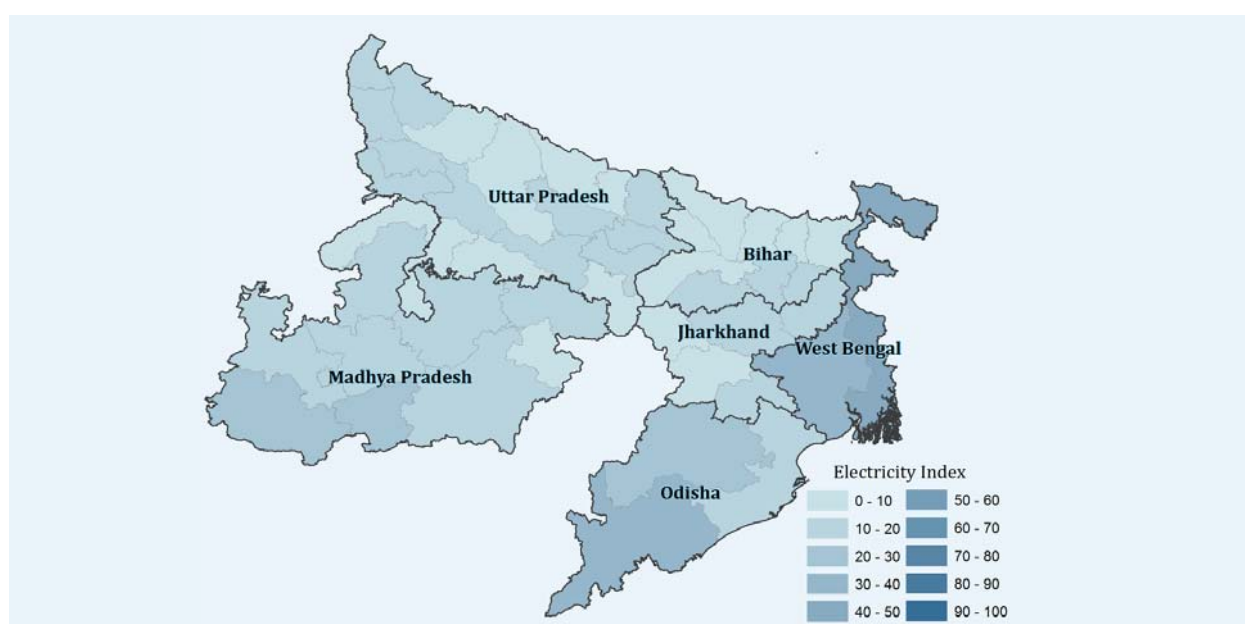
5. Talking about affordability aspects, it strongly depends on the elicited monthly household expenditure. While NSS estimates monthly household expenditure in an itemised manner, we use only a single direct question to gather the same information. Thus, introducing the possibility of recall bias. Moreover, the fact that a part of the rural expenditures could be in kind or out of home grown sources, could further complicate the actual estimation of monthly expenditure values.
6. The actual survey took place in three different languages. Significant effort was made to control (and prevent) translation and interpretation errors. However, given the nature of the survey and the level of comprehension of the respondents, there is a likelihood that some questions may not have been administered as expected.
7. The threshold levels for the tiers have been constructed using the best available knowledge and information. The interpretation of the results from the multi-tier framework is contingent on the definition of tiers. However, in the absence of published literature in this space, threshold levels for the tiers can be a point of contention. We hope that in subsequent rounds of this exercise, academic research catches up and provides us with more concrete bases for defining the tiers.

4. Results

4.1 Electricity access

The evaluation of electricity access, using the multi-tier framework, paints a grim picture of the rural areas in the six states. On a scale of 0 to 100, the electricity index across the six states ranges from as low as 8.1 for Bihar to 41.8 for West Bengal. A map, highlighting the electricity access situation of each division across these six states, is shown in Figure 1. Darker shades represent a better electricity access situation. Majority of areas are in lightest shades, especially in Bihar Jharkhand and Uttar Pradesh, and points to the poor electricity access situation in these areas. It is also important to note that no division across these states achieves an electricity index score beyond the 60-70 band (the highest possible score being 100).

Figure 1: Electricity access index for six states



Though the states exhibit variation in the distribution of households across tiers and in the various factors that limit their progress to higher tiers, there are some similarities across the states. In an attempt to identify key areas for action, we provide an in-depth analysis of issues faced in each state in the subsections below.

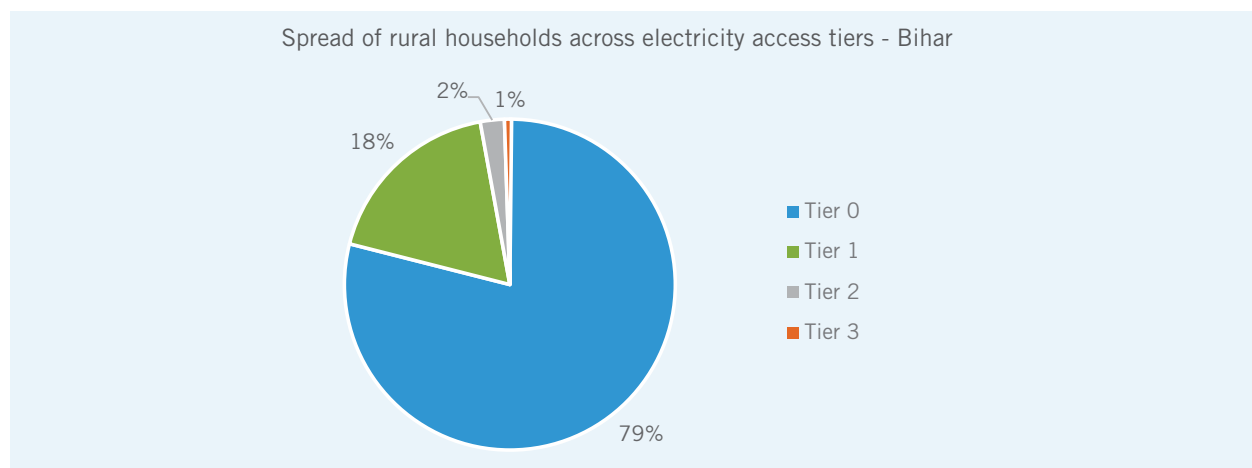
4.1.1 Bihar

Bihar performs the poorest among the states surveyed in this study, when assessed for rural electricity access. Our survey data indicates that only 20 per cent of the rural households use electricity as their primary source of lighting in Bihar. As compared to the Census (2011), the fraction of households reporting

electricity as the primary source of lighting is nearly double. There has clearly been an improvement in the intervening five years. However these indicators are in stark contrast to reports indicating that 95.5 per cent of villages in Bihar are electrified (CEA, 2015), owing to the definition of village electrification followed by the rural electrification program.¹³

Bihar, with an electricity access index of 8.1 has the lowest aggregated index among all the states surveyed. The electricity access index for different administrative divisions in the state ranges from 5 to 12 (on a scale 0 to 100). The issue of poor access is prevalent across the state and not limited to specific pockets.

Figure 2: Eighty per cent households in Bihar experience almost zero access to electricity



The lack of electricity access to 80 per cent of the population of Bihar is corroborated by the fact that these many households indicated kerosene to be their primary lighting source. These households include both those without an electricity connection as well as those, who lie in Tier 0 because of other limiting dimensions such as reliability, duration and quality of electricity supply.

4.1.1.1 Tier 0 Households in Bihar

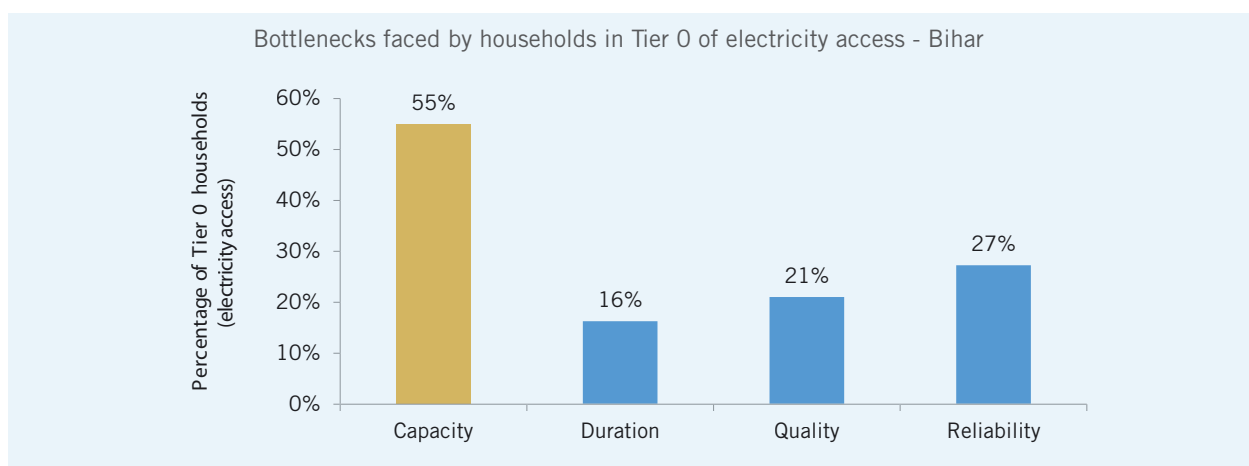
Analysis of the households in Tier 0 revealed that 55 per cent of these suffer from a lack of capacity (see Figure 3), implying the absence of any source of electricity, be it grid, micro-grid, solar home system or even a solar lantern. The remaining households that are in Tier 0, despite possessing an electricity connection, suffer from issues such as poor reliability, low duration of supply, and/or poor quality of supply. With five or more days of complete black-out in a month, more than a quarter of Tier 0 households are plagued by poor reliability of electricity. Similarly, 21 per cent of the households in this tier suffer from poor quality of electricity, captured by the number of days with high or low voltage supply. The duration of electricity supply is another impediment faced by households, with as many as 16 per cent of the households in this tier receiving electricity for less than 4 hours a day.

As per the framework used in this report, households without any source of electricity automatically fall in Tier 0. However, for those with a source of electricity, several of the other challenges, as discussed above, may co-exist. This can be better understood by considering a household that is connected to the grid but receives only three hours of electricity a day and has an average of six days a month with no

¹³ A village is deemed as electrified if basic infrastructure such as transformers and distribution lines are provided in the inhabited areas. In addition, public spaces are required to be electrified. The requirement also states that at least 10% of the households in the village must have an electricity connection.

electricity supply at all. Our framework would then place such a household in Tier 0 because of both the duration and reliability of electricity supply challenges. In order to understand the various bottlenecks that households face, it is important to count such a household as experiencing both bottlenecks. This explains why the duration, quality and reliability proportions in Figure 3 below do not add up to 45 per cent. The same principle is applicable throughout the analysis for other tiers and states and equally for cooking energy as well.

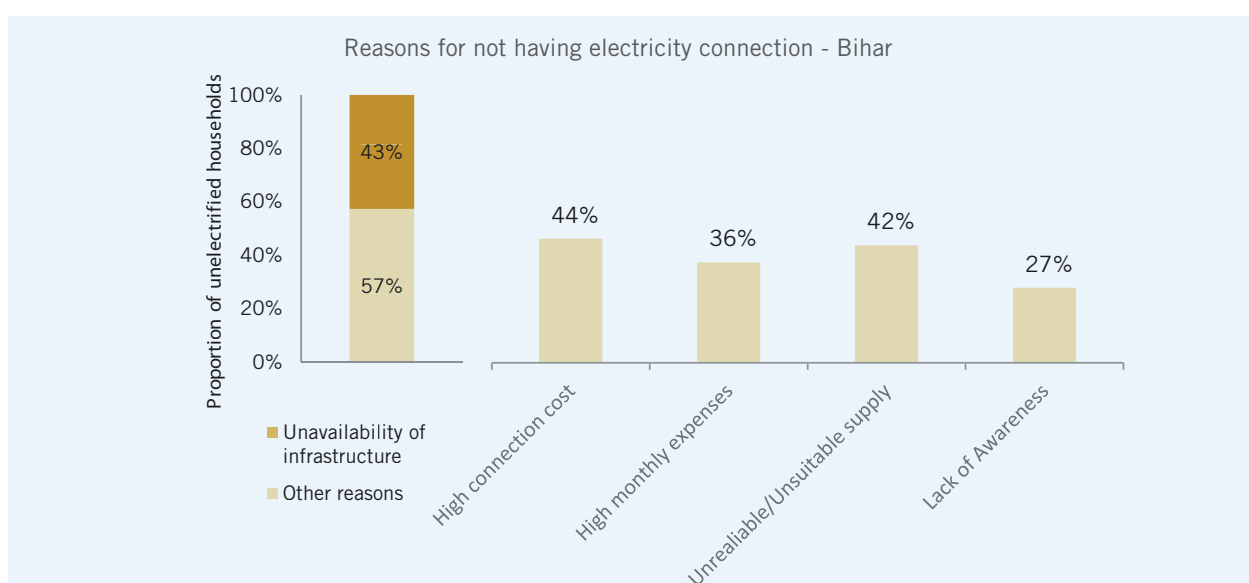
Figure 3: Reasons for household's lacking electricity access (being in Tier 0)



4.1.1.1.1 Un-electrified Households in Tier 0

Among those that do not have an electric connection, nearly 43 per cent indicated the lack of the necessary infrastructure (grid) in their vicinity, as the reason for their household not having a connection (Figure 4). However, a large fraction of households did not have a connection despite having the necessary physical infrastructure in the vicinity. These households identified high connection cost and unreliable electricity supply as the main reasons for not getting a connection. In addition many were of the view that recurring monthly expenditure would be high and a large number were just unaware of the process of getting a connection.

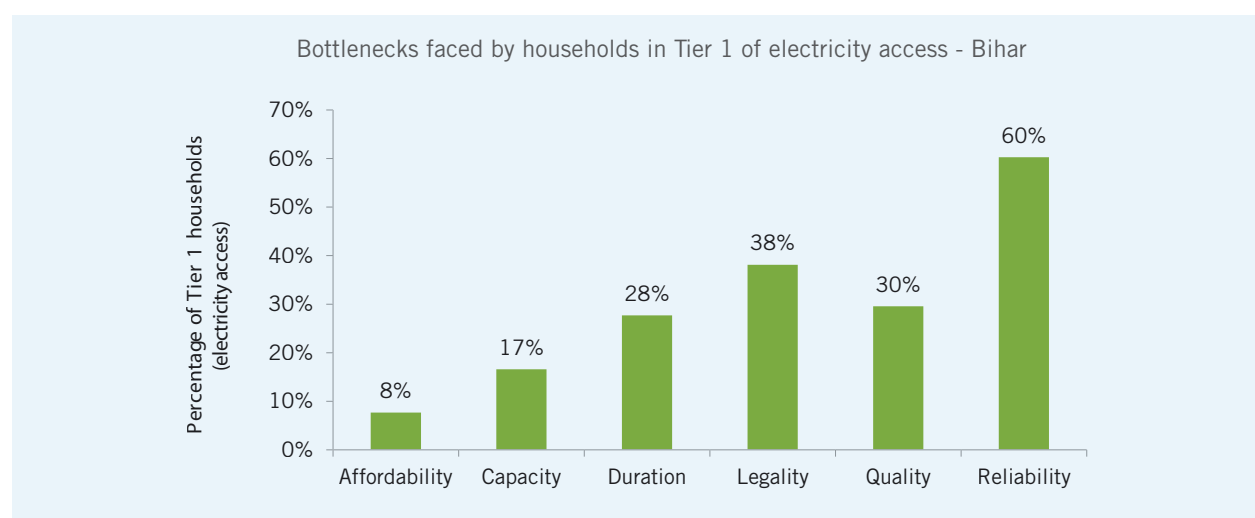
Figure 4: Majority of un-electrified households chose to remain un-electrified due to several challenges that may co-exist



4.1.1.2 Tier 1 Households in Bihar

For the small proportion (18 per cent) of households in Bihar that are categorised in Tier 1, reliability of electricity supply emerges as a key limiting factor. A large fraction of households face two to four black out days in a month. A large proportion of households in this tier are also constrained by the legal status of their connection. This alludes to households either connecting illegally (tapping), or not paying the bills for their legitimate connections. A further analysis suggests that 90 per cent of the households having an illegal connection would have found their electricity consumption affordable, had they chosen to pay. It is confounding to see 38 per cent of Tier 1 households risking an illegal connection or not paying their dues against a legal connection.

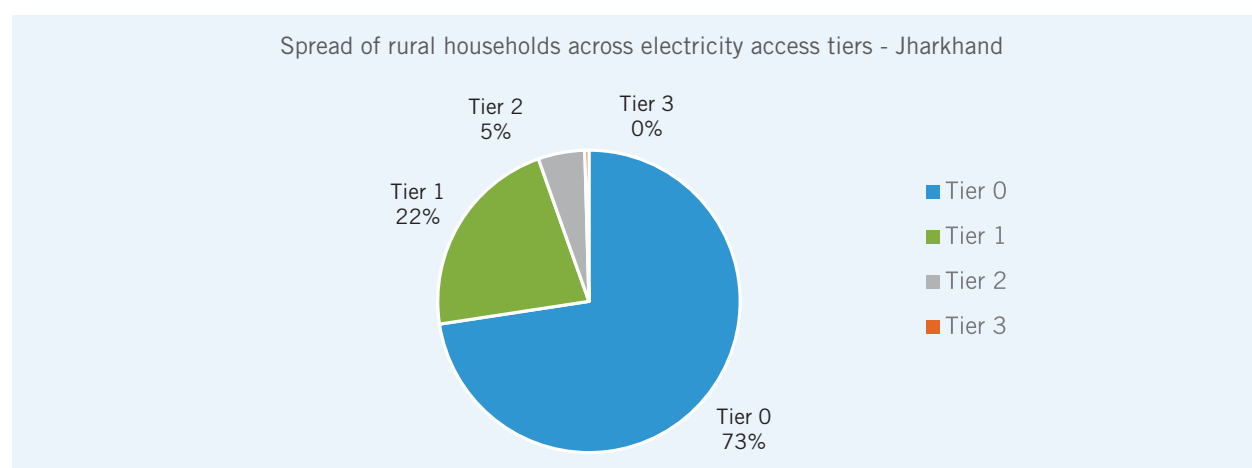
Figure 5: Limiting factors for Tier 1 households in Bihar; several of which may exit simultaneously



Only two per cent of Bihar's rural population was categorised in Tier 2. Though a detailed analysis is not presented here, the key bottleneck for households in Tier 2 was the duration of supply. More than 80 per cent of the households in this tier received electricity for less than 20 hours. Quality of provision, i.e. voltage issues were also an important barrier for nearly 50 per cent of the households.

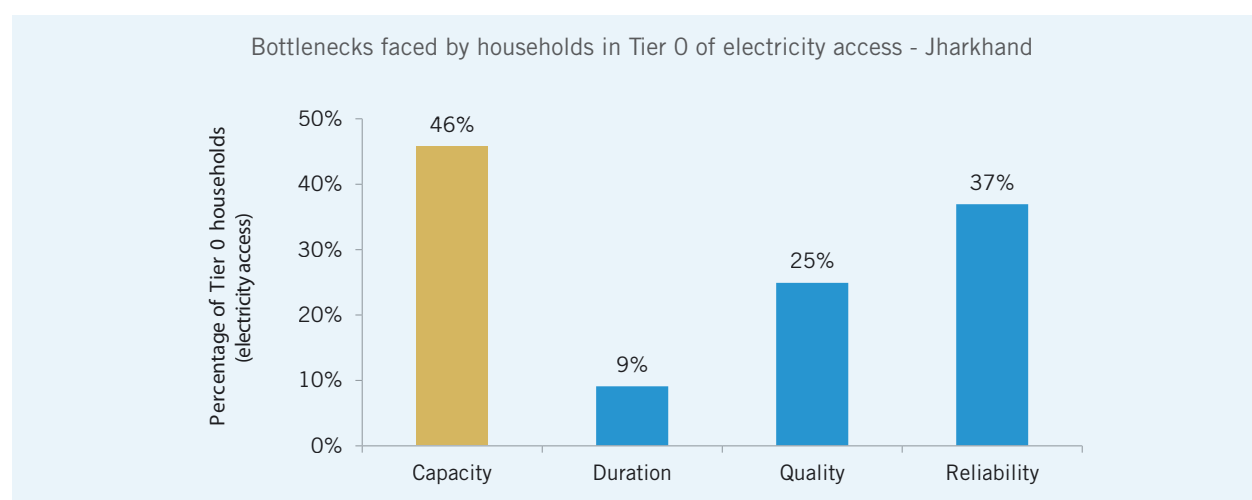
4.1.2 Jharkhand

In terms of electricity access, Jharkhand is comparable to Bihar with only 20 per cent of rural households using electricity as their primary source of lighting. However, Census 2011 suggested that over 32 per cent of rural households in Jharkhand use electricity as their primary lighting source. Using the multi-tier classification, almost 73 per cent of households in Jharkhand were categorised in Tier 0, 22 per cent in Tier 1 and about 5 per cent in Tier 2 (refer Figure 6). Less than 0.5 per cent of households were categorised in the higher tier. The aggregated electricity access index for Jharkhand is slightly greater than Bihar at 11.1. The administrative divisions of Jharkhand show significant variation in the overall electricity access index, ranging from 4.8 to 17.9.

Figure 6: No electricity access for three quarters of the rural population of Jharkhand

4.1.2.1 Tier 0 Households in Jharkhand

Nearly 46 per cent of the households in Tier 0 have no form of electricity supply (see Figure 7). The remaining 54 per cent face issues of reliability, quality and duration, in decreasing order. Reliability of supply remains a major bottleneck for electrified households, with 37 per cent of Tier 0 households facing five or more days of black-out in a month.

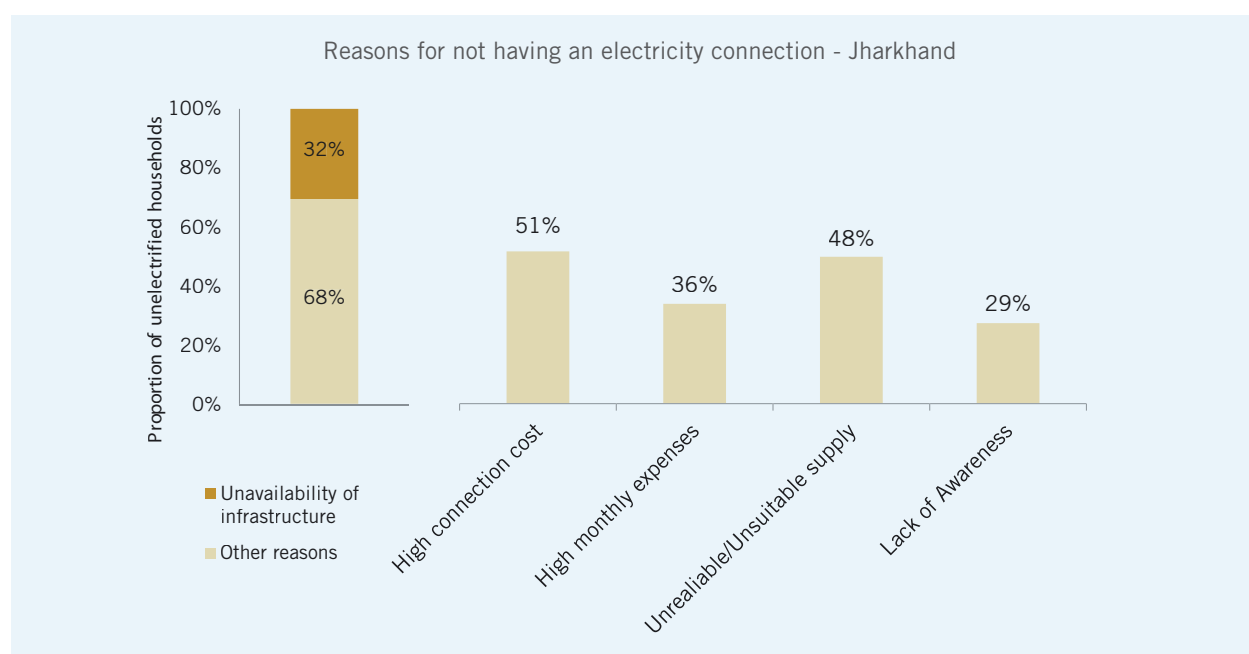
Figure 7: Households lacking electricity access due to the lack of connection, or due to other supply factors that may exist simultaneously

4.1.2.1.1 Un-electrified Households in Tier 0

Among those households that had no electricity connection, 32 per cent reported that the absence of basic infrastructure in the local area is the biggest challenge (see Figure 8). This implies that the remaining 68 per cent of the un-electrified households do not have an electricity connection, despite living in area with grid availability. For a majority of these households, the high initial installation cost of grid connection was the primary challenge. This is followed by issues of unreliable supply, recurring monthly cost and lack of awareness on the process to obtain a connection.

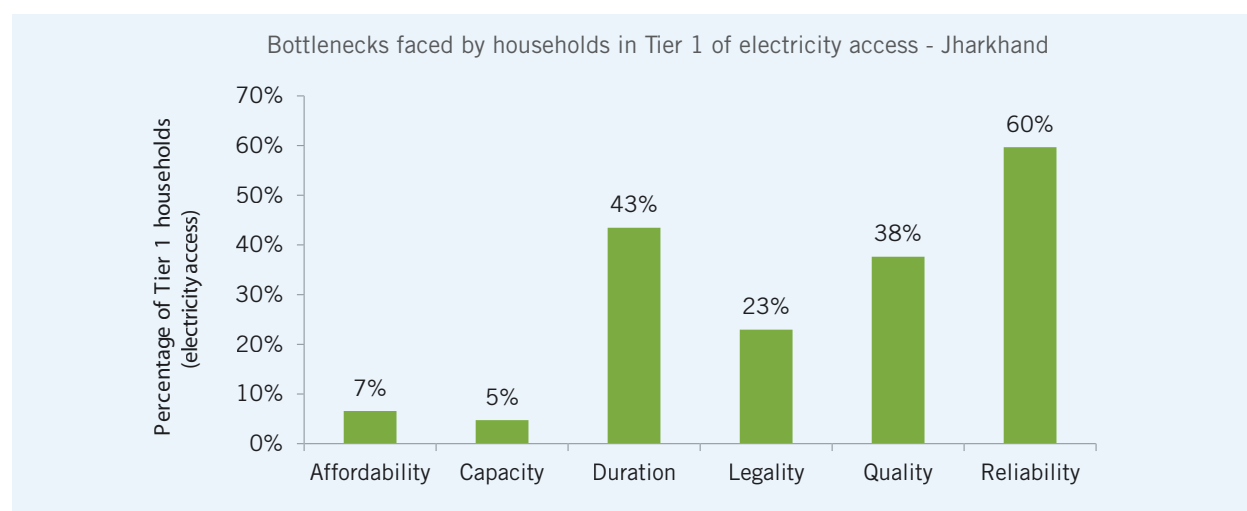
Nearly 55 per cent of such households (which did not have connection) stated that the high monthly expenditure is a major impediment. In the hypothetical scenario that all these unelectrified households were connected to the grid, we analysed the outlay for these households and determined whether electricity would be affordable to them. If all of these households were connected to a metered connection, electricity would be classified as unaffordable for less than one per cent of these households. If they were provided an unmetered connection, fewer than five per cent of these households would have found recurring expenses beyond their affordability limit. The disparity between households' perception and our evaluation of their electricity affordability could be a result of two possibilities. First, the misgivings associated with expenses incurred in electricity consumption, second the economic realities of these households preventing them from allocating even a small percentage (4% of monthly expenditure) towards threshold electricity consumption.

Figure 8: Majority of un-electrified households chose to remain un-electrified due to several challenges that may co-exist



4.1.2.2. Tier 1 Households in Jharkhand

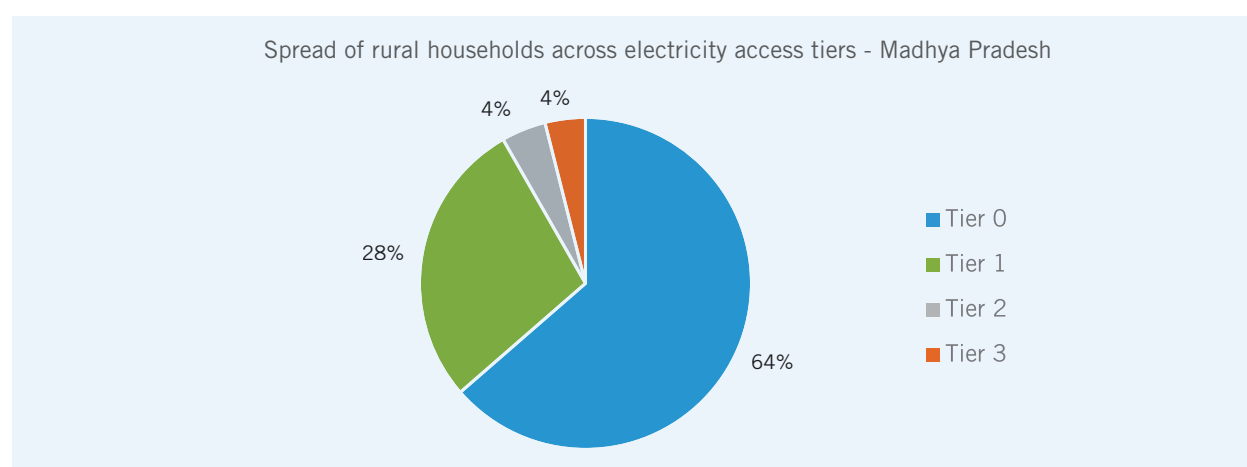
For households in Tier 1 the biggest hindrance to sustained consumption of electricity is the poor reliability of service. It precludes as many as 60 per cent of the households in this tier from progressing further (Figure 9). This is followed by the challenge faced by poor quality of supply due to voltage fluctuations and limited duration of electricity supply. Unlike Bihar, the legal status of connections is not as significant an issue. On the brighter side, affordability did not pose any major barriers to Tier 1 households in Jharkhand, to move into the higher tiers.

Figure 9: Limiting factors for Tier 1 households in Jharkhand, several of which may exist simultaneously

A mere five per cent of the rural households in Jharkhand were categorised in Tier 2. Just as in Bihar, the primary barrier for households in Tier 2 is the duration of supply. Almost no rural household in Jharkhand reported getting electricity for longer than 20 hours in a day. A small fraction of households also reported challenges with quality and reliability. Only 0.4 per cent of households in Jharkhand made it to the highest tier.

4.1.3 Madhya Pradesh

Nearly three quarters of the households in rural Madhya Pradesh reported the use of electricity as their primary source of lighting. This is further corroborated by reports from the Census (2011) which stated that 58 per cent of the households rely on electricity as their primary lighting source.¹⁴ However, the multi-tiered framework used in this report indicates that despite these encouraging statistics, nearly 64 per cent of all households still lie in Tier 0 (see Figure 10). The aggregated electricity access index for the state is 16.2, with the specific values for the various administrative divisions exhibiting a significant range - from 7.1 to 27.6.

Figure 10: A majority of households in rural Madhya Pradesh lie in Tier 0 despite high levels of electrification

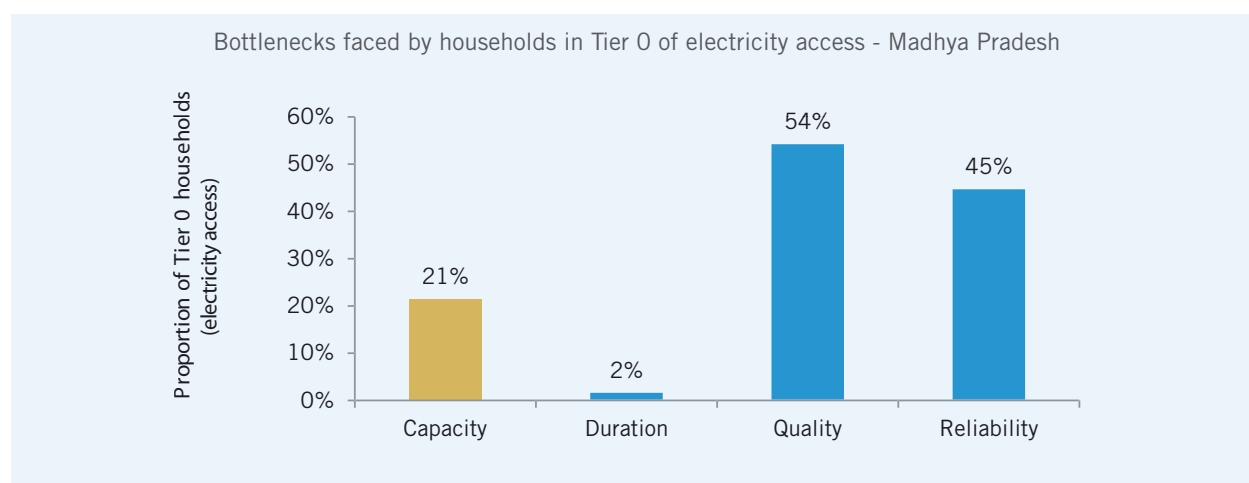
¹⁴ The proportion of households using electricity as their primary lighting source was higher in 2001 (62.3%)

4.1.3.1 Tier 0 Households

Although 72 per cent of the households report using electricity as their primary source of lighting, as many as 64 per cent of the households are classified in Tier 0. This indicates that the capacity and duration of supply were not major impediments for Tier 0 households. Our multi-tier framework further establishes this fact, and points to some of the key reasons for such a large proportion of electricity users being categorised in Tier 0 (see Figure 11).

Over 54 per cent of the households in Tier 0 experience quality issues. These households experience voltage surges on four or more days or have experienced low-voltage situations for seven or more days (in a month), which can adversely impact appliance life and use, respectively. Apart from the issues of quality associated with the supply, nearly 45 per cent of Tier 0 households experienced five or more black out days in a month, resulting in poor reliability as well.

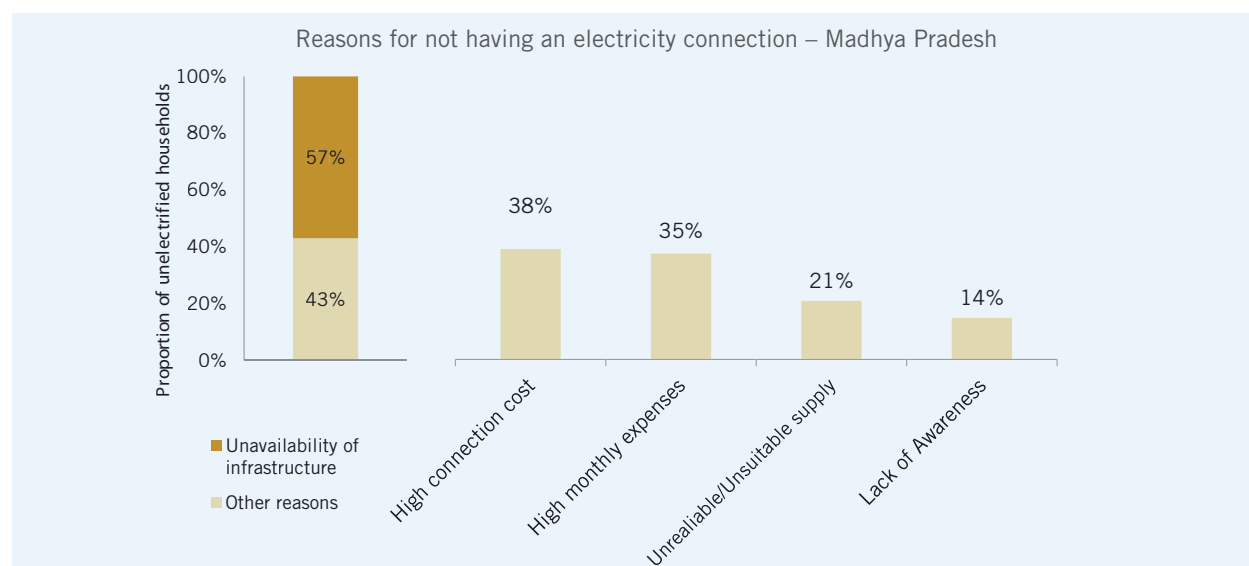
Figure 11: Quality and reliability of supply emerged as biggest bottleneck for Tier 0 households in Madhya Pradesh



4.1.3.1.1 Un-electrified Households in Tier 0

Madhya Pradesh has only a small proportion of rural households with no form of electricity supply. Among those who are un-electrified, 57 per cent report the absence of the electricity grid in their vicinity as the reason for not having a connection (see Figure 12). The remaining (43 per cent) that are unelectrified, despite having the option to connect to the grid, report affordability issues, both in terms of initial cost of subscription as well as monthly recurring costs. Further, 21 per cent of the un-electrified households attributed their non-subscription to unreliable supply.

Figure 12: Un-electrified households in Madhya Pradesh are battling the lack of grid infrastructure, but face several other challenges too

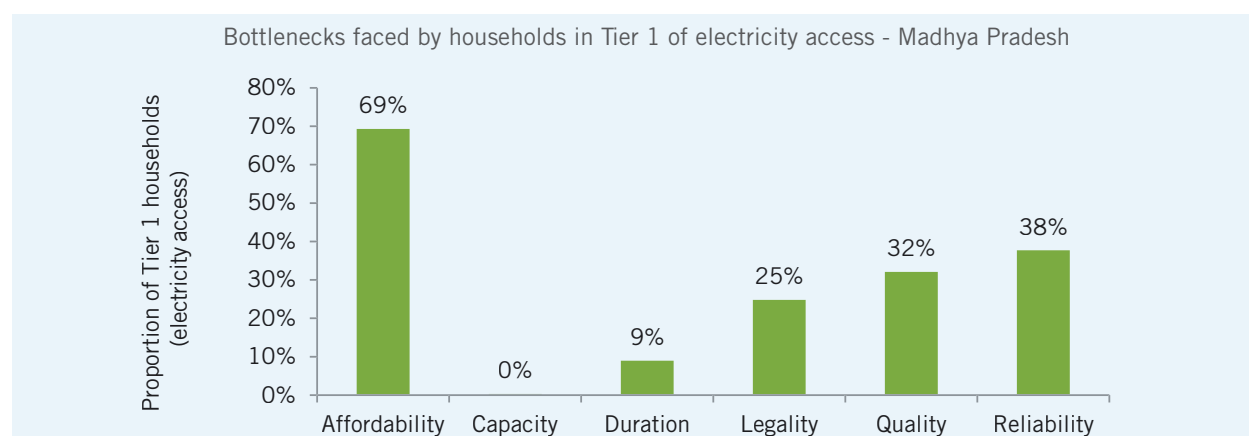


4.1.3.2 Tier 1 Households in Madhya Pradesh

Our analysis indicates affordability as a major barrier, limiting the progression of 69 per cent Tier 1 households to higher tiers (see Figure 13). Reliability and quality of electricity also pose barrier to 32 per cent and 38 per cent of Tier 1 households, respectively.

Further analysis using the affordability metric reveals that unmetered households face this issue disproportionately, as compared to metered households. For nearly 90 per cent of the unmetered households in Tier 1, affordability is a limiting factor, as opposed to 51 per cent of the metered households. In an attempt to bring out this comparison effectively, we will reiterate the underlying assumptions in establishing affordability of consumption. We assume that a household should be able to afford at least 30 units per month. As per the Madhya Pradesh tariff order (for 2014-15), all unmetered households are charged for a monthly consumption of 75 units at INR 3.4/unit. This works out to be INR 285 per month for un-metered households, irrespective of whether they consume the said number of units. Metered households, on the other hand, would pay only INR 129 per month for consuming the 30 units/ month. While the assumption that unmetered households did not consume their full quota is not entirely valid, it is very likely, given the poor reliability and quality of electricity supply.

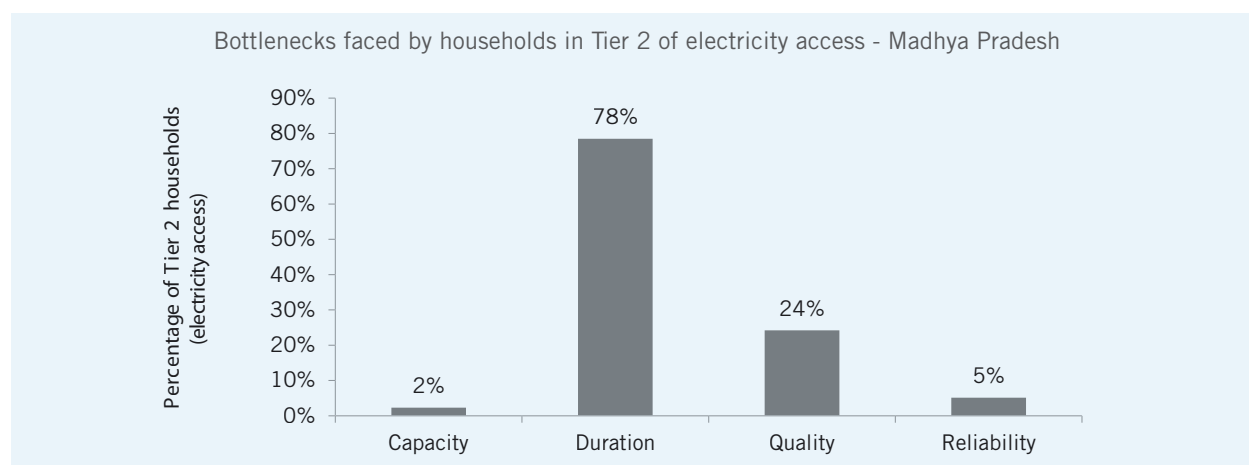
Figure 13: Limiting factors for Tier 1 households in Madhya Pradesh, several of which may exist simultaneously



4.1.3.3 Tier 2 Households in Madhya Pradesh

Once households graduate to Tier 2 of electricity access in Madhya Pradesh, duration of supply is the greatest challenge limiting them from progressing to the highest tier (see Figure 14). Within Tier 2, 78 per cent of the households receive an average of 8 to 19 hours of electricity a day. Almost one fourth of these households, which received supply for 18 hours or more, but less than 20 hours, was narrowly denied progression to the highest tier.

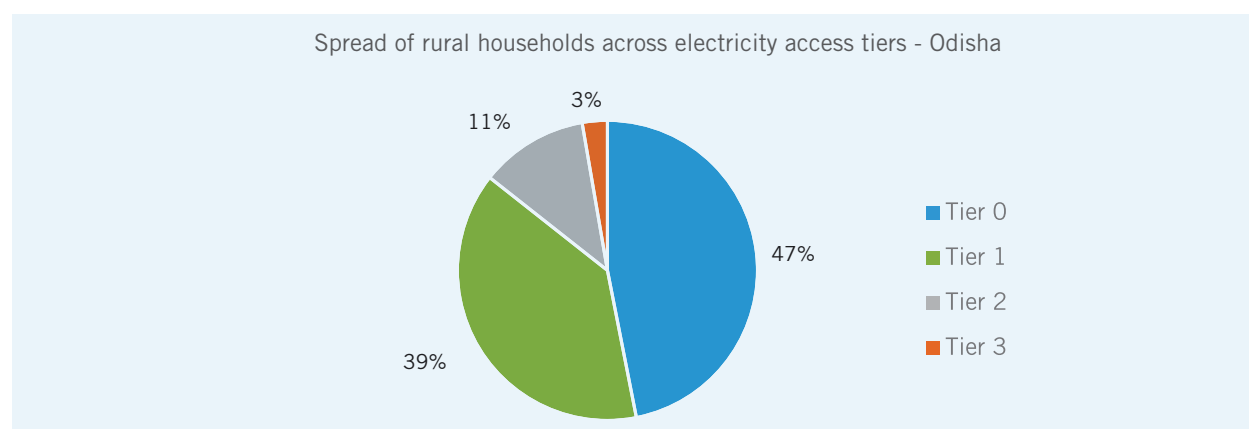
Figure 14: Duration of supply is the greatest impediment to Tier 2 households in Madhya Pradesh, with other issues often occurring simultaneously



4.1.4 Odisha

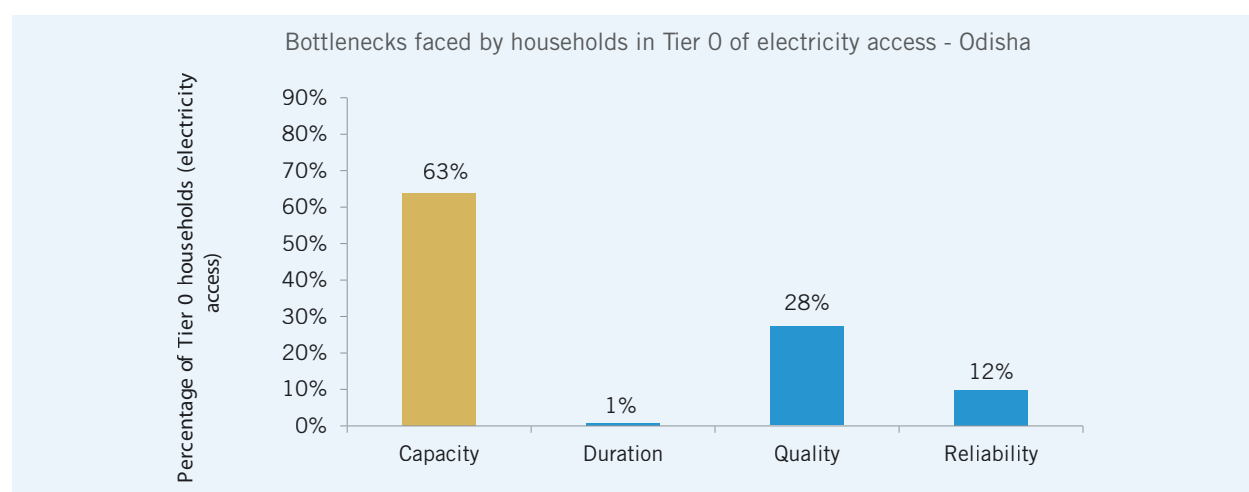
As per Census 2011, 35.6 per cent of the rural households in Odisha reported electricity as their primary source of lighting. Our survey reports this number to be significantly higher at 63 per cent. The observed increase could be a result of increased electrification and/or an improvement in the service of electricity supply. Further analysis of our survey data from Odisha indicated that almost 63 per cent of the surveyed households gained access to grid-based electricity only in the last five years, corroborating our hypothesis about increased availability and uptake of electrification in the intervening years between the Census exercise and our survey.

Of the households connected to grid electricity, over 90 per cent report electricity as their primary lighting source, thus indicating relatively better quality of supply as compared to other states. Looking at the tier results, although less than half the households are categorised in Tier 0, most of the remaining households are limited to Tier 1, with only 15 per cent progressing to Tier 2 and Tier 3 (see Figure 15). The aggregate electricity access index for the state is 23.4, which is second only to West Bengal. The electricity access index values for the various administrative divisions of Odisha range from 18.4 to 33.1.

Figure 15: Odisha emerges as one of the better performers on rural electricity access, among six surveyed states

4.1.4.1 Tier 0 Households in Odisha

The main challenge faced by Tier 0 households in Odisha was that of electricity capacity. Nearly 63 per cent of households in Tier 0 did not have access to any source of electricity (see Figure 16). A much smaller proportion of the households remained without access because of other challenges related to electricity supply. Survey responses suggest that 28 per cent of the households in this tier experience quality issues (high number of days with voltage spikes and low voltage), while only 12 per cent experience reliability related issues (five or more black-out days in a month).

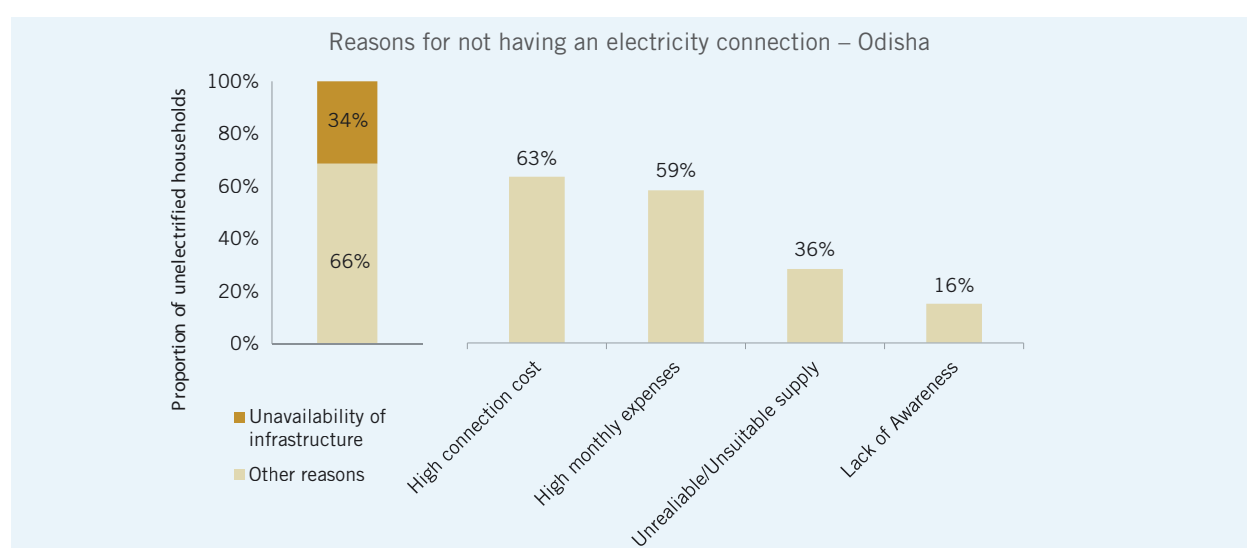
Figure 16: Complete absence of electricity is the main challenge for majority of Tier 0 households in Odisha

4.1.4.1.1. Un-electrified Households

For 34 per cent of the households lacking electricity capacity/connection, the absence of the electricity grid was reported as the main roadblock (see Figure 17). Among those that did not have an electricity connection despite having the necessary infrastructure in the vicinity, high expenditure associated with the initial connection and recurring expenses were the primary bottlenecks. Far fewer households stated reliability as a factor in deciding not to have an electricity connection.

Bottlenecks of Tier 0 and un-electrified households collectively indicate that making grid connection affordable to households could go a long way in improving electricity access for Tier 0 households in Odisha.

Figure 17: High costs of electricity connection and supply are attributed as major barriers by un-electrified households in Odisha

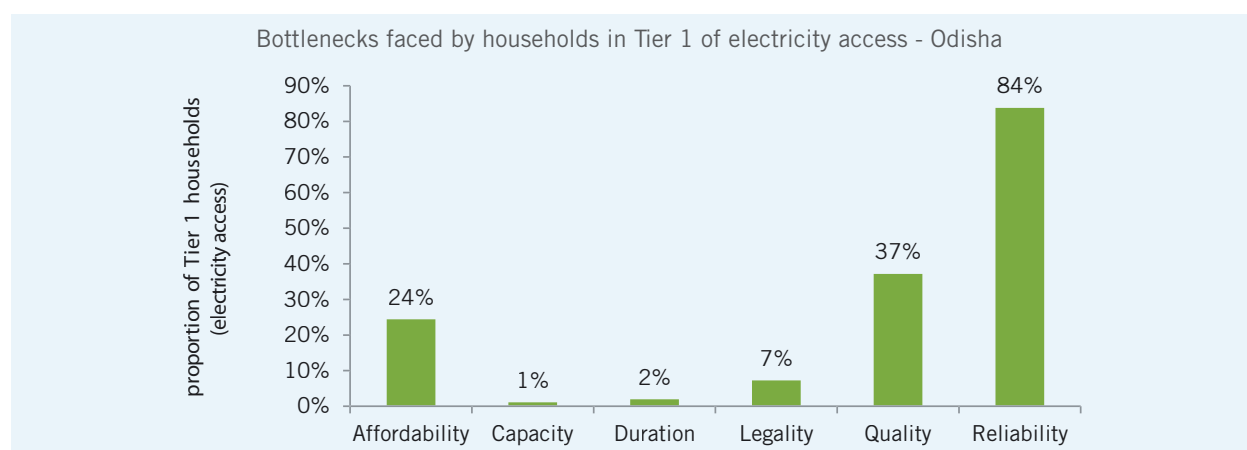


4.1.4.2 Tier 1 Households in Odisha

Reliability of supply is the single largest issue faced by Tier 1 households in Odisha, with nearly 84 per cent of the households experiencing two to four days of blackout in a month (see Figure 18). However it is important to note that the issue of duration is not a major problem for Tier 1 households. Given that duration of electricity supply is not a limiting factor; the issue of blackouts is confounding. Blackouts typically could be attributed to faults in the infrastructure but given that much of the electrification in Odisha has taken place in the last decade or so, decrepit infrastructure seems like an unlikely cause.¹⁵ It is then likely that the day-long blackouts (resulting in low reliability) are a result of intended outages by the utilities to balance demand or poor levels of monitoring and response. However, only a detailed inspection of load curves and discussions with the local distribution companies can provide the necessary insight into the reasons for frequent blackouts.

Poor quality of supply was another significant limiting factor, experienced by 37 per cent of Tier 1 households. Odisha has been successful in achieving a high metering rate and establishing an appropriate tariff structure. As a result, more households find electricity to be within the affordability limits.

Figure 18: Blackouts is the biggest issue plaguing Tier 1 households in Odisha

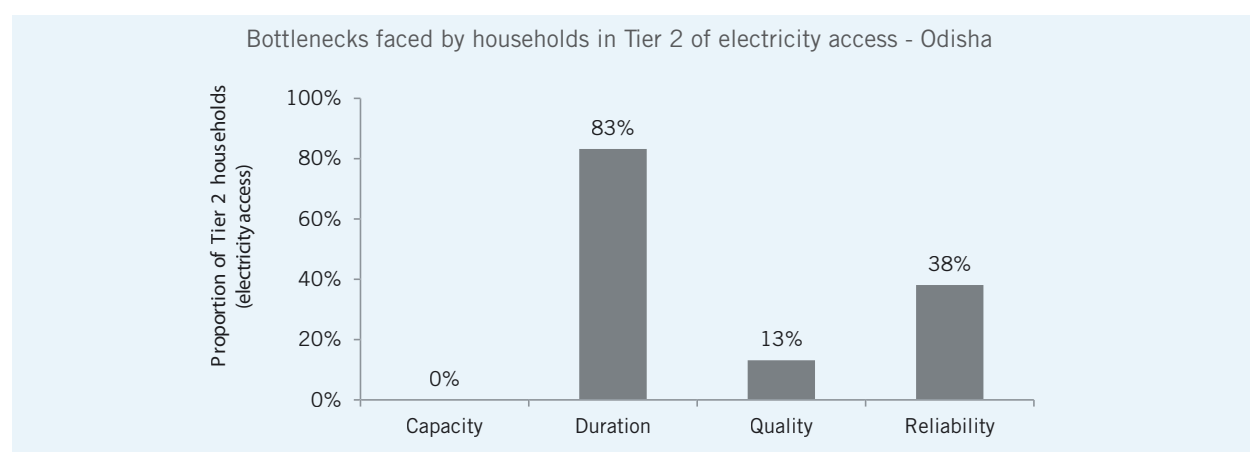


¹⁵ Census 2001 reports 19.4% of households using electricity as their primary source of lighting as opposed to 35.6% in 2011

4.1.4.3 Tier 2 Households in Odisha

For Tier 2 households in Odisha, duration of supply is the main limiting factor. Eighty-three per cent of Tier 2 the households receive electricity for 8 to 19 hours a day (see Figure 19). As per our framework, households must have 20 or more hours of electricity supply to progress to Tier 3. Sixty-three per cent of households with duration as limiting factor in Tier 2, miss it by margin, as they receive 18 hours or more hours of supply. Apart from duration, poor reliability of supply is the other main challenge for Tier 2 households. However, it is experienced by much smaller proportion of households in Tier 2 as compared to Tier 1.

Figure 19: Duration of supply acts as the greatest impediment for Tier 2 households in Odisha, even as other challenges exist simultaneously



Box 2 : What has RGGVY delivered so far?

Rajiv Gandhi Gramin Vidyutikaran Yojana (now DDUGJY) has been under implementation for over a decade now. Earlier this year, the overall village electrification rate in India was reported as 96.7%. However, this number is based on a rudimentary definition which deems a village as electrified even if only 10 per cent of households in the revenue village have an electricity connection. The true impact of efforts in rural electrification can only be measured by the number of households that actively use electricity - whether from conventional grid sources or otherwise. The substantial focus of the RGGVY program has been on the extension of the convention grid. As part of the survey, questions were posed – both at the village and household level, to gauge the **true penetration** of RGGVY and get a better perspective on its effectiveness, as per the stated goals of the rural electrification program.

Overall, it is observed that there is a significant **lag** between the time when electricity was first brought to the villages and the households in these villages actually getting electrified. The median lag ranges from 2 years (in the case of Jharkhand) to more than 25 years in Orissa and about 15 years in the case Madhya Pradesh and Uttar Pradesh. It is worthwhile mentioning that the electricity provision even at the village level, in Bihar and Jharkhand, has happened only in the last decade.

Among all the villages surveyed for the study, nearly 43% were part of the RGGVY implementation, as reported by village heads. Households in Bihar show marked benefits of participating in RGGVY: ~20% higher household electrification rates were seen in those villages that were part of the scheme. In villages which were beneficiaries of the RGGVY scheme, the household electrification rates vary from 47% in Bihar to 92% in West Bengal. UP (60%) and Jharkhand (61%) showed low levels of household electrification, while MP (83%) and Orissa (74%) fared well. In villages that witnessed RGGVY, in the states of Bihar, Jharkhand and Uttar Pradesh, more than 60% of the households that had an electricity connection (at the time of the survey) got one only after the program commenced in the villages. Intensive electrification under RGGVY does seem to have impacted villages in these three states in a positive manner.

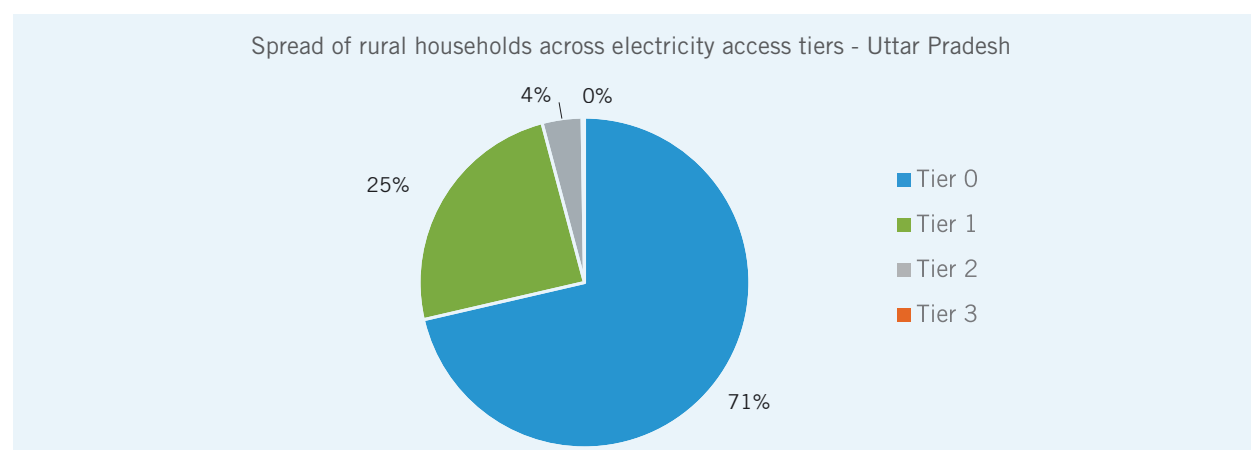
Average electrification rates of important facilities like dispensaries, primary and middle schools, anganwadis, etc. vary from 67% to 90% across states. This is an important performance metric of rural electrification and suggests that more work remains to be done. Surprisingly, the electrification rate for these shared facilities in the states of Bihar and Jharkhand are at the higher end, whereas states like West Bengal and Orissa report the lowest rates.

In summary, the dedicated electrification program has benefited the states of Bihar, Jharkhand and Uttar Pradesh. However, household attainments suggest that rural electrification is far from complete in these three states. Given the diverse technological options available, it is probably an opportune time to review the route to electrification for the millions of households in these states that still do not have electricity connections and adequate supply.

4.1.5 Uttar Pradesh

Uttar Pradesh shows many similarities to Jharkhand and Bihar in the overall distribution of households across the electricity access tiers. Over 71 per cent of all households in Uttar Pradesh are classified into Tier 0 and 24 per cent in Tier 1 (see Figure 20). The aggregate electricity access index for the state is 11.0 (on a scale of 100). The various administrative divisions of Uttar Pradesh have index values ranging from 4.8 to 18.8. As per Census 2011, nearly 24 per cent of rural households used electricity as their primary source of lighting. Our survey results show similar results, with 22.6 per cent of the households surveyed indicating that electricity is their primary source of lighting. Further analysis indicates that while 57 per cent of rural households gained access to electricity in the last five years, only 36 per cent of the newly electrified households actually use electricity as their primary source of lighting. This clearly indicates that poor electricity supply remains a challenge for the state, even as it progresses on the binary electrification indicator.

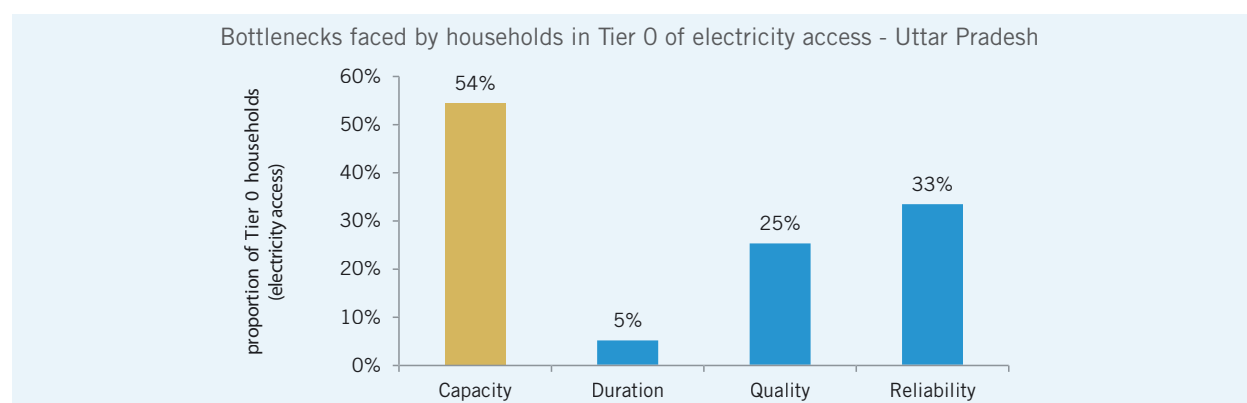
Figure 20: Electricity access in rural Uttar Pradesh remains low even as more households get electricity connection



4.1.5.1 Tier 0 Households in Uttar Pradesh

Lack of electricity capacity is the leading cause of households being placed in Tier 0 in Uttar Pradesh. In addition to capacity constraints, more than a third of the households witness five or more days of total blackouts in a month, thereby making reliability a significant challenge. Furthermore, a quarter of the households in this tier experience at least four days of high voltage and/or seven days of persistent low voltage, making the quality of electricity supply an important impediment (see Figure 21).

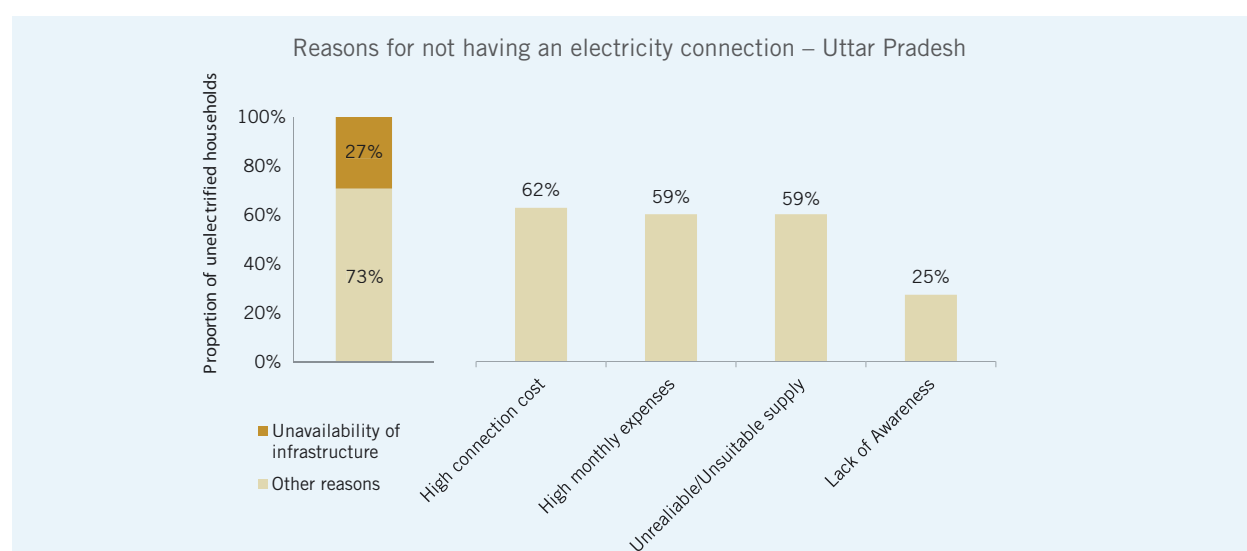
Figure 21: Both lack of electricity capacity as well as supply attributes of electricity plague Tier 0 households in Uttar Pradesh



4.1.5.1.1. Un-electrified Households in Tier 0

Further analysis of households lacking electricity capacity reveals that while 27 per cent of these households do not have the necessary infrastructure in their area, the remaining 73 per cent chose not to obtain a connection despite the presence of grid in their vicinity. For the latter group, affordability of acquiring and maintaining an electricity connection, as well as unreliability associated with the grid were the most prevalent issues (see Figure 22). It is also interesting to note that as many as one in four of the un-electrified households are unaware of the process of getting an electricity connection.

Figure 22: Majority of un-electrified households chose to remain un-electrified due to several challenges that may co-exist



4.1.5.2 Tier 1 Households

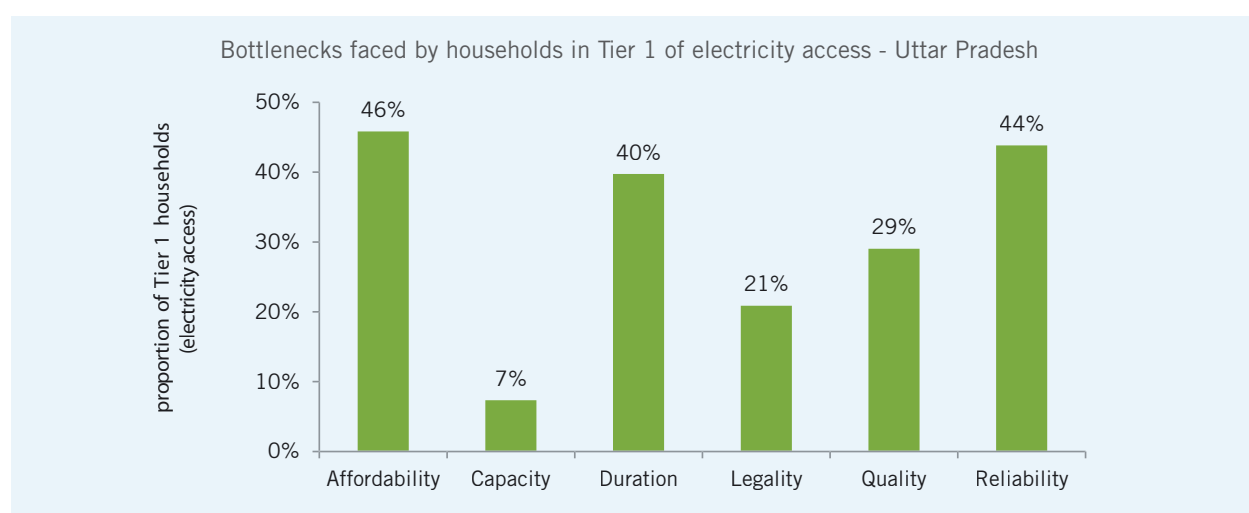
For households that were limited to Tier 1, affordability, reliability and duration of supply are the most prevalent issues (see Figure 23). Affordability restricted 46 per cent of the Tier 1 households from moving into the next tier.¹⁶

¹⁶ As per the UP SERC Tariff Order 2014-15, cost of consuming 30 units a month would be INR 167 per month for metered customers and INR 180 per month for unmetered customers.

The second most prevalent issue is that of reliability, which restricts 44 per cent of the households in Tier 1. This means that 44 per cent of Tier 1 households in Uttar Pradesh experience between two and four days of complete blackout in a month. Challenges associated with duration of supply closely follows reliability, with 40 per cent of households receive only four to eight hours of electricity a day. Quality of supply is also an issue with 29 per cent Tier 1 households witnessing issues of voltage fluctuation and low voltage days.

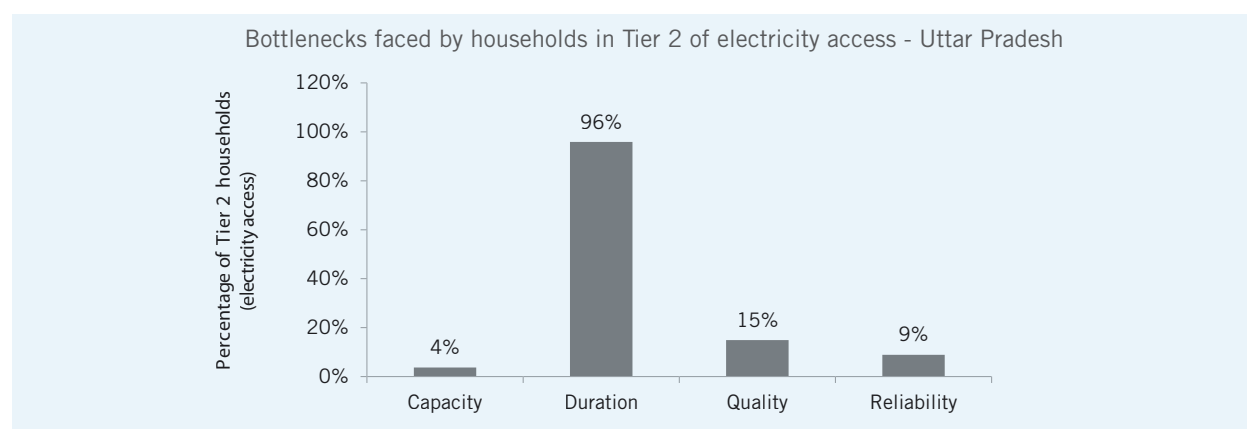
Finally, 21 per cent of the households placed in Tier 1 are restricted by the legal status of their connection. Among those who are classified as having illegal connections, an overwhelming number of households said that they did not have to pay for the consumption. It is also interesting to note that in some parts of the state, households that have recently been connected to the grid (1 to 2 years) report that they have never received a bill for their consumption. Not receiving a bill or not knowing who to pay do not warrant the classification of a household's connection as being illegal. These are administrative oversights and need to be addressed.

Figure 23: Tier 1 households in Uttar Pradesh are constrained by multiple challenges, some of which may co-exist



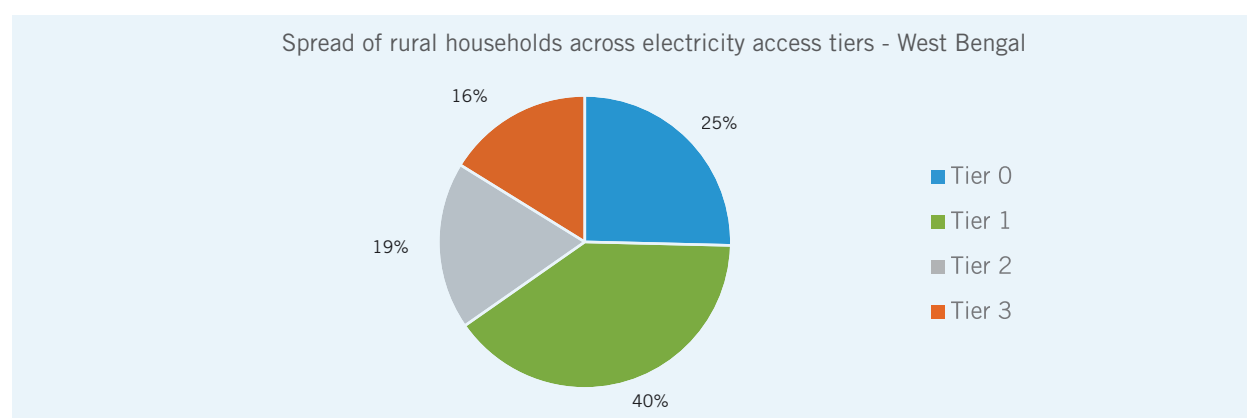
4.1.5.3. Tier 2 households in Uttar Pradesh

Less than 5 per cent of the population in rural Uttar Pradesh was categorised in Tier 2, while only 0.2 per cent household made it to the highest tier. The struggle, just as in Bihar and Jharkhand, is in the duration of supply experienced by households in Tier 2. Nearly 95 per cent of Tier 2 households get supply for less than 20 hours. Other bottlenecks were not prominent and are likely to be of more significance when overall supply hours increase.

Figure 24: Limited duration of supply is the most prevalent barrier for Tier 2 households in Uttar Pradesh

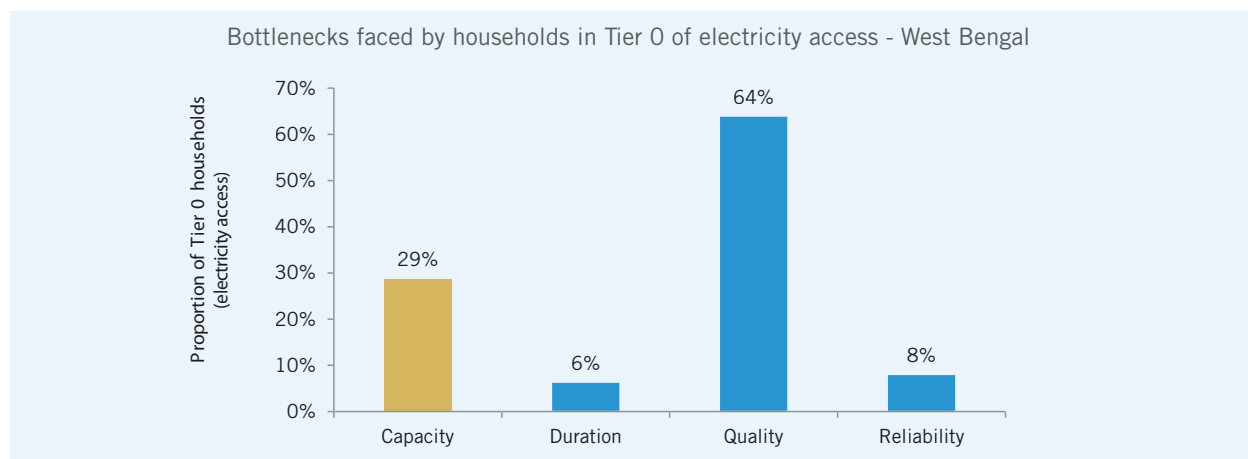
4.1.6 West Bengal

Among the six states we surveyed, West Bengal performed the best on electricity access when evaluated using the multi-tier framework. The state has the lowest proportion of households in Tier 0 and the highest proportion in Tier 2 and Tier 3, among the six surveyed states (see Figure 25). The aggregated electricity access index was highest at 41.8, with the three administrative divisions of West Bengal exhibiting values between 39.8 and 44.3. In terms of primary source of lighting, Census 2011 suggests that only 40 per cent of rural households use electricity as their primary source of lighting, whereas our survey pegs this number at 92 per cent. This is explained by one key observation from the survey that 51 per cent of the rural households gained access to electricity in the last five years, and nearly all grid connected households use electricity as their primary lighting source.

Figure 25: West Bengal performs better than all other states surveyed with three quarters of the rural households having some level of access to electricity

4.1.6.1 Tier 0 Households

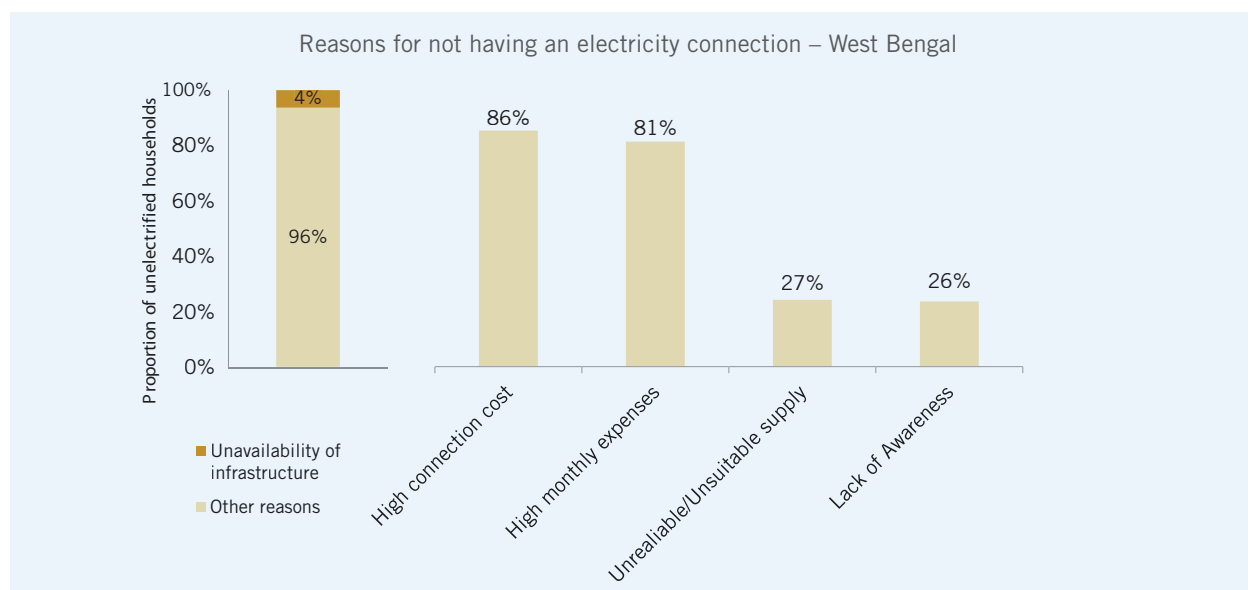
Given the high level of household electrification rate in rural areas of West Bengal, capacity is not the leading cause restricting households in the Tier 0. In fact, voltage issues related to electrical supply, experienced by an overwhelming majority of 64 per cent households, is the greatest limiting factor (see Figure 26). Further analysis reveals that a greater proportion of households experience voltage fluctuations on the higher side (resulting in appliance failure) than those experiencing persistent low voltages days.

Figure 26: Quality of electricity supply is the prime limiting factor for Tier 0 households in West Bengal

4.1.6.1.1. Un-electrified Households

An analysis of the 29 per cent of Tier 0 household that lack any electricity provision reveals that more than 96 per cent of these have grid in their vicinity. Among these households, high expenses associated with the initial connection and the recurring monthly expenditure was cited as the leading cause of non-subscription. With only four per cent of the un-electrified households not having the grid in the vicinity, West Bengal is in stark contrast to the other surveyed states, which suffer from poor electricity infrastructure.

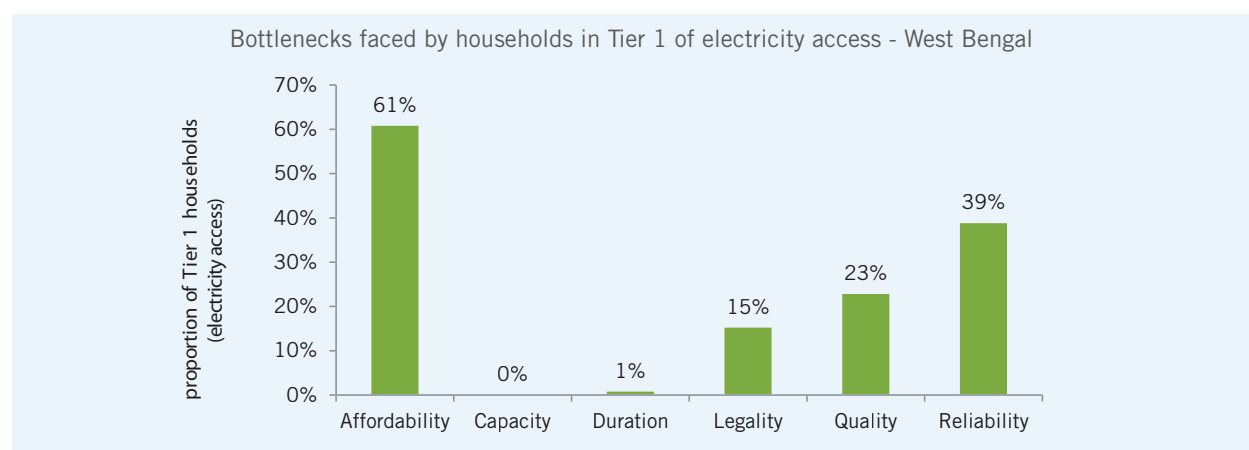
Since West Bengal includes a large proportion of households that indicate high monthly expenditure as a reason for not subscribing to electricity, we further analysed the extent to which this would be a barrier, had these households subscribed to the grid. Among those households that view the recurring costs as being high, close to 30 per cent would find the consumption of electricity affordable, had they subscribed to a connection.

Figure 27: Affordability of electricity connection and supply are the primary barrier for un-electrified households in West Bengal

4.1.6.2 Tier 1 Households in West Bengal

Even for Tier 1 households, affordability is the main bottleneck (see Figure 28). For over a third of all electrified rural households in West Bengal, consumption of threshold electricity (1 kWh per household per day) emerges as unaffordable.¹⁷ Apart from affordability, as many as 39 per cent of Tier 1 households were constrained by reliability, implying that these households experienced two to four days of blackout in a month.

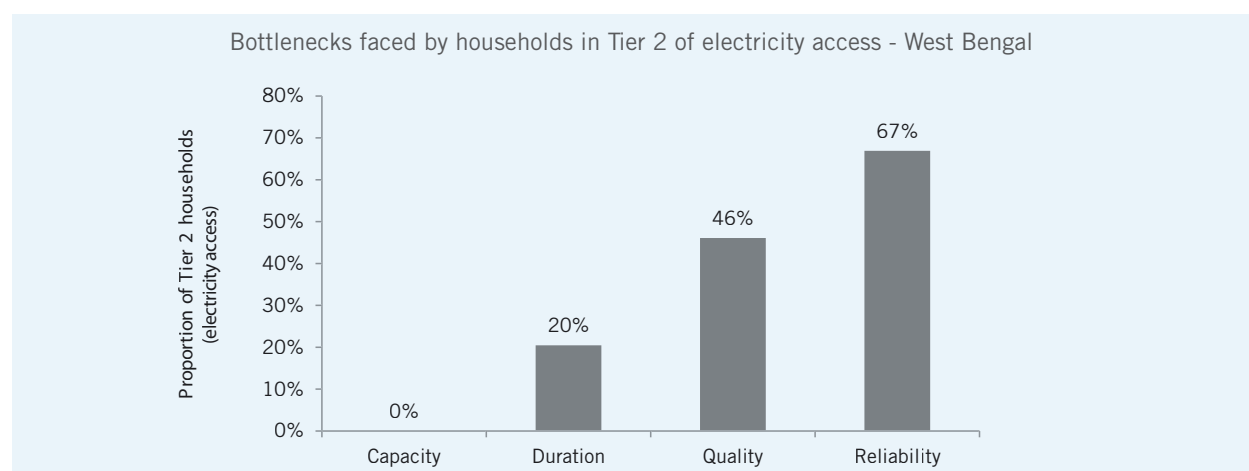
Figure 28: Affordability of electricity supply is a major impediment for Tier 1 households in rural West Bengal, even as other challenges may co-exist



4.6.2.3 Tier 2 Households

For households classified in Tier 2, reliability of supply becomes a major challenge (see Figure 29). In other words, 67 per cent of Tier 2 households experienced one blackout day in a month. Quality of supply, which affected 46 per cent of the households, was also a significant roadblock for Tier 2 households. Finally, 20 per cent of the Tier 2 households experience the duration of supply as a limiting factor, with supply for 8 to 19 hours a day.

Figure 29: Black-outs are the main challenge limiting households to graduate to highest tier

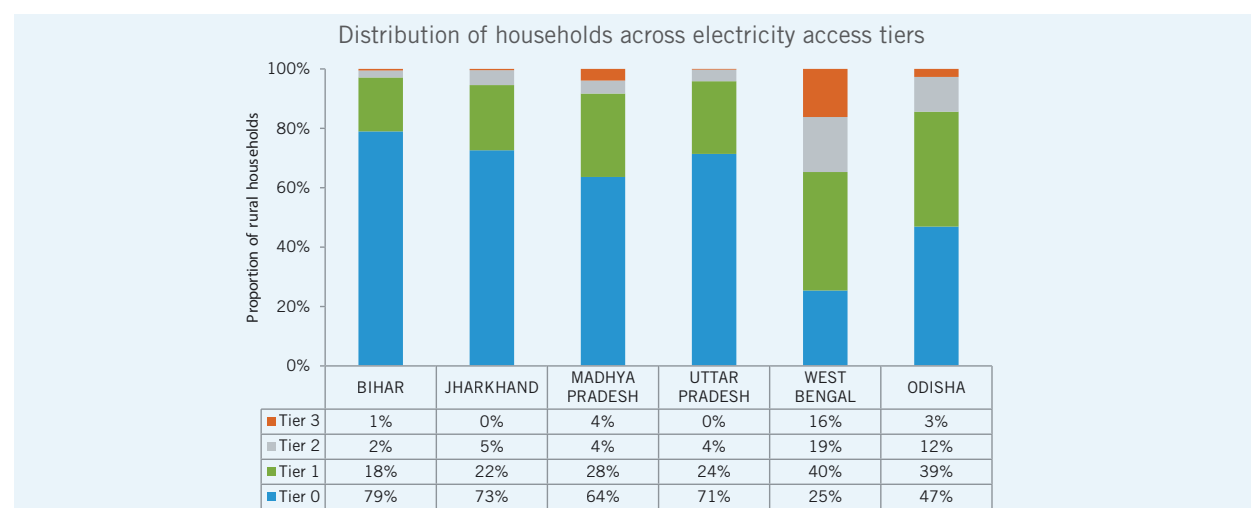


¹⁷ For the very few households who report an unmetered connection, we assumed same monthly electricity expenditure for consuming threshold electricity, as for metered connection. This is because the Tariff Policy of West Bengal did not include any information for unmetered consumers.

4.1.7 Electricity access – summarising key findings and insights

Summarising our findings across six states, it is clear that Bihar, Uttar Pradesh and Jharkhand lag significantly in terms of their progress in overall electrification at the household level, and as a result have the highest proportion of households in Tier 0. Madhya Pradesh, while exhibiting high levels of household electrification, suffers from poor quality of electricity provision consigning a large share of households to the lowest tier as well.

Figure 30: Four out of six states perform badly on electricity access



The proportion of households across tiers in the six states are summarised in Figure 30. Based on their current status, different states will need to focus on households in different tiers. For instance, Tier 0 households should be the clear choice for targeting actions in Bihar, while in West Bengal, the government should focus on both Tier 0 and Tier 1 households.

The issues highlighted in detail in this section, using the multi-tier framework, have been outlined in Table 4 to provide a quick overview. These insights would be useful for stakeholders involved in improving the state of electricity access in the six states.

Table 4: Key challenges faced by households in different tiers and states

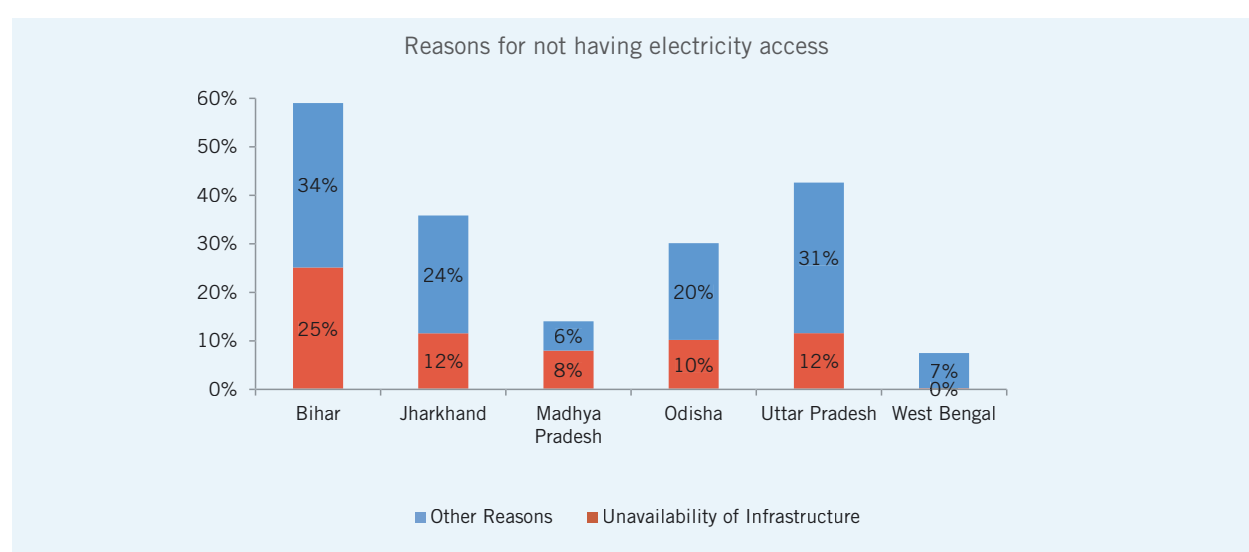
Tiers	Bihar	Jharkhand	Madhya Pradesh	Odisha	Uttar Pradesh	West Bengal
Tier 0	Capacity	Capacity	Quality and reliability	Capacity	Capacity	Quality
Tier 0 (Un-electrified Households)	Availability of infrastructure, affordability and reliability	Availability of infrastructure, reliability and affordability	Availability of infrastructure and affordability	Affordability	Affordability and reliability	Affordability
Tier 1	Reliability	Reliability	Affordability	Reliability	Affordability, reliability and duration	Affordability
Tier 2	N/A	N/A	Duration	Duration	N/A	Reliability and quality
Key Results	Reliability of supply is a key issue across tiers that need to be dealt with as houses are electrified.	Electrification needs to be tackled together with reliability of supply. As the latter is one of the chief cause of many households from not subscribing to grid-based electricity.	Lack of electrification is not a major problem. Quality, reliability and affordability are key aspects that need to be improved in the existing system.	Overall a fair performer, the state needs to focus on addressing issues of information on affordability for non-subscribers and reliability for grid-based customers.	For UP, along with increasing the penetration of electricity, affordability and reliability are key focus areas.	Overall the best performer. Affordability is an issue in West Bengal that requires further analysis.

Some of the issues which are recurring across the states are further discussed in following few sections:

4.1.7.1 Availability of Infrastructure

While the most often reported reason for a household remaining un-electrified is the unavailability of grid infrastructure required for a connection, other issues such as unreliability of the supply or unaffordability of the initial cost/ monthly expenditure also pose a challenge for a significant proportion of households. Unavailability of grid infrastructure leaves a household with no choice in its decision to electrify.¹⁸ Bihar has the highest proportion of un-electrified households lacking access to an electricity grid. West Bengal has the lowest proportion of such households, implying that households remain un-electrified because of the other limiting factors discussed above.

Figure 31: Lack of grid availability remains a challenge in some states, but issues beyond infrastructure also act as major bottlenecks



4.1.7.2 Affordability

Affordability emerges as an issue for most of the states, both for upfront connection cost and recurring monthly expenditures. Due to a lack of data from public sources, we were unable to include an analysis on the cost of connection in the different states. However, there is a clear need for the relevant stakeholders to understand the impact of the cost of connection as well as the awareness about this cost. Incorrect information about the cost of connection can often lead households to believe these costs to be prohibitive and choosing to remain un-electrified.

In the case of recurring costs, one common issue across states is the difference in rates charged to metered and unmetered households. The higher fixed cost for unmetered households, with the (implicit) assumption that households consume more than 1 unit per day, is an important reason why many unmetered households are classified in the unaffordable tier for the affordability dimension. The difference in the monthly outlay for the threshold consumption for both the categories is listed in Table 5. In the interest of consumer welfare and with the long term need to charge all consumers for the appropriate level of consumption, there is an urgent need to convey the benefits of metering and expand this universally.

¹⁸ Due to the very limited penetration of distributed energy systems that pose a challenge in making any useful observations at a state-level, we did not delve into the availability of off-grid solution providers.

Table 5: Monthly expenditure on procuring threshold level of electricity

State	Metered	Unmetered
Bihar	61	160
Jharkhand	63	100
Madhya Pradesh	129	285
Odisha	110	NA
Uttar Pradesh	167	180
West Bengal	155	NA

Source: Compiled by CEEW from state tariff orders

Box 3: Evening Hours of Supply

Since evening hours of supply are particularly important for the purposes of lighting, we carried out a detailed analysis for electricity supply between sunset and midnight. This usually translated in to a six hour window but could vary across states and seasons. We chose not to include this dimension in our main framework to retain the simplicity of our framework. The threshold levels chosen for evening hours of supply are provided below in Table 6.

Table 6: Multi-tier framework to assess evening hours of supply

	Tier 0	Tier 1	Tier 2	Tier 3
Evening hours of supply	<2hrs	2-3 hrs	>=4hrs	

We tried to see that what change would the evening hours of supply have on the overall electricity tier, had this dimension been part of the overall framework.

Considering evening hours into the overall electricity access framework illustrates a marginally gloomier picture for Jharkhand and Uttar Pradesh. Whereas for states of Bihar, Madhya Pradesh, West Bengal and Odisha, the consideration of evening hours of supply does not pull down a significant number of households, as can be noted by Figure 32 and Figure 33.

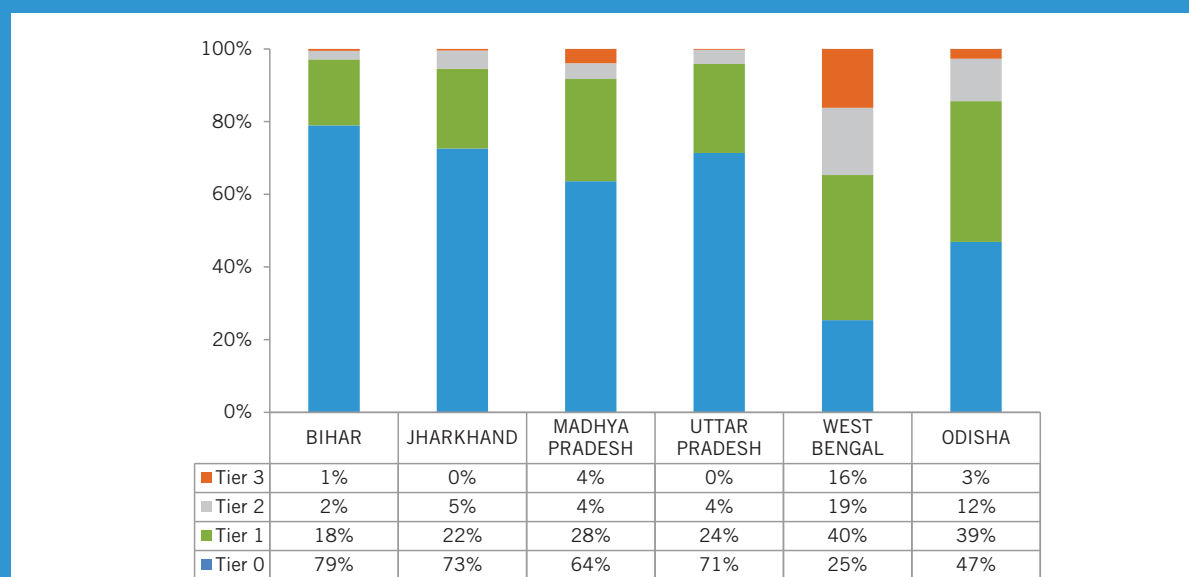
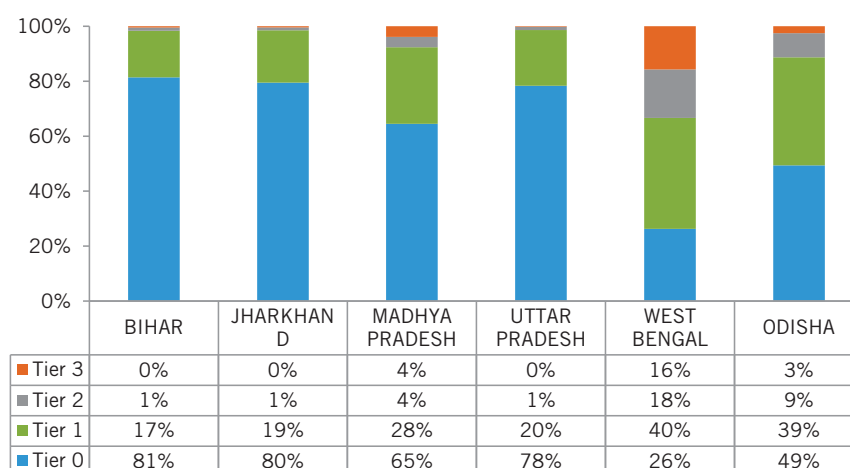
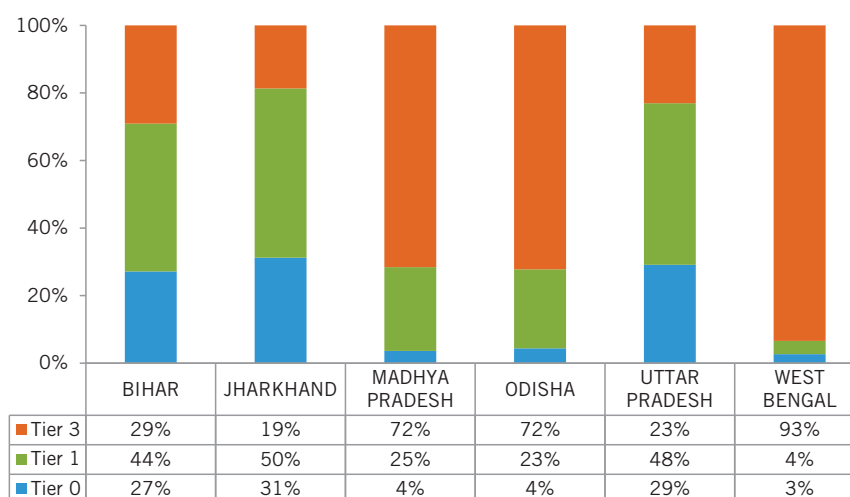
Figure 32: Electricity access tiers for all six states

Figure 33: Electricity access tiers considering evening hours of supply



It is also useful to see the distribution of households across tiers for only the evening hours of supply dimension (refer Figure 34). As is evident, West Bengal outperforms the remaining states with over 90 per cent of all electrified households receiving four or more hours of electricity in the evening. Bihar, Jharkhand and Uttar Pradesh, fare poorly in providing sufficient evening hours of supply. In the case of Bihar, poor evening hours supply do not result in an appreciable change in overall tiers as it scores poorly on most of the other dimensions as well. In the case of Jharkhand and Uttar Pradesh, low evening hours supply does impact overall electricity access tiers, marginally (as shown in Figure 32 & Figure 33).

Figure 34: Status of evening hours of supply



4.2 Access to clean cooking energy

Excessive dependence on traditional biomass fuels continues to be a major challenge in rural India. We find that only 14 per cent households in rural areas across the six states have stated BLEN (Biogas / LPG / Electricity / Natural Gas)¹⁹ as their primary source of cooking. Across the six states, we find little variation in the distribution of households among the various tiers for cooking energy access. Although significant variations exist in the mix of traditional (biomass-based) fuels across states, access to modern cooking fuels is limited in all the states. The range of aggregated cooking energy access index across states and across divisions (within states) is provided in Table 7. On a scale of 0-100, all states are concentrated towards the very low end of spectrum.

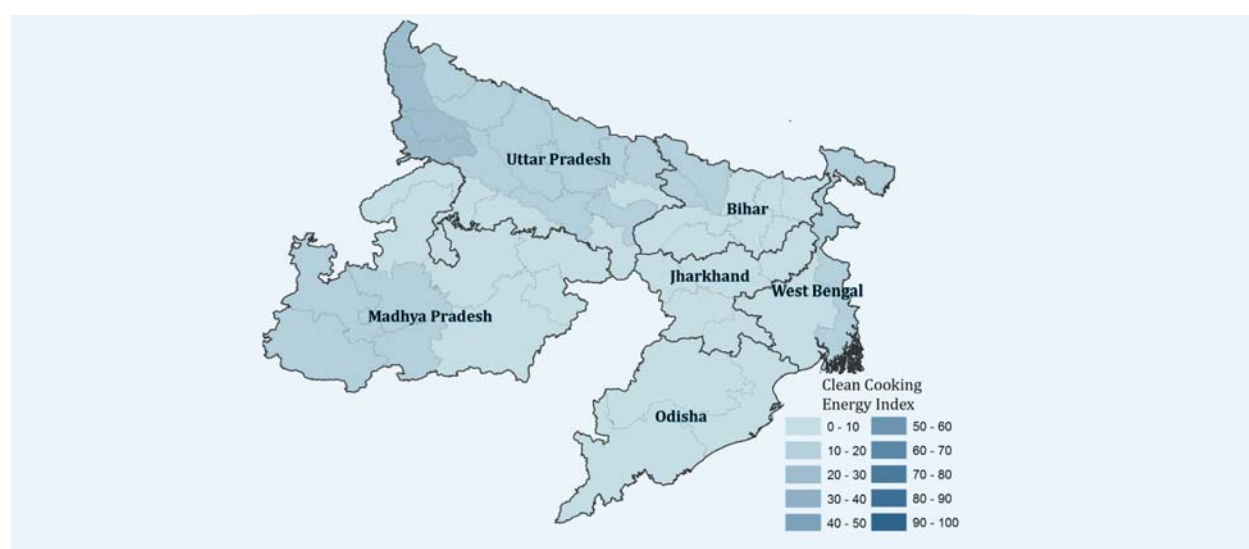
Table 7: Aggregated Cooking Energy Access Index

State	Aggregated Cooking Energy Access Index	Index Range Across Geographic Divisions Surveyed
Bihar	8.7	3.4 – 13.1
Jharkhand	3.4	2.2 – 5.2
Madhya Pradesh	8.2	2.6 – 17.5
Odisha	4.2	1.6 – 7.3
Uttar Pradesh	14.0	5.2 – 24.4
West Bengal	11.1	6.3 – 18.0

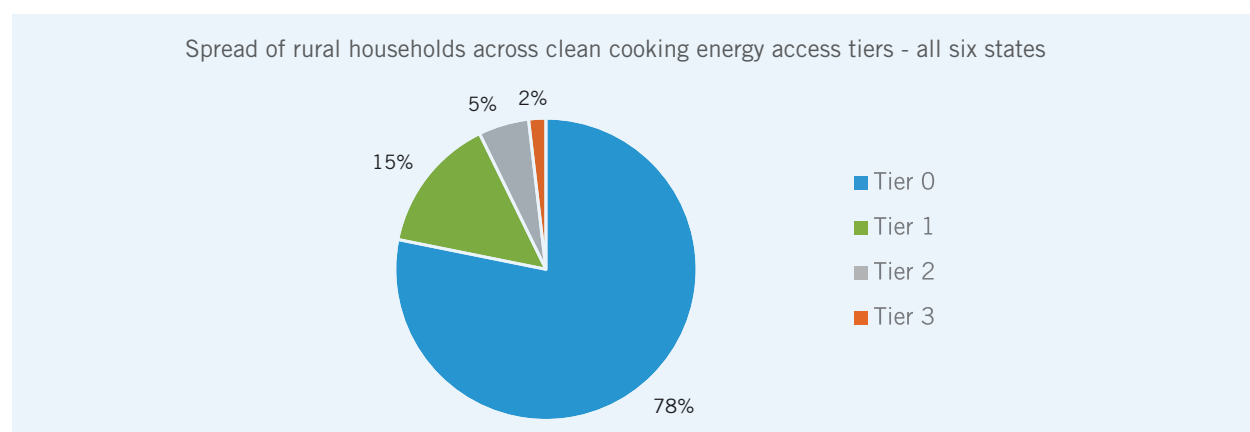
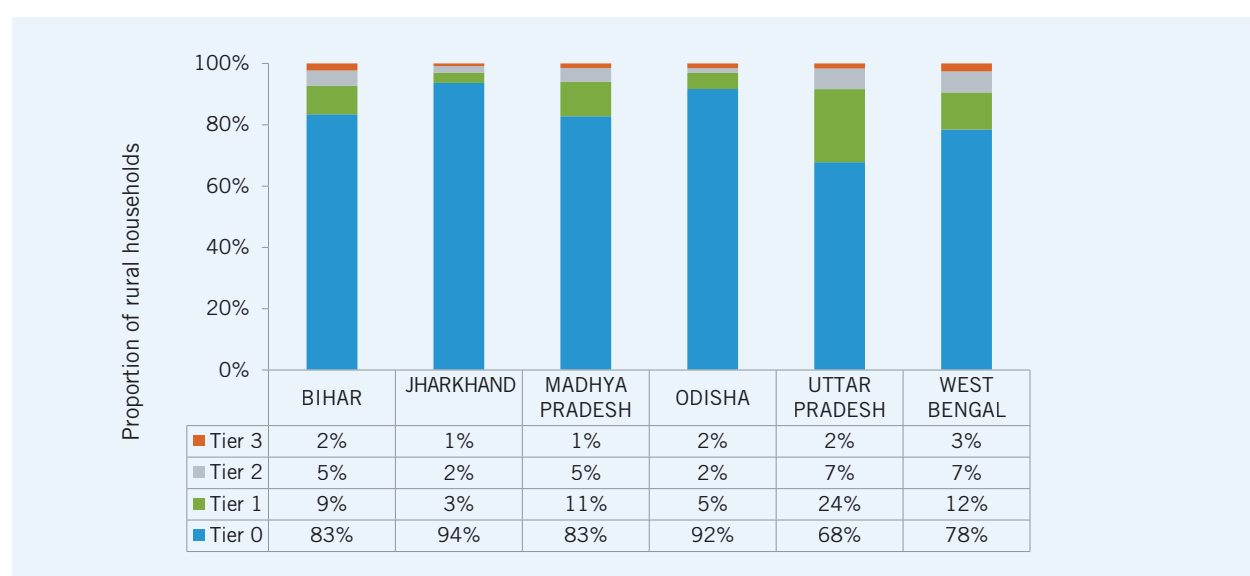
A thematic map of the state of access to clean cooking energy is provided in Figure 35. Barring some regions of Uttar Pradesh, Madhya Pradesh and West Bengal, most of the rural areas in these six states have very poor access to clean cooking energy, as shown by the light colours in the choropleth map.

The overall state of access to clean cooking energy across six surveyed states is shown in Figure 36. At an aggregate level, almost 78 per cent of the households lie in Tier 0, representing the complete lack of access to clean cooking energy. Of the remaining, two-thirds lie in Tier 1. The proportion of households in Tier 2 and Tier 3 are five per cent and two per cent respectively.

Figure 35: Clean cooking energy access index across six states



¹⁹ BLEN is standard terms used to refer the cleanest class of cooking fuel, from the perspective of indoor-air pollution. For rural areas in India, BLEN mostly implies LPG followed by biogas or electricity (in miniscule numbers) for cooking. Natural Gas is virtually non-existent in rural areas for domestic cooking purpose.

Figure 36: more than three-fourth of rural population across six states has no access to clean cooking energy at all**Figure 37: All six states perform poorly in terms of access to clean cooking energy**

Among the states surveyed (see Figure 37), Uttar Pradesh has the greatest access to clean cooking energy with the lowest proportion of households in Tier 0 (68 per cent). On the other hand, Jharkhand (94 per cent in Tier 0) has the poorest access to clean cooking energy, followed closely by Odisha (92 per cent in Tier 0). The following sections present an aggregated analysis of tiers across all six states. However, state specific numbers and graphs are available in Annexure II.

4.2.1 Tier 0 households

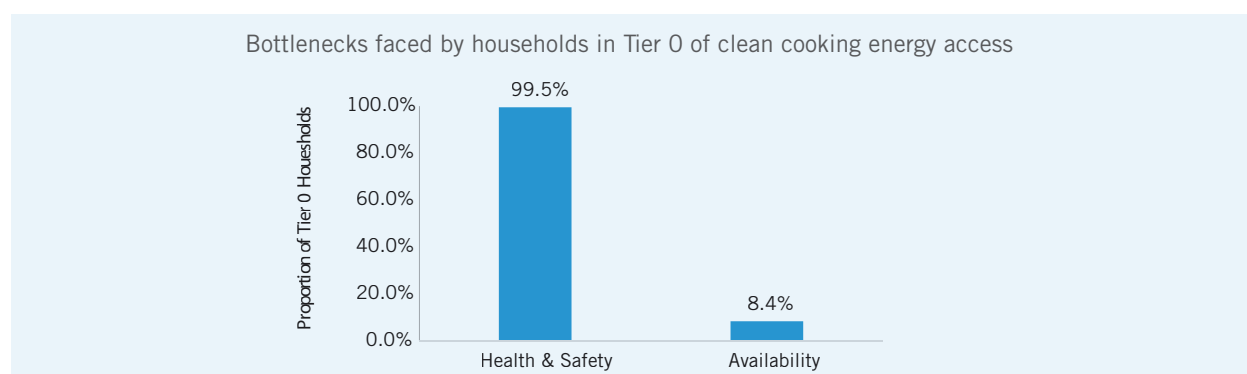
Given the way we define tiers clean cooking energy access framework, households fall in Tier 0 only under two extreme situations:

- Complete dependence of cooking energy on traditional fuels
- Lack of fuel availability to the extent that it adversely impacts the amount of food cooked

These two situations pertain to ‘*health and safety*’ and ‘*availability*’ dimensions of cooking energy access. Almost 99.5 per cent of the households in Tier 0 fail the health & safety dimension as they rely entirely

on traditional fuels for cooking (Figure 38). In addition, 8.4 per cent of the Tier 0 households also face challenges in fuel availability to the extent that it limits their cooking.

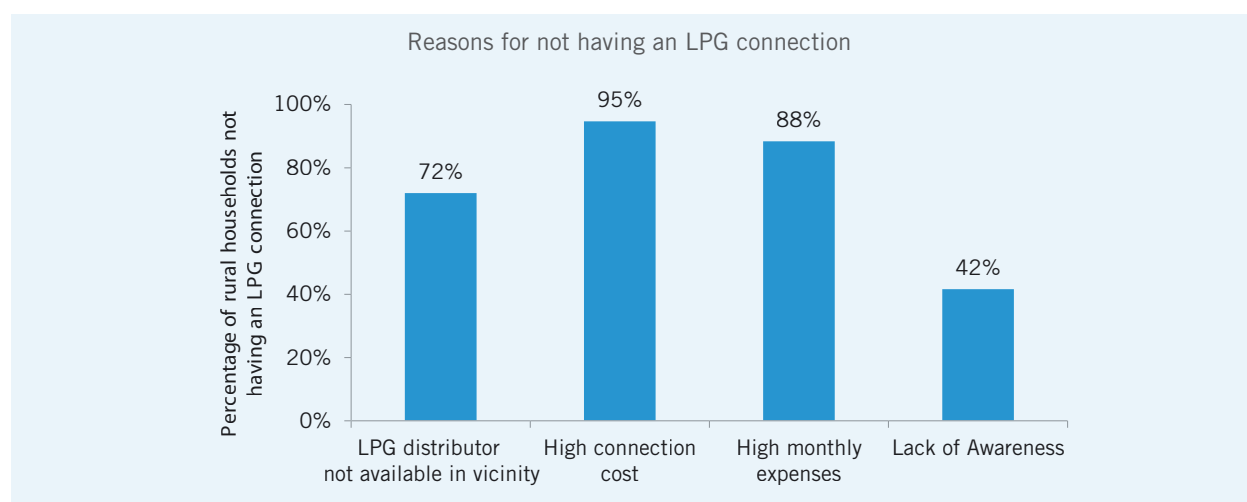
Figure 38: Complete dependence on traditional biomass is the biggest limiting factor for Tier 0 households



Given that the *health and safety* dimension is a major bottleneck, it is essential to understand why almost 78 per cent of rural households in these states lack access to clean cooking energy solutions. Analysing the penetration of clean cooking energy solutions across these states, we found that only 0.74% and 0.21% rural households report using an improved biomass cookstove and biogas for cooking, respectively. This is in-line with the figures suggested by the Census and NSS. Given these numbers, the current clean cooking energy access in these states could be entirely attributed to LPG. Given its predominance, we specifically analysed the reasons for poor adoption of LPG in these areas.

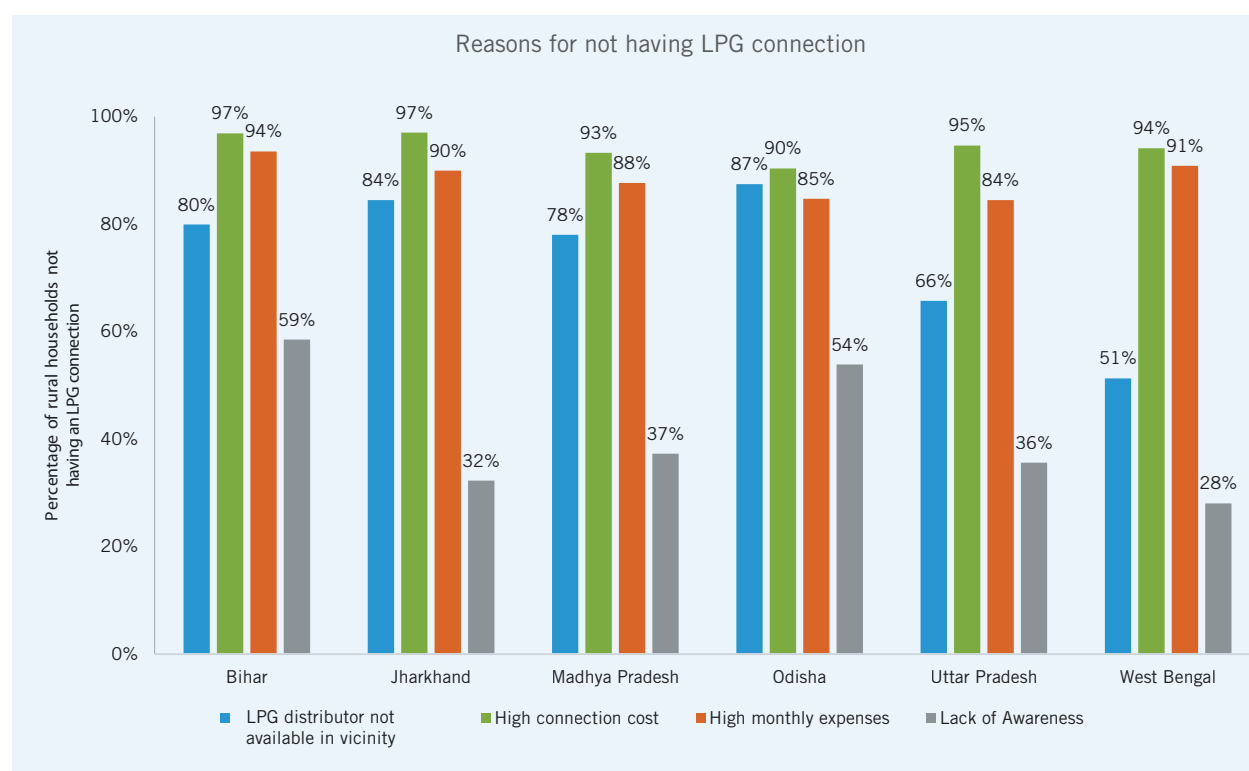
We find that high upfront cost to secure an LPG connection is cited as the biggest hurdle to increased adoption. Furthermore, the recurring monthly expenditure (88 per cent), and poor reach of distribution infrastructure of the fuel (72 per cent) also act as significant impediments to LPG adoption (Figure 39). Nearly 42 per cent of the households surveyed also state *lack of awareness about how to get a connection*, as a reason for non-subscription to LPG. Further, though more than 75 per cent of rural households across the six states believe that cooking is more convenient on LPG as compared to a traditional stove, only about 64 per cent of the households believe that using LPG over a traditional *chulha* has positive health impacts. This suggests a critical gap in awareness on important health benefits of cooking with LPG as compared to a *chulha*. Such poor awareness about accessing the fuel as well as its benefits, contributes significantly to the low demand for clean cooking fuel options in rural India.

Figure 39: Multiple factors limiting LPG adoption; many of which may co-exist



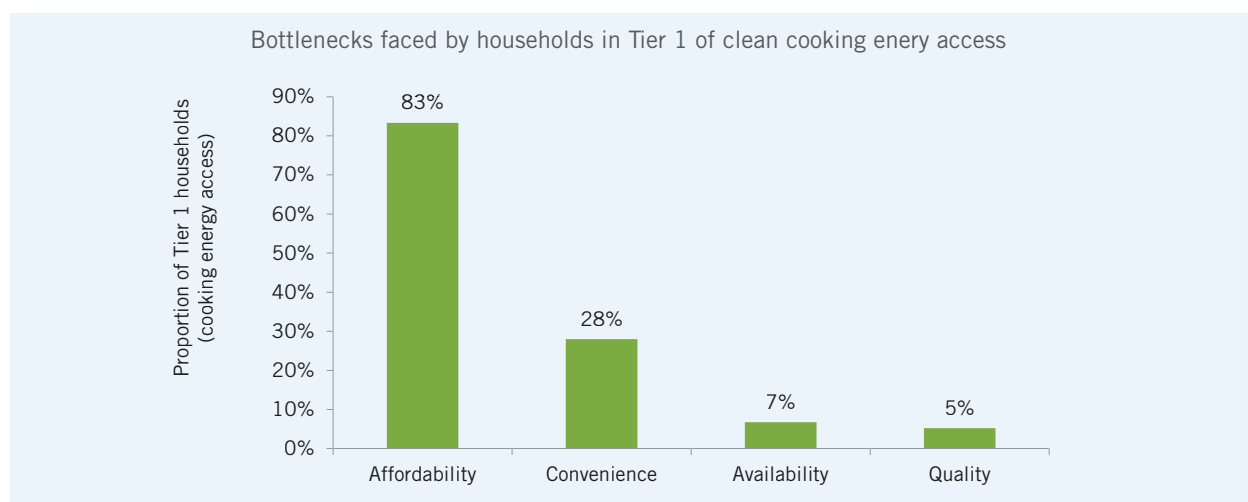
For each factor limiting the LPG adoption, the proportion of households citing it as a bottleneck varies one state to another. However, the prevalence of these bottlenecks remains relatively similar across states (see Figure 40). Comparing Uttar Pradesh and West Bengal, both of which have relatively higher proportion of households having LPG connection, we found that despite lower infrastructure availability and lower awareness, the share of population having an LPG connection is higher in Uttar Pradesh than in West Bengal. Furthermore, in Uttar Pradesh, only nine percent households that have a connection get LPG cylinders delivered at their door step, whereas the number is as high as 60 per cent in West Bengal. Those who travel to get their LPG cylinder, the median one-way distance is seven kilometres in Uttar Pradesh, as compared to only three kilometres in West Bengal. Juxtaposing these findings, it is perplexing that why Uttar Pradesh has higher adoption of LPG as compared to West Bengal. A possible explanation could be that in Uttar Pradesh, there are only 31 per cent of rural households who use free-of-cost biomass for all their cooking energy needs. Whereas in West Bengal, as many as 66 per cent of the households rely entirely on free-of-cost biomass. This indicates that economics associated with cooking fuels play an important consideration in the transition to cleaner cooking energy options.

Figure 40: Relative prevalence of bottlenecks to LPG adoption remain similar across states



4.2.2 Tier 1 households

For rural households who fall in Tier 1, the biggest bottleneck was affordability of cooking energy. As many as 83 per cent of Tier 1 households spend more than 6 per cent of their monthly expenditure on procuring cooking energy (Figure 41). It is important to note that affordability is calculated on the basis of the entire expenditure of households on all cooking energy procurements (in case of fuel stacking).

Figure 41: Affordability of cooking energy is the biggest limiting factor for Tier 1 households

Apart from affordability, 28 per cent of the households in Tier 1, also face challenges associated with convenience of cooking. As per our framework, convenience related issues of the primary cooking arrangement arise when it is perceived to be time consuming and/or difficult to use. Further analysis shows that Tier 1 households, who state that their primary cooking solution is inconvenient, only 10 per cent of them use LPG as their primary cooking fuel. This indicates that inconvenience associated with the use of LPG is very limited. Further, of the households reporting LPG as their primary cooking fuel, less than four per cent state that it is both time-consuming and difficult. In contrast, more than 50 per cent of the household relying on traditional fuel reported these issues. The convenience dimension is further explored in Tier 2 discussion.

Looking at other bottlenecks of Tier 1, seven per cent of the households face the issue of poor fuel availability. Importantly, in 48 per cent of these households, LPG is the primary fuel. Currently, though this is a very small population share (0.5 per cent)²⁰ which faces this issue, availability may become a larger issue as more people adopt LPG.

The observations on bottlenecks for Tier1 are very similar across all the states. Individual, state specific charts are presented in Annexure II.

4.2.2.1 Affordability

As affordability of cooking fuel remains a major bottleneck for Tier 1 households, we analysed it further. Specifically, we looked at the cooking energy expenditure across households that face affordability as a challenge. We found that 60 per cent of them spend more than 10 per cent of their monthly expenditure on cooking. Further, as many as 25 per cent of the households spend more than 20 per cent of their monthly expenditure on cooking energy. However, since majority of these households are stacking fuels, understanding the contribution of LPG and traditional fuels to affordability is important.

Among households who use only LPG to meet their entire cooking energy needs (about five per cent of the rural households in these six states), almost 46 per cent spend more than six per cent of monthly expenses on cooking energy, thereby making it 'unaffordable'. However, only 16 per cent of these households spend more than 10 per cent of the monthly expenditure on cooking energy. Thus, even though

²⁰ A total of 15% of the households are in Tier 1. Only 7% of these score low on availability and of these only 48% report LPG as primary fuel.

affordability is a challenge for households relying entirely on LPG, the extent of challenge is not as severe as in case of households which stack fuels. For households using only LPG, the median expenditure (monthly) on cooking energy is INR 383. However, the median monthly expenditures on cooking are much higher for households that stack fuels (INR 436). This could be due to the following possibilities:

1. *Gap in perception of the relative cost of firewood and LPG.* Even at prices of INR 6 or more per kg of wood, which is the average price reported across states, this is equivalent to 87.5 kCal of useful energy per INR spent, as opposed to 183 kCal per INR spent on subsidised LPG.
2. *Over-reporting of fuel consumption quantities by households who stack fuels.* Recollection of actual quantities could be difficult, especially when consumption varies regularly over time and does not follow a pattern, unlike in cases of households who use only one type of fuel.
3. *The methodological limitation of approximating expenditure on traditional fuel based on the product of price and quantity.* In reality, this could be different from the actual outlay.

Looking beyond Tier 1, at the overall rural population base, it is also evident that a significant proportion of rural households in these six states do not spend real money to procure their cooking energy. These numbers show significant variation across states, ranging from 69 per cent in Odisha to as low as 31 per cent in Uttar Pradesh (Figure 42).

Figure 42: Entire dependency on free-of-cost biomass varies across states

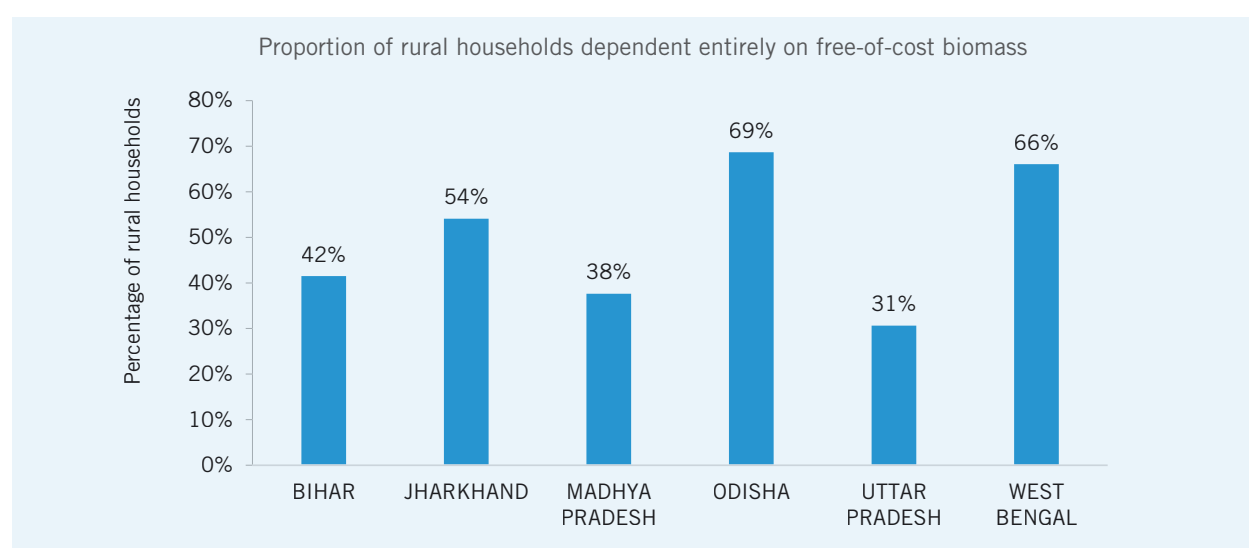
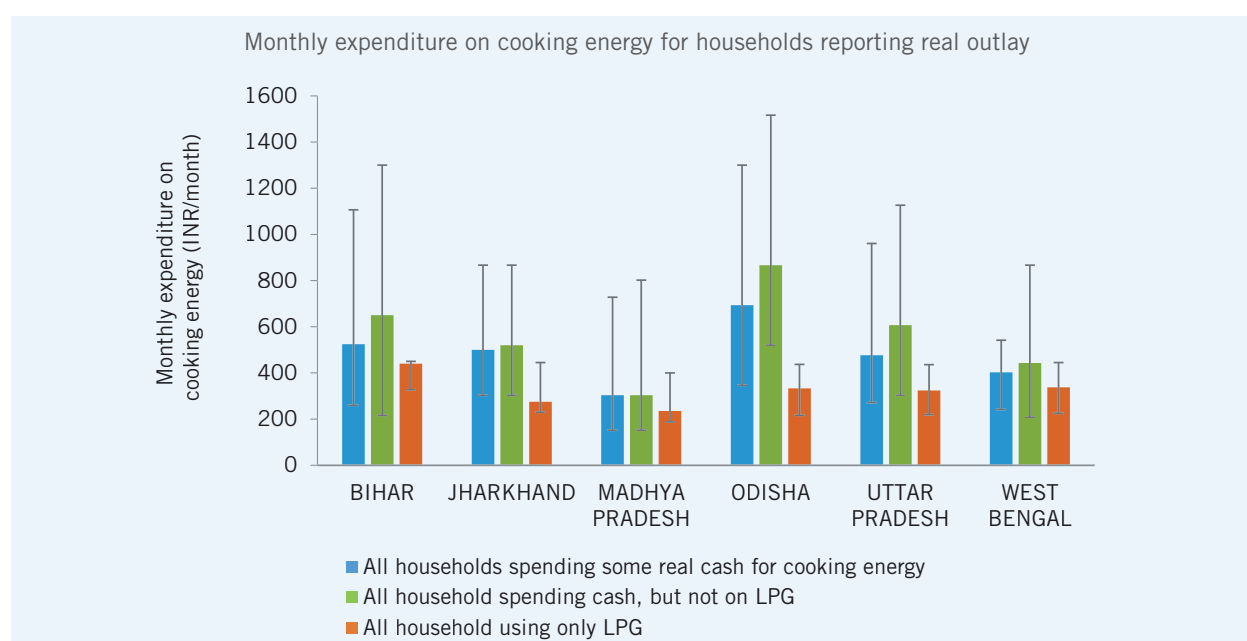


Figure 43: LPG turns out to be cheaper than market procured biomass fuels

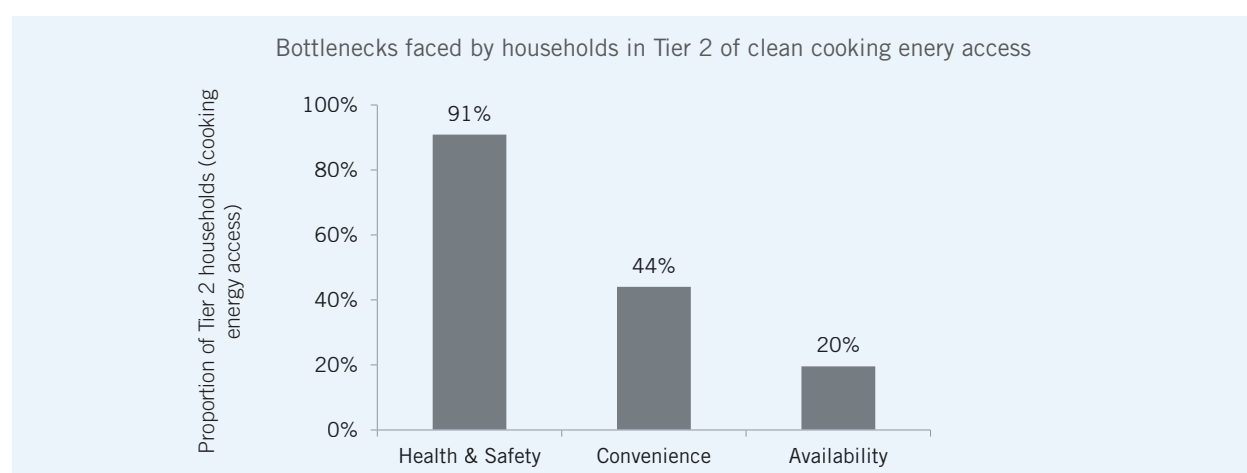
The median monthly expenditure is shown in columns, with lower and upper bounds indicating the 25th and 75th per centile level of expenditure.

However, those households that procure firewood from informal markets report high levels of expenditure (Figure 43). It is important to note (Figure 43) that for households not consuming LPG (green columns), the expenses are higher than those who consume LPG as part of their fuel mix (blue columns). One reason for this could be the prevailing prices of traditional biomass and the poor efficiency with which it is used. Substituting some of the consumption by LPG (even though an expensive commodity) results in total savings. This is because the subsidised LPG is cheaper on a useful energy basis (on account of higher efficiency of combustion) when compared with market procured firewood at prevailing prices. Similarly, for LPG-only households their monthly cooking expenses are even lower, further corroborating the cost-effectiveness of LPG (at the subsidised prices) as compared to traditional biomass at prevailing prices.

Consequently it appears that switching to subsidised LPG is an economically beneficial choice for many rural households and also has positive health benefits. However, the limited adoption and use of LPG potentially points to the challenges of initial upfront cost, prevailing information and perception gap that needs to be bridged, and even limited penetration of LPG distribution infrastructure in rural areas.

4.2.2 Tier 2 households

For Tier 2 households, representing five per cent of the households, the biggest bottleneck to further progression is the ‘*health and safety*’ aspect (Figure 44). This is due to the continued use of traditional fuels, despite consuming LPG for some portion of the cooking needs. Simultaneous use traditional fuels with LPG (fuel stacking) implies continued exposure to harmful emissions, especially particulate emissions. While the extent of stacking influences the emission exposure, health impacts are also governed by various other factors such as room condition, provision of ventilation, proximity to cooking device and so on. Thus, all households who stack traditional fuels with cleaner cooking energy options are classified in same bracket, Tier 2, for ‘*health and safety*’ dimension.

Figure 44: Stacking of traditional fuels with clean cooking energy options is the major limiting factor at Tier 2

Apart from health and safety, limited convenience of cooking is also a bottleneck. These households either find it difficult to cook with their primary cooking arrangement, or spend high amount of time for cooking. We further analysed the issue of convenience by categorising all households into two sub-sets – those which use traditional *chulha* as primary arrangement and those which use LPG (Tables 8, 9). At one end, 51 per cent of the households who use traditional *chulha* report problems of both high time-consumption, as well as difficulty in cooking. In contrast for those using LPG as primary cooking arrangement, only 10 per cent find it time consuming and only 15 per cent find it difficult to cook with.

Table 8: Cooking convenience for traditional *chulha* using households

For HHs with traditional <i>chulha</i> as primary cooking arrangement		Too Time Consuming	
		No	Yes
Difficult to Cook	No	11%	33%
	Yes	5%	51%

Table 9: Cooking convenience for LPG using households

For HHs with LPG as primary cooking arrangement		Too Time Consuming	
		No	Yes
Difficult to Cook	No	79%	6%
	Yes	11%	4%

Finally, availability is also stated as a limitation by 20 per cent of the households, as they were not completely satisfied with the availability of the fuel. Distance to LPG distributor's location (to procure the cylinder) is cited as the main reason.

4.2.4 Clean cooking energy access – summarising key findings and insights

Key Findings

1. Almost 78 per cent of the population in the rural areas of these six states consume only traditional biomass to meet their cooking energy requirements and are relegated to the lowest tier.

2. Only 14 per cent of the rural households use clean energy as their primary fuel for cooking and less than five per cent use only LPG. Among different types of clean cooking energy options, LPG is by far the most prevalent.
3. Of the households lacking access to LPG, nearly 95 per cent stated high initial cost as a challenge.
4. Apart from the high capital cost, the high recurring expenditure as well as the non-availability of cleaner fuels in the area emerges as major barriers to achieve initial subscription. As high as 88 per cent of the households, not subscribing to LPG, state high recurring cost as one of the bottlenecks, whereas 72 per cent of the households also state that lack of LPG distribution in the area is an inhibiting factor.
5. For households who have made the initial jump to get an LPG connection and move beyond Tier 0 on health and safety dimension, affordability of fuel is the major bottleneck. It becomes the bottleneck for 88 per cent of the households in Tier 1. However, on a slightly promising side, the extent of un-affordability for these households is small. Among these households, 82.4 per cent would spend only up to 10 per cent of their monthly expenditure on cooking, should they entirely shift to LPG.²¹

Key Insights

1. With 44 per cent of the population, across six states, relying entirely on *free-of-cost* biomass, it would be a major challenge for such households to transition to cleaner fuels (LPG). It appears that LPG may not be able to compete with free-of-cost biomass on 'direct' economic terms. But our analysis suggests that even among such households who currently spend no real cash on procuring cooking energy, entire switch to LPG would be affordable for about 24 per cent of the households. Further, about 82 per cent of the free-of-cost biomass households would not spend more than 10 per cent of their monthly expenditure of procuring LPG, should they chose to make a complete transition.²² Information and awareness generation could play a role in enabling transition for such households, once the barrier for upfront connection cost could be taken care.
2. Lack of information/awareness on the positive health benefits of using LPG needs to be addressed. Even though almost 72 per cent of households using only traditional biomass believe that it has adverse impacts on their health, only 59 per cent believe that LPG has positive health benefits over traditional biomass based cooking.
3. Our results clearly indicate that traditional fuels, when procured from the market, are more expensive than subsidised LPG (on useful energy terms). For households that currently pay for traditional fuels, their misperception on cost-effectiveness of traditional fuel over LPG needs to be addressed.
4. It is likely that the abundance of free-of-cost biomass has an impact on LPG subscription. Uttar Pradesh, despite having a lower reach of LPG distribution as compared to West Bengal, has a greater adoption of LPG; and this is inversely correlated to the number of households relying on free-of-cost biomass. As a corollary, LPG subscription directly correlates to average spending of households on traditional fuels, given lack of distribution infrastructure does not become a bottleneck.
5. Broadly, it appears that convenience of cooking is directly affected by the primary cooking energy arrangement. As households transition towards LPG as their primary cooking energy source, their convenience of cooking directly improves. Thus apart from direct benefit at health and safety dimension, it appears that LPG also improves household ranking on convenience tier.

²¹ Affordability for LPG use is estimated at a consumption rate of 9 cylinders per annum per household.

²² Ibid

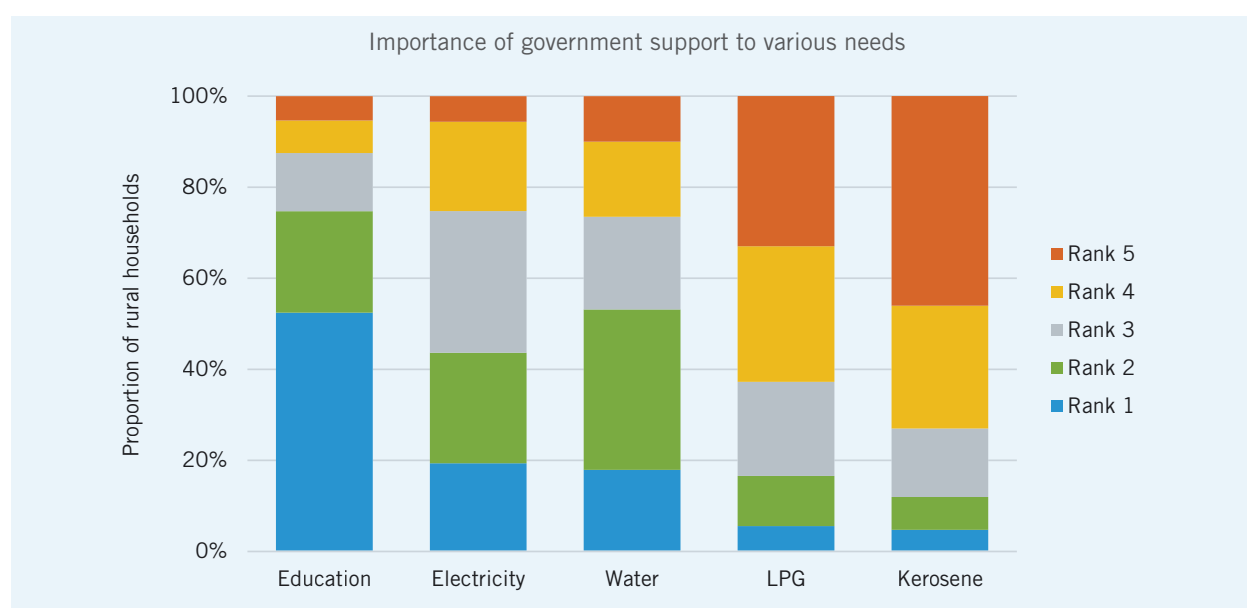
5. Understanding Policy Preferences

The focus of the study was primarily to bring to light the state of energy access – both electricity and cooking energy, in the six states that were surveyed. The sample (and thereby the population) was classified into the various tiers based on their levels of achievement in the various dimensions that were used to evaluate their state of energy access. This is already valuable insight from the perspective of the policymakers. The recommendations really flow from the barriers that have been identified. Systematically addressing these issues – be it increasing availability, or awareness or increasing subsidy levels, would go a long way in addressing the challenges faced by the population in achieving higher levels of energy access. However, there is one important component that has a bearing on the future course of actions. This is to do with the preferences of those who currently lack access to modern energy sources. How do they prioritise energy access over other necessities? Who is best placed (in their view) to deliver energy services/ commodities? Given the large financial outlay and scope for foul-play do they see corruption as a big challenge? Finally, we also explore the important question of whether people have a proclivity for certain technologies in the delivery of energy. The following section carries out these analyses and suggests areas of prioritisation for government action.

5.1 Importance of electricity and cooking energy relative to other services

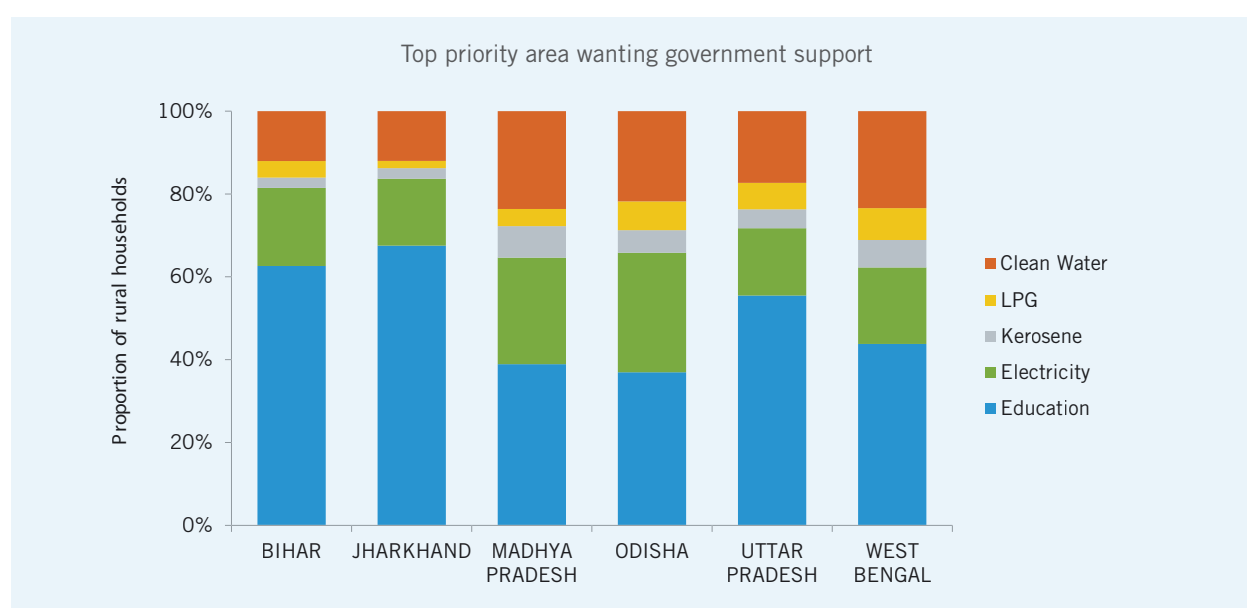
We start our discussion by situating the perceived importance of electricity and cooking fuels in the broader context of economic development. Specifically, we asked respondents which of the following five areas the government should prioritize: Education, clean water, electricity, kerosene, and LPG. Respondents were requested to rank each from the most to the least important.

Overall, we find that people value education the most. About 52 per cent of households ranked it as the most important item for government support (refer Figure 45). This is not to say that energy was deemed unimportant. About 19 per cent considered that electricity is the most important topic, and overall almost 44 per cent ranked electricity first or second. Compared with electricity, LPG and kerosene were seen less important.

Figure 45: Education emerges as the priority need wanting government support; followed by electricity and water

Who are the people who prioritise electricity the most? We find some evidence that the households lacking electricity access are more likely to rank electrification higher than other issues. About 45 per cent of the respondents from the lowest tier of electricity access rank electricity first or second. Whereas only 38 per cent of respondents from the highest tier do so. Unsurprisingly, people who are unsatisfied with their access to electricity are also more likely to consider electricity a high priority. Among those unsatisfied with the electricity situation in their household, 20 per cent place electricity first; among those who are satisfied, only 14 per cent do so.

The priority varies considerably across states. In Jharkhand, only 16 per cent of the respondents ranked electricity first; in sharp contrast, 29 per cent of Odisha's respondents prioritized electricity highest (refer Figure 46).

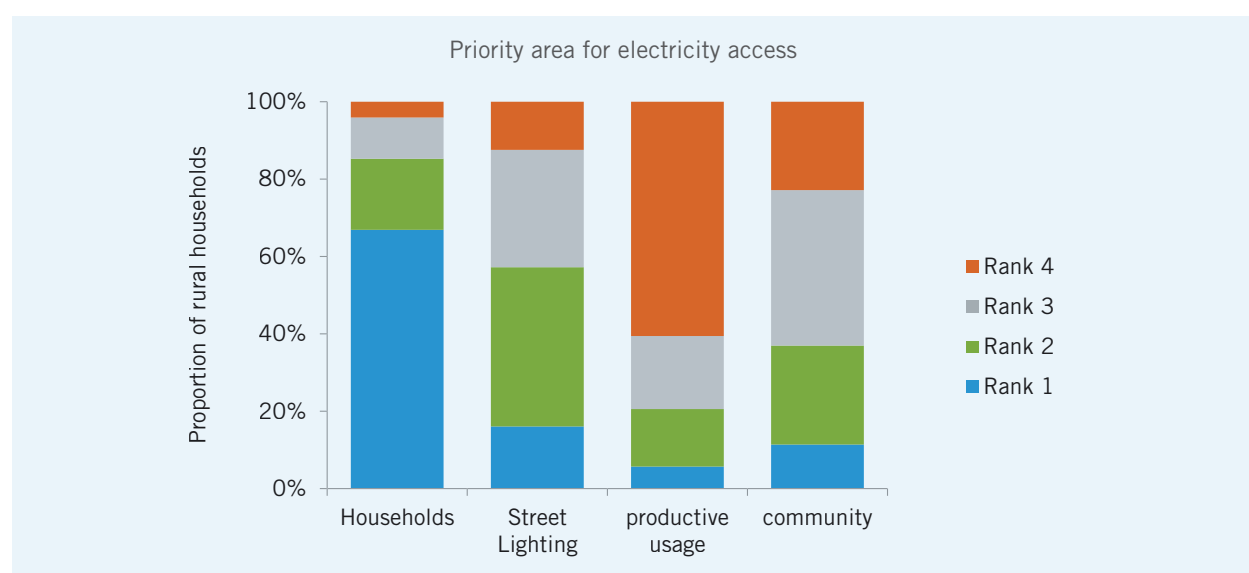
Figure 46: Education remains the top priority across states

Few people considered government intervention urgent for LPG. Less than 2 per cent of Jharkhand's respondents ranked LPG as the most important issue. Even in West Bengal, the state with the highest level of support for LPG, only 7.7 per cent considered it to be the top priority. Given the paucity of support for LPG, it is difficult to detect the reasons that make people support – or not – LPG. Nonetheless, it appears that it is households in higher tiers in cooking access that put more emphasis on government support for LPG. We find that 25 per cent of all households in Tier 3 rank government support for LPG first or second; among households in Tier 0, only 15 per cent do so. This may reflect the higher reliance of households on government support for the provision of modern cooking fuels and technologies.

5.2 Importance of various types of electricity access

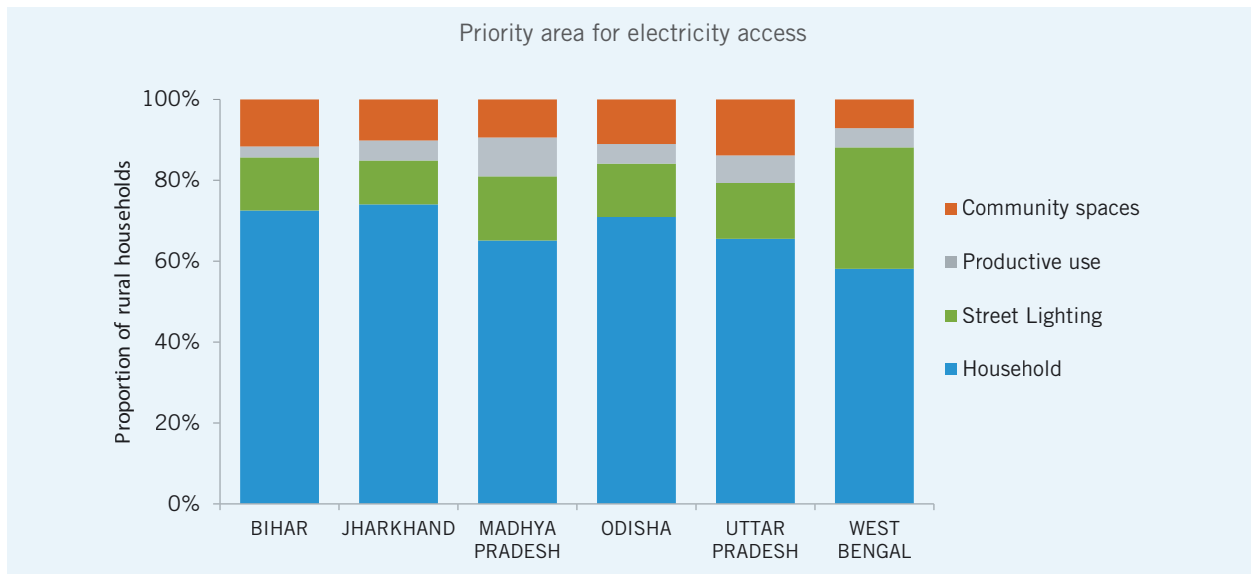
Electricity access is not just about connecting individual households to the grid. Electricity can also be used to provide lighting for streets or community spaces (such as schools), and to power productive (income generating) endeavors. We therefore asked people to rank these possible targets from the most to the least important. Unsurprisingly, most respondents (67 per cent) considered that providing electricity to households should be the first priority (see Figure 47).

Figure 47: Household electrification is the top-most priority of rural population



Perhaps the most surprising finding is that few people consider productive use to be a priority. More than half of the respondents ranked it last. Interestingly, street lighting came second with 16 per cent of all respondents considering this to be the most important issue.

Respondents from Jharkhand were particularly likely to rank household access first, with 74 per cent of them doing so (refer Figure 48). People from West Bengal were (relatively) the least likely to prioritise household access, although a sizable share still did so (58 per cent).

Figure 48: Household electrification remains the top-most priority across states

Our tiers shed some light on these patterns. We find that household access is ranked particularly highly for respondents in the lowest tiers of electricity access. Among those in Tier 0, 71 per cent consider this item to be the highest priority. In contrast, among those in Tier 3, only 56 per cent do so (the proportion even declines somewhat to 51 per cent in Tier 2). Unsurprisingly, two-thirds of those who are unsatisfied with their electricity situation want to prioritise household access.

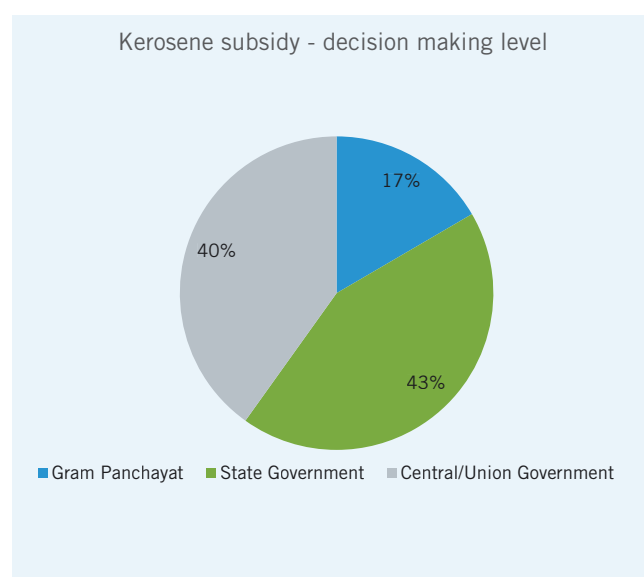
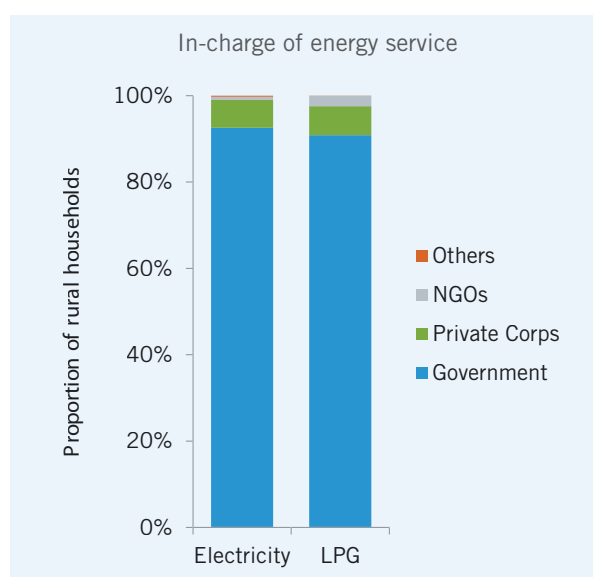
What then, do those who are in the upper tiers consider to be the most important? Quite clearly, the answer is “street lighting.” More than one quarter of all respondents in Tier 3 see street lighting to be the most important type of electricity access, whereas only 13 per cent of respondents from Tier 0 think so. It therefore appears that once basic electricity needs are covered, people prioritize the provision of electricity for street lighting and community purposes. At this stage, it is unclear why this is the case. Safety is only part of the answer; Tier 2 and 3 respondents who don’t believe that street lighting increases safety are still somewhat more likely to prioritize street lighting than respondents from Tier 0.

5.3 Energy decision-making

We examined peoples’ priority on decision making for energy provision through two questions. First, we ask who should take care of the provision of utility services like electricity and LPG. Second, we investigate whether people have a preference for the *level* of government administration that should be in charge to determine level of subsidy for kerosene.

We find overwhelming support for the notion that governments should be in charge of energy provision. Overall, 93 per cent of the respondents wanted the government to be responsible for electricity, and 91 per cent wanted the same with respect to LPG (see Figure 50). Support for non-governmental actors was slightly higher for LPG: About 9 per cent wanted either private firms (6.7 per cent) or NGOs (2.4 per cent) to provide it.

Furthermore, we find little evidence that these preferences are related to the tier to which respondents belong to. Regardless of a person’s current access to electricity, most people want the government to be

Figure 49: Who should decide kerosene subsidy?**Figure 50: People want government to continue as being in-charge of service delivery**

in charge. That being said, we do find that support for government management is highest for those who report high levels of satisfaction with their access to electricity.

If the government ought to be in charge, the question then is: Which level of government jurisdiction? In India, government power is mainly divided across three levels: central government, state authorities, and *Gram Panchayats* in rural areas. Examining the case of subsidised kerosene, we find that the almost equal number of household prioritise central and state governments: 43 per cent of respondents want state government as the main decision-maker while another 40 per cent think the central government should assume such responsibility. Interestingly, a sizable minority believes that Gram Panchayats ought to be in charge (refer Figure 49: Who should decide kerosene subsidy?).

These preferences are not affected by the respondent's material situation: The proportions remain about the same for each tier of electricity access. Nor do the responses vary much across electricity satisfaction levels. Instead, we find that most variation is geographic in nature (See Table 10). In Bihar, Jharkhand, and West Bengal, around half of households indicated state government as the most important decision maker while in Uttar Pradesh the plurality of households (48 per cent) chose central government. In Madhya Pradesh, all three options received relatively equal proportion (around 30 per cent; the largest is central government, 35 per cent). In Odisha, state government, finally, slightly dominated other two options (43 per cent), which received relatively equal attention.

Table 10: State-wise comparison on the preference of level of government responsible for energy provisions

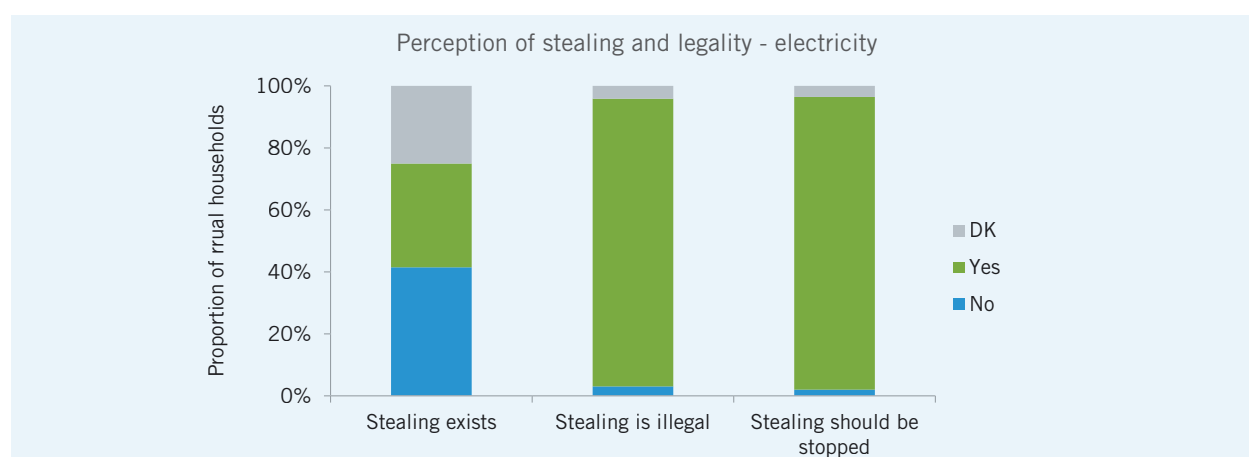
	Bihar	Jharkhand	Madhya Pradesh	Odisha	Uttar Pradesh	West Bengal	All States
Gram Panchayat	14.5%	10.4%	31.7%	27.5%	12.0%	14.9%	16.6%
State Government	46.7%	51.9%	33.2%	43.1%	39.9%	51.8%	43.3%
Central Government	38.8%	37.7%	35.1%	29.3%	48.1%	33.4%	40.1%

5.4 Perceptions of corruption and legality

One of the main obstacles to energy reforms is energy theft. When people can steal electricity or get more subsidized kerosene than their fair share, it become politically very hard to improve the service. Theft reduces income and reduces available cash to improve the grid. Furthermore, those who benefit from the system are unlikely to support any meaningful reform.

We first asked respondents whether they were aware of electricity theft, whether they knew that it was illegal, and whether it ought to be stopped. Unsurprisingly, nearly all respondents reported knowing that stealing is illegal and wanted it to be stopped (refer Figure 51). Intriguingly, it is much less clear whether people were aware of theft in their village. Respondents were divided about between those who reported knowing about theft (33 per cent) and those who replied “no” to this question (41 per cent). A large proportion (about 25 per cent) responded to the questions as “don’t know”; this rate is much higher than for other questions, and suggests that the question is very sensitive.

Figure 51: Significant population claimed ignorance when asked about existence of electricity stealing in the village



The idea that electricity theft is taboo is further underscored by examining how responses vary by electricity access tier. Those in Tier 3, who presumably have the most to lose from theft, are much more likely to report theft (44 per cent, with 24 per cent non-responses) than those in Tier 0 (30 per cent with 25 per cent non-responses).

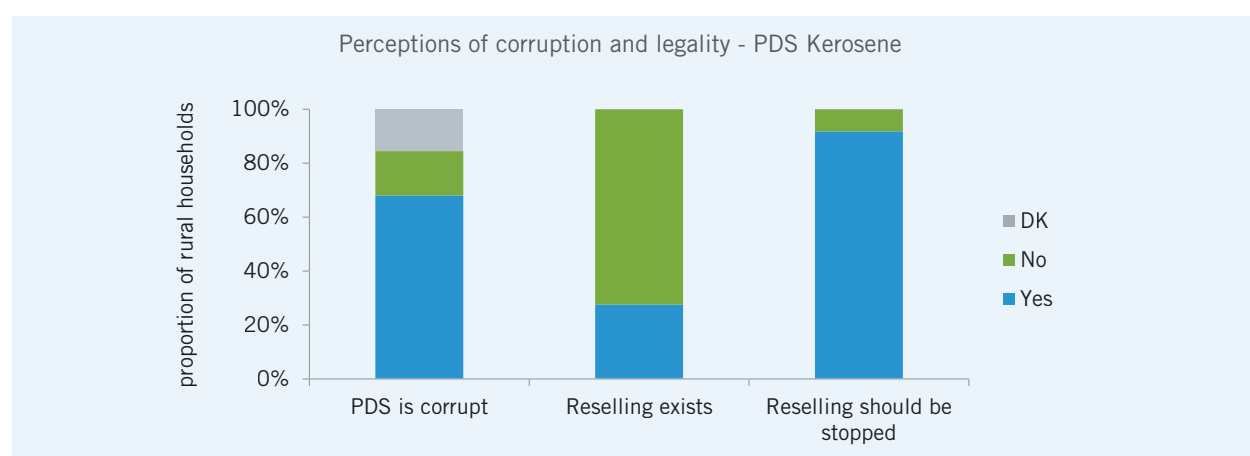
Given how tightly electricity theft is associated to the enforcement of regulations, one would expect considerable variation across states. Indeed, we find that this is the case. Among all six states, Bihar, Jharkhand, and Odisha witnessed the lowest self-reported rates of electricity stealing, 9.7 per cent, 8.8 per cent, and 7.4 per cent respectively, although these three states also have the highest no-response rates, around 40 per cent. In Madhya Pradesh and Uttar Pradesh, 37 per cent and 45.8 per cent of households report the presence of stealing. West Bengal has the highest rate; around 56.6 per cent (see Table 11).

Table 11: State-wise comparison on the perception of electricity theft

	Bihar	Jharkhand	Madhya Pradesh	Odisha	Uttar Pradesh	West Bengal	All States
Stealing Exists?							
Yes	9.7%	8.8%	37%	7.4%	45.8%	56.6%	33%
DK	40%	41%	14.8%	37.2%	15.5%	19.6%	24%
Yes+DK	49.7%	49.8%	41.8%	44.6%	61.3%	66.2%	57%
Stealing is Illegal?	81.5%	94.5%	93.8%	64.7%	94.4%	97.1%	89.5%
Stealing should be Stopped?	86%	88.4%	95.1%	80.1%	93.8%	95.3%	91%

We next asked a similar question about (illegally) reselling kerosene obtained through the PDS. Since kerosene is subsidized, people may find it profitable to resell it at a higher cost to people who need more than their quota.

Three-fourths of the households report that people do not resell subsidized kerosene, as shown in Figure 52. More than 50 per cent of households indicated the PDS for kerosene is “corrupt” and nearly all households think reselling PDS kerosene is illegal. About 53 per cent of respondents from Electricity Access Tier 3 claim that there is illegal reselling in their village, against only 24 per cent in Tier 0 (the rest is in between). We believe that these responses may actually reflect a deeper fear of reporting illegal activities.

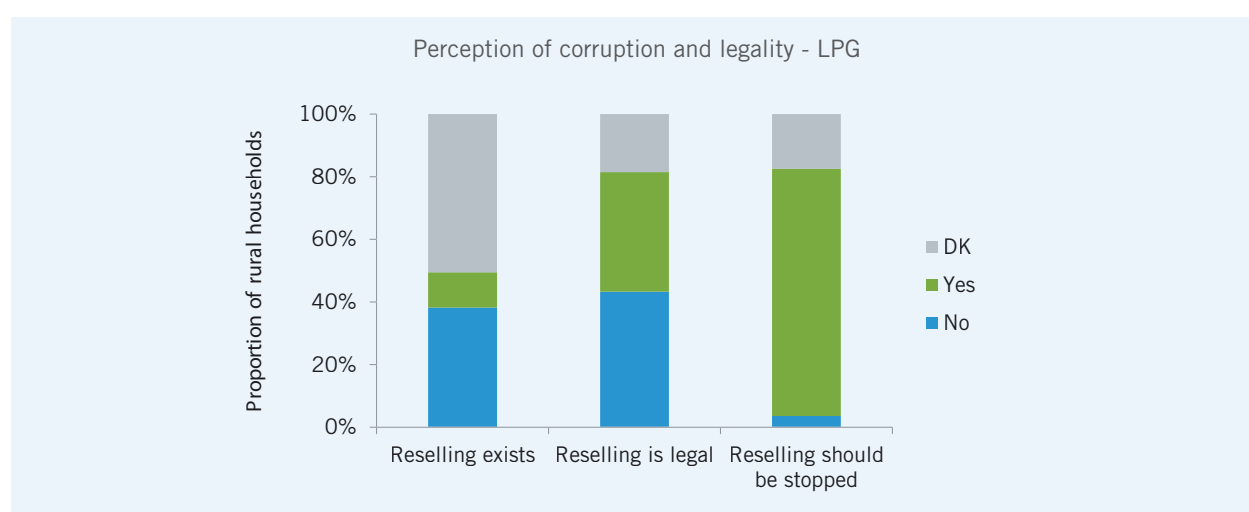
Figure 52: Majority of household believe that PDS for kerosene is plagued with corruption

Beliefs that the PDS is corrupt are uneven across the six states we examined. Except for Jharkhand and Odisha, 50 per cent of households in the other states claim that the PDS for kerosene is corrupt or refused to answer the question. Across all states, Odisha has the highest no-response rate, with more than a third of respondents saying they did not know whether the PDS is corrupt or not. Meanwhile, West Bengal saw the highest rate of reselling PDS kerosene – nearly 70 per cent of households said their fellow villagers resell subsidized kerosene. There seems no apparent state-level variation on whether reselling should be stopped or not – in all states nearly every households agreed so (see Table 12).

Table 12: State-wise comparison on the status of PDS resale

	Bihar	Jharkhand	Madhya Pradesh	Odisha	Uttar Pradesh	West Bengal	All States
PDS is Corrupt?	49.0%	43.0%	63.4%	18.3%	58.3%	48.4%	51.2%
Reselling Exists?	18.1%	15.0%	30.6%	19.4%	19.8%	68.3%	27.6%
Reselling should be Stopped?	97.1%	96.6%	81.4%	82.8%	97.3%	81.8%	91.8%

Finally, we investigate the same question for the case of LPG (refer Figure 53). Nearly 50 per cent of households reported they did not know whether or not people are reselling subsidized LPG in their villages. Interestingly, while around three quarters of households say reselling subsidized LPG should be stopped, opinions regarding whether reselling subsidized LPG is legal are a bit mixed with “No” moderately dominating “DK” and “Yes.”

Figure 53: Significant proportion of households are unaware that reselling of LPG cylinder is illegal

Again, West Bengal has the highest self-reported rate of reselling (48.9 per cent) while households in the same state also almost universally consider reselling is legal (99.4 per cent). Compared with previous questions, no-response rates are relatively high across all states when being asked whether or not villagers are reselling subsidized LPG. In Bihar, Jharkhand, Odisha, and West Bengal, more than 65 per cent of households said they did not know whether or not reselling is taking place. Nearly 60 per cent of households in Madhya Pradesh did not say whether reselling is legal and whether reselling should be stopped (see Table 13).

Table 13: State-wise comparison on the status of LPG resale

	Bihar	Jharkhand	Madhya Pradesh	Odisha	Uttar Pradesh	West Bengal	All States
Reselling Exists?	25.6%	8.5%	10.5%	9.4%	22.7%	48.9%	22.7%
Reselling is Legal?	32.8%	16.9%	72.7%	81.9%	31.1%	99.4%	46.9%
Reselling should be Stopped?	98.8%	97.9%	82.9%	83.8%	96.5%	99.1%	95.7%

5.5 Renewable energy: An alternative?

Reforming the energy sector is tricky. Entrenched interests create political and social obstacles that are hard to overcome. An easier path for policymakers could be to focus on the deployment of new technologies instead of attacking ‘old’ ones. Renewable energy devices such as solar lanterns may therefore be more palatable for policymakers.

In order to measure people’s interest in renewable electricity sources, we asked them whether they preferred to be connected to the regular grid or to a micro-grid, assuming both cost the same. We find that most people would rather be connected to the regular grid, as indicated in Figure 55. This being said, the share of respondents who preferred a micro-grid was not trivial: 34 per cent. Given the novelty of the system, this is a promising finding for the proponents of renewables. Micro-grids are particularly popular among the energy poor (Tier 0), where the rate climbs to 36 per cent.

Figure 54: People overwhelmingly support subsidising solar lanterns over kerosene subsidy

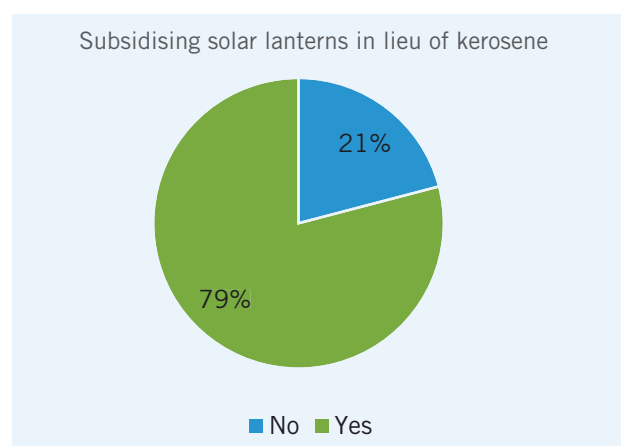
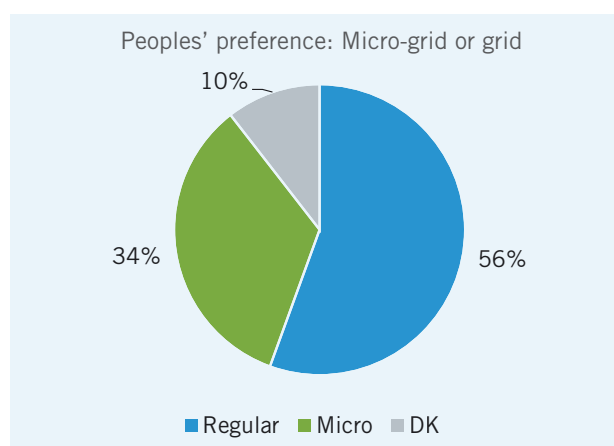


Figure 55: Grid remains the choice for electrification, but significant rural population prefers micro-grid over grid



We next examined whether people would support solar lanterns subsidies even if doing so would result that kerosene subsidies were cut. We find surprisingly strong support for such a proposal, with 79 per cent in favor (see Figure 54). The energy poor and those dissatisfied with their electricity situation are marginally more likely to support such a proposal.

We find that these responses vary considerably with the state. Compared with other states, more than 50 per cent of households in Uttar Pradesh are interested in the micro grid system; in the same state, nearly 90 per cent of households expressed interest in solar lantern (see Table 14).

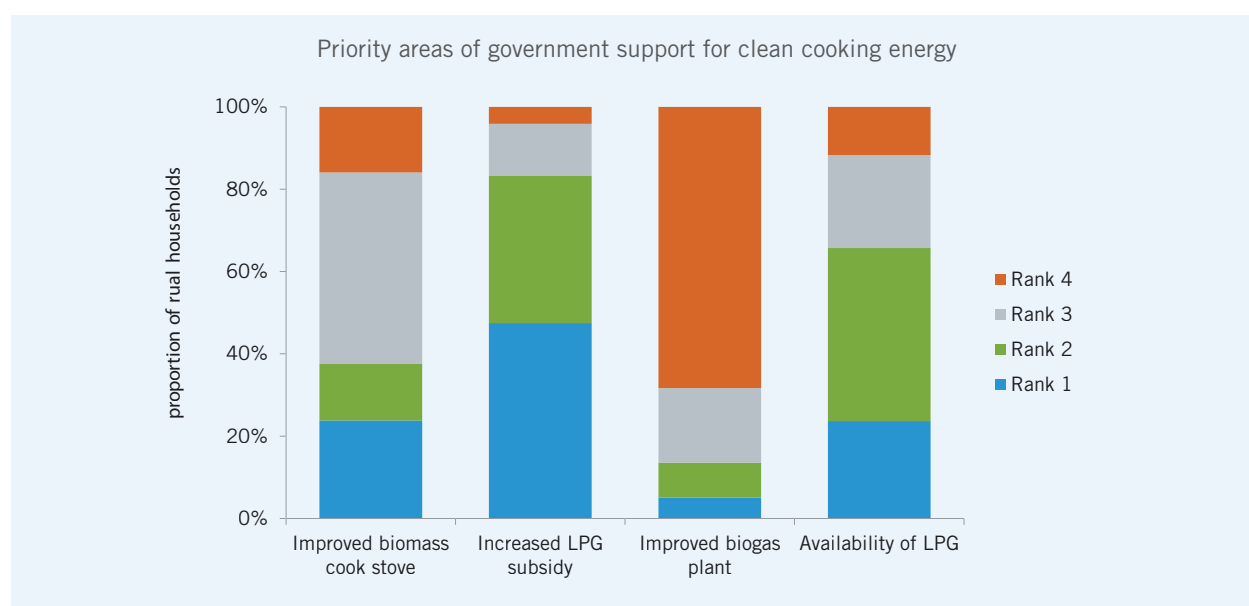
Table 14: State-wise comparison on the support for solar lantern subsidy at the cost of kerosene subsidy

	Bihar	Jharkhand	Madhya Pradesh	Odisha	Uttar Pradesh	West Bengal	All States
Micro Grid	19.1%	38.7%	36.0%	21.2%	50.8%	17.4%	33.9%
Solar Lantern	72.3%	75.4%	84.3%	63.0%	89.9%	68.2%	79.1%

We conclude by studying people's preferences with respect to cooking technologies. We asked respondents what should be the government's highest priority: Improved biomass cook stoves, improved biogas plants, LPG subsidies, or making LPG cylinders more accessible (refer Figure 56).

The answer is quite clear: People considered LPG to be more of a priority than biogas or biomass based solutions. About half want the government to increase LPG subsidies, and a further 24 per cent of the respondents want LPG cylinders to become more available. Few people think that biomass stoves should be the highest priority (24 per cent); even fewer consider that biogas plants should be it (5 per cent). Support for LPG subsidies is particularly high among those respondents who belong to the three highest cooking access tier; between 53 per cent and 57 per cent of the respondents rank it first. Support declines in the lowest tier, with 45 per cent ranking LPG first.

Figure 56: LPG remains the preferred clean cooking energy options



There is also some variation across states, with Odisha being an outlier: Support for LPG seems more lukewarm than in other states. Bihar stands out as a state with strong support for LPG subsidies, with about 91 per cent of the respondents ranking it first or second (see Table 15).

Table 15: State-wise comparison on support for LPG subsidy

Rank	Bihar	Jharkhand	Madhya Pradesh	Odisha	Uttar Pradesh	West Bengal	All States
1 st	58.2%	50.4%	52%	37.2%	47.1%	33.1%	47.5%
2 nd	33%	38%	27.1%	33.6%	41.6%	32.9%	35.7%
3 rd	7.3%	10.5%	15.8%	20.1%	8.7%	24.8%	12.7%
4 th	1.5%	1.2%	5.1%	9.1%	2.6%	9%	4.1%

5.6 Key insights from peoples' preferences

Based on the findings and preferences (as stated by the people), following are the key insights and take-aways:

- Comparing clean cooking energy against electricity, the latter fares much higher in terms of peoples' priority for government action.
- Looking at various spaces to be electrified, household electrification is a clear priority, followed by street lighting. Surprisingly, electrification for productive use did not emerge at a major priority. A potential reason could be lack of awareness and understanding of potential of electricity for productive uses.
- Comparing electrification through grid or micro-grid, there is phenomenal inclination among people to opt for micro-grid. Though the inclination vary significantly across the states. Also, households in higher tiers have strong preferences for the regular grid, even when they are not entirely satisfied with their current situation.
- People overwhelmingly believe that the government should oversee energy management. However, they disagree about the appropriate level of government (in particular state vs. central government). This leaves open the possibility of following a flexible policy-making model of devolution tailored on a state-by-state basis. Different states might suit various degree of autonomy in tackling state-specific issues. Alternatively, our results suggest that energy policy-making requires close collaboration between the central and state government authorities.
- People are largely willing to switch to solar lantern at the exchange of kerosene subsidies; the government may encourage the transition toward solar power for lighting to complement the effort of household electrification.
- Among cooking fuels, LPG gathers the most support across all states and across all tiers. To the extent that policymakers have to make trade-offs, a focus on LPG over less popular biomass might be warranted.

Concluding Remarks

The multi-tier framework provides numerous novel insights on energy access, which could be used by policymakers to refine the existing schemes and their implementation for increasing access to modern forms of energy. The issue of energy access in India is truly a multi-dimensional one. For instance, it is as much a problem of availability of infrastructure and resources as it is of understanding the benefits of opting to consume a modern form of energy. While conventional policies advocate for a supply side response, the findings in this study suggest that there is also a need to address the demand for clean energy, especially on the cooking energy side. On the electricity access front, the priority must shift not only to the provision of a connection to the households, but also to ensure a decent level of duration of supply, quality and reliability in the service. On the cooking front, the study suggests that users of traditional fuels do not necessarily pay less (or no) charges for accessing energy, though many of them perceive modern commercial energy sources as being more expensive. There is also a lack of awareness about the full benefits of transitioning to cleaner fuels. Consequently, the two types of energy access that we capture in this study require interventions that are different in their nature and targeted level of governance. This point is further strengthened by the observation that a very weak correlation exists between the electricity and cooking energy access tiers at the household level. This is also a uniform observation across the states.

While this is a static evaluation at one point in time, the state of access is likely to change rapidly as a result of the increased focus on providing universal energy access. Going forward, we plan to conduct similar survey exercises, while increasing the geographical scope and widening the focus beyond household access. Overtime, this would help to build a dynamic database to effectively track the state and progress of energy access in the country. Alternatively, a more cost effective approach could be to add certain energy access related questions to the existing pan-India surveys, such as the NSS household expenditure survey which is conducted in a periodic manner.

As penetration increases with each passing year, the bottlenecks of energy access may change over time. The multi-tier, multi-dimensional framework is ideally suited to track such developments and can be the authoritative basis for decision makers to evaluate the impact of their programs and take stock of open challenges.

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Annexures

Annexure I

Energy Access Schemes and Programmes (1947-Present)

Policy/ Programme	Objectives, Scope and Impacts
Supply of kerosene through public distribution system (PDS) with quantity restriction, in 1957	Ensure benefits are reached to the poor and needy people. Households are allotted kerosene consumption quotas that vary by state and region (urban and rural), and whether they have an LPG connection or not. Nearly 40% of the PDS kerosene gets illegally diverted and is used to adulterate diesel and petrol for transport. Subsidy is prevalent to this day.
Subsidies on household cooking fuels like kerosene and LPG in late 1960s	Provide affordable access to modern fuels for the poor. Subsidy on LPG is available for all the consumers irrespective of their income levels. Subsidy on kerosene is available for those without an LPG connection. Thus, subsidies for both costing about Rs. 485 billion (in 2008) are not targeted at the poor
National Project on Biogas Development (NPBD) in 1982	Disseminate family type biogas plants. Modern fuel for cooking and organic fertilizer to rural households, mitigate drudgery of women, reduce pressure on forest. Biogas plants built till 2009 is estimated at 4.17 million. Estimates suggest that only about 28% of them provide primary cooking fuel to relatively rich rural households
National Programme on Improved Chulhas (NPIC) or cookstoves in 1983	Disseminate advanced biomass cookstoves. Efficient use of fuel wood and avoid deforestation, reduce drudgery for women and health hazards caused by indoor pollution. By 2003, over 35 million stoves had been built; however, the NPIC was found to be ineffective in promoting a shift to improved stoves therefore the funding was stopped in 2002
Expanding rural lighting energy access Rural electrification corporation (REC) established in 1969	Support rural electrification schemes & rural electricity co-operatives. Two major thrust areas of REC are irrigation pump electrification and village electrification. REC acts as the nodal agency for the centrally sponsored programmes
Minimum Needs Programme in 1974	Provided 100% loans from the central government for last mile connectivity for rural electrification projects in less electrified states
Kutir Jyoti (bright hut) Scheme in 1988	Provided a single point lighting connections to households below the poverty line (BPL). Connected nearly 7.2 million rural households to the grid till March 2006 with a total grant amount of about Rs. 6.12 billion
Pradhan Mantri Gramodaya Yojana (Prime minister's village development programme) in 2000	Rural electrification was one of the many programmes. It offered financing through loans (90%) and grants (10%). It was coordinated and monitored by the Rural Development Division of the Planning Commission
Rural Electricity Supply Technology Mission in 2002	Electrification of all villages and households progressively by year 2012 through renewable energy sources and decentralized technologies, in addition to conventional grid connection

Accelerated Rural Electrification Programme (AREP) in 2003	Interest subsidy of 4% was provided on loans availed by state governments/ power utilities from financial institutions for carrying out rural electrification programme. It was limited to electrification of un-electrified villages, smaller settlements of lower-caste people and tribal villages, and through both conventional and non-conventional sources of energy
The Electricity Act 2003	Specific directions for expanding rural electricity access and for the first time mentions rural electrification in a statute. Mandates universal service obligation and formulation of a national policy on rural electrification. States that the state and central governments shall jointly endeavor to provide electricity access to all
Accelerated Electrification of One lakh villages and One crore households in 2004	Village and household electrification. Accelerated electrification of 100,000 villages and 10 million households by merging the interest subsidy scheme of AREP and Kutir Jyoti programme. Provision was made for providing 40% capital subsidy and the balance as loan assistance on soft terms from REC
National Electricity Policy in 2005	Access to electricity for all households and demand for power to be fully met by 2012, and minimum lifeline consumption of 1 kWh/household/day by 2012
Rajiv Gandhi Grameen Vidyutikaran Yojana (rural electrification programme) in 2005	Scheme for developing rural electricity infrastructure and expanding household electrification with 90% capital subsidy and 10% loan assistance. Final connection is provided free of cost for BPL households. The total cost of the programme is Rs. 287 billion and the achievements as on April 2010 are electrification of 79,000 villages and 12 million rural households
Rural Electrification Policy in 2006	The rural electrification policy elaborates on the issues mentioned in the national electricity policy and makes specific recommendations for effective implementation of the rural electrification programme
National Biomass Cookstoves Programme (NBCP) in 2009	Claims to be different from the failed NPIC. The initiative stressed the setting up of state-of-the-art testing, certification and monitoring facilities and strengthening R&D programmes. The aim is to design and develop the most efficient, cost effective, durable and easy to use device.
Rajiv Gandhi Gramin LPG Vitruk Yojana (RGGLVY) in 2009	Aims to eliminate ailments due to use of chulhas and to provide clean cooking fuel to rural women folk. By 2015, the scheme aims to have a minimum of one LPG distributor per block in the country, all districts to have 50% LPG coverage, all states to have minimum 60% LPG coverage and 75% LPG coverage in all of India.
DBTL (2013/ 2014)	Launched originally in 2013, the current revamped version has been active since October 2014 and facilitates the transfer of subsidy for LPG consumers directly to their bank accounts. LPG will be sold at market prices to all consumers and those who desire to have the subsidy will receive it in their bank accounts which would be linked through an ID unique to the consumer.

Source: Adapted from (Ganesan & Vishnu, 2014)

Annexure II

State-specific cooking energy bottlenecks in Tier 1 households

Figure 1: Cooking energy access - Bottlenecks for Tier 1 households in Odisha

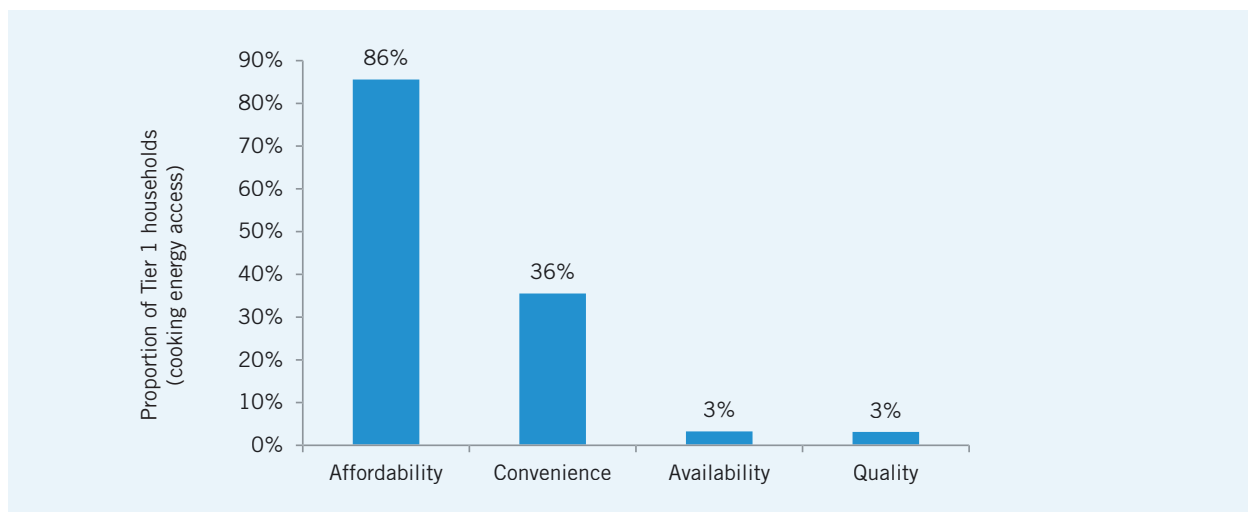


Figure 2: Cooking energy access - Bottlenecks for Tier 1 households in West Bengal

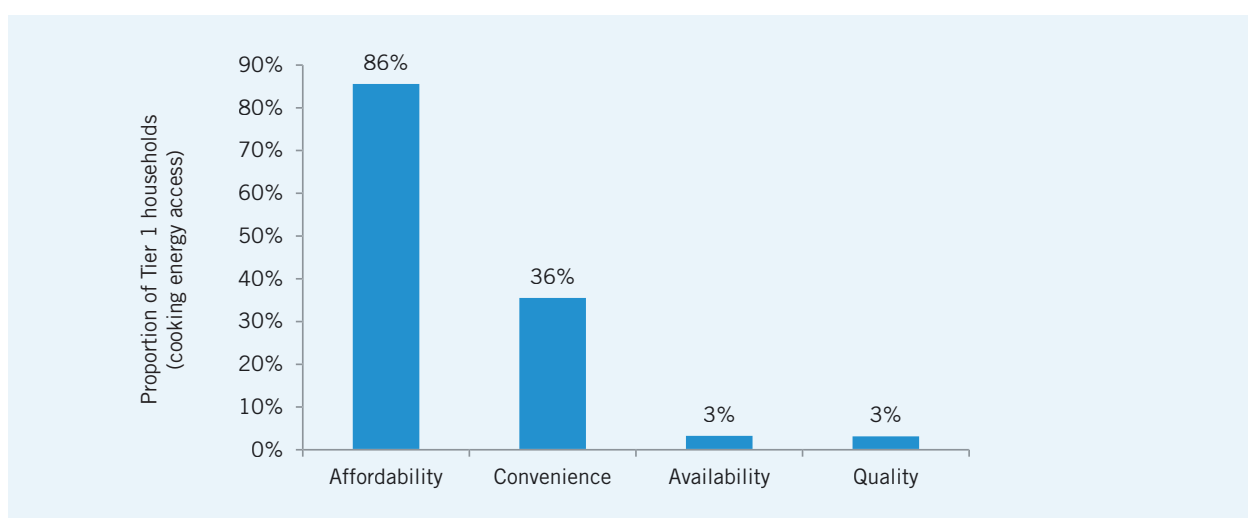


Figure 3: Cooking energy access - Bottlenecks for Tier 1 households in Uttar Pradesh

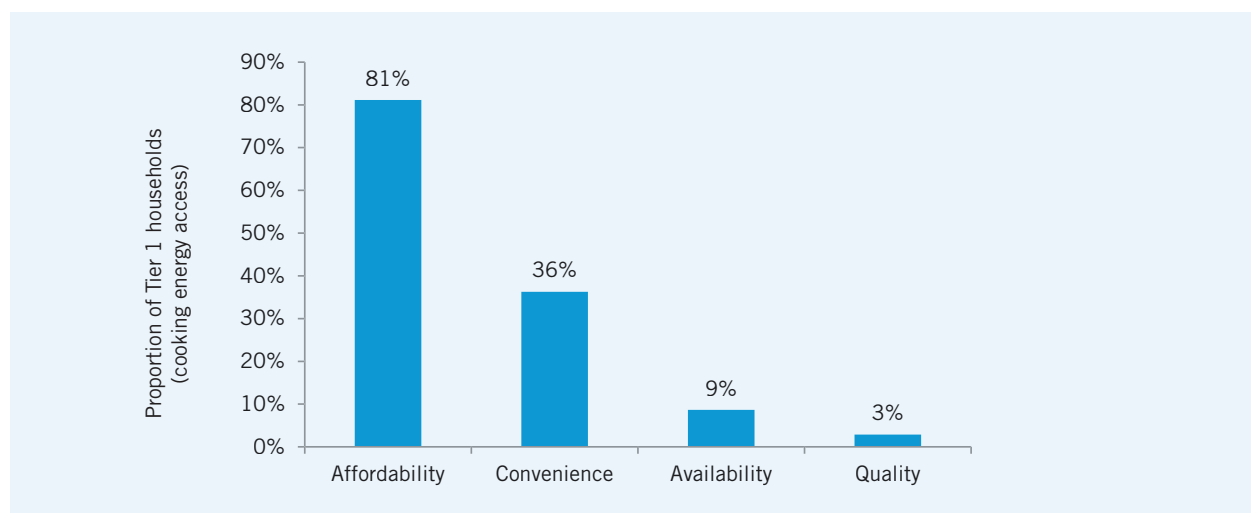


Figure 4: Cooking energy access - Bottlenecks for Tier 1 households in Madhya Pradesh

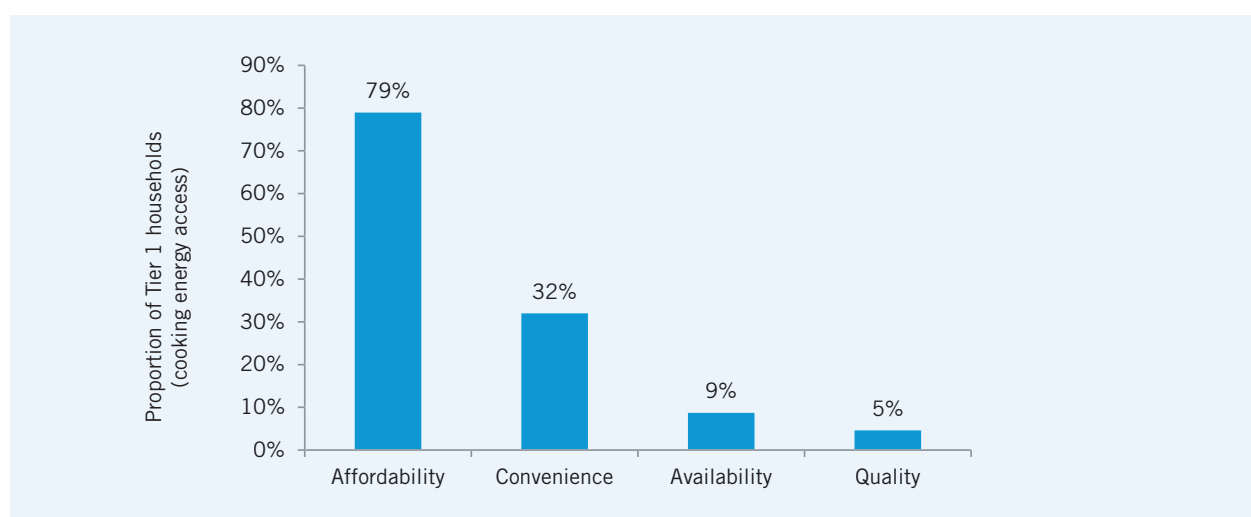


Figure 5: Cooking energy access - Bottlenecks for Tier 1 households in Jharkhand

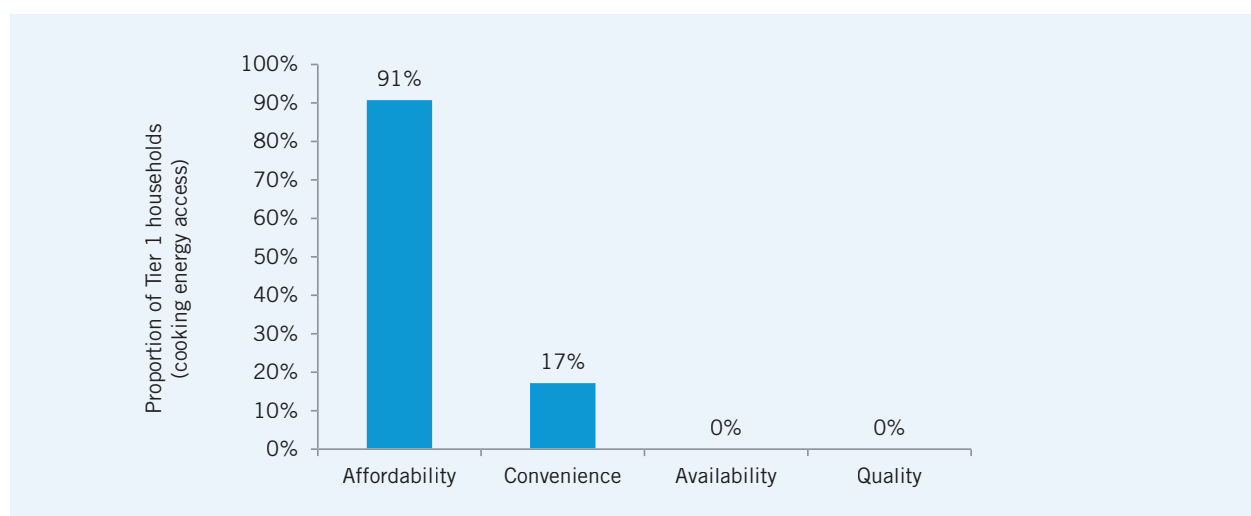
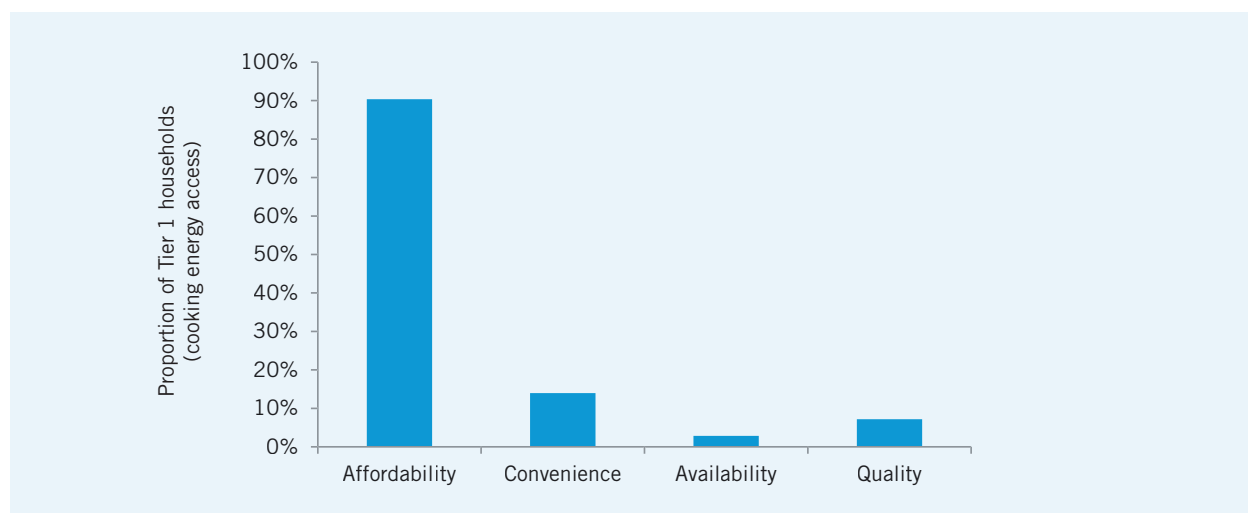


Figure 6: Cooking energy access - Bottlenecks for Tier 1 households in Bihar



Annexure III

Sensitivity analysis for energy access measurement framework

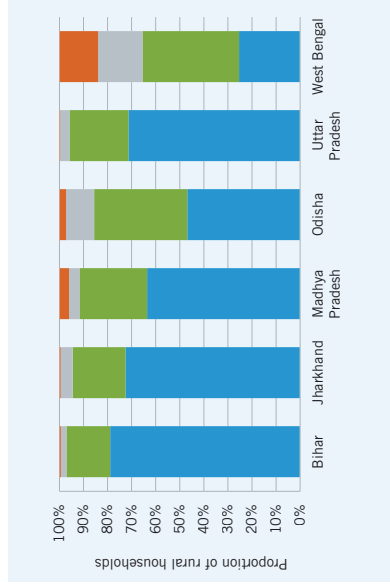
In order to understand that how effective are the tier definitions across various dimensions, we tried to reproduce the overall tiers with varying definition of tiers for each dimension. Two sets of additional tier structure are defined for each dimension. In comparison to base case, one case is slightly relaxed, whereas the second has more stringent sets of definition.

To start with, we modify the tier definitions for duration dimension. If we compare the tier results based on modified definition of tiers against the base case results, it is evident that the variation is not significant in the overall tier spread for states, except in the case of West Bengal, that too towards the higher tiers (2 & 3) and only for stringent case. This indicates that the duration dimension, as defined, is fairly robust.

1. Duration

	Tier 0	Tier 1	Tier 2	Tier 3
Base Case	<4 hrs	4-8 hrs	8-20 hrs	>20hrs
Relaxed	< 4 hrs	4-8 hrs	8-16 hrs	>16 hrs
Stringent	<6 hrs	6-12 hrs	12-22 hrs	>22hrs

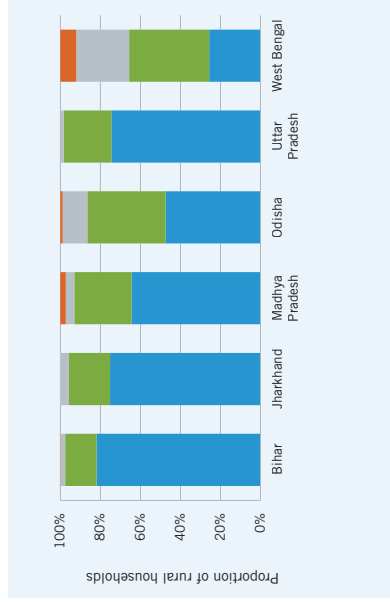
Base case



Relaxed Tiers - Duration



Stringent Tiers - Duration

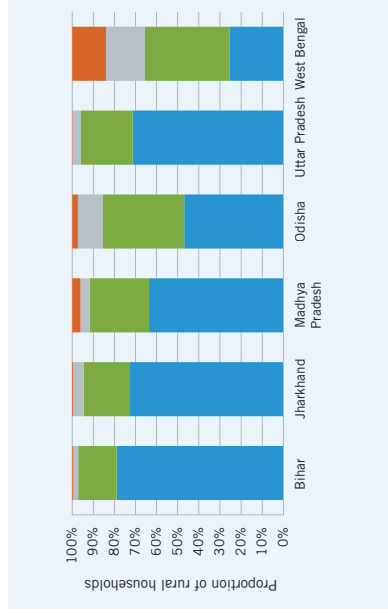


2. Reliability

Blackout days per month	Tier 0	Tier 1	Tier 2	Tier 3
Base Case	4 or more	2 – 4 days	1 day	0
Relaxed	6 or more	3 – 6 days	2 days	1 day
Stringent	2 or more	1 - 2 days	0	0

Base case

Relaxed Tiers - Reliability



Stringent Tiers - Reliability



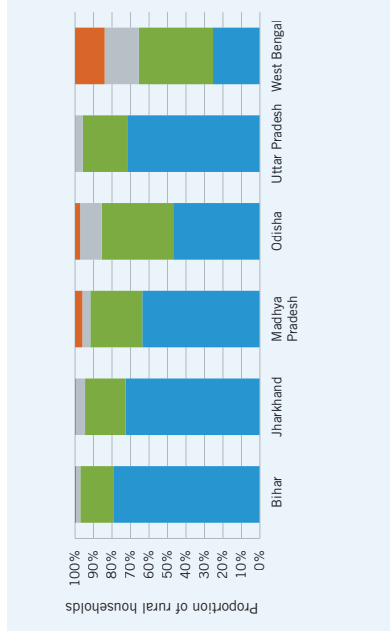
The overall tiers with altered categorisation of reliability are shown above. It can be observed that the West Bengal and Odisha data shows significant sensitivity to change of tier definitions. It also spurs from fact that reliability tiers are defined very minutely, as each blackout day can means significant loss of reliability. Moreover, Odisha and West Bengal anyway exhibit reliability as a bottleneck issue (as shown in electricity access section), conforming the observations here.

3. Quality

High (H) and Low (L) voltage days per month	Tier 0	Tier 1	Tier 2	Tier 3
Base Case	H>3, L>6	H=0-3, L=0-6	H=0-1, L=0-3	H=0, L=0
Relaxed	H>5, L>10	H=0-5, L=0-10	H=0-2, L=0-5	H=0-1, L=0-1
Stringent	H>1, L>4	H=0-1, L=0-4	H=0, L=0-2	H=0, L=0

Base Case

Relaxed Tiers - Quality



Stringent Tiers - Quality

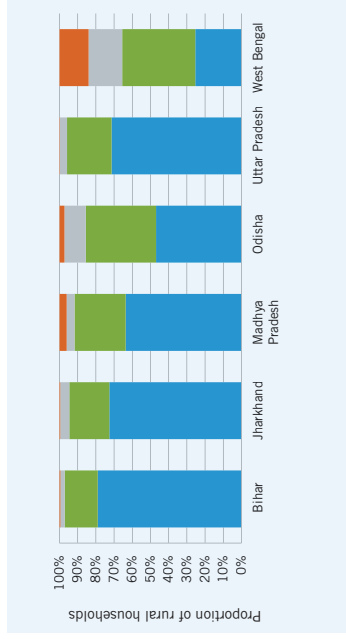


The limited variations in overall tiers results across states with changed definition of quality, shows that the metric used for defining quality issues is fairly robust. Relaxed and Stringent cases, respectively exhibit the marginal changes, especially towards the lower tiers – indicating that the quality dimension as measured, could be slightly sensitive for those who are in lower tiers (Tier 0 or 1).

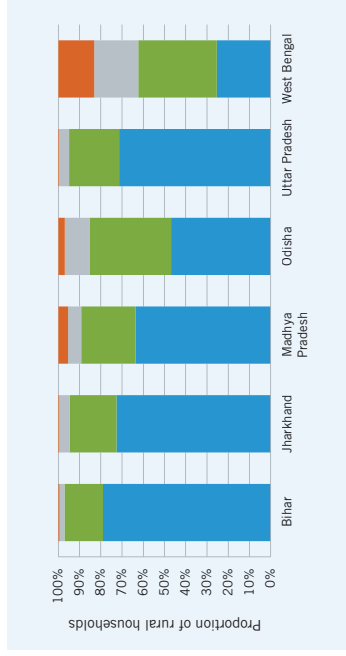
4. Affordability

Affordability Limit (Percentage of monthly expenditure)	
Base Case	4%
Relaxed	5%
Stringent	3%

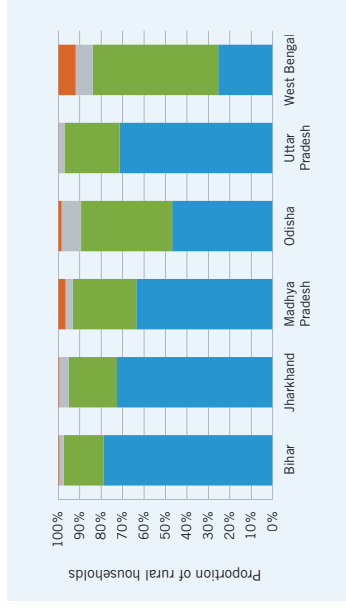
Base Case



Relaxed Tiers - Affordability



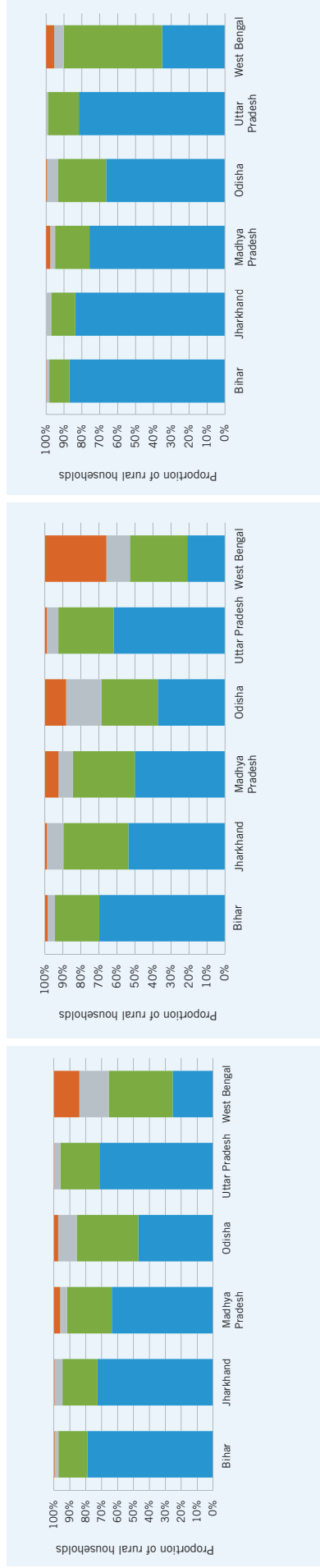
Stringent Tiers - Affordability



Affordability dimension is alternatively defined with affordability limit of 3 % and 5 % to procure minimum threshold electricity to run basic services, as opposed to base case of 4%. The figures above indicate that the definition of affordability is also fairly robust to the extent that it does not significantly affect the overall tier spread by shift in affordability limit.

5. Overall

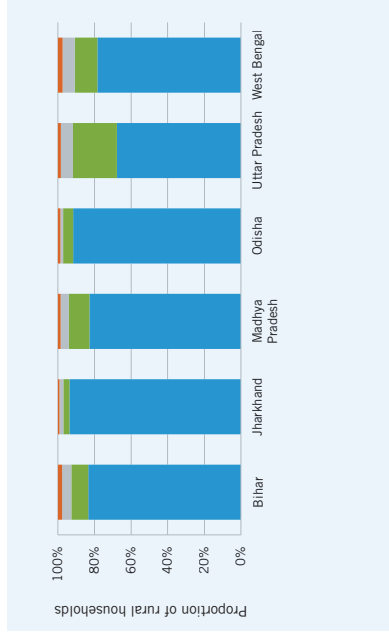
Finally, to test the extreme cases of sensitivity around tiers definition, the definition of all tiers for all dimension is simultaneously shifted to ‘relaxed’ and ‘stringent’, respectively. As shown in the figures below, the simultaneous definition shift does lead to significant changes in overall results, but does not lead to any drastic shifts.



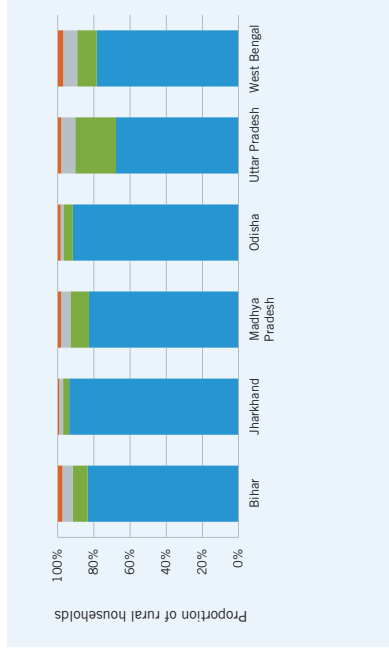
6. Affordability – Cooking Energy

Affordability Limit (Percentage of monthly expenditure)	
Base Case	6%
Relaxed	7%
Stringent	5%

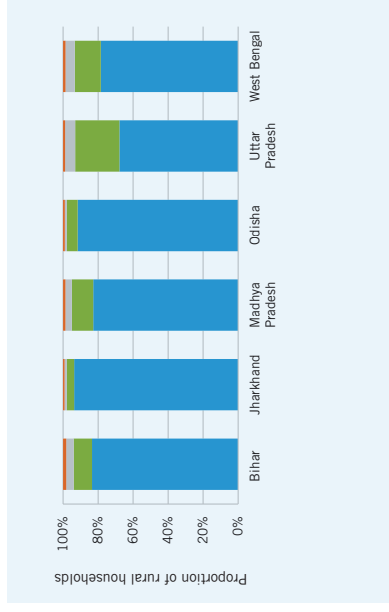
Base Case



Relaxed Tiers



Stringent Tiers



Similarly, altered definitions of affordability for cooking energy, illustrates that its definition is fairly robust to not affect the overall tiers spread significantly, upon minutely changing the affordability limits.



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