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**Working Paper**

## Valuing Electricity Service Attributes: A Choice Experiment Study in Madhya Pradesh, India

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## ADB Economics Working Paper Series



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Herath Gunatilake, Sumeet Patail, and Jui Chen Yang

No. 316 | November 2012



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## **ABSTRACT**

This paper presents the results of a choice experiment study undertaken to value electricity service attributes in Madhya Pradesh, India. Primary data was collected from 2,083 households using stratified random sampling method. Results show that existing service is very poor and consumers have substantial willingness to pay (WTP) for changing the status quo. Amongst the studied service attributes, hours of supply captures the highest WTP and WTP declines significantly with reduced hours of supply. However, quality, customer service, and accuracy of billing together accounts for 56% of the total WTP. Assessment of WTP with different service attribute combinations show that value of other service attributes become relatively more important when supply is less than 24 hours. Simulations show that uptake rates increase substantially when improved hours of supply is supplemented with other service attributes. Development impact of \$1.2 billion worth physical infrastructure investments on Madhya Pradesh power distribution network for 24-hour supply can be significantly enhanced if quality, customer service, transparency, and accuracy of billing are also improved simultaneously.

**Key Words:** Unbundling Demand, Value of Electricity Service Attributes, India

**JEL Classification:** Q40; Q51; C93





## I. INTRODUCTION

Valuing energy services and matching consumer preferences with service quality of electricity is important for policy planning and well-being of households. What motivates this study is the use of the choice experiment (CE) method to examine the willingness to pay (WTP) for improved electricity services, to enhance the development effectiveness of \$1.2 billion investment on electricity distribution improvements in rural Madhya Pradesh (MP), India. There are very few studies in energy literature on valuation electricity services in developing countries and this is the first of this kind in India. Numerous stated preference studies such as contingent valuation (CV) and choice experiments (CE) have been undertaken in developed regions, namely North America and Europe. According to a World Bank (WB) report (Silva and Pagiola, 2003), the WB has funded environmental valuation of projects in developing countries and recorded a high number of studies involving water supply, sanitation, and flood protection. By contrast, the energy, transport, and agriculture sectors have received less attention in valuation studies.

Inadequate and poor quality power supply in rural areas is one of the major obstacles for economic development of MP. In MP, out of 52,074 villages, 15% are unelectrified. No household in 4,949 villages and less than 10 % households in 3,036 villages had access to electricity (PMPSU, 2011). A recently conducted survey reveals that only about 60% of the households in rural areas of MP have access to electricity (Gunatilake, Maddipati, and Patail, 2012). Even those who have access receive very poor service In rural areas of MP, poor quality electricity is supplied only 6–8 hours per day. Subsidized, un-metered power supply to agricultural pumps together with the illegal power use have been a major problem in MP power sector. Common feeders which supply electricity to farmers and households make it difficult to improve power supply to rural households without incurring further losses to the power distribution companies.

The government of MP has launched a feeder separation project with the assistance of the Asian Development Bank (ADB) with the following features: 24 hours of electricity supply for domestic/commercial use and 8-hours supply for agricultural use; installation of high voltage distribution systems (HVDS); 100% metering, accurate billing for domestic consumption; remote metering for energy audits and tracking the use of subsidized power by agriculture sector; and maintain good voltage and avoid abnormal loading to feeders and failure of distribution transformers mainly attributed to excessive and often illegal usage of power by farmers.

Gunatilake, Maddipati, and Patail (2012) estimated WTP for improved power services to rural households. The improved service in this case is characterized by: uninterrupted or 24-hour power supply; good quality of power i.e., no brownouts or voltage fluctuations; transparent and accurate billing; and improved customer service, mainly focusing on quick and efficient attendance in repair and other inquiries. Thus, the improved service valued in that study is a composite commodity. Public utilities in developing countries generally focus on engineering aspects of the service improvement, i.e., 24-hour supply and perhaps quality of power. How valuable are the other service attributes such as accurate and transparent billing and improved customer service for the electricity customers? This paper attempts to value the service attributes separately using a CE method.

## II. LITERATURE SURVEY: CHOICE EXPERIMENTS

### A. Theory

The stated preference (SP) methods elicit preferences of respondents for predefined alternatives and the contingent valuation (CV) is the most used SP method in valuing nonmarket goods. In a CV study, the economic value of a composite commodity is estimated while the CE method allows unbundling the demand for the commodity to its attributes and valuation of attributes separately. For example, when the CV study values improved service of electricity, hours of supply, its quality, customer service, and accuracy of billing are set at a predetermined level and there is no systematic variation in attributes of the prescribed good. Consumers however may prefer different levels of these service attributes, they may prefer 18-hour supply rather than 24-hour supply, for example. Different combinations of service attributes may provide different levels of welfare increases, i.e., values to the consumers. CE thus broadens the valuation prospects by allowing estimation of values of attributes separately. In the case of public utility services, CE method helps the utility managers understand the relative importance of service attributes and realign the service provision to suit consumer preferences. Thus, understanding the consumer preferences for service attributes can help enhance the development impacts of electricity service improvement projects.

The CE has its origin in conjoint analysis, which is a well-known technique applied in marketing studies to assess the demand for new products (Boxall et al., 1996). Initial application of CE method was mainly in transport economics. Its application has been extended to other areas like geography, water supply, and energy in recent times. According to Alpizar, Carlsson, and Martinsson (2001), the first study to apply choice experiments to non-market valuation of environmental services was by Adamowicz, Louviere, and Williams (1994). Since then, there has been an increasing number of applications of CE in environmental valuation (e.g., Adamowicz, Boxall, and Louviere (1998); Boxall et al. (1996); Layton and Brown (2000), Ryan and Hughes (1997); and Vick and Scott (1998). As shown below, CE is increasingly used to value utility services but these studies are mainly in developed countries.

The CE method shares a common theoretical framework (random utility theory) used in CV method. In a choice experiment, as in a CV survey, an economic model is intrinsically linked to a statistical model. The economic model is the basis of the analysis and, as such, affects the design of the survey and the analysis of the data. In this sense, it is argued that the realization of a choice experiment is best viewed as an integrated and cyclical process that starts with an economic model describing the issue. This model is extended to an econometric model by incorporating an error term to the results of the utility model. An appropriate experimental design to package the attribute into conceivable alternative states of the commodity follows the development of the econometric model.

The basis for most microeconomic models of consumer behavior is the maximization of a utility function subject to a budget constraint. Choice experiments were inspired by the Lancasterian microeconomic approach (Lancaster, 1966), in which individuals derive utility from the characteristics of the goods rather than directly from the goods themselves. As a result, a change in price can cause a discrete switch from one bundle of goods to another that will provide the most cost-effective combination of attributes. In order to explain the underlying theory of choice experiments, one needs to link the Lancasterian theory of value with models of consumer demand for discrete/continuous choices (Hanemann, 1984 and 1999). In the case of electricity, for example, consumer faces two choices: first to decide whether to get a power connection; and once the decision is made to get a power connection. Next choice is to decide

what levels of service attributes, (hours of supply, quality of power, customer services, accuracy of billing).

Alpizar, Carlsson, and Martinsson (2001) provide a detailed account of the underlying economic models and here we specify only the econometric model. The choices between alternative combinations of electricity service attributes are modeled in a random utility framework. The model represents the utility associated with an alternative by a systematic component and random/error component, taking into account the unobserved utility of the alternative. Following Landenburg and Dubgaard (2007) and we present the econometric model as:

$$U_{na} = V_{na} + \varepsilon_{na} \quad (1)$$

$U_{na}$  is the utility which respondent  $n$  associates with alternative  $a$ ,  $V_{na}$  is the systematic component, and  $\varepsilon_{na}$  is the error component. Thus, both  $V$  and  $\varepsilon$  are alternative and individual specific.

In a choice set consisting of two alternatives  $a$  and  $b$ , respondent  $n$  chooses alternative  $a$  if and only if the respondent  $n$  finds the utility associated with alternative  $a$  larger than the utility of  $b$ , that is  $U_{na} > U_{nb}$ .

The probability that respondent  $n$  chooses alternative  $a$  over  $b$  can then be expressed as

$$\begin{aligned} P_{na} &= \Pr(V_{na} + \varepsilon_{na} > V_{nb} + \varepsilon_{nb} + \forall b \neq a) \\ &= \Pr(\varepsilon_{nb} - \varepsilon_{na} < V_{na} - V_{nb} \forall b \neq a) \end{aligned} \quad (2)$$

That is, the difference in the systematic utility of alternative  $a$  and  $b$  is larger than the difference in the random utility of alternative  $b$  and  $a$ . The difference in the observed utility  $\nabla V_{nab}$  between two alternatives is defined as

$$\nabla V_{nab} = \Delta x'_{nab} \beta, \quad (3)$$

where  $\Delta x'_{nab} \beta$ , represents the difference in the attributes between alternatives  $a$  and  $b$  ( $x_{na} - x_{nb}$ ).

Defining  $t$  as the number of the choice set evaluated by the respondent and assuming a conditional utility function (linear in parameters), the difference in the systematic utility is defined as (Maddala, 1983):

$$V_{nt} = x'_{nt} \beta + z'_m \delta, \quad (4)$$

where  $x_{nt}$  in our case is the difference in the attributes of electricity service and  $z_n$  is the characteristics of the respondent. In general, only a limited number of the parameters incorporated in  $z_n$  are observable and can be controlled for in the model by the analyst. The unobserved individual effect is captured by the error term. Given that  $t = 1, 2, 3$ , and  $4$ , and assuming that the individual fixed effect is time invariant—and the error term is logistically distributed—the unobserved individual effects can be controlled in a fixed effect binary logit model as described by Chamberlain (1980).

The conditional utility function is now

$$U_{nt} = x'_{nt}\beta + z'_{nt}\delta + \alpha_n + \varepsilon_{nt}, \quad (5)$$

where  $\alpha_n$  is the individual effect and  $\varepsilon_{nt}$  is the error term, which is logistically distributed.

The above fixed effect logit model can be estimated by maximizing the likelihood conditional on the  $\alpha_n$  (Chamberlaine, 1980).

From the conditional fixed effect logit function, the parameters representing the characteristics of the electricity service can be estimated. The marginal rates of substitution between the electricity service attributes can be calculated by dividing parameter estimates from two attributes. Using the cost attribute,  $\beta_{price}$  as the denominator, the marginal rate of substitution denotes the WTP for changing the attribute from the baseline level to a predetermined level. Thus the marginal WTP is equal to

$$WTP = \frac{\beta_{xi}}{-\beta_{price}}. \quad (6)$$

## B. Applications in Energy Sector

In one of the earliest studies in energy sector, Goett, Hudson, and Train (2000) have studied customers' choices of attributes of electricity suppliers in the United States (US). The attributes used in this study are (i) price and contract terms, (ii) green energy attributes, (iii) customer services, (iv) value added services, and (v) community presence. The study found that customers consider marginal price increase is more onerous when price is low than when price is high. It also found that respondents have different WTP per kilowatt-hour (kWh) of electricity from different suppliers. Estimates show that majority of customers prefer hydropower to wind power. Customers preferred talking directly to service provider rather than to voice mail. They also preferred option to choosing frequency of bills and bundling of all fuel services.

Bergmann, Hanley, and Wright (2006) have used choice experiments method to find household preferences for investments of different renewable energy sources in Scotland. The renewable energy sources differ with respect to external effects such as landscape quality, wildlife, and air quality. Renewable technologies considered include hydropower, on-shore and off-shore wind power and biomass. Welfare changes for different combinations of impacts associated with different investment strategies are estimated. Differences in preferences towards these impacts between urban and rural communities and between high- and low-income households are also tested. Paper provides some evidence that accepting negative environmental impacts from the renewable energy development projects is more acceptable to the rural population and rural respondents are willing to pay an additional £1.08 per year from each household for each additional full-time job created by the renewable projects.

Mackerron et al. (2009) estimate the WTP for carbon offset certification and co-benefits among young adults in the United Kingdom using a choice experiment study. The study estimates WTP for certified and uncertified offsets with or without co-benefits in an aviation context. Results suggest that uptake of voluntary offsets may be encouraged by investing in projects with co-benefits and by emphasizing those co-benefits to consumers. Certification regimes will add value to offsets, helping compensate for increased costs when consumers are fully aware of them. Banfi et al. (2008) apply the CE method to estimate WTP for energy-saving measures in residential buildings in Switzerland. Results show that residents place significant value for energy saving building attributes such as individual energy savings, environmental attributes, and comfort attributes such as thermal comfort, air quality, and noise protection.

Zorić and Hrovatin (2011) used choice experiments method to explore customers' preferences for electricity service attributes in Slovenia. In the choice experiment, each respondent faced five choice sets and each choice set having three alternatives to choose. The first alternative is the current choice of electricity bundle as a status quo option. Each bundle or set of service attributes consists of five attributes with different attribute levels, namely monthly electricity bill, contract duration, single tariff vs. peak/off-peak tariff, green electricity offer, and conservation program offer. Results from the choice experiment show that monthly electricity bill is not the only attribute that influences the household choice between different electricity bundles. The customers tend to prefer offers that include green energy and conservation programs. Young and high-income households are willing to pay for green electricity, while households with low education background are less likely to choose green offers.

Söderberg (2008) used the CE method to study a different problem of finding preferences of distribution utilities and industrial users of electricity for price and quality attributes in Sweden. Swedish Electricity Act states that electricity distribution must comply with both price and quality requirements. It is therefore important first to define quality attributes and second, to determine customers' priorities concerning price and quality attributes. In the CE, utilities and industrial customers are asked to evaluate 12 choice situations in which price and four specific quality attributes are varied. It is found that the preferences expressed by the utilities correspond quite well to the preferences expressed by the largest industrial customers. Kataria (2009) uses a choice experiment study to estimate how Swedish households value different environment improvements for the hydropower-regulated rivers. This study finds that WTP for remedial measures that improve the conditions of fish, benthic invertebrates, river margin vegetation, and birds are significant.

Landenburg and Dugaard (2007) use a choice experiment study in Denmark to estimate WTP for reduced visual amenities from offshore wind farms. The study shows that average WTP to locate wind farms at €46 for 12 kilometers (km), €96 for 18 km, and €122 for 50 km per annum, from the coast instead of 8 km from the. This study also shows that age of respondents and previous experience with offshore wind farms are important determinants of the WTP. Brochers, Duke, and Parsons (2007) also uses the CE method to assess WTP for green energy sources and found that there is a positive WTP for green energy electricity in the US. WTP for green energy electricity however, vary by the source. Solar energy is preferred over the generic green energy, and biomass and farm methane found to be the least preferred sources.

Sabah and Mariel (2010) used the CE method to estimate WTP for quality of electricity service by rural households of Kenya. Conditional logit model is used to identify the various socioeconomic and demographic characteristics which determine preferences in reducing power outages or blackouts among households. Authors conclude that several of the socioeconomic and demographic characteristics outlined in this paper can assist service differentiation to accommodate the diverse households' preferences towards the improvement of the electricity service.

### III. METHODS

#### A. Design of Choice Sets

There are four steps involved in the design of a choice experiment: (i) definition of attributes, attribute levels, and customization, (ii) experimental design, (iii) experimental context and



questionnaire development, and (iv) choice of sample and sampling strategy. These four steps should be seen as an integrated process with feedback.

The first step in the development of a CE is to conduct a series of focus group discussions (FGDs) aimed at selecting the relevant attributes. As the first step in designing the choice sets, a study team visited Bhopal to meet with electricity distribution company (DISCOMs) officials. Information on existing billing and technology options of feeder separation project were collected from the relevant authorities during this visit. In addition, the study team conducted key informant interviews with district DISCOM officials and a subcenter DISCOM official to understand the power distribution system, power demand, concerns from supply side, and also piloted some of the questions to generate detailed code list of possible answers. Based on the FDGs, this study uses four attributes: hours of supply (four levels); quality of supply (two levels); customer service (two levels); and billing (two levels). Table 1 provides the attributes and their respective levels.

**Table 1: Service Attributes and their Levels**







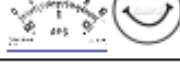
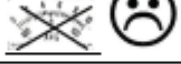
Attribute	Levels
Hours of Supply	(i) 24 hours (ii) 18 hours: 5:00 a.m. to 11:00 p.m. (iii) 12 hours: 5:00 a.m.–12 noon and 6:00 p.m.–11:00 p.m. (iv) 8 hours irregular
Quality of Supply	(i) No or minimal voltage fluctuations, dimming of lights, burning of small electronic equipment. (ii) Continue to face voltage fluctuations which result in dimming of lights, burning of small electronic equipments, etc.
Customer Service	(i) A dedicated customer service officer easily reachable through direct phone line. (ii) Continue to get the same level of customer service currently receiving. It will not be any better or worse than what it is now.
Billing	(i) Receive regularly an easy-to-read bill each month which is accurate to your meter reading. (ii) Receive bills every month the way you or others are currently getting bills. If you did not have an official connection before, you will start getting bills just like the other households which currently have connection and receive bills.

In CE, we offered each respondent a choice between two schemes that differ in service attribute and monthly bill for the offered services. We offered four such choices or sets to each respondent. Since we are offering different monthly bills for different schemes and the WTP is sensitive to current level of electricity use, we offered different set or range of prices (monthly bills) to no electricity or only light and fan households (low use); households that use small electrical equipment such as TV, radio (medium use); and households that use heavy electrical equipment such as refrigerators and air conditioners (high use). Note in analysis, we drop the sample for high use respondents because there are only 41 households in heavy-user category. Since the stratification was not done based on heavy electricity use or high income, inclusion of this subcategory would result in sample selection bias. Each of these three types of households were randomly assigned one of the eight versions of the choice sets.

The next step is to use an experimental design to rationalize the choice sets. Experimental design is concerned with how to create the choice sets in an efficient way. A design is developed in two steps: (i) by obtaining the optimal attribute levels and combining attributes to be included in the experiment, and (ii) combining those profiles into choice sets. A starting point is a full factorial design, which is a design that contains all possible combinations of the attribute levels that characterize the different alternatives. A full factorial design is, in general, very large and not tractable in a choice experiment. Therefore, a subset of all possible combinations need to be selected while following some criteria for optimality.

Huber and Zwerina (1996) identify four principles for an efficient design of a CE based on a non-linear model: (i) orthogonality; (ii) level balance; (iii) minimal overlap; and (iv) utility balance. Experimental design for this study was prepared by Research Triangle Institute, USA, incorporating the above desirable features. Each version differs in the set of attributes and prices offered to maximize the efficiency in survey without taxing respondent with a task of answering too many choice sets. The versions are numbered A to H and household types are numbered 1 to 3. Therefore, in effect, we created 24 versions. Also, to conduct scope test, which determines whether the offered prices are indeed in the range of plausible response, slightly higher price range in each of the above 24 versions was offered. We administer these scope test versions to only 10% of our sample. Figure 1 provides a sample of a choice set and Box 1 provides the description of a choice set of the experiment.

**Box 1: Example of a Choice Set**

Scheme 1		Scheme 2	
24-hour supply		8-hour supply but irregular times	
Quality of power / voltage as poor as now		Quality of power / voltage is improved	
Improved customer service		Customer service remains as poor as now	
Improved and accurate billing		Metering remains as it is. May not be metered or inaccurate	
<b>Monthly bill</b>	<b>Rs. 125 / -</b>	<b>Monthly bill</b>	<b>Rs. 100 / -</b>
Select one answer: [ 1 ] Scheme 1      [ 2 ] Scheme 1      [ 3 ] None of the two			

## Box 2: Description of Attributes for the Choice Experiment

**Until now, we talked about 24 hours supply** of good quality electricity, and transparent and accurate billing. In reality, some households may not want 24 hours supply but want good quality electricity. Some households want only few hours of supply but accurate billing. Similarly, different households like to have different preferences for supply and quality. To know what exact type of scheme of preferences your household will like, I am going to ask you a few questions.

In each question, I am going to show you two schemes with different number of hours of service, high or low quality of service, and better than current or current customer service. For each scheme, monthly payment you have to make will be different. **Please select the one which you think is most acceptable and affordable.**

The schemes will be different from each other in three main ways.

**1st Way – timing of supply:** There are four options for timing of supply

- a) 24-hour supply
- b) 18-hour supply from 5:00 a.m.–11:00 p.m.
- c) 12-hour supply from 5:00 a.m.–12 noon and 6:00 p.m.–11:00p.m.
- d) 8-hour supply, but irregular (no fixed time)

**2nd Way – accuracy and ease of billing:** There are two options for billing

- a) You will receive an easy-to-read bill regularly each month which will be accurate and based on your meter reading
- b) You will continue to receive bills every month the way you are getting bills now. If you did not have official connection before, you will start getting bills just like the houses which currently have connection and receive bills.

In both options described, you will have to pay, but only ease of understanding and accuracy of bill may be different.

**3rd Way – Customer Service:** Households often have complaints about power outage, quality of supply, errors in bills, broken wire, getting shocks, etc for which they need to contact electrical department. There are two options for customer service

- a) A dedicated customer service officer with a direct phone number available to you. Urgent complaints will be attended in a few hours and others in a few days.
- b) You will continue to get the same level of customer service you and others in the village are getting now. It will not be any better or worse than what it is now.

It is important that you have understood all items correctly. If you have any question or want to me repeat above information again, let me know. It will not be a trouble for me at all.

The findings from the FGD were also used to design the detailed household and community surveys. The draft questionnaire was prepared based on FGD findings, community surveys, and previous survey instruments of similar studies, and other surveys in the public domain. Some of the questions were piloted during the scoping trip to mainly develop/refine questions and their answer code list. The draft questionnaire was reviewed by ADB staff assigned to the project and his comments were also incorporated in revising the questionnaire. The questionnaire is finalized during training post feedback from enumerators after pre-testing, in-class training, and field practice.

The first section in household questionnaire collects administrative information such as identification of households, informed consent, survey dates, and others. The second section is a household member roster of member age, sex, education, and occupation. Third section is on access to electricity. For household business and domestic use, we ascertain the level of service received, satisfaction with the service, equipment used, expenses incurred, customer



service quality, billing accuracy, quality of supply, and perceived benefits of 24-hour supply. The fourth section is the elicitation section as described earlier. Section 5 is similar to Section 3, but it collects information on any shop or manufacturing unit the household may have away from their home in the same GP. Section 7 collects socioeconomic characteristics of households (income, expenditure, and assets).

## **B. Sampling**

Stratified random sampling method is used to choose a representative sample from the study area. In the first stage of selection, two districts were selected (Rajgarh and Guna) where an ADB-funded feeder separation project will be implemented. Three blocks were randomly selected from each district. Habitation survey conducted in 2003 was used to define sampling universe, which provides the information about the number of households in the villages and GPs (gram panchayats). Only GPs having 200–500 households were considered for drawing a sample of households for the study so that too small and too big GPs could be avoided. Only 455 GPs met this criterion out of 1,013 GPs. From these 455 GPs, 40 GPs were randomly selected. These 40 GPs consisted of 110 villages, but for several villages population was too low to obtain representative sample. Therefore, we further restricted our sample to 76 villages that have at least 20% of the population of their respective GPs.

In each GP, 50 households were selected from all eligible villages in proportion to the population of the villages. In each village, households are selected by dividing the village into three or four segments and randomly selecting households from each segment to meet the target sample size. The survey teams divided the required sample size in a village equally in three or four segments, selected a household randomly from each segment. Head of the household was interviewed as the main respondents but responses from other members to relevant questions are accepted.

## **C. Enumerator Training and Survey Implementation**

The study team recruited experienced enumerators and supervisors from mainly Lucknow and Nagpur area and a few local enumerators. All enumerators had at least a bachelors degree, 2 years of experience and worked on at least one large social research project. This study employed 4 teams of 7 people each—five enumerators, one on-field editor, and one team supervisor. Two teams worked in Guna and the other two worked in Rajgarh. Both sites were supported by two field executives from NEERMAN—the company hired to conduct the survey. All interviews followed survey research protocol for seeking verbal informed consent, ensuring confidentiality, and minimizing risk to respondents.

The enumerator training was conducted in Bhopal over 10 days. The in-class training included: discussions on the purpose of the study; reviews the structure of the survey; reviews the structure and purpose of the stated preference methodology; and mock sessions where enumerators administer the entire survey to each other. The training included a mix of lectures, role plays, and field trials. Lectures introduced the enumerators to the basic elements of the study and its relevance, concepts underlying the study, the importance of key questions, and how the data will be interpreted. Role playing and mock sessions generated the most intensive learning. In-class training pretests were conducted for the entire draft questionnaire for 2 days, followed by a day for debriefing and revising questionnaires. Then, in-class sessions were conducted again for 2-days and further practices were performed. The study team also had a day of full dress rehearsal before moving the teams to Guna and Rajgarh districts.

Several quality control and quality assurance activities, summarized most recently by Scott, Steele, and Temesgen (2005), were key elements of field supervision of the study. Supervisors selected households for the survey, spot- and back-checked questionnaires, accompanied interviews in the initial days of project, and conducted community interviews. Editors checked completed questionnaires for skipping pattern, legible numbering, and basic consistency checks on the field. Executives randomly accompanied and visited teams, checked filled questionnaires, prepared status reports and field logs, oversaw field based data entry and scrutinized questionnaires before dispatching them for data entry.

The data was entered using CSPro template, employing three quality assurance and quality control procedures in the CSPro template: range check, intra-record check, and final consistency check (Munoz, 2003). Range and intra-record checks were done during the data entry. That is, the operator was allowed by the data entry system to proceed to the next question only if the data for the current question fell within the allowable range of responses for each question. An intra-record consistency check was administered immediately after entry of each questionnaire. For example, family size reported by the household head should equal the number of family members listed in the family roster. A final scan for overall consistency was conducted when all questionnaires have been entered. This final consistency check ensured that values from one question are consistent with values from another question. Errors identified post-data entry were corrected using the original completed questionnaires. Data from CSPro and Excel were exported to STATA format with appropriate labels.

## IV. RESULTS

### A. Service Quality Assessment

The household survey covered various energy-related aspects and we only report households' responses to questions related to quality of electricity supply. Table 2 shows households' experience with current power supply and their attitude towards the prevailing service. Average number of hours of supply is less than 6 hours per day and the longest duration of supply is about 3 hours at a time. Over 80% of the households are very unsatisfied with the hours of supply of electricity.

Only about 22%–24% of the households report that they know the power outage times in advance. About 55%–62% report that there is no prior knowledge about times of power outages. Overall, about 80% of the surveyed households are very unsatisfied with the regularity of the power supply. A very high percentage (about 98%) reported that they experience poor voltage. About 80% of the households are very unsatisfied with the overall quality of electricity supply.

**Table 2: Access and Satisfaction with Service Attributes**  
(households using electricity)

Attribute	Summer Season	Other Season
Number of days household get power per month	25.3	25.8
Number of hours household get power in a day	5.7	5.9
Number of times in a day supply is interrupted	3.0	3.1
Longest duration for continuous power	3.0	3.0
Shortest duration for continuous power	1.2	1.2
<b>Attitude Questions</b>	<b>% Households Reporting</b>	
Satisfaction with hours of service electricity		
Very unsatisfied	84.32-	81.59-
Somewhat unsatisfied	10.91-	11.31-
Neutral	1.59-	2.95-
Somewhat satisfied	2.95-	3.90-
Very satisfied	0.16-	0.08-
Households not getting electricity	0.08-	0.16-
Power outage fixed or goes off any time abruptly		
Always know times of power outage	24.42	22.50
Sometimes know about timings	20.10	15.05
Power goes off at uncertain times	55.48	62.45
Satisfaction with regularity of Electricity		
Very unsatisfied	82.00	79.84
Somewhat unsatisfied	13.68	15.04
Neutral	1.76	1.76
Somewhat satisfied	2.00	2.80
Very satisfied	0.56	0.56
Symptoms of poor voltage quality seen in power supply	98.08	98.31
How often do bad quality problems occur		
Rarely	46.00	39.06
Sometimes	17.23	19.98%
Almost always	36.77	40.96
Satisfaction with quality of electricity		
Very unsatisfied	80.21	80.65
Somewhat unsatisfied	14.80	14.11
Neutral	2.17%	1.94%
Somewhat satisfied	2.25%	2.58%
Very satisfied	0.56%	0.73%

Source: Authors' estimates.

Table 3 shows the responses related to the customer service. Only about 4% of the surveyed households indicated that they are satisfied or very satisfied. About 65% indicated that they are very unsatisfied. As shown in Table 4, about 59% of the households who reported use of electricity do not get a bill. Of the 34% household who receive the bills, about 80% of the households get the bill on time. Households have mix reaction to the question on easiness to understand the bill. About 58% households do not trust the accuracy of the bill at all. Only 21% of households trust the accuracy completely. About 64% of the households are very unsatisfied with the current billing system. Overall the survey results clearly show the poor quality of the service and customers' unhappiness about it.

**Table 3: Household\* Satisfaction with Customer Service**  
(%)

Did not need customer service (not applicable)	13.99
Do not receive any government service/Do privately	5.09
Very unsatisfied	64.80
Somewhat unsatisfied	8.06
Neutral	3.90
Somewhat satisfied	2.80
Very satisfied	1.36

Includes only households using electricity.

Source: Authors' estimates.

**Table 4: Accuracy and Reliability of Electricity Bills Reported by Households\***  
(%)

Household get bill	
No	59.03
Yes, we used to but not now	7.00
Yes, we do now	33.97
Households receive bill on time (as % of HH who receive(ed) bills)	79.81
Bill receive or used to receive was easy to understand	
Don't know	1.36
Not at all easy	30.54
Somewhat uneasy	23.54
Neutral	7.59
Somewhat easy	22.37
Very easy	14.59
Household trust accuracy of bill	
Don't know/ can't tell	1.76
Not at all	58.24
Somewhat	19.22
Yes	20.78
Satisfaction with billing from electricity department	
Very unsatisfied	64.31
Somewhat unsatisfied	19.02
Neutral	7.25
Somewhat satisfied	7.84
Very satisfied	1.57

Includes only households using electricity.

Source: Authors' estimates.

## B. Choice Experiment Results

In choice experiments, each respondent was offered four choices of two schemes each. Each scheme differs in hours of supply, quality of supply, level of customer service, accuracy and ease of billing, and monthly bill amount. Respondent can choose either scheme or none of them. We analyzed the choices fixed effects logit specification as,

$$\begin{aligned}
Lt(choice=1)_{ij} = & \beta_1 \cdot bill_{ij} + \beta_2 \cdot echr24_{ij} + \beta_3 \cdot echr18_{ij} + \beta_4 \cdot echr12_{ij} + \beta_5 \cdot ecquality_{ij} + \\
& \beta_6 \cdot ecservice_{ij} + \beta_7 \cdot ecbilling_{ij} + \beta_8 \cdot optout_{ij} + \beta_9 \cdot echr24 \bullet ecquality_{ij} + \beta_{10} \cdot echr24 \bullet ecservice_{ij} + \\
& \beta_{11} \cdot echr24 \bullet ecbilling_{ij} + \varepsilon_{ij}
\end{aligned} \tag{7}$$

where, in addition to notations explained above,

j	=	offered scheme to the household;
bill	=	monthly bill amount offered for the scheme;
echr24	=	effect codes for 24 hours supply (1 if scheme offers 24 hours supply, -1 if 8 hours of irregular supply, 0 otherwise);
echr18	=	effect codes for 18 hours supply (1 if scheme offers 18 hours regular supply, -1 if 8 hours of irregular supply, 0 otherwise);
echr12	=	effect codes for 12 hours supply (1 if scheme offers 12 hours regular supply, -1 if 8 hours of irregular supply, 0 otherwise);
ecquality	=	effect codes for good quality / voltage of supply (1 if scheme offers improvement; -1 if no change from current conditions);
ecservice	=	effect codes for good customer service (1 if scheme offers improvement; -1 if no change from current conditions);
ecbilling	=	effect codes for accurate and easy billing (1 if scheme offers improvement; -1 if no change from current conditions);
optout	=	1 if respondent does not choose any one of the two schemes in the choice set; 0 if he chooses any scheme;
echr24•ecquality	=	interaction term between <i>echr24</i> and <i>equality</i> ;
echr24•ecservice	=	interaction term between <i>echr24</i> and <i>ecservice</i> ; and
echr24•ecbilling	=	interaction term between <i>echr24</i> and <i>ecbilling</i> ;

We specified the logit by clustering the standard errors at the Gram Panchayat (GP) level. We first specify the logit model without the interaction terms. Then, we included the interaction terms to assess if household socioeconomic characteristics-related variables influence WTP. The effect codes are used so that we can assess the utility of opt-out or status quo option (known as alternative specific constant or ASC) that the households have exercised. The estimated marginal WTP for an attribute of the service depends on the values we assume for the other variables.

Typically, the values for other variables are held constant at the mean when we estimate the WTP for an attribute. In the estimated logit model, if we divide the coefficient for an attribute by the coefficient for the *bill* variable, then we obtain the WTP for that attribute when all other attributes are held at their mean values. For example,  $\beta_2 / \beta_1$  gives the WTP for 24-hour supply when other attributes—quality, service, and billing—are held constant at their mean value.

However, the marginal WTP will change with the assumption of values at which other variables are held constant. For example, we may want WTP for 24 hour supply when quality, service and billing attributes are held constant at their current inadequate levels (not at their mean values as above), which is a more realistic scenario. We estimate this WTP by combining the coefficient as follows<sup>1</sup>:

<sup>1</sup> The proof of these calculations is beyond the scope of this paper. Please refer to Hensher, Rose, and Greene 2005 and Champ, Boefe, and Brown 2003.

$$24 \text{ hours supply} = 2\beta_2 + \beta_3 + \beta_4 + \beta_9.ecquality - \beta_9 + \beta_{10}.ecservice - \beta_{10} + \beta_{11}.ecbilling - \beta_{11} \quad (8)$$

$$\text{Good quality supply} = 2\beta_5 + \beta_9.echr24 - \beta_9 \quad (9)$$

$$\text{Better customer service} = 2\beta_6 + \beta_{10}.echr24 - \beta_{10} \quad (10)$$

$$\text{Accurate billing} = 2\beta_7 + \beta_{11}.echr24 - \beta_{11} \quad (11)$$

$$\text{Coefficient on monthly bill} = \beta_1 \quad (12)$$

The underlined terms enter the calculation only when interaction effects between attributes are included. When interaction effects are included, marginal WTP at interesting values of other variables can be estimated. For example, WTP for 24 hours can be estimated when customer service also improves (*ecservice* = 1), or when it does not improve (*ecservice* = -1). In this study, we estimate the WTP for different combinations of attributes, different hours of supply, good quality of supply, better customer service, and accurate billing by adding marginal WTP for these attributes.

Table 5 presents the results of estimated conditional logit models using the CE data. CE data enables us to identify the relative contribution of each service attribute—hours of supply, quality/voltage of supply, customer service, and accuracy and transparency in billing—in the WTP. Model 1 in Table 5 presents the results without any interaction terms, whereas, in model 2, we include interaction terms between *echr24* and the three service attributes: *ecquality*, *ecservice*, *ecbilling* because households may value these differently as a bundle.

The WTP estimated from conditional logit models represent incremental WTP relative to base case scenario or current scenario (8 hours without improved customer service, quality of supply, and billing). These results are based on responses where the respondents have selected either of the scheme offered to them and not reject both schemes. Rejection of both schemes is represented by *optout* variable which is high in magnitude and statistically significant. We exclude 12% households who did not vary their choice across all four choice sets or rejected all choice sets.

**Table 5: Conditional Logit Models Using Choice Experiment Data**

	Model 1: Conditional Logit					Model 2: Conditional Logit with Interactions				
	Effects Codes			Estimation		Effects Codes			Estimation	
	Coeff	Std Err	P> z	Coeff	WTP	Coeff	Std Err	P> z	Coeff	WTP
<b>Offered bill</b>	-0.015*	0.001	0.00			<b>-0.015*</b>	0.001	0.00		
<b>24-Hr Supply</b>	0.882*	0.042	0.00	<b>1.64</b>	106	<b>0.884*</b>	0.043	0.00	1.63	106
<b>18-Hr Supply</b>	0.049	0.039	0.21	<b>0.81</b>	52	0.042	0.040	0.29	0.79	52
<b>12-Hr Supply</b>	-0.173*	0.042	0.00	<b>0.59</b>	38	<b>-0.177*</b>	0.042	0.00	0.57	37
<b>Quality</b>	0.413*	0.024	0.00	<b>0.83</b>	54	<b>0.419*</b>	0.025	0.00	0.84	55
<b>Customer Service</b>	0.293*	0.022	0.00	<b>0.59</b>	38	<b>0.286*</b>	0.023	0.00	0.57	37
<b>Billing</b>	0.344*	0.024	0.00	<b>0.69</b>	45	<b>0.343*</b>	0.025	0.00	0.69	45
<b>Optout</b>	-1.805*	0.077	0.00			<b>-1.802*</b>	0.079	0.00		
<b>24-hour and quality</b>						<b>-0.005</b>	0.041	0.91	-0.01	-1
<b>24-hour and service</b>						<b>0.059</b>	0.042	0.17	0.12	8
<b>24-hour and billing</b>						<b>0.009</b>	0.045	0.84	0.02	1
<b>WTP (24 Hrs + Quality + C Service + Billing)</b>					243					251

WTP = willingness to pay.

\* Indicates coefficients are statistically significant at 0.05 significance level.

Source: Authors' estimates.



The preference weight or coefficient for *optout* (alternative Specific Constant) in both models is significant and negative as expected. This is consistent with similar studies in literature where individual attaches utility to changing the status quo situation. A significant proportion of the respondents did not even have access to the basic level of service. Therefore, the survey population certainly desires change from their existing electricity access situation. We estimate the value of utility of *optout* option at Rs205 based on the coefficient and average bid price. This is the WTP or "value" the respondent puts on changing the current situation. The WTP for improved service is estimated from the base of 8-hour unimproved service so that the value of *optout* option does not enter the calculation discussed below.

The variables show the expected signs and all of them are statistically significant, except for 18 hours of supply. The 12-hour supply variable shows a negative sign but this does not mean a negative WTP. As discussed earlier, the coefficients in Table 1 need to be re-estimated using the equations 8–12 to obtain the coefficient to estimate WTP compared to the base or current scenario of 8-hours supply with unimproved service attributes. These coefficients (bold in Table 5) were used for estimating the WTP for electricity service attributes. Results show that 24 hours of supply has the highest utility for the households across both models. Models 1 and 2 both estimate WTP of Rs106 per month to obtain 24 hours of electricity, while all other service attributes are held constant at current or base level. As number of hours of supply declines, the WTP also declines significantly. When supply hours decline from 24 hours to 12 hours, WTP drops by about Rs68 (about 64%). This clearly shows the importance of uninterrupted service to the customers.

Distribution company managers often pay attention to hours of supply in designing power distribution improvement projects. Quality of power also may receive sufficient attention. However, other service attributes such as customer services, accuracy and transparency in billing, often overlooked by utility managers are also important contributors to the total WTP. Results clearly show that electricity consumers put high value on them as well. For example, while holding all other service attributes to their current situation, households' WTP for improved supply quality or voltage is Rs54. The WTP for better customer service is Rs38 and it is Rs45 for accurate and easy-to-understand billing as per Model 1. Accurate billing is more valuable to customers compared to customer service. The total WTP for 24 hours supply together with improvements in all three service attributes yields a mean WTP of Rs243 and only 44% of the total WTP is from uninterrupted supply. This clearly shows that consumers value service attributes other than hours of supply, significantly.

Model 2 predicts marginal WTP for different service attributes by incorporating the interactions between some of the attributes. As shown in Table 5, the interaction terms are not significant. Estimated WTP for different attributes with interaction terms are very close to those without interaction terms. Total WTP with interaction terms is a bit higher (Rs251). This increase is due to 24-hour supply interaction with customer service. These minor differences are not considered any further due to statistical insignificance of the interaction terms. Using the coefficients in Table 5 for Model 1, Table 6 presents the WTP for different combination of services. The WTP is Rs243 for 24-hour supply with all other service attributes are also improved. However, if only 24 hours supply is provided, then the WTP is Rs106; a drop of Rs137 (56%).

**Table 6: WTP for Different Combination of Services**  
(using Model 4 results)

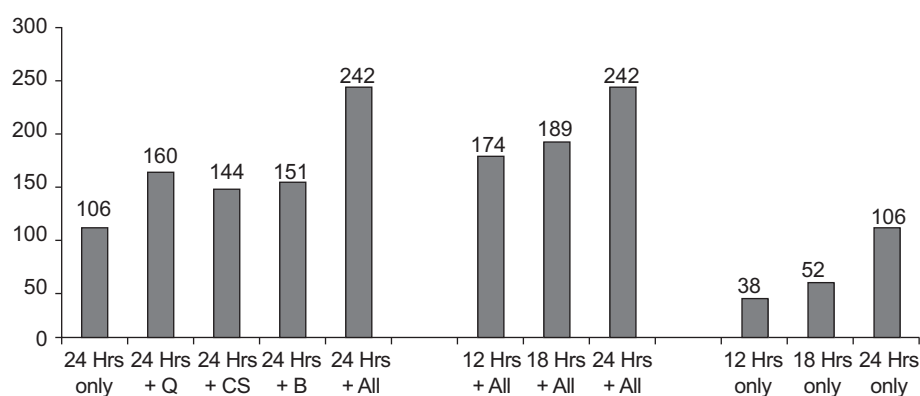
	24 Hrs + All	18 Hrs + All	12 Hrs + All	24 Hrs Only	12 Hrs Only	24 Hrs + Quality	24 Hrs + CS	24 Hrs + B
24-Hr Supply	106			106		106	106	106
18-Hr Supply		52						
12-Hr Supply			38		38			
Quality	54	54	54			54		
Customer Service	38	38	38				38	
Billing	45	45	45					45
Package WTP	243	189	174	106	38	160	144	151

B = accurate billing, CS = customer service, Q = quality, WTP = willingness to pay.

Source: Authors' estimates.

Different combinations of service attribute levels and corresponding total WTP are given in Figure 2. Most notable is that the WTP significantly increases for 24-hour electricity. The WTP for only 12 hours of supply (4 hours more than the base case of 8-hour supply) without improved service attributes is only Rs38. For 18 hours (10 hours more than base case), WTP increases only by Rs14 to Rs52. This increase is without improving the other service attributes. Once they are also simultaneously increased, total WTP increase substantially.

**Figure 1: Comparison of WTP for Combination of Service Attributes**

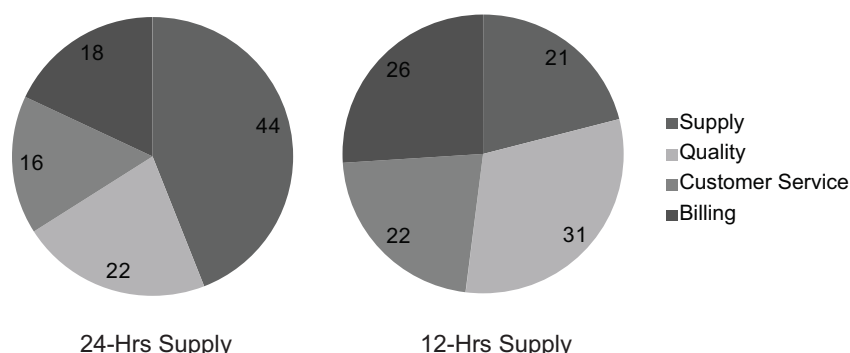


B = accurate billing, CS = customer service, Q = quality, WTP = willingness to pay.

Source: Authors' estimates.



**Figure 2: Relative Contributions to WTP of Attributes for Different Hours of Supply (%)**



Source: Authors' estimates.

Figure 3 presents the relative contribution of different service attributes in total WTP for two scenarios: 24-hours supply with improvement in all other attributes and 12-hours supply with improvements in all other attributes. With 24-hours supply, all other attributes are also valued highly, but the relative contribution of hours of supply remains approximately 44% and the rest is for other service attributes. However, when only 12 hours of supply is provided along with improvements in other attributes, the contribution of improved quality of supply is most significant at 31% whereas the relative contribution of 12-hour supply is 21% behind, even improved billing (Rs45). This shows that when hours of service improved marginally from the current level, other service attributes become more important for consumers. This is mainly due to marginal increase in WTP when hours of supply increase only by 4 hours from the current level. In summary, the service attributes other than hours of supply play a key role in determining WTP, particularly when hours of supply is less than 24 hours. As hours of supply increase, relative importance of the other attributed decreases.

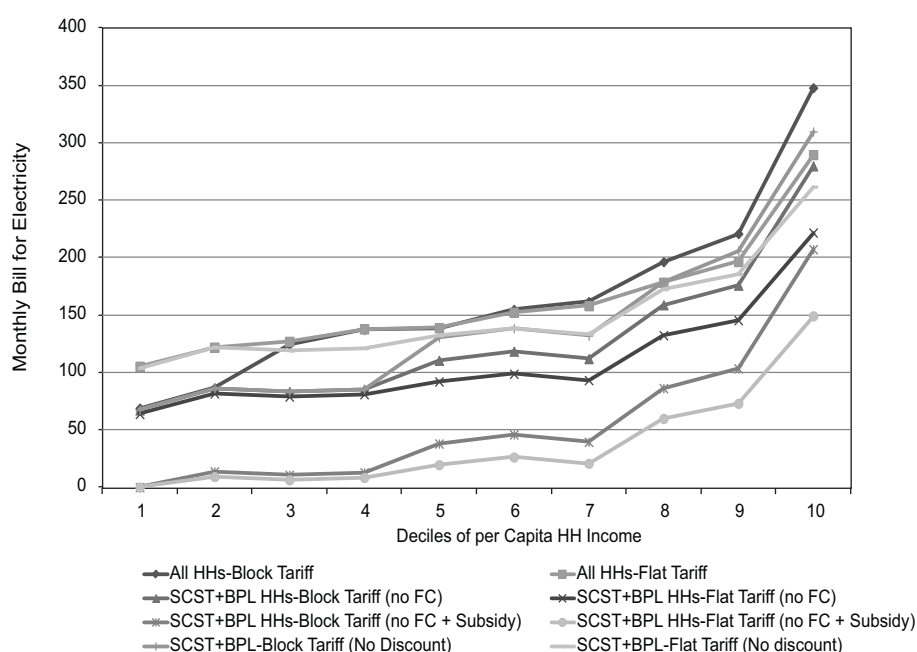
### C. Simulations

In this section, we simulate the uptake of services for different combinations of service attributes by different deciles of income groups. To estimate the electricity bills for different income groups, consumption of electricity at household level and associated monthly bill per different tariff structures were estimated. Information on number of equipment and approximately hours of use per day was collected for 21 electrical equipments. For each of these equipments a standard wattage<sup>2</sup> was assumed. Based on these data and assumptions, the number of units (kwh) that a household will consume in a month was estimated. However, this estimation is possible only for households that are currently using electricity (60%). For the rest of the 40% households, units consumed was estimated using a regression model. Thus, for each income decile, mean units consumed per month were estimated. These estimates were increased by 20% to account for purchase and use of additional electrical equipments with the availability of improved service. The estimated units per month were used for predicting the bill amount under block and flat tariffs.

<sup>2</sup> Personal communication with Mr. R.B. Patil (Technofocus Consultants, Mumbai) on various technical matters and specifications related to electrical equipments, electricity supply, and billing.

As monthly bill increases, the likelihood that the household will use the service at the usual level of consumption reduces. Figure 4 depicts how the monthly bills vary by income deciles for different tariff structures and population subgroups. Based on the estimated consumption bills, there is drastic increase for high-income groups under the block tariff. Bill increase for all the groups are less under flat tariff.

**Figure 3: Average Monthly Bills by Income for Different Tariff Structures**



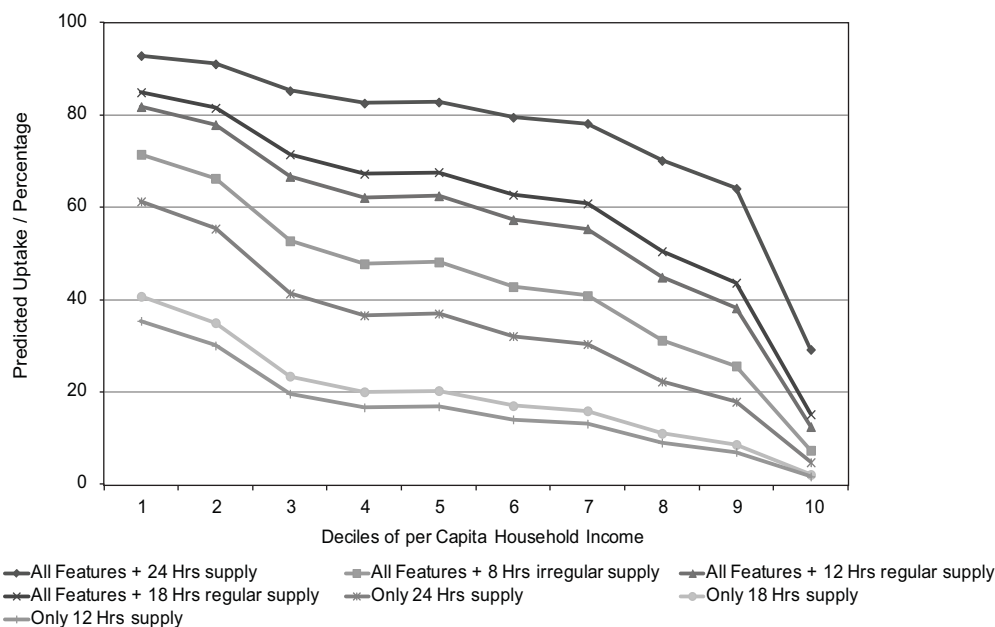
BPL = below poverty line, FC = fixed cost, HH = household, SCST = schedule cast.

Source: Authors' estimates.

Conditional logit model by design cannot model the effect of income in a straightforward way because for a given household income remains constant while the choices of schemes offered differ. A way to model the effect of income is to include it as an interaction term with bill attribute of the scheme offered to respondents. A conditional logit model similar to the model described in Section IV., B. was estimated including an additional variable *incbill* (multiplication of natural log of household income and bill offered for the given scheme). Coefficients were re-estimated as described previously and use these to estimate uptake for different combinations of income and monthly bills as depicted in Figure 4.

The results of simulation are shown in Figure 5. The uptake reduces systematically as the income increases and corresponding monthly bill amount increases. 24-hour supply along with improvement in all three service attributes results in more than 80% uptake in the first six deciles of income. Providing electricity for 18 or 12 hours along with improvement in other three attributes results in approximately 60% uptake in the first six deciles of income. Interestingly, improvement in service attributes but restricting the supply to 8 hours of irregular supply also results in uptake of more than 50% in the first five deciles and more than 40% in 7th decile. Providing only 12 hours or 18 hours of supply without any improvement in service, quality, and billing results in lower than 40% uptake in all income groups.

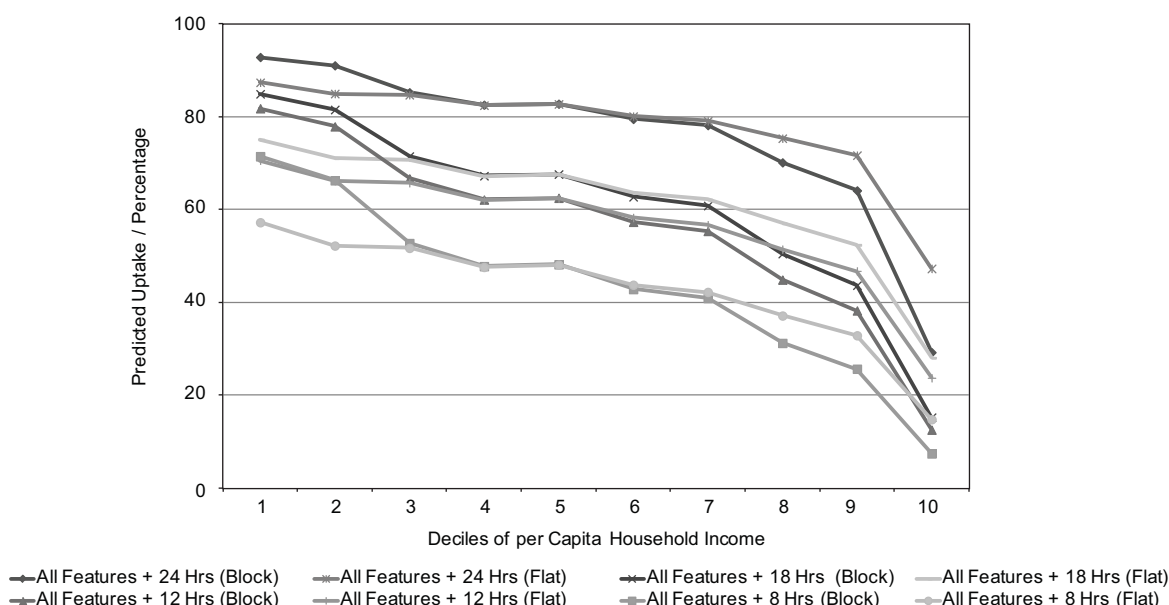
**Figure 4: Predicted Uptake (%) by Income for Different Levels of Service Provision with Block Tariff**



Source: Authors' estimates.

Consumers' valuation of service attributes such as quality, customer service, and accurate billing can be further demonstrated by analyzing various combinations of attributes. For example, less than 20% uptake is predicted when service hours increase to 12 hours without any other improvement for the 5th income decile. If all the service attributes are increased with 12-hour supply uptake, rate increases up to about 65%. This is a very large increase. Similarly, the 24-hour supply result in about 36% uptake and increases to over 80% when other three service attributes are added to the service. This indicates that the households are indeed placing a high premium on obtaining a package of better quality supply, customer service, and accurate billing instead of only more number of hours of supply.

In Figure 6, we compare the uptake rate by income deciles for different service packages block and flat tariff structures. While overall findings are similar to those based on Figure 5, we find that before the 5th decile of income, block tariff yields a higher uptake because the bill for lower income groups is also low. For the 6th income decile onwards, flat tariff yields higher uptake because bill based on flat tariff is lower for higher income households. The sharp drop in uptake rates in Figures 4 and 5 should not be viewed as higher income consumers stop using electricity. They always have the option to reduce their consumption by adopting energy saving technologies. Incentives to use energy saving technologies are higher under block tariff.

**Figure 5: Comparison of Predicted Uptake with Block and Flat Tariff (%)**

Source: Authors' estimates.

## V. CONCLUDING REMARKS

This research undertook a CE study to value service attributes for electricity supply improvements in Madhya Pradesh, India. Study covered 2,083 households using a stratified random sample. Four service attributes were considered in the study: hours of supply, quality, customer service, and accuracy and transparency in billing. Four attribute levels of hours of supply and two levels each of the other attributes were used in the study. About 15% of the sample was excluded from the analysis because these households rejected all the scenarios. Debriefing question results show that about 97% of the households reject all the scenarios due to affordability. To our knowledge, this is the first power sector CE study conducted in South Asia and our field experiences construct validity tests and reasonable WTP estimates suggest that respondents in rural areas are capable in understanding the choice scenarios well and responding to them reasonably. Overall, the study team feels CE studies in the power sector can be successfully conducted in South Asia.

Survey results confirm existing poor electricity service in rural Madhya Pradesh. Results clearly show that electricity consumers place their highest value on the increase hours of supply as a single attribute. However, quality, customer service, and accuracy and transparency in billing together captures about 56% of the total WTP indicating the importance of other service attributes. When hours of supply is limited to marginally improved 12 hours per day from the current 8 hours of supply, hours of supply captures only 21% of the total WTP. Thus the importance of quality, customer service, and accuracy of billing magnifies when hours of supply is low. The importance of service attributes other than hours of supply is further evident from the simulation undertaken with the estimated conditional logit model. Average predicted uptake rate for the 5th income decile is about 36% when 24-hours supply is provided without improving the other attributes, and increases to over 80% when other three service attributes are added to the service.

This CE study was undertaken as a part of the preparatory analytical work of an ADB project—Madhya Pradesh Energy Efficiency Improvement Investment program. This project was part of the bigger distribution improvement project in Madhya Pradesh with the total investment under this project is about \$1.2 billion. This analyses clearly shows that consumers' value for service does not depend only on hours of supply. Electricity consumers perceive significant benefits from other service attributes: quality, customer service, accuracy, and transparency in billing. Understanding these preferences and aligning the improved electricity services with these preferences will certainly enhance the development impacts of the distribution improvement project.

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**Valuing Electricity Service Attributes: A Choice Experiment Study in Madhya Pradesh, India**

This study unbundles and values electricity service attributes using a choice experiment study covering 2,083 households in Madhya Pradesh, India. Uninterrupted supply accounts for highest willingness to pay while quality, accuracy of billing, and customer service together are likewise important. Improving other service attributes enhances the development impact of projects aimed at uninterrupted supply of power.

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