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Demand for Electricity Connection in Rural Areas: The case of Kenya

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Abstract

A modern form of energy, in particular electricity for household use, is an important vehicle in alleviating poverty in developing countries. However, access and costs of connecting to this service for most poor in these countries is inconceivable. Policies promoting electricity connection in rural areas are known to be beneficial in improving the socio-economic and health well-being for households. This paper examines willingness to pay (WTP) for rural electrification connection in Kisumu district, Kenya, using the contingent valuation method (CVM). A nonparametric and a parametric model are employed to estimate WTP values for two electricity products: grid electricity (GE) and photovoltaic (PV) electricity. The results indicate that respondents are willing to pay more for GE services than PV and households favoured monthly connection payments over a lump sum amount. Some of the policies suggested in this paper include: subsidizing the connection costs for both sources of electricity, adjusting the payment periods, and restructuring the market ownership of providing rural electricity services.

1.   Introduction

The demand for electricity services in developed and developing countries differs from one sector to another. This paper addresses the residential sector particularly in developing countries' rural areas because these areas tend to be poorer and larger than urban ones and are neglected in accessing modern forms of energy such as electricity. In Kenya where this case study is based, the residential sector consumes 84% of all biomass compared with 25% of electricity. Conversely, the industry sector consumes 7% of biomass compared with 62% of electricity. One of the problems arising from limited electricity use in most households is the use of traditional energy, which results in a debilitating state of economic, environmental and health conditions. There are benefits of electricity use to households namely: increased lighting, entertainment and running small income generating activities, ecological (air quality and forest protection) and health well-being. As a result, the demand for electricity for many households provides a change in welfare when households are able to engage in more income generating activities, safer activities, and when educated communities use lighting and entertainment services.

The rationale for this study is to apply a stated preference approach, namely contingent valuation (CV) method, to provide new evidence about demand for electricity connection in a developing countries' context. The selection of CV as an appropriate approach to value electricity connection in developing countries' context is based on previous utility studies conducted in developed countries where CV has been used to value both use and non-use values. This study's key objective is to estimate and compare willingness to pay (WTP) to connect to two electricity goods (grid electricity and photovoltaic) using two forms of payment plans (monthly and one time lump sum).

Most developing countries' rural electrification programmes (REP) rank and prioritize locations to receive electricity (Barnes and Foley, 2004). In Kenya, the priority locations for REP are economic and social centres in rural areas. Hence, electricity transformers are generally located to serve these areas due to large population density around these locations. This selective principle, however, alienates locations that are dispersed and distant from the transformers. In the case of Kenya, politicians are known to pledge electrification to communities in order to secure votes (Wamukonya, 2007). And in some developing countries, REP have been privatised; whereas in others, governmental agencies still play a major role in implementing these programs. In Kenya, the Kenya Power Lighting Company (KPLC) is the primary contractor carrying out the whole REP, although the assets are owned by the Government of Kenya (GoK). The GoK objective is to increase rural electrification to 20% by 2010. Despite this ambition, Kenya's rural population access to electricity is considerably lower than that of the urban population (more than 80%), with some 99.5% of rural households not having access to electricity (Rabah, 2005)[1].

REP in most developing countries is catered by grid and off-grid electricity sources. Grid electricity (GE) widely covers heavily populated areas albeit the off-grid systems such as photovoltaic (PV) systems and mini-hydros or diesel operated systems cater to relatively less-populated areas. Some perceive the electricity from the grid-based sources in competition with PVs, though this is not true as there are divergences between the two sources (Barnes and Foley, 2004). Others view PV (solar electricity) as a 'pre-grid' electricity option for rural areas (van der Plas and Hankins, 1998). Nonetheless, PV may appeal to rural households over GE, where the PV is more reliable than GE, as the latter is prone to power outages also known as

blackouts. Overall, both PV and GE are preferred over petroleum products such as kerosene and liquefied petroleum gas (LPG) because in the long run these products are highly priced and subject to shortages as they are imported from politically volatile regions in the Middle East.

For the consumption shift from traditional to modern energy, factors such as increasing income levels, affordability, availability and high quality of modern sources are needed to support the energy switch (Barnes *et al.*, 2005). Affordability is considered one of the main constraints for the adoption of modern fuels in rural Kenya. The Ministry of Energy (MoE) acknowledges the shortcoming in electrification for the poor masses in Kenya and concurs that a new direction is needed to increase the rate of electricity supply to the poor.

One of the main limitations of rural electrification expansion in Kenya is the connection fee for households. These costs are the greatest barrier, more than the monthly electricity payments (Barnes and Foley, 2004). One recommendation to ease the connection charges is to provide financing schemes (Sanghvi and Barnes, 2001). Another is spreading the fee over many years and charging more per unit of electricity consumed (Barnes and Foley, 2004).[2]

To address affordability and new paths to electrification, this paper investigates the valuation of the electricity connection in rural areas and draws policy recommendations based on monetary estimates. The importance of valuing services associated with rural electrification policies is relevant to policy makers and project leaders in two main ways. Firstly, the amount households are willing to pay for electricity service is relevant to stakeholders when making tariff decisions. Secondly, the estimation of aggregate WTP for electricity and the corresponding use and non-

use values is important in examining the welfare impacts of such services and viability of these projects in rural areas.

This paper is structured as follows: section 2 presents a brief review of the contingent valuation literature related to energy studies; Section 3 elaborates on the survey methodology. Section 4 provides the theoretical and econometric framework. Section 5 presents the empirical results, and section 6 concludes the paper.

2. Methods for Valuing Energy Services

Economic valuation has been widely used, for example in the health, transport and the environment sectors. The use of valuation methods has increased due to the number of interest groups, corporations, governments and researchers demanding economic values for non-marketed goods or services. Moreover there are various incidents at the global level that have compelled and accelerated the valuation, particularly, of environmental goods and services. One notable example is the publicized incident in 1989 involving the Exxon/Valdez oil tanker that struck a reef in Prince William Sound, Alaska, spilling at least 11 million gallons of crude oil and killing many birds and mammals.

The valuation framework has evolved from a simple tool of cost-benefit analysis to 'state-of-art' methods. Cost-benefit analysis (also known as benefit-cost analysis) assists in calculating the benefits and costs of policies or projects. However, cost-benefit analysis (CBA) has shortcomings in applying the economic concepts to environmental goods. Problems experienced when applying CBA include: non-market goods are not valued; complexity of the ecosystem; discount rate and discounting; institutional capture; and uncertainty and irreversibility (Hanley and Spash, 1993).

The CV method, compared to other stated preference (SP) approaches such as conjoint analysis (CA), also known as choice experiment or choice modelling, is used highly in both developed and developing countries. Whittington (1998) contends that CV surveys in developing countries are easier to manage and the response rates are higher compared to developed nations. The common application of SP method in sub-Saharan Africa has been in areas such as agriculture, tourism and wildlife, with limited studies related to the energy sector.

According to the Energy Sector Management Assistance Program (ESMAP 2000), deriving the WTP for improved water and energy services in developing countries using surveys is challenging. Difficulties include unidentified biases, false demand responses and onerous sample selection. These hardships are acknowledged in this study and are described further in the survey methodology section. The NOAA panel guidelines are based on CV studies in the US and developed countries. It is worth noting that developing countries differ from developed countries in the social-economic and political structures, making the NOAA guidelines relatively difficult and costly to implement in the former compared to the latter nations.

The commonly used SP in the energy sector involves choice experiment (CE) as applied by Goett *et al.*, 2000; Roe *et al.,* 2001, Alvarez-Farizo and Hanley, 2002; Arkesteijn and Oerelemans, 2005; Bergmann *et al.,* 2006; Longo *et al.,* 2008; Ladenburg *et al.* , 2005; An *et al.,* 2002; Han *et al.,* 2002; and Beenstock *et al.,* 1998. In reviewing some of the SP studies, the WTP estimates were significant and varied according to income, age, type of energy sources (green electricity, wind farms and biomass), service attributes, and power outages and/or fluctuations.

While the above mentioned energy studies concentrated primarily in developed countries' energy markets; limited studies have addressed CV in

developing countries context in relation to electricity market. As a result, this study is determined to measure the economic value of electricity connection in rural areas when household's preferences and attitudes towards electricity connection, when a new directive is introduced by government or the private sector in connecting households to electricity services.

In most SP manuals (Champ *et al*, 2003; Bateman *et al.*, 2002; Alberini and Kahn, 2006), the need to examine either the quality or quantity of changes as a result of a policy change is emphasized. In this paper, one of the policy changes being examined in relation to electricity connection services is the introduction of payment schedules (one time lump sum and monthly) to access two electricity sources, namely PV and GE.

3.   Survey Methodology

In the whole month of August 2007, 200 households with 100% response rate were interviewed by five enumerators in Kisumu district.   Kisumu district is the third largest city in Kenya and is located in Nyanza province. This district is one of the twelve districts in Nyanza and was selected because of its political and economic vigour relative to the other districts in Nyanza. Around 13% of Nyanza's total population of 5,051,562 is Kisumu's population, while nearly 53% of the total population in this district lives below the poverty line. The electrification rate in Kisumu rural area is 36 % compared to urban areas of around 64 % (Ministry of Finance and Planning (MoFP), 2002).

TABLE 1: Socio-Economic Demographic at District, Province and National Level

	Kisumu District	Province Level	National Level
Total population 2006	650,846	5,051,562	35,514,542
Rural Population 2002 (%)	36.03%	87.10%	67.20%
Urban Population 2002 (%)	63.97%	9.15%	32.80%
Annual per Capita 2004 (Ksh.)	17,535	12,616	24, 836
Electrification cover 1999 (%)	11.62%	4.80%	13.50%
Poor Individuals 1999 (%)	47.1%	42.1%	43.7%
Household Mean size 1999	4.9	5	5.2

Source: Various (World Bank, Kenya CBS, Kenya Ministry of Communication, Kisumu District Development Plan 2002-2008)

3.1   Sample Design

The sample design was chosen based on cluster listing implemented by Kenya's national census. This cluster sampling framework, known as NASSEP IV,[3] involved the compilation of 1,800 clusters on a nation wide basis, two thirds rural and one third urban.   In the case of Kisumu district, 39 clusters were identified under this framework, 15 rural and 24 urban.   From this it can be seen that Kisumu is substantially urbanized. In this regard, 9 of the 15 rural clusters were identified as being electrified. An electrified cluster was defined as one in which there existed at least one electricity transformer in the cluster area and the identification of a cluster as being electrified was attributed by Kenya National Bureau of Statistics (KNBS) officials. Most electricity transformers and lines in rural areas are located in commercial or major trading areas, alongside tarmacked public roads. Almost all the clusters selected in this study were located on public or government roads and were accessible by public transport. Moreover, commercial or trading centres of villages were the central point for commencing the process of mapping the sample and for identifying the households to be interviewed. Each cluster was readily identifiable as a distinct entity. Moreover, the process of household identification was facilitated by

employing two experienced KNBS enumerators who had worked on previous surveys using the same clusters. Once a chosen cluster was located, it was divided into five zones, one for each enumerator.

For every zone, following footpaths or minor roads leading to rural residences was considered to be a random way for selecting the sub-populations. Consequently, a systematic sampling technique was adopted and carried out in the five zones. That is, starting from the transformer, each enumerator selected every third household, to either the left or the right of a foot path or minor road, for the purpose of interviewing. Non-electrified households were easily identified as it became evident that there were no electricity wires attached to the homes in question. In situations where the number of non-electrified households was not sufficient in one zone, the zones were further sub-divided and re-assigned to the enumerators, until the quota of 20 for each zone was reached.

The present condition for non-electrified households (i.e. the status-quo) is the consumption of traditional fuel sources such as wood fuel and charcoal. Nevertheless, the change is the connection of electricity services by PV and GE and an introduction of a policy where varied payment schedules are introduced. GE is transmitted and distributed by KPLC, a public limited company, with the Kenyan government owning 51%. Conversely, PV is dominated by the private sector with limited incentives to market the goods.

3.2   Focus Group Discussions (FGDs)

Prior to the actual survey in August 2007, FGDs involving in-depth discussions of prospective respondents were carried out in April 2007. They assisted

in identifying local description of the hypothetical scenarios. The FGDs were important for two primary reasons: firstly, to understand how the limitation and benefits of energy sources like grid, PV, and other fuel sources affect households' choices; secondly, FGDs as recommended by practitioners help identify the important characteristics or attitudes needed prior to the valuation exercise.

The FGDs provided insight into some of the participants' observations and experiences of energy services and characteristics of energy service in their own words and images. For instance, one female, non-electrified participant remarked:

> *"Wood is hard to get. We face a big shortage of wood in the market and it is expensive e.g. 3 sticks go for Ksh. 10. There are no trees these sides. Sometimes we also face shortage of paraffin"*

Notable uses of electricity such as ironing, lighting, security lights, mobile phone charging and pumping water for irrigation, were mentioned by households.

> *"With electricity you are a brave man. You can plant tomatoes under irrigation. So you don't have to wait for the rains".*

Most respondents thought traditional fuels were expensive in the long run, particularly when fuel shortages are experienced, resulting in increased prices. As a result, households adopt conservation measures such as purchasing improved *jikos* (ceramic stove) or behavioural changes such as cooking food in a short time. All in all, participants distinguished between the benefits of grid electricity and traditional fuels in terms of cleanliness, convenience, and costs:

> *"To me [a female head of an electrified household] it has made me economically empowered because now I can dress well, eat well, I can iron and I can watch news and I can run my shop and get money".*

Additionally, participants were able to point out the advantages and disadvantages of PV, grid-electricity, and traditional fuel (firewood or charcoal). Indeed, nearly all participants were able to recognize the costs and the economic trade- off when PV and grid-electricity were compared. The following illustrates this point:

> *"This thing [PV] what I am feeling to be honest I will have to renew this panel and the battery after sometime. The cost therefore in the long run will be higher than the power brought from KPLC"*

Another distinction found among non-electrified groups vis-à-vis electrified groups is the perception of a 'class-distinction' between those who have and those who do not have electricity:

> *"Their [electrified households] houses are bright and clean. They are able to watch news".*

The dissatisfaction among electrified and non-electrified households involving the sole supplier, KPLC, was reflected when one electrified participant described this state:

> *"You know these guys are enjoying monopoly. They don't attend to our problems appropriately. Their case is not a willing seller, willing buyer".*

One non-electrified household noted corruption as a hindrance to electricity connection:

> *"There are also a lot of corruption cases where they will work faster and better if you bribe them…"*

The major problem of GE connection in contrast to PV as cited by participants was poverty. Some participants favoured an instalment system for PV systems, which

already exists among private providers, and suggested decreasing the connection cost to connect to GE.

3.3   The Questionnaire

The survey was implemented using personal interviews also known as face-to-face or in-person interviews. Compared with other methods like postal service and telephone, personal interviews are commonly used in developing countries because they are relatively low cost methods. Like many other developing countries, Kenya's mail and telephone infrastructure is limited, poor, and costly. Despite the low cost of personal interviews, there are other administrative costs such as training and hiring of enumerators which increase the total survey costs.

The survey questionnaire is divided into four main sections: the first section includes 'warm-up' questions. Warm-up questions are introductory questions with an aim to make respondents feel comfortable with the interviewer and the questions. The second section of the questionnaire contains the CV scenario. The third section examines the different fuel sources, use and patterns as recommended by the World Bank dossier (O'Sullivan and Barnes, 2006). The final section includes socio-economic questions which are mostly considered sensitive to interviewees. To avoid non-response bias, the socio-economic questions are included in the last section of the questionnaire. At the end of the questionnaire, debriefing questions were included to rate the interviewee understanding and comments about the questionnaire.

One of the common CV biases is the hypothetical bias, where the hypothetical WTP overestimates the real WTP. In hypothetical bias, a respondent states that s/he will pay for a good when in real life s/he will not, or s/he will actually pay less when placed in a comparable purchase decision. Hence, to minimise this bias, the

hypothetical scenarios were translated into the local language (*Luo*) and local enumerators were hired and trained.

4. Theoretical and Econometric Framework

The importance of examining the theoretical framework in the context of attitude theory and economic theory is to determine the decision making process. Nevertheless, understanding this framework may explain how different WTP values are decided by respondents. According to Green and Tunstall (1999), preferences and values are the foundation of CV design and the extension of the Fishbein-Ajzen model (a reasoning model which holds that beliefs determine attitudes and attitudes are known to impact the behavioural intentions) with one plausible behavioural intention is WTP. This conceptual framework examining preferences, attitudes, and behaviour is relevant to economic application of random utility theory.

The double bounded dichotomous choice (DBDC), also referred to as "dichotomous choice with follow-up," was the question format used in the face-to-face interviews of this study. DBDC is a closed-ended question consisting of a binary response of a yes or no answer to initial and follow-up questions. There is a closed set of four possible outcomes (yes-yes; no-no; yes-no; no-yes) all of which are mutually exclusive, and therefore the respondent can select only one. In this study, DBDC has two distinct questions for two goods, PV systems and GE for two payment types, namely: monthly and one time lump sum. The first question was a simple yes or no question "Are you willing to pay amount X to connect to PV electricity or GE?" If the answer was yes (or no), another question followed to elicit a maximum (or minimum) value. Hence, the respondents identified two amounts that limited their maximum WTP (Bateman *et al.* 2002).

In this method, unlike the single bounded question, a yes or no response to the follow-up question, sharpens the WTP estimates (Hanemann and Kanninen, 1999). Moreover, the advantage of introducing a follow-up question to a single answer helps reduce the variance of the WTP estimates (Whitehead, 2006). A DBDC model is more efficient than a single bounded method, because it acts like an 'insurance' against poor choice of bid values (Hanemann *et al*., 1991). Haab and McConnell (2002) stated that there are three ways why DBDC is more efficient than single bounded. First, the yes-no and no-yes provides a clear bound of WTP, second the 'no-no' and 'yes-yes' estimate efficiency gains, and third the number of responses is substantially increased, especially for larger sample sizes. To avoid initial bid biases, the initial bids were randomly assigned to respondents in the four sub-samples as shown in Table 2:

TABLE 2: WTP Bids in Kenya Shillings[a] as applied in the Kenya Energy Household Survey (2007)

Sub-groups for bids	GE and PV Lump			GE and PV Monthly		
	Initial bid (Ksh.)	Upper bid (Ksh.)	Lower bid (Ksh.)	Initial bid (Ksh.)	Upper bid (Ksh.)	Lower bid (Ksh.)
1	34,000	41,000	27,000	800	960	640
2	35,000	42,000	28,000	820	970	660
3	36,000	43,000	29,000	840	1000	680
4	37,000	44,000	30,000	870	1,030	700

Source: Survey 2007
[a] August 2007, US$1 was approximately equal to 80 Kenyan Shillings

To estimate WTP, two econometric methods are considered, namely: nonparametric (NPM) and parametric (PM) distribution. Nonparametric, unlike parametric, eliminates all fixed assumptions of distribution and functional forms (Greene, 2002). Indeed, nonparametric is referred to as a distribution-free estimation.

Consequently, there are no assumptions on the distribution of WTP in a nonparametric estimation, unlike the parametric estimation. NPM estimation has been used in many CV studies (see Kristrom (1990), Haab and McConnell (1997), Carson *et al.* (2003), and Loureiro *et al.* (2004). In other cases, nonparametric is mixed with parametric estimation to create semi-parametric estimations (Burton, 2000). On one hand, nonparametric models are 'robust and offer greater flexibility'; whereas on the other hand, these models provide minimal economic information (Hanemann and Kanninen, 1999). The first advantage of NPM, is the robustness against distributional misspecification. Secondly, the computations are simple to use and these calculations can be done "on the back of an envelope" (Kristrom, 1990). Haab and McConnell (1997) stated that NPM is a novel and straightforward method which allows for estimates and standard errors to be estimated by a hand calculator.

To illustrate the nonparametric method, consider a case where a discrete question is posed to respondents with a statement like: would you be willing to pay an amount c_j?, where c_j is indexed $j=0, 1…M$ and $c_j>c_k$ for $j>k$, and $c_0=0$. Let p_j be the probability that respondent's WTP denoted by W is in interval c_{j-1} to c_j as:

$p_j=P (c_{j-1} < W \leq c_j)$ for $j=1… M+1$

In most cases respondents are asked c_j for $j=1$ to M and $c_{M+1} = \infty$ or in another way, the cumulative distribution function (cdf) is presented as:

$F_j=P(W \leq c_j)$ for $j=1, …M+1$, where $F_{M+1}=1$ and F_j is the proportion of observed no response.

Then $p_j=F_j-F_{j-1}$ and $F_0 \equiv 0$

The Turnbull estimator is derived by treating either the F_j, $j=1 \longrightarrow M$ or

p_j, $j=1 \longrightarrow M$ as parameters. When the F_j are parameters the likelihood function is written as:

$$L\ (F;\ N,\ Y) = \sum_{j=1}^{M} [\ N_j\ ln\ (F_j) + Y_j\ ln\ (1\text{-}F_j)], \tag{1}$$

where N_j = *number of "no" respondents to* c_j,

Y_j = number of "yes" respondents to c_j, and,

$(1\text{-}F_M) = p_{M+1}$ = the probability that W is greater than highest finite bid

Equation *(1)* can also be written as:

$$L\ (p;\ N,\ Y) = \sum_{j=1}^{M} [\ N_j\ ln\left(\sum_{i=1}^{j} p_i\right) + Y_j\ ln\left(1 - \sum_{i=1}^{j} p_i\right)] \tag{2}$$

where in equation *(1)* the p_js add up to unity, though for the p_js to derive a reliable density function, they must be non-negative and stay within the unit interval.

To obtain a valid estimate of probability density function (pdf) of W from equation *(2)*, the p_i must be constrained to be positive and falling within the unit interval. [4]

This ensures that $p_i > 0$, so long as $N_1 \neq 0$, hence the first order condition for p_i always hold with equality when at least one respondent provides a no-response to c_1

Deriving the unconstrained first order condition for equation (2) and solving for p_1 yield:

$$p_1 = \frac{N_1}{N_1 + Y_1}, \tag{3}$$

and similarly, solving for p_2, we obtain:

$$p_2 = \frac{N_2}{Y_2 + N_2} - p_1$$

p_2 is positive if $\dfrac{N_2}{Y_2 + N_2} > \dfrac{N_1}{N_1 + Y_1}$, where the responses are monotonically increasing

In a case where $\dfrac{N_2}{Y_2 + N_2} < \dfrac{N_1}{N_1 + Y_1}$, a non-monotonic response, the unconstrained

maximum likelihood estimate of p_2 will be negative. Generally, when p_j is negative, a

Kuhn-Tucker solution is to combine the *jth* and *(j-1)th* cells and re-estimate p_j.

The mean lower bound WTP used in this study, as depicted by Haab and McConnell

(1997), is given by:

$$E_{LB}(WTP) = 0.P(0 < W < c_1) + c_1 P(c_1 \leq W \leq c_2) + ... c_m P(c_m \leq W \leq c_{m+1}) = \sum_{j=1}^{M+1} c_{j-1} p_j \quad (4) \text{ where}$$

$(1-F_M) = p_{M+1}.$[5]

PM distribution, unlike NPM, allows for the inclusion of exogenous variables,

such as: income and other socio-economic variables, in the model estimation. The use

of these covariates provides the validity and reliability of the CV method and

confirms the *a priori* expectations and extrapolates estimates from the sample to the

general population (Haab and McConnell, 2002). Three models commonly estimated

to derive willingness to pay from double bounded CV include the bivariate probit

model as proposed by Cameron and Quiggin (1994), the random effects probit model

(Alberini *et al*., 1997) and the interval-data logit model, also known as the standard

double bounded model i.e. double bounded model (DBM)(Hanemann *et al.*, 1991).

The three models differ by the assumptions about the mean and variance of WTP

estimates for the initial and subsequent questions, and ρ, the correlation coefficient between the error terms of WTP in the first and second questions.[6]

It is the double bounded or interval-data logit model by Hanemann *et al.* (1991) which was used in this study. As Alberini (1995) forcefully points out, estimates from DBM are preferred to those from BPM when there are small biases and large gains in efficiency when correlation coefficient ρ is close to one. In our case, the correlation coefficient ρ was estimated at 0.999 for both product and payment types.

Haab and McConnell (2002) showed that the WTP estimates derived from each question are the same for this model i.e. for the ith individual the WTP is as shown in equation *(5)*.

$$WTP_{ij} = \mu_j + \varepsilon_{ij}, \quad with\ j=1,2 \tag{5}$$

Following Hanemann *et al.* (1991), the likelihood of four outcomes from the DBDC is π^{yy}, π^{nn}, π^{yn} and π^{ny} with the following likelihoods:

$$\pi^{yy}\ (B_i,\ B^u_{\ i}) = Pr\ \{B_i \leq max\ WTP\ and\ B^u_{\ i} \leq max\ WTP\}$$

$$= Pr\ \{B_i \leq max\ WTP/B^u_{\ i} \leq max\ WTP\}\ Pr\ \{B^u_{\ i} \leq max\ WTP\}$$

$$= Pr\ \{B^u_{\ i} \leq max\ WTP\} = 1 - G\ (B^u_{\ i};\theta), \tag{6}$$

In the above outcomes, B_i is the initial bid and when respondents say "yes" to the initial bid the second bid is B^u_i, which is greater than initial bid ($B^u_i > B_i$). Otherwise a "no" response to the initial bid if B^d_i is smaller than initial bid ($B^d_i < B_i$).

Since $\quad B^u_i > B_i$, Pr $\{B_i \leq max\ WTP|B^u_i \leq max\ WTP\} \equiv 1$

Similarly $\quad B^d_i < B_i$, Pr $\{B^d_i \leq max\ WTP|B_i \leq max\ WTP\} \equiv 1$

$$\pi^{nn}\ (B_i,\ B^d_{\ i}) = Pr\ \{B_i \geq max\ WTP\ and\ B^d_{\ i} > max\ WTP\} = G\ (B^d_{\ i};\theta), \tag{7}$$

$$\pi^{yn} (B_i, B^u_i) = Pr \{B_i \leq max \ WTP \leq B^u_i\} = G (B^u_i; \theta) - G (B_i; \theta), \qquad (8)$$

$$\pi^{ny} (B_i, B^d_i) = Pr \{B_i \geq max \ WTP > B^d_i\} = G (B_i; \theta) - G (B^d_i; \theta), \qquad (9)$$

Where $G (. ; \theta)$ is the cumulative density function (cdf) of the individual's true maximum WTP. Thus, the corresponding log likelihood function then becomes:

$$ln \ L^D (\theta) = \sum_{i=1}^{N} \begin{Bmatrix} d_i^{yy} \ln \pi^{yy}(B_i, B_i^u) + \\ d_i^{nn} \ln \pi^{nn}(B_i, B_i^d) + d_i^{yn} \ln \pi^{yn}(B_i, B_i^u) + d_i^{ny} \ln \pi^{ny}(B_i, B_i^d) \end{Bmatrix} \quad (10)$$

where $d^{yy}_i, d^{nn}_i, d^{yn}_i,$ and $d^{ny}_i,$ are binary-valued indicator variables.

Shown in Table 3, the frequency distribution of the DBDC responses for the survey shows that the vast majority were "no-no", the exception being the responses for monthly grid electricity, where only approximately a quarter were "no-no".

TABLE 3: Number of total responses in DBDC format

	No_No	Yes_No	No_Yes	Yes_Yes	Total
Grid Electricity Lump	163	10	19	8	200
Grid Electricity Monthly	56	69	34	41	200
Photovoltaic Lump	174	5	16	5	200
Photovoltaic Monthly	120	24	37	19	200

Source: Survey 2007

5.   Data Results and Discussion

The survey for the CV study had 200 usable interviews collected from 20 villages in Kisumu district. Table 4 shows the variable definitions and summary statistics of the data. The main variables used in the analysis include income (incm_shl), highest level of education (heduclev_c), age of respondent (age_c), number of household members (hseresid), interest in starting a business (int_buss_yes)

and own a house (rtoption_own). We also used a set of dummy variables such as unemployment, home business ownership, bank account holders, head of household and interest in business. Other explanatory variables, such as: annoyance levels, gender, marital status and proportion of fuel costs, were excluded from the model, because they were later found to be insignificant or highly correlated.[7]

TABLE 4: Summary of variables used in the models[a]

Variable	Description	Obs	Mean	Std. Dev.	Min	Max
Incm_shl	Income (natural log)	200	2.1411	0.69863	-0.478	3.989
Heduclev_c	Highest education level	200	8.47	4.08934	0	16
age_c	Age	200	39.03	13.7065	19	78
Yrstay_c	Years of residence	199	27.0905	20.9193	3	50
Hseresid	Household size	200	5.385	2.32244	1	14
Numrms	Number of Rooms	195	2.8	1.10108	1	8
Married	Married (dummy)	200	0.675	0.46955	0	1
int_buss_yes	Interest in Business (dummy)	196	0.58673	0.49368	0	1
Rtoption_own	Rent option own (dummy)	200	0.825	0.38092	0	1
Sexmale	Sex male (dummy)	200	0.315	0.46568	0	1
unemployed	Unemployed (dummy)	200	0.1	0.30075	0	1
Homebus_yes	Home business (dummy)	198	0.37374	0.48502	0	1
Bnkacc_yes	Bank account (dummy)	198	0.33838	0.47436	0	1
Engfarm_yes	Engage in Farming (dummy)	200	0.865	0.34258	0	1
Hsehead_yes	Household Head (dummy)	200	0.635	0.48264	0	1
Thrd_pre_yes	Third party presence (dummy)	194	0.37113	0.48436	0	1
anny_yes	Annoyance yes (dummy)	199	0.81407	0.39003	0	1

Source: Survey 2007
[a]varying sample sizes for the means reflects elimination of 'don't know' and missing responses.

Table 5 shows the four models using DBM namely grid lump sum (GE_lump), grid monthly (GE_mon), photovoltaic lump sum (PV_lump) and photovoltaic monthly (PV_mon), with selected SED variables. The DBM model is evaluated with various SED factors as the explanatory variables. These SED variables or covariates were significant in the analysis, with varied signs and significance levels. A negative

(positive) sign and significance of these covariates implies that households have decreased (increased) WTP for a specific product and/or payment method. For instance, as shown in Table 5, the coefficients on income and interest in business variables are significant and positive. These results are consistent with economic theory, implying that respondents with higher income and those with an interest in business are more likely to pay more for an electricity programme. Conversely, regressors like age and years of residence are significant and negative. Hence, this indicates that the older the household head and the longer the time in residence the less likely the households are willing to pay for GE or a PV system irrespective of payment type.

The highest level of education has an impact on WTP as in *a priori* expectations. This variable is positive and significant for models 1, 2 and 3, the exception being model 4, where the sign was negative but insignificant. Similarly, home ownership is positive and significant in all models except in model 2. Moreover, household size, which refers to the number of people living in a household, is positive and non-significant at all levels for all the four models.

TABLE 5: WTP estimates using a double bounded model for product and payment options (without protests) [a][b]

Variable	Model 1	Model 2	Model 3	Model 4
	GE_lump	GE_monthly	PV_lump	PV_monthly
Income	0.98**	0.59**	0.91**	0.60**
	(-0.38)	(-0.23)	(-0.44)	(-0.28)
Highest education level	0.16**	0.05	0.23**	0.00
	(-0.07)	(-0.04)	(-0.09)	(-0.05)
Interest in business	2.21***	0.83***	2.73***	0.66*
	(-0.61)	(-0.30)	(-0.88)	(-0.35)
House ownership	1.62**	0.48	1.53*	1.09**
	(-0.75)	(-0.44)	(-0.92)	(-0.53)
Age	-0.02	0.00	-0.06**	-0.02*
	(-0.02)	(-0.01)	(-0.03)	(-0.01)
Years of residence	-0.02	-0.02***	-0.01	-0.01
	(-0.01)	(-0.01)	(-0.01)	(-0.01)
Household size	0.11	0.03	0.11	-0.12
	(-0.11)	(-0.07)	(-0.12)	(-0.08)
Constant	9.19***	-3.55***	12.39***	-2.95***
	(-3.05)	(-0.84)	(-4.21)	(-0.93)
Bid	-4.96***	-6.96***	-6.06***	-5.09***
	(-0.85)	(-0.61)	(-1.23)	(-0.59)
Observations	175	183	158	165
Log-likelihood	-105.68	-243.86	-72.53	-189.32

Source: Survey 2007
[a]Standard errors in parentheses
[b]* p<.1, ** p<.05, *** p<.01

The two tests used to confirm the validity of the estimation were the t-test and the Wald test. The Wald test is generally used in hypothesis testing from unrestricted models only. It was chosen in preference to the likelihood ratio test and Lagrange multiplier test, because it is distribution free and computationally simpler[8] (Greene, 2002). In all four models, the coefficients were jointly significant at all significance levels using the Wald test.

As shown in Table 6, the PM values are higher than the NPM estimates and are consistent with the statistical theory. However, when making a comparison

between NPM and PM the issue of distributional assumption that applies to the parametric form does not apply to the former and may account for this difference. For the parametric WTP estimates, the confidence intervals and standard errors were derived using Krinsky and Robb (1986).[9] Results from both NPM and PM show that respondents were willing to pay more for GE than PV regardless of the payment method. However, consistent with Loureiro *et al.* (2004), WTP from NPM is lower than that PM, as shown in Table 6. This was attributed to the Turnbull estimator which calculates lower bound of WTP.

TABLE 6: Comparison between nonparametric and parametric mean WTP values excluding protests (in Kshs)

	Parametric lower bound mean	Nonparametric lower mean
Grid Electricity (GE) Lump	16,640	7,214
Grid Electricity (GE) Monthly	840	775
Photovoltaic (PV) Lump	14,010	5,469
Photovoltaic (PV) Monthly	660	344

Source: Survey 2007

One way to validate CV studies is to compare the survey WTP estimates with other non-market valuation studies. In this respect, a government-funded survey conducted in 2007 for 1,766 households in 31 rural districts revealed a higher WTP for rural households. In this survey, most households were willing to pay a minimum of Ksh. 32,500. Results from a nonparametric model using the government-funded survey data indicate that, for a one-off payment, the total WTP is Ksh. 55,542 (US$ 830). This amount is nearly three times more than the annual one time WTP reported in the Kisumu sample. One reason for this difference can be attributed to the fact that the government survey included 145 localities and around 1,776 non-electrified households across the country. Moreover, the government admitted that the survey

did not interview all types of rural households in equal measure, but concentrated on rural households' living in densely populated areas and market centres throughout Kenya (Deutsche Energie-Consult (DECON), 2007).

The monthly income levels, by deciles for the sample, as tabulated in Table 7, indicate that about 60% of respondents fall under an income level of less than Ksh. 10,000 (US$ 150). This figure is comparable to the poverty levels of the district where 53% of Kisumu's total population is living below the poverty line. Regarding a one-off payment method, the WTP as a percentage of yearly income shows the first decile having to pay 58 % to 55% of their earnings towards GE and PV electricity, respectively. On the other hand, for those in the highest decile a lump sum payment would cost 5% of their total income for either the GE or PV types. A rule of thumb that sets a budget limit for energy services is 10% of total expenditures or income (Fankhauser and Tepic, 2005), which is regarded as the ability to pay (ATP). For income above the fifth decile, the ATP a lump sum payment for connection increases because households would not have to pay more than 20% of their income.

TABLE 7: WTP as percentage of yearly income by income deciles (in Kshs)

Deciles	Mean monthly income (Ksh)/decile	Mean WTP of GE lump as % of annual income	Mean WTP for PV lump as % of annual income	Mean WTP for GE monthly as % of annual income	Mean WTP of PV monthly as % of annual income
1	2,692	58%	55%	31%	24%
2	4,531	35%	33%	19%	14%
3	5,579	28%	26%	15%	12%
4	6,676	23%	22%	13%	10%
5	7,766	20%	19%	11%	8%
6	9,223	17%	16%	9%	7%
7	11,298	14%	13%	7%	6%
8	14,154	11%	10%	6%	5%
9	16,838	9%	9%	5%	4%
10	30,630	5%	5%	3%	2%

Source: Survey 2007

6. Policy Implication and Conclusion

The importance of understanding household demand, behaviour, WTP and ATP, is relevant to welfare measures as well as project evaluation. Table 8 depicts the total WTP for a year, for the total nonelectrified population in the district. The total WTP values for both GE and PV electricity, for one time payment, indicate nearly comparable payments. However, the total WTP estimates for GE and PV electricity, for monthly payments, are one-half of the lump sum. Indeed, for GE and PV systems, the total monthly payments for households (in 5 years) are US$32 million and US$24 million, respectively. [10] These values are relevant for policy making when governments, administrators, donors and investors need to estimate, at the district level, electrification services to rural households using various payment options.

TABLE 8: Annual median WTP for the nonelectrified by household level and total rural population of Kisumu district.

	Annual WTP per household (sample)		Total Annual WTP for population (district) in millions	
Scenario	Total WTP (Ksh)	Total WTP (US$)[a]	Total WTP (Ksh)	Total WTP (US$)[a]
Grid Electricity Lump	18,780	235	991	12
Grid Electricity Monthly	10,080	126	532	7
Photovoltaic Lump	17,740	222	936	12
Photovoltaic Monthly	7,800	98	412	5

Source: Survey 2007
[a] August 2007, US$1 was approximately equal to 80 Kenyan Shillings

Valuing access to rural electrification for various payment and product options is related to optimal investment by households and institutions involved in REPs. Despite the high costs of rural electrification, the following proposals presented in this paper are policy recommendation to increase connection for the nonelectrified population namely: subsidizing the connection costs, support financial schemes to

connect to electricity services, adjusting the appropriate payment period to meet the affordability needs of the target population and restructuring the market ownership and institutions related to REP.

A proposition to subsidize the connection costs for both GE and PV systems, is needed, that is to say, the GoK, through the local authorities, could subsidize a third of the connection cost with the rest being paid by the households. However, this connection subsidization would not cover the wiring and consumption costs, for which end-users are responsible. As shown in Table 9, without subsidy, only the highest two income deciles can afford GE systems, if accepting the 10% rule of thumb, as discussed previously. This figure rises to the four highest deciles when considering a non-subsidized PV system. However, when a subsidy of a third is included, the proportion of GE households coming within the 10% affordability benchmark rises to four deciles and perhaps more importantly, regarding PV systems, seven deciles fall within this range. This indicates that subsidizing PV would be a far more effective way of meeting the REP objectives in Kenya.

TABLE 9: Comparison of monthly charges for connection at actual and subsidized payment cost for grid electricity (GE) and photovoltaic (PV) systems as % of income

Monthly income deciles	GE actual connection cost (monthly) inclusive of 50 kWh use charge[a]	PV actual connection cost (monthly)[b]	GE subsidized-connection cost 1/3 off inclusive of 50 kWh consumption charge (monthly)	PV subsidized-connection cost 1/3 off, (monthly)
1	58%	39%	43%	26%
2	34%	23%	26%	15%
3	28%	19%	21%	12%
4	23%	16%	17%	10%
5	20%	13%	15%	9%
6	17%	11%	13%	8%
7	14%	9%	10%	6%
8	11%	7%	8%	5%
9	9%	6%	7%	4%
10	5%	3%	4%	2%

Source: Survey 2007

In other developing countries, the subsidization policies vary according to governments objectives, with regards to REP targets. For example, in the case of Chile where rural electrification stands at around 80%, the average state subsidy per household was US$1,080 in 1995, which was later increased to US$1,510 (1999), owing to the priorities set by the state for maximizing rural electricity coverage (Jadresic, 2000). In the case of Kenya, there needs to be a distinction made among various provinces. Regions like Coastal, Western and Eastern provinces are perceived as being poorer and as having certain climatic and geographic conditions that can affect the cost of supply for both grid and off-grid systems. Hence, there needs to be a sliding scale of subsidies with regard to cross-subsidizing for the different Kenyan regions.

The other proposal involves the financial programmes in place to increase connection of electricity services. Most financial institutions in rural areas cater for salaried rural employees, such as civil servants, teachers and self-employed proprietors. Moreover, for the first-time user wanting to connect to grid-electricity or PV systems, financial schemes through banks or microfinance are unavailable. As a result, there is a need to establish long term schemes to finance initial or upfront costs for acquiring PV systems and grid-electricity. One approach could be to involve multilateral institutions more in providing revolving funds to the GoK, which they would then give to financial institutions as loans and they in turn would provide unsecured loans to households. However, careful attention will need to be paid to the details as to how to deal with defaults, where customers end up not paying the

monthly payments. Indeed, delinquent consumers are difficult to manage and require high administrative costs to monitor. Ledgerwood (1999) has suggested that once defaulters have been identified, field staff should follow up arrears payments. If the method fails to work, then some of the following initiatives should be employed: public announcements in the press as to who is a delinquent payer, repossession of assets and erecting of signage outside the borrower's home and charging a defaulter with a crime.

As mentioned earlier, the upfront or connection costs are an impediment to electrification in rural areas. The financial programmes available to connect to electricity services differ between different goods and services. For example, in Kenya, the financial schemes to connect to these services are far better for solar PV systems than for grid-electricity, as monthly instalments by hire purchase systems or banking loans exist. According to World Bank surveys, respondents have indicated their willingness to take medium-term loans to pay for the upfront cost and pay them back through their monthly bills over five years or more (Townsend, 2000). A good example is the case of Bolivia, where the number of new customers doubled when connection cost was spread over 5 years, despite 25 to 30 cents per kWh increase on grid-electricity cost (Barnes and Foley, 2004). This is unlike Malawi's case, where new customers were charged upfront full cost line extension, (with a 30 year life) which resulted in 2% rural electrification rates.

Market ownership for grid-electricity lies with the KPLC, which controls both the transmission and distribution sides. This model is a one-distributor approach and it could be modified to accommodate private sector participation and ownership. Kenya has a number of well established IPPs; however, the transmission and distribution are

not privatized, as the KPLC is partially state owned. If privatization was allowed then there would be alternative options for transmission and distribution.

On one hand, charging full cost to customers is beneficial, but on the other hand, these charges can be too high for consumers to afford, hence creating an incentive for self-generation. Analyzing international private participation in power projects, an ESMAP paper reported that nearly 70% of private participation in developing countries was concerned with generation activities, whereas electricity transmission stood at 3% and distribution at 14%. This would suggest that potential investors perceive the latter two areas of operation as carrying significant market and commercial risks (Covindassamy *et al.*, 2005). However, the government role is important in keeping the various competitive approaches, both on and off grid, at competitive rates. In other words, their role is to oversee provincial equity to ensure that electricity prices are on a level playing field and also minimize the investment risks.

One suggestion emerging from this study is that there is a need for an alternative model for addressing the REP objectives by offering both grid and off-grid options and not simply concentrating on the former. This paper proposes that part of Kenya's REP strategy could be to set up a rural energy service company (RESCO) to provide electricity for households. Households would then contract RESCOs for on-grid and off-grid electricity services and they could own, maintain, and repair equipment. In other cases, the equipment is owned by the household after a specified payment period. A good example of this system can be found in India, where local electricity retailers, like the independent rural power producers (IRPP), own small businesses or cooperatives and they secure credit financing to establish an off-grid system or mini- grid. The latter is achieved by either creating a new distribution

system or leasing a sub-station already in existence (ESMAP, 2000). Another effective approach has been one in Sri Lanka, where the World Bank/GEF Energy Services and the national utilities established "non-negotiable" power-purchase tariffs and contracts (PPAs) with third-party mini-hydro developers (Miller and Martinot, 2001). The introduction of these IPPs and PPAs, along with concessions, has accelerated the privatization of the markets. In Kenya, various PPAs have been established with the IPPs at the generation level, but what appears to have played an important role in securing these deals is the involvement of multilateral organizations, that provide credibility to the projects (Eberhard and Gratwick, 2005).

The roles of the different service providers, namely the public, private, and community-based agencies that are needed for electrifying households should function in a complementary way and this would create healthy competition among all the protagonists (Barnes and Floor, 1996). Moreover, the Kenyan policy makers as well as the producers and distributors should take the opportunity to learn from other developing or emerging markets' REP models, to guide them in revamping their current programme. The government position, in providing long-term subsidies for operating and maintenance costs to entities, should be diverted to focusing on providing; one-off subsidies to private investors and equity financing or long-term loans to intermediaries in order to help in the financing of rural electrification.

The REP should be a bottom-up approach, where users' needs and preferences determine the electricity policies adopted and in return, policy makers need to formulate regulations that incorporate consumer preferences and to develop, either grid-electricity or decentralized electricity systems, to meet the consumers' needs. In conclusion, the government as a facilitator of the REP, needs to be more transparent

and accountable, so as to increase the efficacy of the electricity services, to both current users and potential consumers.

NOTES

[1] This percentage has not increased significantly since 2003. Indeed, around 4% of rural areas is reported electrified (Kenya Integrated Household Budget Survey (KIHBS), 2005-2006).

[2] In Kenya, the MoE announced that connection fees can be paid as a down payment of Ksh. 10,000 and with six month instalments for the remainder amount or eighteen months instalments pending on a GoK decision (Nation, 2007). New development due to election campaign the government introduced a payment schedule system of 10 month instalment payment in October 2007.

[3] NASSEP is defined as National Sampling Survey and Evaluation Programme (NASSEP)

[4] Equation (2) guarantees that $0 \leq p_1 \leq 1$, $0 \leq p_1 + p_2 \leq 1,\dots,0 \leq \sum_{j=1}^{M} p_j \leq 1$ and $\sum_{j=1}^{M+1} p_j = 1$. By constraining all of p_j to be non-negative, the last constraint ensures that none can be greater than one.

[5] An upper bound on WTP is similarly defined as $\sum_{j=1}^{M+1} p_j c_j$, though in most instances c_{M+1} is infinite and therefore the upper bound is unbounded. If all individuals respond 'no' to the offered largest bid amount, c_M, then $p_{M+1}=0$, and the upper bound takes an infinite value.

[6] See Alberini (1995), which distinguishes the likelihood for both the bivariate probit and interval-data probit models in detail.

[7] The author estimated other dummy variables for categorical variables, namely: highest education level, years of residence, income and age, which produced mixed results and were later converted to continuous variables and as shown in Table 5 provided more robust results.

[8] For more details about the three hypotheses testing methods refer to Hanemann and Kanninen, 1999.

[9] Krinsky and Robb used random draws asymptotic distribution of parameter estimates, involving 5,000 replications of a Monte Carlo simulated distribution at 95% confidence intervals. See Haab and McConnell (2002) for more details. The Stata command –wtpcikr was used to estimate mean willingness to pay and construct the Krinsky and Robb confidence intervals (Jeanty, 2008).

[10] The yearly amount for monthly payment is obtained by multiplying each monthly payment for PV electricity and GE by 12 and by the total number of nonelectrified rural households (2006) in the district which were approximately 42,079 households (88% of 47,817).

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