Norwegian University
of Life Sciences

Master's Thesis 2020 30 ECTS
School of Economics and Business
Supervisors: Mette Wik and Ståle Navrud

Willingness to Pay for Solar Home Systems in Off-Grid Areas in Kilifi County, Kenya

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Acknowledgement

Writing a master thesis can be a demanding undertaking and during this process, I have received support from different quarters. First, I would love to take this chance to sincerely thank my supervisors, Mette Wik and Ståle Navrud. Your guidance, valuable input and reassurance has been immense throughout the whole process and I will always be grateful for this. Secondly, I would love to thank my colleagues at SUNami AS for sponsoring my data collection process and for helping me maneuver in the field.

I would also like to thank Sarah Tione for being supportive and guiding me whenever I had any query. The support from my family cannot go unmentioned, thank you for offering a shoulder to lean on and for enquiring on every step of my writing. Lastly, I would love to acknowledge the divine support and thank God for His strength and grace.

Abstract

The issue of energy access remains a concern in most countries, especially developing ones. This study aims to contribute to the demand dynamics of energy access by determining the willingness to pay and the factors affecting the willingness to pay for solar home systems (SHSs) among households living in off-grid areas in Kilifi County, Coastal Kenya. In the study I undertake a contingent valuation study that sees me collect data from 200 households. The study evaluates the willingness to pay for three different sizes of solar home systems by use of a payment card. The mean WTP is estimated using the payment card values, the interval midpoints and the unconditional interval regression. The mean WTP for system one, the smallest system, is KSh 793, Ksh 1155 and Ksh 1153 using the PC values, interval midpoint and unconditional interval regression, respectively. The mean WTP for system two, the medium system, is KSh 1228, Ksh 1658 and Ksh 1643 using the PC values, interval midpoint and unconditional interval regression, respectively. Finally, for system three, the largest system, the mean WTP is, KSh 1283, Ksh 1708 and Ksh 1706 using the PC values, interval midpoint and unconditional interval regression, respectively. Notably, households were willing to pay 7.84% of their income to pay for system 1, 11.25% for system 2 and 11.6% for system 3. I also estimate different regression models, namely, OLS, interval regression, tobit and logit models from the data. The income elasticity of WTP is observed to be increasing from the smallest and cheapest system to the more expensive systems, system two and three. When analysing the determinants of WTP levels, sex, income, and happiness are statistically significant for system one. Female headed households have a higher WTP for system one. Happiness shows a negative relationship with the WTP levels for system one. Income is the only statistically significant variable for system two whereas income and number of children are statistically significant for system three. There is a negative relationship between the number of children and WTP levels for system three. In all models, income has a positive significant relationship with WTP for system two and system three, and in most models for the smallest and cheapest system, system one. This conforms to economic theory. This study has itself captured the private benefits of SHSs in terms of the WTP levels of households, based on their income levels and income distribution. However, to determine if the government should offer subsidies to support the uptake of SHS in Kilifi County, a Cost Benefit Analysis (CBA) would need to be performed to compare the social benefits of SHSs, including external benefits, to the costs of SHSs.

Table of Contents

List of Tables

List of Figures

Acronyms

CAN- Consistent Asymptotically Normally distributed

CBA- Cost Benefit Analysis

CV- Contingent Valuation

HH- Household

KOSAP- Kenya Off-Grid Solar Access Project

OLS- Ordinary Least Squares

PC- Payment Card

SDG- Sustainable Development Goal

SE- Standard Error

SHSs- Solar Home System

SWB- Subjective Well-Being

UN- United Nations

WTA- Willingness to Accept

WTP- Willingness to Pay

1 Introduction

With a global population of 940 million people living without access to electricity (Ritchie & Roser, 2019), the issue of energy access will continue to linger in most energy conversations. This is a wake-up call to see to it that feasible and sustainable measures are adopted to assist in improving energy access. Achieving the global goal of attaining universal energy access by 2030[1] will require collaborative efforts to promote energy sustainability. Energy sustainability encompasses several factors, among them "sustainable energy sources, reduced environmental impact and increased efficiency" (Rosen, 2009, p. 55). There seems to be a consensus that the adoption of renewable energy will help bridge the energy gap in a sustainable way, as well as drive us towards decarbonization (IRENA, 2018).

Tackling the issue of energy access needs relevant stakeholders to understand the demand and supply dynamics. Supply constraints often seem to be the highlight whenever energy access is spoken about, however, challenges on the demand side may be a greater concern when it comes to electrification (Blimpo & Cosgrove-Davies, 2019). While the call to electrify the world seems to have attracted effort and concern by different institutions, the only way these efforts will be economically feasible largely depends on, a) uptake levels, b) consumption and c), the willingness to pay (Blimpo & Cosgrove-Davies, 2019, p. 39). Understanding these dynamics would assist in the development of realistic electrification strategies. It would for instance enable a country to decide, what portion of their population could be served by the national grid, and what portion is better off served by off grid solutions such as mini grids or standalone solar home systems.

Standalone solar home systems (SHSs) have become a common source of electricity in most developing countries. They have the advantage of being affordable, compared to other alternatives, and in places where the terrain inhibits grid extension SHSs have the advantage of being easy to install. Most households in developing countries also mainly demand electricity for lighting and powering small appliances, needs that can be met by SHSs, and in this case it may be more economically feasible to serve them with SHSs compared to extending the grid that may be costly (Power Africa, 2019).

[1] Goal number 7, in the United Nations Sustainable Development Goals (United Nations, 2015)

This study hopes to contribute to the demand side of energy access by analyzing the WTP for SHSs by residents of Kilifi County, one of the 47 counties in Kenya, located in the coastal region.

1.1 Background

With 25 percent of its population, as of 2018, living without electricity, Kenya is among the countries that are in the journey towards attaining universal access of electricity. The Kenya National Electrification Strategy (KNES), indicates that the country hopes to achieve 100 percent electrification[2] by 2022 (Government of Kenya (GoK), 2018). It specifies four supply approaches to be adopted, two of which are grid based and the other two are off grid. Grid expansion and grid intensification are the two grid based solutions, whereas mini grids and standalone solar home systems are the other two off-grid solutions (Government of Kenya (GoK), 2018, p. 9).

Solar Home Systems are an important component in Kenya's endeavors towards universal access to electricity. The KNES has identified that there exists 1.96 million potential connection of SHSs, a target that the government is working to achieve by 2022 (Government of Kenya (GoK), 2018). Given its rich solar resources, a daily average of 6.5 peak hours of sunshine throughout the year, the country's solar potential is undoubtedly viable (Oloo et al., 2015). It is however important to analyse how financially viable the adoption of SHSs is by evaluating factors such as WTP.

Kilifi county is one of the 47 counties in Kenya. It is located at the coast of Kenya. The county ranked 11th in a survey to identify the most marginalized counties in Kenya (CRA, 2012). Moreover, it has been of focus by the government of Kenya in its electrification projects and is also listed among the fourteen underserved counties expected to receive support through the Kenya Off-Grid Solar Access Project (KOSAP) (George et al., 2019). According to the 2019 population and housing census report, Kilifi county had a total population of 1.4 million and an average household size of 4.8 (KNBS, 2019a). Among the 297,990 households in Kilifi, 38.5 percent used grid electricity as their main lighting source, 33.4 percent depended on kerosene and only 20 percent on solar (KNBS, 2019b).

Overall, we can see that evaluating the issue of energy access is relevant and even more, timely, given the efforts by different stakeholders.

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[2] Electrification encompasses both the grid and off-grid solutions such as mini grids and standalone solar home systems.

1.2 Problem Statement and Research Questions

At the core of this study is, to establish the willingness to pay level for SHS in Kilifi County[3], Coastal Kenya. This study particularly acknowledges that SHS come in different sizes and this influences their contribution to energy access. In this study, I go a step ahead and determine the WTP for three different sizes[4] of SHSs.

Secondly, this study tries to identify demographic factors that might affect WTP for SHS. Additionally, with solar being a renewable energy source, it has a significant contribution to issues on sustainability. This brings us to our third objective which is trying to identify if environmental awareness influences the WTP for SHS. Lastly, I evaluate what I would consider interesting and upcoming, how an individual's happiness level affects the WTP, if at all it does.

1.3 Research Questions

1.3.1 What is the willingness to pay for SHS?

In this study, the mean WTP for SHS by households is estimated. The mean WTP is a useful indicator and can be depended upon by different stakeholders in the SHS sector such as policy makers, public and private institutions. It would play a pivotal role in strategic and informed decision making both at an institutional and national level. Furthermore, categorizing the solar home systems, based on their energy access level, and determining the mean WTP for the three categories, provides us with more refined information.

1.3.2 Which demographic factors affect WTP for SHS?

Demographic factors may explain the WTP for households and need to be considered when carrying out a WTP study (Johnston et al., 2017). In this study, household characteristics and household head personal attributes are considered. On a household level, we focus on income, number of children below 18 years living in the household, and household size. For the household head, we consider sex, age and education level, environmental awareness, and happiness.

[3] Only households in off grid areas are considered in this study.
[4] The Multi-Tier Framework of energy access developed by ESMAP guides our selection of the different sizes (Bhatia & Angelou, 2015).

1.3.3 How does environmental awareness affect WTP for SHS?

An individual's attitude towards environmental conservation may influence their choice of energy source. In this study, I evaluate how environmental awareness may affect the WTP for SHS.

1.3.4 How does happiness affect the WTP for SHS?

The fourth and final research question for this study evaluates how an individual's subjective wellbeing, commonly known as happiness, affects their WTP.

2 Hypotheses and Literature Review

Now that I have looked at the research questions specified in this study, let me discuss the hypotheses and review some literature to support the hypotheses propositions. It is important that each researcher understands the primary research goal of their study. That way, the researcher can formulate proper and informed hypotheses (Christensen et al., 2011). In this study I carefully examined the expected effects of the explanatory variables on WTP. The hypotheses to be tested are guided by economic theory and/or existing literature related to the subject. Supporting literature has been included for each explanatory variable. Table 1 below shows a summary of the hypotheses and the supporting references.

2.1.1 Gender

Do men and women have significant differences in their WTP? Information on gender is often included in most willingness to pay studies and the existence of gender differentials is evaluated. There does not seem to exist a consensus on the effect of gender on WTP. Khandker et al. (2014) in their study conducted in Bangladesh, found that women had a higher WTP for solar home systems. On the other hand, Bollino (2009), in his study conducted in Italy, found that men were willing to pay more for renewable energy sources. Other studies have also found that there are no existing significant WTP differences between men and women. Studies by Abdullah and Jeanty (2011) and Ntanos et al. (2018) focusing on the willingness to pay for renewable energy sources conducted in Kenya and Greece respectively, found no significant WTP gender differentials.

2.1.2 Age

Does an individual's age affect his or her willingness to pay? A study conducted in Rural Uttar Pradesh in India found that there is higher awareness of solar home systems among the younger persons (Urpelainen & Yoon, 2015). Additionally in a study conducted in Ethiopia, Entele (2020) found that younger household heads had a significantly higher WTP for electricity connection from a renewable source.

2.1.3 Education Levels

There is a general consensus in valuation studies that higher education levels are typically linked with higher willingness to pay levels (Gunatilake et al., 2012, p. 11), while holding factors such as income constant, and in the context of this study, this would mean higher education levels are associated with higher WTP for SHSs. A study by the World Bank in Rwanda showed higher willingness to pay for households in which the household head had at least primary education compared to those that had no education (Koo et al., 2018). With no schooling as their base category, Lay et al. (2013) in their study conducted in Kenya, found that solar home systems were more popular among households with higher education levels.

2.1.4 Household size

How does household size affect the household's WTP levels? Different economic valuation studies have found household size as a significant variable in explaining willingness to pay. A study by Mutua (2015) conducted in Kenya found that larger households are more likely to consider having a solar home system. An impact evaluation study on solar home systems conducted in Rwanda also showed that most households with SHS were relatively large, larger than the country's average (Grimm et al., 2016).

2.1.5 Number of Children

To what extent does the number of children in a household affect the WTP? Findings from a study conducted in rural India, showed that as the number of children in a household increased the number of multiple electricity connections increased as well (Gunatilake et al., 2012). Moreover, school going children are a unique section of SHS users. They are potentially the most frequent users of SHS (Grimm et al., 2019) and households with school going children are expected to more likely adopt solar home systems.

2.1.6 Income

Economic theory generally considers income to be one of the key determinants of WTP levels (Bateman & Willis, 2001). Income considerations are usually taken at a household level and not just individually (Bateman & Willis, 2001). It is expected that the share of what you are willing to pay is part of your income and therefore, income and willingness to pay levels move in the same direction (Rahnama, 2019). It is however important to note that, income does not necessarily have to determine whether you are willing or not willing to pay but instead it influences how much you are willing to pay (Liebe et al., 2011).

Different empirical WTP studies focusing on renewable energy have affirmed the positive relationship between WTP level and income through their findings. Abdullah and Jeanty (2011), Mutua (2015), Ugulu and Aigbavboa (2019) and Entele (2020) are some among many WTP studies that have been conducted in Africa covering the uptake of renewable energy sources. In all these studies, income is found to be statistically significant and positively related with WTP levels.

2.1.7 Environmental Awareness

People's attitudes and awareness on environmental issues may play a key role in determining their WTP level for renewable energy options such as solar home systems. Findings from a WTP study conducted in several provinces in Thailand by Suanmali et al. (2018), indicate that higher environmental awareness is associated with higher WTP levels. In addition, a study conducted in Sweden by Ek (2005) showed that individuals with higher environmental awareness levels were more willing to support renewable energy projects. In a study based on secondary data obtained from different studies Mahendar (2017), also finds that WTP levels are higher among individuals who have a higher environmental concern.

2.1.8 Happiness

Interesting literature around happiness and well-being continues to expand. An individual's well-being can be viewed and measured differently. It could be based on one being able to achieve some pre-determined social or psychological needs and can be measured through objective lists (Dolan & Metcalfe, 2012). Secondly, wellbeing may be viewed as a point where one is able to meet their wants. This way, wellbeing is viewed as more of a luxury and not a need. This approach is otherwise known as preference satisfaction (Dolan & Metcalfe, 2012). Finally, when measured by self-reporting, it is considered as subjective well-being (Dolan & Metcalfe, 2012). Subjective well-being and happiness are used interchangeably (Michalos, 2014, p. 6425).

Do happier people have a higher WTP? An individual's level of subjective wellbeing is bound to affect their behaviour, and this may include their willingness to pay levels. Empirical studies trying to establish the effect of happiness on willingness to pay continue to be conducted. Sulemana (2016) analyzes whether happier people are willing to set aside a bigger part of their income for an environmental cause. The findings of his study are based on data from 18 countries and they depict that happier people have a higher WTP for an environmental cause. Another study conducted by Montazer Hojat et al. (2019) conducted in Iran, showed that happier people had a higher WTP level for taxes.

Table 1: Hypotheses

Variables	Direction of effect with respect to WTP	Sources
1. Gender	Ambiguous	Khandker et al. (2014) Bollino (2009) Abdullah and Jeanty (2011) Ntanos et al. (2018)
2. Age	Negative	Entele (2020) Urpelainen and Yoon (2015)
3. Education	Positive	Gunatilake et al. (2012) Koo et al. (2018) Lay et al. (2013)
4. HH Size	Positive	Grimm et al. (2016) Mutua (2015)
5. No. of children	Positive	Gunatilake et al. (2012) Grimm et al. (2019)
6. Income	Positive	Abdullah and Jeanty (2011) Mutua (2015) Ugulu and Aigbavboa (2019)
7. Environmental awareness	Positive	Ek (2005) Mahendar (2017)

		Suanmali et al. (2018)
8. Happiness	Positive	Sulemana (2016) Montazer Hojat et al. (2019)

3 Theory

In this chapter, I discuss economic valuations while laying emphasis on the contingent valuation method which has been applied in this study. I then proceed to expound on the theory of welfare economics which provides the economic theory foundation for CV studies (Pearce et al., 2002).

3.1 Economic Valuations

Placing a value on an asset can be an exciting and involving pursuit for anyone to undertake. "What exactly is it worth?" or even more "Is it worth this much?", are some questions that most of us have had to juggle in our minds from time to time. To try and answer such questions, it is important that an elaborate value elicitation process is adopted. Economic valuation procedures accentuate the economic value of assets by accounting for both use and non-use values of these assets (Johnston et al., 2017). The use value of an asset[5] is the value obtained by the direct or indirect utilization of the asset, whereas the non-use value could be intrinsic, for example the aesthetic or cultural value (Johnston et al., 2017).

Value elicitation techniques rely on data from either existing markets or hypothetical markets. Techniques relying on existing markets are known as revealed preferences methods whereas stated preferences methods are those that depend on hypothetical markets usually created by conducting surveys (Pearce et al., 2002). Valuation through revealed preferences may consider existing market prices, replacement costs, travel costs, and/or, hedonic pricing, usually observed through the price of properties and/or the hedging cost, that is the cost incurred to avoid a risk for example the effects of pollution (Freeman III et al., 2014).

Stated preferences methods on the other hand, are sub divided into two; contingent valuation (CV) and choice experiments (Johnston et al., 2017). The main difference between contingent valuation and choice modelling is the issue of attributes. Choice modelling usually presents a set of choices with attributes taking different levels, whereas contingent valuation assumes the amenity as indivisible and so it doesn't consider attributes (Johnston et al., 2017). An example of a choice modelling question would be where an individual is presented with two car choices. One car has a

[5] Asset in this case has been used to mean a market or a non-market good.

2500cc engine size and the other 1800cc engine size. In these two examples engine size is the attribute and 2500 and 1800 are the different levels.

In this study, the contingent valuation method is used. The method entails asking the subjects of the survey to state their maximum WTP for the asset or proposed change (Mogas et al., 2006). Willingness to pay is a measure of value. It accounts for how much one is willing to sacrifice in exchange of the asset (Mitchell & Carson, 1989) The maximum WTP question can be framed in different ways; " (a) iterative bidding, (b) open-ended elicitation, (c) payment cards (without or with anchors), and (d) binary or dichotomous choice" (Johnston et al., 2017, p. 345) Notably, the open ended elicitation method is discouraged as it has in the past been associated with overstating of the WTP level or high levels of zero responses (Johnston et al., 2017).

The contingent valuation (CV) method has the advantage of being able to measure both use and non-use values (Pearce et al., 2002). In addition, since it is hypothetical, it helps us value into the future which forms a good basis for informed policy making (Balkiz, 2016). CV studies at the same time are exposed to some limitations that may question their validity. First, is the issue of hypothetical bias. Since the markets are hypothetical and respondents sometimes may not have an obligation to pay their stated value, they may inflate their WTP and this may therefore not be a true representation of the total economic value (Johnston et al., 2017). Also, respondents may face challenges in understanding the valuation process. They may lack the knowhow of what exactly is needed of them, especially because most CV studies are full of large amounts of texts and wording (Johnston et al., 2017). Figure 3.1 below is an illustration of the economic valuation classifications.

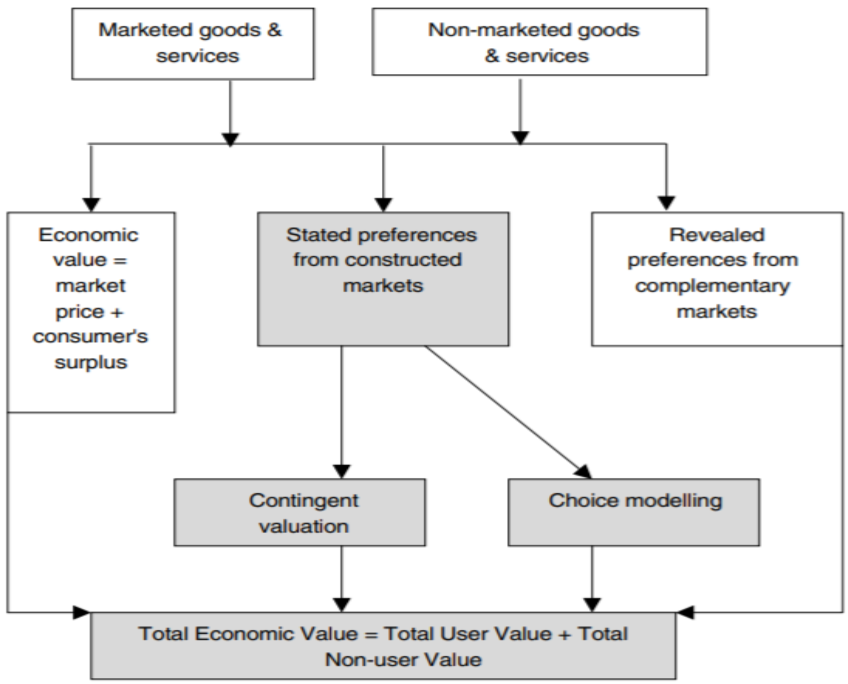

Figure 1: Economic valuation classification as illustrated by Pearce et al. (2002, p. 16)

3.2 Welfare Measures

Welfare economics is the branch of economics that focuses on welfare maximization by considering the utility that the society achieves from consumption and the existing production possibilities (Mitchell & Carson, 1989, p. 18). Society's utility is captured by the Social Welfare Function (SWF) while the production possibilities is captured by the Production Possibility Frontier (PPF). At the point where the SWF is tangent to the PPF, see figure 3.1 below, the society's welfare is said to be maximized (Mitchell & Carson, 1989, p. 18). Furthermore, this point is expected to be pareto optimal, meaning that, beyond this point it is not possible to at least make an individual better off without making anyone worse off (Mitchell & Carson, 1989, p. 19).

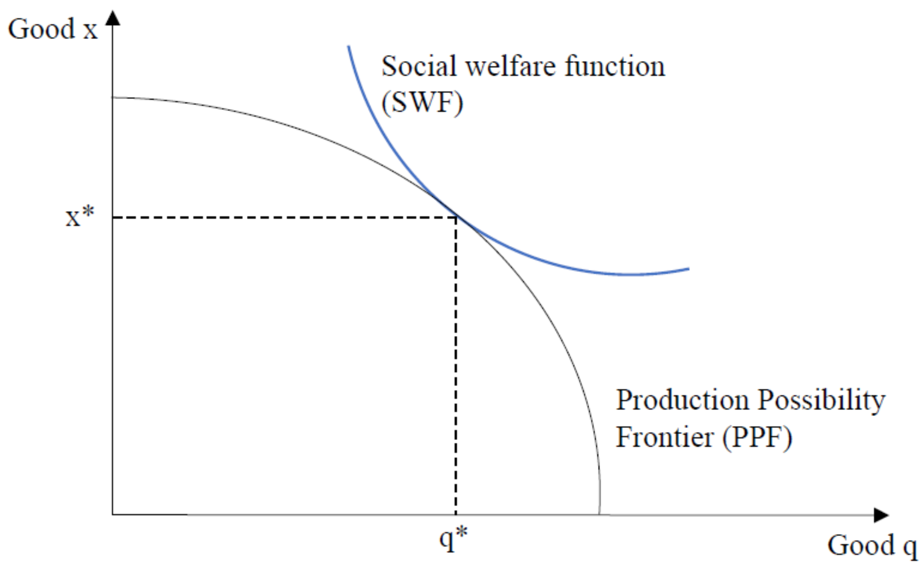

Figure 2: Welfare Maximization

Welfare economics relies on the assumptions of consumer behaviour. First, it is assumed that consumers can make choices, meaning that they have known preferences and also that agents will always try to maximize their utility (Mitchell & Carson, 1989). It is also assumed that they are rational and consistent while determining their preferences and can rank their preferences, this is the transitivity assumption (Lancaster, 1966), and finally, that large quantities of a commodity are also associated with higher levels of utility, called non-satiation (Lancaster, 1966) .

These assumptions are strong considerations in the application of welfare economics such as contingent valuation. When individuals forego a part of their endowment in exchange of a good or a service, they demonstrate how much they value the good or service (Debreu, 1959). The value of the good is translated as the maximum income sacrifice, the individual is willing to forego given their budgetary constraints (Debreu, 1959). On the part of the owner of the good, the value they place on their good is portrayed by the least they are willing to accept to let go of it (Mitchell & Carson, 1989).

Understanding how to measure benefit is an important segment in welfare economics. The consumer surplus is the economists' way of measuring the benefits that consumers' get by consuming a good. The consumer surplus concept was pioneered by Marshall (Mitchell & Carson, 1989). Marshall considered the change in the consumer surplus resulting from price and quantity changes of a good given fixed income, but did not account for changes in the utility level (Mitchell & Carson, 1989). An improvement of this benefit measure was pioneered by Hicks, who came up with four measures of benefit that consider the utility level (Hicks, 1943). Hick's consumer surplus measures, consider that the provision of the good or service should leave utility unchanged either at the initial utility level, "compensation variation and surplus", or at some specified level, "equivalence variation and surplus" (Mitchell & Carson, 1989, p. 23).

Contingent valuation studies borrow from the hicksian benefit measures. Figure 3.2 below adopted from (Mitchell & Carson, 1989) is a summary of the compensation measures and equivalence measures and how they are related to CV studies. The compensation measures relate to maintaining the same level of utility while the equivalence measures relate to a different specified level of utility (Mitchell & Carson, 1989)

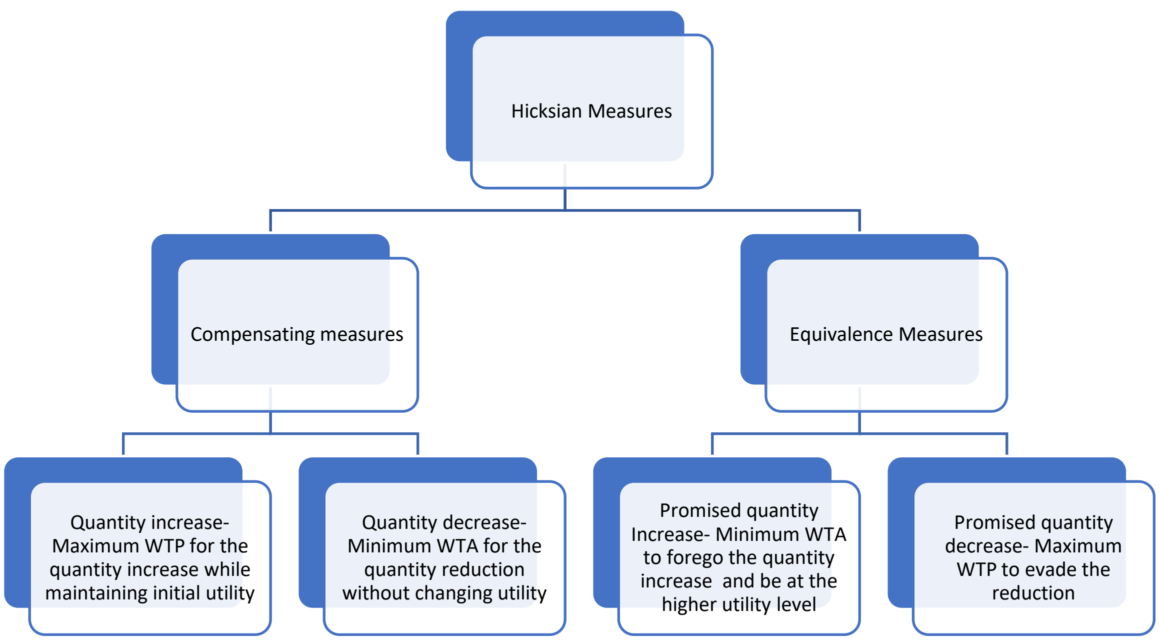

Figure 3: Hicksian measures related with CV studies

Note that quantity increases in the figure 3.2 should be translated as upgrades that are desired while quantity decreases as a deterioration and they are unwanted.

3.2.1 Utility Functions

Let us now put into perspective the hicksian measures by using utility functions. Kindly note that the functions and equations used in this part are adopted from (Carson & Hanemann, 2005) unless otherwise stated. First, let q be the asset to be valued and x the vector of other different market goods. An individual's utility for x and q can be defined as,

$$u(x, q)$$

and the indirect utility function as,

$$v(p, q, y)$$

where p is the price vector for the other different market goods and y is the individual's income. The indirect utility function is obtained by substituting the individual's demand, derived from the maximization of the utility function subject to budget constraints, into his utility function (Haymond, 1996).

A change in q forms the basis for the valuation, "with q" versus "without q". Let q_0 be, the without q situation, and q_1 be, the with q scenario. The individual's utility at q_0 is,

$$u_0 \equiv v(p, q_0, y)$$

and at q_1,

$$u_1 \equiv v(p, q_1, y)$$

If $u_1 > u_0$this means that the change in q is positive and wanted, the reverse holds as well. If $u_1 = u_0$, then it means that the individual is indifferent about the change in q.

The compensating variation hicksian measure, C, for the individual implies that,

$$v(p, q_1, y - C) = v(p, q_0, y)$$

while the equivalent variation hicksian measure, E, for the individual implies that,

$$v(p, q_1, y) = v(p, q_0, y + E)$$

C and E above are measures of value and their interpretation depend on whether the change of q is an upgrade or deterioration. If the change in q is an upgrade, then C represents the individual's WTP to enjoy the upgrade while E is his minimum WTA to miss out from the upgrade (Carson & Hanemann, 2005). On the other hand, if the change is a deterioration, C is the individual's minimum WTA to be subjected to the deterioration and E is his maximum WTP to avoid the deterioration (Carson & Hanemann, 2005).

You may have noticed that in some parts of the chapter both WTP and WTA have been mentioned and this could be confusing. It is important to note that both WTP and WTA are measures that exhibit value. The decision to use either WTP or WTA lies in the individual's property rights with regard to the asset in question (Mitchell & Carson, 1989, p. 23). When the individual has an entitlement of the good then this means that they are entitled to a compensation and in this case the WTA value is what is captured. In the case where the individual has no "ownership rights" the WTP measure is applied. In this study, the latter has been applied. It is also important to clarify that, the WTP question in this study is measuring the Hicksian consumer surplus measure of Compensating Variation since it captures an improvement.

4 Data and Methods

In this chapter I will discuss the sampling, data collection techniques and statistical models I use in this study.

4.1 Population of Interest

Identifying your population of choice is a fundamental step when carrying out any stated preference study. Your target population choice should be guided by "the extent of the market" (Johnston et al., 2017, p. 341). Extent of market refers to the section of people that would face a welfare effect from the change being evaluated (Johnston et al., 2017, p. 341). My study focuses on the willingness to pay for solar home systems. SHSs are stand-alone systems and pretty much used as an alternative source of electricity in areas not connected to the grid. In addition, my jurisdiction of interest is Kilifi county, one of the identified under-served counties in Kenya (Balla & Patrick Thaddayos, 2017). For this reason, 200 households participated in the survey all of whom live in off-grid areas in Kilifi County. Kilifi county has 7 sub-counties.

4.2 Survey Design

The article by Johnston et al. (2017) provides a rich guidance on what to consider when conducting a stated preference study. These guidelines are at the core of my study's survey design and its administration. The survey design of any stated preference study contributes to its degree of reliability and validity (Johnston et al., 2017). A good survey design enhances minimal bias and consistency of the results, and this translates to improved representativeness.

To achieve the valuation objective of any stated preference study, it is necessary that there exists a clear distinction between the status quo and the proposed change (Johnston et al., 2017). It is this distinction that forms the basis of the valuation by the subjects. The survey design affects how subjects approach the valuation process and this has a spill-over effect on the results obtained. It is therefore important that a proper survey instrument choice is made (Johnston et al., 2017).

The survey instrument developed for my study was a thirteen-page Swahili translated questionnaire, originally in English (attachment A1). The questionnaire consisted of seven parts. The first part of the questionnaire contained questions on the attitudes to different public services. Respondents were asked how important or unimportant they thought it was to address or achieve the listed public services. This part of the questionnaire was aimed at setting the atmosphere for the interview and building rapport. Part two of the questionnaire introduced to the respondents what solar home systems are. The households were asked whether they owned one. Those households that answered yes, were asked additional questions to capture the attributes of their solar home systems. In addition, part two of the questionnaire captured the energy sources that the households had used in the last month for different tasks.

The third part of the questionnaire covered willingness to pay. With the growing solar home systems market, packages with varying attributes keep emerging. Arguably solar home systems in general provide electricity, but it is necessary to differentiate between them based on their performance. The multi-tier framework developed by ESMAP acts a guideline in classifying the quality of energy access by different sources of electricity (Bhatia & Angelou, 2015). Generally, solar home systems range between tier 1 and tier 3. Small solar home systems of between 3 to 49 Watts lie within tier 1, mid-size solar home systems of between 50 to 199 Watts are placed in tier 2 and large solar home systems with a minimum of 200 watts, which are rare, lie within tier 3 (Bhatia & Angelou, 2015).

In the study, three different types of solar home systems were described, namely system 1, system 2 and system 3. It was important for us to not only measure the willingness to pay for solar home systems in general, but to separate them according to their energy access level. Respondents were issued a card that had attributes of the three different solar home systems. The card had photos of the three[6], as well as written characteristics to enable the respondents to identify the differences between the three systems. The attributes of the solar home systems were randomly selected from the Lighting Global products section that lists certified solar home systems (Lighting Global, 2019). System 1 described was a tier 1 15 watts SHS, system two was a tier 2, 50 watts SHS and the last system was a tier 3, 200 watts SHS. The power (watts) was not disclosed to the respondents to prevent the, from linking the systems to specific SHS providers, as this may introduce bias.

Respondents were asked to state the maximum amount their households would certainly be willing to pay, for each system monthly for a period of three years. The payment card amounts ranged from 0 to 5,000 Kenya shillings[7]. The study adopted payment options similar to those of the Pay

[6] The photos of the card can be seen in Part IV of the questionnaire, A.1.4
[7] 1 USD = 100 Ksh as at 3rd February 2020 (Central Bank of Kenya, 2020)

As You Go (PAYG) model that is widely used in the Kenyan solar home system market (Adwek et al., 2019). Though hypothetical, it is important that stated preference studies mirror what the actual markets look like to improve the validity (Johnston et al., 2017).

The questions in part four and five captured, knowledge about and attitudes to solar home systems, and, environmental awareness, respectively. Respondents were asked to what extent they agreed or disagreed with the different statements. Part six was simply a self-reported happiness index measured on a scale of 1 to 10. Respondents were asked to rate how satisfied or dissatisfied they were with life in general, with 1 being extremely dissatisfied and 10 being extremely satisfied. The last part of the questionnaire comprised of household demographics. The respondents were also asked how they felt about the study and their comments were welcomed. This kind of question captures the subjects' feedback on the survey instrument (Johnston et al., 2017) .

4.3 Survey Pretesting

An elaborate understanding of the survey instrument by subjects can be considered as one of the desirable milestones for any value elicitation procedure. It is very important that a researcher is convinced that the survey instrument of choice meets its objective before rolling out the main survey. Survey pretesting is a vetting process for the intended survey instrument. By rolling out a pre study, the researcher captures the comprehensibility and suitability of the survey instrument to the target population (Johnston et al., 2017). It is essential that respondents understand exactly what is being asked of them without too much struggle.

The pre study should mirror the intended main survey as much as possible. It is important that the subjects interviewed are part of the target population to enable informed inferences (Johnston et al., 2017). Findings gathered from the pre study are analysed and necessary adjustments to the instrument are made to increase the validity of the study.

This study was not exemptional from a survey pretesting. A pre-study involving 25 households was conducted. This helped to learn how the respondents perceived the questions asked, and whether the questions met their objective. From the survey pretesting we realized that the respondents had some difficulties interpreting the payment card. It was easier for them to have daily payment rates included besides the monthly, yearly, and three-year price breakdown. Some respondents received their income daily and it was simpler for them to make a realistic decision of their willingness to pay with daily rates available. This was adopted in the main survey.

4.4 Sampling and Data Collection

Proper sampling is one of the key elements to a successful survey and its importance can never be over-emphasized. A sample should be a mini version of the population of choice (Fink, 2003). The sample should be able to "speak" for the population with high accuracy, and the specific research questions of the study should form the baseline of who to include and who not to include, otherwise known as the eligibility criteria (Fink, 2003). Sampling procedures are divided into two broad categories, namely probabilistic sampling and non-probabilistic sampling (Ferligoj & Mrvar). Probabilistic sampling involves random samples, and, in this case, it is possible to calculate the chance of being selected, while non-probabilistic sampling consists of non-random samples. Non-random samples are mostly drawn out of convenience, and it is not possible to calculate the chance of selection (Fink, 2015).

Sampling for this study was done in two main phases. Stratified sampling was applied for the villages, and random walk and systematic sampling for the households. Stratified sampling entails dividing the target population into sub-sets otherwise known as "stratas", and then drawing a random sample from the strata (Fink, 2003). Random walk and systematic sampling are a combination of two sampling procedures. For the random walk, you determine a starting point and randomly select the direction to follow. The households to participate are then selected systematically such that there is a pre-determined sampling interval, for example every 4^{th} household.

k=N/n where k==sampling interval

N==Population size

n==sample size

The starting point for a random walk usually is determined using a map that has clearly marked boundaries. Obtaining administrative boundary maps often proves difficult especially in developing countries, and for this reason the expanded programme of immunization (EPI) method is applied (Bostoen & Chalabi, 2006). The EPI method allows you to choose a central location as the starting point, for example a market or a landmark within the community and then randomly select the direction to follow (UNICEF, 1995).

In the study, the villages were stratified according to their distance from the grid; four villages were closer to the grid while the remaining 4 were further away from the grid. The households' distance from the grid ranged from 0.5km to 36km. To select our households, we had a local guide who joined us to help us maneuver. The market served as starting point in 7 of our villages and a school served as the starting point for the remaining village.

To estimate the number of households in each village, a local "Nyumba Kumi" elder was consulted. "The "Nyumba Kumi" initiative is a community policing strategy in Kenya. It allows community policing at the household level or any other generic cluster" (National Police Service, 2017, p. 3). Knowing the estimated number of households in the village helped us calculate the sampling interval. We then randomly chose the direction to start for each interviewer by flipping a pen. Most of the households were scattered and practically did not follow a straight path. As a rule, we alternated right and left each time we came across a turn. The process continued until we reached the targeted number of households for each village.

4.5 Sample Representativeness

Sample representativeness entails the generalizability of the sample data to the population (Johnston et al., 2017). Whereas it may be possible that unrepresentative samples have some traits that are present in the population, to some degree, the unrepresentative nature hinders generalizability (Johnston et al., 2017, p. 368). It is important that stated preferences studies try to demonstrate the representativeness of the sample or otherwise disclose that the sample is not representative.

In this study, as advised by Johnston et al. (2017), I have compared some socio-economic variables in my sample with the data from Kenya's 2019 Population and Housing Census conducted (KNBS, 2019a, 2019b) to try and see how generalizable the sample is. When comparing our sample data to the entire Kilifi County, we observe a variation, as shown in table 2 below. This is expected given that our study only focuses on the rural villages that are not served by the grid and yet Kilifi County has several metropolitan towns and cities. When I compare the sample data to that of Ganze Sub-County in Kilifi County, we see a smaller deviation. I chose Ganze Sub- County, first because it was one of the sub-counties that we drew our sample from and secondly, it is listed as one of the Sub Counties in Kilifi County with least access to electricity (Norken International Ltd, 2017).

Table 2: Sample Versus Population Characteristics

Variable	Sample	Ganze Sub-County	Population in Kilifi[8]
Average Household Size	6	6.2	4.8
House ownership: Owning	90.5%	93.3%	66 %
Iron sheet roofs	57.5%	79.2%	71.6%
Dirt Floor	71.5%	86.9%	54.3%
Use firewood for cooking	76%	91.1%	58.2%

4.6 Data Analysis Techniques

Correctly estimating the true willingness to pay is key in the empirical analysis of CV studies. The true willingness to pay is unknown for most individuals and CV studies have adopted different methods to assist in the value elicitation procedure (Cameron & Huppert, 1989). The payment card (PC) approach is one of the adopted methods. The PC presents individuals with a range of ordered values, and the individuals are then asked to state their maximum WTP (Cameron & Huppert, 1989). Responses to the payment card, the observed values, are considered to be "the minimum indicator of the true maximum WTP" (Voltaire, 2015, p. 2238).

In this study, the WTP model[9] specified for the 3 systems, is,

$$WTP = \beta_0 + \beta_1 hh_{sex} + \beta_2 hh_{age} + \beta_3 hh_{edu} + \beta_4 hh_{child} + \beta_5 hh_{income} + \beta_6 hh_{happiness} + \beta_7 hh_{env_{awar}}$$

Five econometric models are considered in our WTP estimation in this study. These models borrow from the models developed by Hackl and Pruckner (1999) on how to estimate WTP while using

[8] Population statistics based on 2019 Population and Housing Census.
[9] Distance from the grid was not included in the model because it is highly positively correlated with income.

the payment card approach. The chosen values from the PC can be considered directly, and thus, an ordinary least square (OLS) model can be estimated using the PC values. From the fact that the PC gives an ordered range of values, we can infer that the true WTP lies between the chosen value and the next highest value in the given range (Cameron & Huppert, 1989). Model 2 estimates the true WTP from the interval mid-point, that is, the mean of the chosen value and the next highest value. The midpoint is used as a proxy and an OLS model estimated.

An interval regression model is the third model estimated. The HH true WTP is taken to lie between an interval; the chosen values from the PC and the next highest value. Another model estimated is the logit model. For the logit model we create a binary dependent variable of the WTP, where 0 indicates a zero WTP and 1 indicates a positive WTP. Finally, we use the tobit model. The model is relevant since we have zeros among our observed WTP and in addition the observed WTP is censored by the PC ranges. To shed more light, I will in the next sub-headings discuss each estimation model and explain the conditions that must be satisfied. All the model illustrations used are guided by (Wooldridge, 2016) unless stated otherwise.

4.6.1 OLS

The OLS estimation method can be used in multi-linear regression models. This method "minimizes the sum of square residuals" (Wooldridge, 2016, p. 59). We will now discuss the different assumptions that need to be considered when deriving OLS estimators.

Consider the model

$$y_t = x_t\beta + \mu_t$$

y_t is the dependent variable, in our case WTP and $x_t\beta$is the vector of the independent variables and $\mu_t$is the error term.

When assumptions 1-4 below are met, the OLS estimators are said to be CAN, that is, Consistent and Asymptotically Normally distributed. This yields unbiased estimators to the population parameter, that is, the sample estimate do not have significant disparities from the population value (Wooldridge, 2016).

$$E(\hat{\beta}) = \beta$$

These assumptions have been clearly outlined by Wooldridge (2016, pp. 74-76) and can be referred upon.

1. The population model is "linear in parameter".

$$y = x\beta + \mu$$

2. The data has been obtained through random sampling
3. There exists no perfect correlation between the independent variables. This would lead to perfect collinearity.
4. The expected value of the error term given the independent variables is zero. The error term and the independent variables should not be correlated. Correlation between the error term and the independent variable results in an endogeneity problem.

$$E(\mu|x) = 0$$

The OLS estimator is more efficient when a fifth assumption is met; the homoskedasticity assumption.

5. The variance of the error term is constant regardless the values the independent variables take.

$$Var\ (\mu|x) = \sigma^2$$

When all the five assumptions have been met, the OLS estimator is termed as BLUE, best (small variance) linear unbiased estimator. These five assumptions are the Gauss-Markov assumptions when dealing with cross-sectional data(Wooldridge, 2016).

4.6.2 Interval Regression

The interval regression model is a censored regression used when we only know the range in which the true value lies, but not the actual observation (Wooldridge, 2016). In our case, the true WTP, WTP* is unknown. Our PC had seven ordered WTP choices from zero to 5,000. Let us assign a value WTP_1 for the 1st choice, WTP_2 for the second all the way to WTP_7 for the seventh choice where $WTP_1 < WTP_2 < WTP_3 < \ldots\ldots < WTP_7$. Assuming a household chooses WTP_3, the true WTP for this household lies within the interval $WTP_3 \leq WTP^* < WTP^4$ in the interval regression approach. The interval regression model on stata assumes two dependent variables, a lower limit, and an upper limit (StataCorp, 2013).

The interval regression model is estimated using maximum likelihood (Wooldridge, 2016). Consider the model below which is borrowed from (Cameron & Huppert, 1989)

$$y_i = x_i\beta + \varepsilon_i \; \varepsilon_i|x_i, \sim\text{Normal}(0, \sigma^2)$$

The subscript i represents a random draw for HH i. y_i in our case would represent the true WTP for HH i. We can take y_i to lie within a lower limit l_l and an upper limit l_{l+1}. The probability of y_i occurring is therefore

$$\Pr(l_l \leq y_i < l_{l+1}) = \Pr(l_l \leq x_i\beta + \varepsilon_i < l_{l+1}$$

The log-likelihood function for n number of observations is,

$$\ln L = \sum_{1=1}^{n} \log\,[\Phi\,(l_l) - \Phi(l_{l+1})]$$

where $\Phi$is the cumulative standard normal distribution.

4.6.3 Logit

The logit model is a type of a binary response model. In a binary response model, the dependent variable takes the value of 0 or 1, and we are interested in finding the probability of the responses (Wooldridge, 2016) .

$$P(y = 1|x)$$

The model above would in our case be explained as the probability of a positive WTP given a set of explanatory variables. y=1 when there is a positive WTP and 0, otherwise.

In probability theory we know that the probability of an occurrence should lie between zero and one (Feller, 2008). Binary response models are specified to satisfy this condition as illustrated below.

$$P(y = 1|x) = G(x\boldsymbol{\beta})\; and \; 0 < \text{ G(z) } < \text{ 1}$$

The function G takes on values that are strictly between 0 and 1, and this in turn ensures that the probabilities lie between 0 and 1(Wooldridge, 2016, p. 525).

The logit model assumes a logistic distribution of the G function.

$$G(z) = \frac{e^z}{1 + e^z}$$

It can be derived when we have a latent, unobserved variable. Consider the model below.

$$y^* = x\beta + \mu ,$$

$$y = 1_{[y^*>0]} = \begin{Bmatrix} 1, & y^* > 0 \\ 0, & y^* \leq 0 \end{Bmatrix}$$

y* represents the latent variable, in our case the unobserved True WTP, and y, the observed WTP. You observe whether a household is willing to pay or not to pay, that is y. When the household has a positive willingness to pay, y=1. It therefore translates that the observed WTP, y =1 when the true WTP, y* is greater than 0 and it is 0 when y* is less than, or equal, to zero.

When you are dealing with a logit model, you are interested in knowing the effect of an explanatory variable, say x_j on the probability P(y=1|x). The first derivative shows the direction of change unlike in other models, such as OLS where this represents the marginal effect. β_j below represents the directional change and not the effect of $x_j$on y^*.

$$\frac{\partial E(y^*/x)}{\partial x_j} = \beta_j$$

The direction tells us whether x_j has a positive or a negative effect.

If the explanatory variable x_j is a continuous variable, the marginal change in the response probability as a result of x_j is given as

$$\frac{\partial P(y = 1|x)}{\partial x_j} = \frac{\partial p(x)}{\partial x_j} = g(x\beta)\beta_j \text{ where } g(z) \equiv \frac{\partial G}{\partial z}(z)$$

We could also possibly have a variable x_2 as a dummy explanatory variable. In this case, the marginal change in the response probability resulting from changing x_2 from zero to one is

$G = (\beta_0 + \beta_1 x_1 + \beta_2 + \cdots + \beta_k x_k) - (\beta_0 + \beta_1 x_1 + \cdots + \beta_k x_k)$.

In the case of a discrete or continuous variable say x_l the marginal change in the response probability as a result of x_l , moving from c_l, to c_{l+1} , can be derived as

$$G[(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_l(c_l + 1)] - G(\beta_0 + \beta_1 x_1 + \beta_2 x_2 \ldots + \beta_l c_l).$$

Logit models are estimated using the maximum likelihood estimation method. "Because MLE is based on the distribution of y given **x**, the heteroskedasticity in Var $(y|x)$is automatically accounted for"(Wooldridge, 2016, p. 528).

The log-likelihood function for observation i is obtained by taking the log form of the density function.

Density function: $f(y|x_i, \beta) = [G(x_i\boldsymbol{\beta})]^y\,[1 - G(x_i\boldsymbol{\beta})]^{\mathbf{1}-\boldsymbol{y}}\ , y = 0{,}1$

Log-likelihood function: $l_i(\boldsymbol{\beta}) = y_i \log[\,G(x_i\boldsymbol{\beta})] + (1 - y_i)\log[\,1 - G(x_i\boldsymbol{\beta})]$

With a sample size n, the sample log-likelihood function is a summation of the above

Log-likelihood function for n: $L(\boldsymbol{\beta}) = \sum_{i=1}^{n} l_i(\boldsymbol{\beta})$

4.6.4 Tobit

The tobit model is used with strictly positive limited dependent variables that include zeros with positive probability. In our case, the observed WTP for SHS ranges from zero to 5000. A portion of households state their WTP to pay as zero and this results in a mass point of 0 in our data. Applying the tobit model caters for these corner solution responses, the censoring resulting from the PC ranges. and ensures that we do not have negative predicted values for the WTP.

The observed WTP, y, is expressed as a latent variable y*. A representation of the tobit model is shown below.

$$y^* = x\beta + \varepsilon \quad \varepsilon|\mathrm{x} \sim \mathrm{Normal}(0, \sigma^2)$$

Observed outcome: $$y = \begin{cases} 0 \ \ if\ y^* < 0 \\ y^*\ if\ 0 \le y^* \le 5000 \\ 5000\ if\ y^* \ge 5000 \end{cases}$$

The tobit model uses the maximum likelihood estimation method. The estimator is said to be CAN and efficient if,

1. The latent variable population model is linear in parameters
2. Data has been obtained through random sampling
3. No perfect correlation among the regressors
4. The expected value of the error term given the regressors is zero
5. The error terms are independent and identical normally distributed. (Wooldridge, 2016)

5 Results

In this chapter, I will analyse and discuss the results of this study. In the last part of the chapter I will compare the hypotheses and the findings.

5.1 Descriptive Statistics

5.1.1 Sample Summary

The data from this study was collected from 200 off grid households across Kilifi County. Sample descriptive statistics are summarized in Table 3 below. The average distance of the households from the grid was 14.14 km, with 0.5km being the closest and 36km the furthest. 81.5% of the interviewed households were male headed households while the remaining 18.5% were female headed households. In addition, 79% of the household heads were married and 10.5% never married. The remaining 10.5% were either separated, divorced, or widowed

The mean age for the household heads was 41.5 years, with the youngest being 19 and the oldest 76. On average, the household size was approximately 6 individuals per households. The range of the household size was between one and 23. For each household there is on average at least one individual with paid work. Furthermore, the average number of children below the age of 18 years is 3 for each household.

When asked about their education level, 52% of the household heads reported to have a primary school education level, 22.5% high school level and 16% had no schooling. The remaining 10% had an above high school level of education. Looking at the occupation status, 47% of the household heads were self-employed, 29% worked on a part-time basis, 16% on full-time basis and 8% had no occupation.

Seventy percent of the respondents acknowledged to having received income in the previous month and 30% did not. The respondents were also asked how frequently they received their earnings. 42% responded that their income frequency varied, 29% said they received their income daily, 17.5% said they received their income monthly and 5.5% on a weekly basis. Data on average household income was collected in ranges. 30% of the households received a monthly income of between Ksh10,001-20,000, 28% received a monthly income of between 3,000-10,000 and 12% and 11% received a monthly income of between 20,001-30,000 and 30,001-40,000 respectively.

When asked about their total monthly household expenditure, the households reported to spend on average Ksh 14725. The household with the lowest monthly expenditure spent Ksh 2500 and the highest monthly expenditure was Ksh 72500. Looking at the item specific expenditures, households reported a monthly average of Ksh 2734 on school fess, Ksh 6226.4 on food and Ksh 5422 on other goods and services. In addition, the average monthly rental expenditure for the whole sample was Ksh 408. It is however important to note that only 9.5% of the sample lived in a rented house, the remaining 90.5% owned their houses. The average rental expenditure for those households who lived in rented houses was Ksh 4294.

In terms of non-productive asset ownership, 91% of the households owned a mobile phone, 60% owned a radio, 26.5% owned a TV, 26% owned a bicycle, 22.5% owned a motorbike and only 2.5% owned a car.

As for the living conditions, 49.5% of the households lived in a semi-permanent house, 25.5% in a permanent house and 25% in temporary houses. 57.5% had iron sheets roofs and 42.5% thatched houses. 71.5% of the households' houses had dirt floors, 24.5% concrete floors and 4% tiled floors.

Lastly, the mean happiness level was approximately six, with the minimum reported being 1 and the maximum 10. Just a reminder that the happiness question was asked before the demographics data was collected to try to avoid any bias that may be caused by the personal questions on household characteristics and income.

5.1.2 Solar Home Systems

Forty three percent of the households owned solar home systems. The 40W SHS size was the most popular, covering 55.81% of the households owning a SHS. Table 33 in the appendix shows the distribution of the different sizes of the solar home systems owned. Following the lighting global multi-tier classification (Bhatia & Angelou, 2015), 66.27% of the households that owned a SHS had a tier 1 SHS and 31.4% had a tier 2 SHS. On average the respondents reported to get 12 hours of light from their SHS with the least number of hours being 6 and the maximum 20 hours.

Seventy out of the 86 households that owned solar home systems, were on a Pay as you Go (PAYG) payment plan. On average the households paid Ksh 2070 monthly with the minimum monthly payment being Ksh 900 and the maximum Ksh 6000.The average total amount that the households would have to pay before they can fully own the SHS was Ksh 53949, with the lowest being Ksh 7000 and the highest Ksh 163000. The remaining 16 households who already fully owned the SHS had paid on average Ksh 12225 for their SHS, with the cheapest being Ksh1000 and the most expensive Ksh 81000. Out of these 16 households, 11 had made one payment while acquiring their SHS while the remaining five had acquired it through the PAYG payment plan.

Table 34 in the appendix summarizes the payment options that the respondents preferred. More than 87 percent of the respondents preferred leasing the SHS and finally owning it after the leasing period is over, and 5.5% preferred making a one-off payment with a service agreement. When the respondents were asked what their willingness to pay for the service agreement was, 100% reported "don't know".

Table 3: Descriptive Statistics

Variable	**Description**	**Mean**	**Std. Dev.**	**Min**	**Max**	**Obs**
Dist	Distance from the grid in kilometres	14.145	12.995	.5	36	200
Hhead_age	Household head age in years	41.57	12.973	19	76	200
Sex	Sex dummy, 1 if female 0. otherwise	.185	.389	0	1	200
HH_Children	Number of children below 18 years in the Household	2.845	2.599	0	14	200
HH_paidwork	Number of people with paid work in the Household	1.52	1.435	0	17	200
Income	Income in Ksh based on midpoints of income ranges	19574.36	16222.15	1500	95000	195
Schfees	School Fees Expenditure in Ksh	2734.48	4383.628	0	43000	200
Food	Food Expenditure in Ksh	6226.4	4316.155	500	30000	198
Rent_Exp	Rent Expenditure in Ksh	408	1766.618	0	15000	200
Other_exp	Other Expenditure in Ksh	5422.52	8509.765	0	75000	200

tot_exp	Total expenditure in Ksh	14725.93	10800.79	2500	72500	198
Happiness	Happiness level measure from a scale of 1 to 10, with 1 being extremely dissatisfied and 10, extremely satisfied.	5.875	2.528	1	10	200
SHS_ind	Dummy 1 if owning SHS 0, otherwise	.43	.496	0	1	200
SHS_Fullypaid	Total amount paid for SHS for HH that fully own it	12225	19807.15	1000	81000	16
SHS_total	Total amount to be paid, in Ksh, for SHS for HH that are still paying	53949	38278.86	7000	163000	70
SHS_monthly	Monthly amount, in Ksh, HH are paying for the SHS	2070	924.5634	900	6000	70
SHS_Hrs	Average number of hours of light HH reported to be getting from their SHS	12.197	3.009	6	20	86
Radio	Dummy 1 if owning radio, 0 otherwise	.6	.491	0	1	200
TV	Dummy 1 if owning TV, 0 otherwise	.265	.442	0	1	200
Mobile	Dummy 1 if owning mobile phone, 0 otherwise	.91	.287	0	1	200
Bicycle	Dummy 1 if owning bicycle, 0 otherwise	.13	.337	0	1	200
Motorbike	Dummy 1 if owning motorbike, 0 otherwise	.225	.419	0	1	200
Car	Dummy 1 if owning car, 0 otherwise	.025	.157	0	1	200
Income_last month	Dummy 1 if did not receive income last month, 0 otherwise	.3	.459	0	1	200
House_own	Dummy 1 if owning house, 0 otherwise	.905	.294	0	1	200

5.2 Public Issues

To warm up the interview, respondents were first asked on how important or unimportant they perceived different public issues. Improving access to health facilities stood out as most important at 97% followed by extending the grid to the area at 93.5%. Only 43% of the respondents perceived stricter enforcement of restriction to the forest to collect firewood as very important. Table 4 below shows a summary of their perception for the different public issues from the 200 respondents.

Table 4: Public Issues Perception, by percentage of respondents

Public Issue	**very important**	**somewhat important**	**somewhat unimportant**	**not important at all**	**don't know**
Improving Primary and Secondary Schools	83.5	11.5	3.5		1.5
Extending the grid to your area	93.5	4.5	2		
Stricter enforcement of restricting access to the forest to collect firewood	43	14	22	20	1
Improving access to health facilities	97	2.5	0.5		
Making private solar equipment more affordable	81.5	15	2	1.5	
Improving security	88.5	7.5	3.5	0.5	

5.3 Energy Use

Data on household's energy sources for different tasks was analysed, as shown in table 5 below. For lighting, 42% of the households depended on electricity from solar, 39% from kerosene and 10.5% from battery. Seventy six percent of the households depended on firewood for cooking and 14% on charcoal. Only 8% of the households used gas for cooking.

For mobile charging, only 191 responses were captured, from which 76.44% relied on electricity from solar and 20.94% relied on battery. Despite only 86 households owning solar home systems, 146 households depended on solar for mobile charging. The households without SHS depended on neighbours for mobile charging. This came at a small fee of around Ksh 20 per charging.

For the households that owned a TV or a radio, 66.67% depended on electricity from solar and 32.26% depended on battery energy. Only 13 households responded that they were using an energy source for farming, all of whom used diesel. None of the households used any energy source for refrigeration or cooling.

Table 5: Energy sources for different tasks, by percentage of respondents

Energy Source	Solar	Gas	Kerosene	Diesel	Charcoal	Firewood	Dung	Battery	Other	Freq.
Lighting	42		39	0.5				10.5	8.0	200
Cooking		8	1.5		14	76	0.5			200
Mobile Charging	76.44							20.94	2.62	191
Television/ Radio	66.67			1.08				32.26		93
Farming				100						13

5.4 Willingness to Pay

5.4.1 Mean WTP

To determine the WTP levels for solar home systems is one of the specific objectives for this study. The mean WTP in this study is analyzed in three ways; based on the payment card (PC) values, based on the interval midpoint values, and based on the censored interval. The results of the three are summarized in table 6, table 7 and table 8.

I first present the analysis using the PC values. Based on the PC value, the mean and median monthly WTP for system one was Ksh 793 and Ksh 833 respectively with the minimum WTP being 0 and the maximum Ksh 3500. For System two, the mean and median monthly WTP was

Ksh 1227 and Ksh 1450 with a minimum of 0 and a maximum of 3500 based on the PC values. The mean and median monthly WTP for system three was Ksh 1283 and Ksh 833 with a min of 0 and a maximum of Ksh 5000 based on the PC value.

When using the interval mid-points, the mean and median WTP was Ksh 1154 and Ksh 1141.5 for system one. For system two the mean and median WTP was Ksh 1658 and Ksh 1875, respectively. System three, on the other hand, had a mean and median WTP of Ksh 1708 and Ksh 1141, respectively.

Lastly, an unconditional mean was estimated using interval regression. This was achieved by estimating an interval regression while excluding the explanatory variables. The unconditional mean WTP was Ksh 1153 for system one, Ksh 1642 for system two and Ksh1705 for system three.

Using total expenditure as a proxy for income, households were willing to pay 7.84% of their income to pay for system 1, 11.25% for system 2 and 11.6% for system 3.

I used a t-test to establish whether there exist, statistical differences between the mean WTP of the three systems. The t-tests results have been attached in the appendix; tables 22, 23 and 24. While using the raw data from the PC, the results show that there exists statistical differences between the mean WTP for system one and system two, as well as system one and system three. However, for system two and system three their mean WTP are not statistically different. The results interpretation does not change when the interval mid-point WTP is used.

Table 6: Mean monthly WTP in Ksh for system one

WTP for system 1	Obs	Mean	Median	Std. Dev.	Min	Max	95% confidence. interval	
Payment card value	200	792.9	833	579.964	0	3500	710.3	875.5
Midpoint value	200	1154.49	1141.5	599.807	416.5	3850	1070.86	1238.13
Interval censored value	200	1153.29					1074.3	1232.28

Table 7: Mean monthly WTP in Ksh for system two

WTP for system 2	Obs	Mean	Median	Std. Dev.	Min	Max	95% confidence. interval	
Payment card value	200	1227.78	1450	947.6364	0	3500	1095.64	1359.91
Midpoint value	200	1657.97	1875	989.201	416.5	3850	1520.04	1795.90
Interval censored value	200	1642.86					1507.13	1778.59

Table 8: Mean monthly WTP in Ksh for system three

WTP for system 3	Obs	Mean	Median	Std. Dev.	Min	Max	95% confidence. interval	
Payment card value	200	1283.4	833	1500.765	0	5000	1074.13	1492.66
Midpoint value	200	1708.29	1141.5	1492.705	416.5	5000.5	1500.15	1916.43
Interval Censored Value	200	1705.74					1498.37	1913.10

Figures four, five and six below show the distribution of the WTP in Ksh using the PC values and the interval midpoints. The distributions show that WTP is skewed to the right. A skewness test on stata confirms this by rejecting the null hypothesis of normality. The results have been attached in table 25 in the appendix.

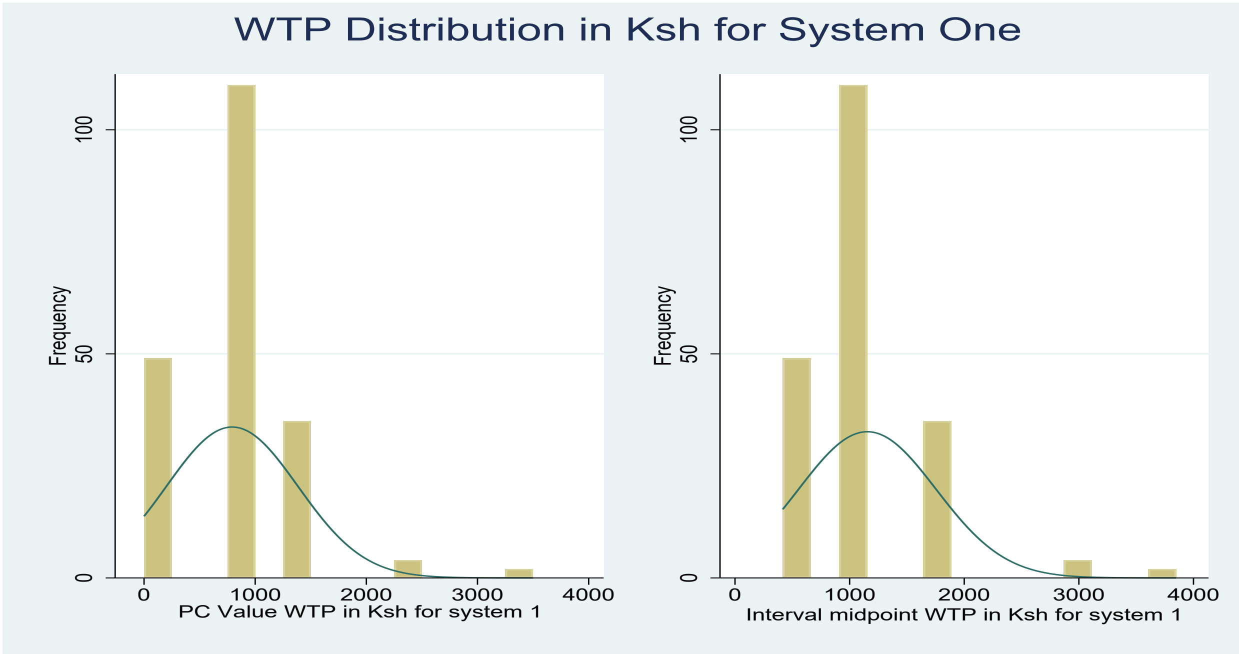

Figure 4: WTP Distribution for system one

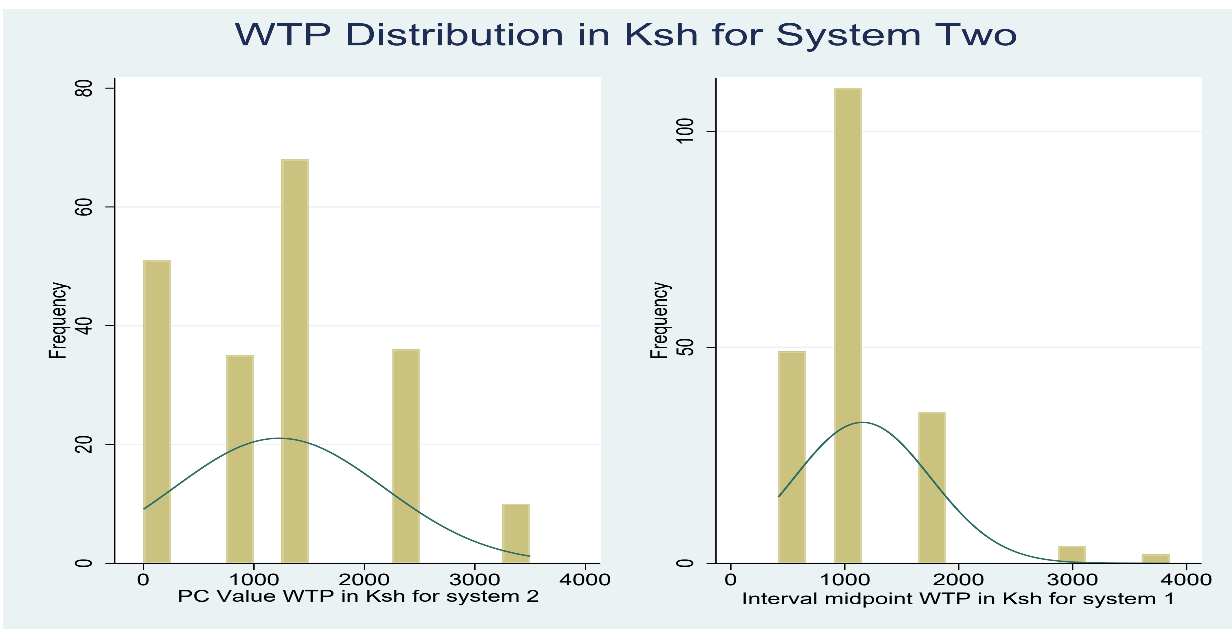

Figure 5: WTP Distribution for system two

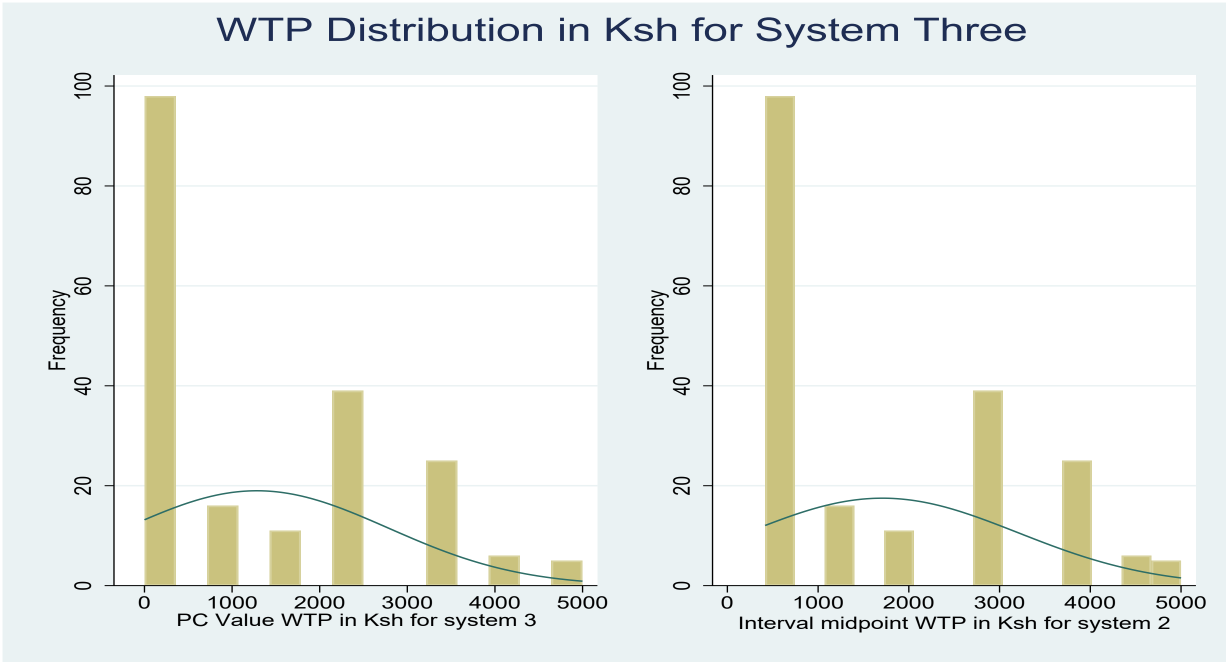

Figure 6: WTP Distribution for system three

5.4.2 Zero WTP

Respondents who had a zero WTP were asked to give their most important reason for having a zero WTP. For system 1, 48.89% of the respondents said they would need a bigger system and 28.89% said they cannot afford it. For system 2, 66% said they cannot afford it, 14% said they only need a smaller system and 12% said they only need a bigger system. Lastly, for system 3, 82.18% said they cannot afford it and 14.85% said they only need a smaller system.

Table 9: Reasons for Zero WTP, by percentage of respondents

Reason for zero WTP for system 1	**Freq.**	**Percent**	**Cum.**
I cannot afford it	13	28.89	28.89
I am better off waiting until the grid	6	13.33	42.22
I do not own my house and cannot have it up in a rented house	1	2.22	44.44
I only need a smaller system	1	2.22	46.67

I only need a bigger system	22	48.89	95.56
Other, please specify	2	4.44	100.00
Total	45	100.00	
Reason for zero WTP for system 2	**Freq.**	**Percent**	**Cum.**
I cannot afford it	33	66.00	66.00
I am better off waiting until the grid	3	6.00	72.00
I do not own my house and cannot have it up in a rented house	1	2.00	74.00
I only need a smaller system	7	14.00	88.00
I only need a bigger system	6	12.00	100.00
Total	50	100.00	
Reason for zero WTP for system 3	**Freq.**	**Percent**	**Cum.**
I cannot afford it	83	82.18	82.18
I am better off waiting until the grid	2	1.98	84.16
I do not own my house and cannot have it up in a rented house	1	0.99	85.15
I only need a smaller system	15	14.85	100.00
Total	101	100.00	

It is important to also evaluate whether there are protests zeros in my sample. In this study, I do not have any real protest zeros, as the reasons stated for zero WTP do not show protest behavior but rather state that they prefer for example system 2 to 3 because system 2 has what they need.

For the 31 respondents who gave the same WTP for 2 or more systems, 70.97% said the main reason was because they could not afford to pay more, and 29.03% said they did not see the difference between system 1 and 2.

Table 10: Reasons for same WTP

Same WTP	**Freq.**	**Percent**	**Cum.**
I cannot afford to pay more	22	70.97	70.97
I do not see the difference	9	29.03	100.00
Total	31	100.00	

5.5 Knowledge and attitudes to Solar Home Systems

The questions in this part of the questionnaire were divided into two; the first four questions sought to capture the attitudes that the households had on solar home systems and the remaining four aimed at analysing to what degree respondents knew how SHS work and what they can be used for. Fifty-six percent of the respondents disagreed that the grid would reach their village in the next 3 years. More than 92% strongly agreed that they would retain a private SHS even after the grid reached the village. Eighty-three percent of the respondents also agreed that a SHS was sufficient for their electricity need and 85% disagreed to wanting only to lease a SHS and stop the lease once the grid reaches them.

More than 91% of the respondents agreed that SHS can be income generating, 75.5% agreed that SHS can power appliances, 79.5% agreed that SHS power DC appliances and 91% agreed that SHS vary in size and capacity.

Table 11: Knowledge and attitudes to solar home systems by percentage of respondents

Knowledge and Attitudes Statements	**Strongly Agree**	**Agree**	**Disagree**	**Strongly Disagree**	**Don't Know**
1. In 3 years time, the grid will reach our village.	32.5	6.5	28	28	5
2. I would retain a private solar system even after the grid reaches the village	92.50	4.5	1.5	1.5	

3. A solar home system is sufficient for my household's electricity needs.	63.00	20.5	8.5	8	
4. I prefer not to own but to lease a solar home system and stop the lease once the grid reaches us.	7.00	8.00	20.0	65.00	
5. Solar Home Systems can be income generating.	77.50	14.00	1.50	3.00	4.00
6. Solar Home Systems can power appliances.	50.00	25.50	4.00	18.00	2.50
7. Solar Home Systems power DC appliances.	74.5	5.00	1.00	1.00	18.50
8. Solar home systems vary in size and capacity.	88.00	11.00			1.00

5.6 Environmental Awareness

To evaluate the respondent's environmental awareness levels, they were asked a set of six questions that had an environmental theme. Table 12 shows the degree to which the respondents agreed or disagreed to the given statements. 60.5% of the respondents agreed that they try not to deforest and the remaining 40% reported that they engage in deforestation. At least 92% of the respondents were aware that plastics are not good for the environment, at least 76.5% agreed that they plant trees at least once a year. 61.5% agreed that they try to keep their compound smoke free and the remaining 38.5% disagreed. 92% of the respondents agreed that they are careful on their water usage and 79% preferred to use manure than fertilizers.

Table 12: Environmental awareness by percentage of respondents

Environmental Awareness Issues	**Strongly Agree**	**Agree**	**Disagree**	**Strongly Disagree**	**Don't Know**
1. I try my best not to cut down trees	46.00	14.50	19.0	20.50	
2. I am aware that plastics are not good for the environment	76.00	16.00	0.5	4.00	3.5
3. I plant trees at least once a year.	61.50	15.00	8.50	14.50	0.50

4. I try to keep my compound smoke free	37.00	24.50	17.0	21.50	
5. I am careful on my water usage	63.00	26.00	9.50	1.50	
6. I prefer to use manure than fertilizers	71.50	7.50	4.00	11.50	5.50

To include a measure of environmental awareness in our regression models, I created an additive environmental index based on the responses to the above six statements. Each of these statements had a variable associated with it and the responses ranked from one to four, with one being "strongly agree", two "agree", three "disagree" and four, "strongly disagree". When creating the environmental awareness index, I considered the ranks assigned to each degree of response and used them as weights. For the response "don't know", I assigned it the weight five. It is important to note that, the, "don't know" option was not included in the interview to discourage non-response.

A variable summing the weights was generated. An individual who for instance responded strongly agree to all the six statements would have a weight of six and an individual who responded don't know to all the six statements would have their sum as 30. The final step was to convert the weights in an ascending order so that a higher number represents higher environmental awareness. This was done by subtracting 31 from the sum and using the absolute value of the resulting figure. I used 31 since as earlier mentioned the maximum possible value of the sum was 30. By subtracting 31 from the sum we now see that an individual who may have answered don't know to all the six statements now has a weight of one, and one who responded strongly agreed in the six statements had the maximum possible weight of 25, $1 \leq environmental\ index \leq 25$.

From our sample the mean and median value of our environmental awareness index was 20.21 and 20 respectively, with a minimum of 10 and a maximum of 25.

Table 13: Environmental index

Variable	Obs	Mean	Std. Dev.	Min	Max

Environmental index	200	20.21	3.460604	10	25

The histogram below is a graphical representation of the environmental awareness in the sample.

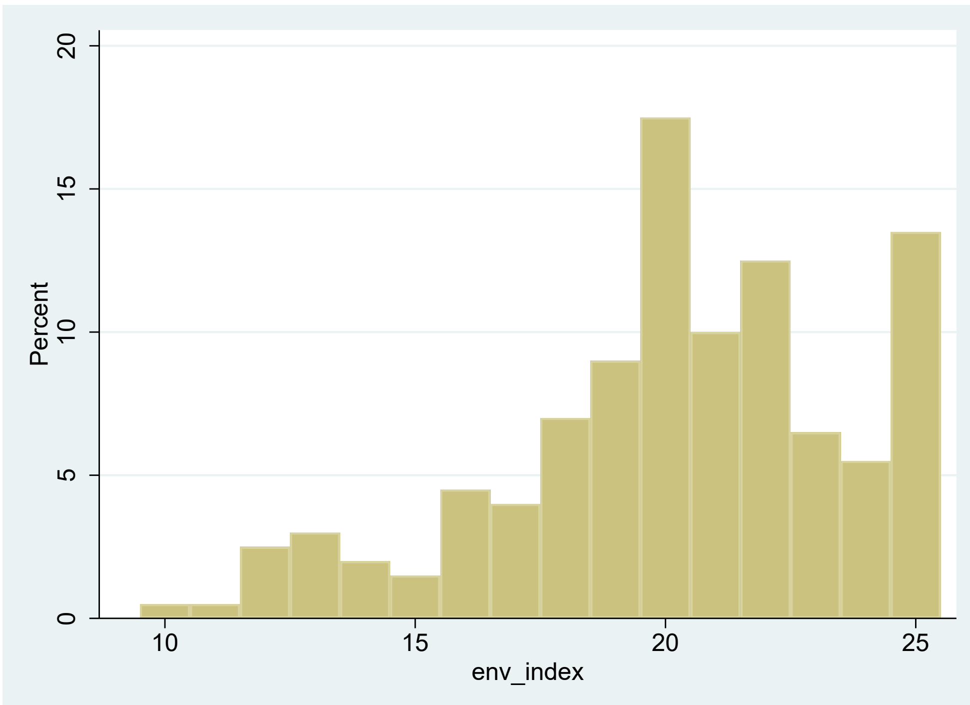

Figure 7: Environmental index distribution

5.7 Regression Results

Now we will look at the regression results of the models estimated for the three systems. Economic reasoning and common sense form grounds in the selection of variables (Wooldridge, 2016). You want to make sure that the variable selected guide you into obtaining an unbiased estimate that establishes a causal effect. In our model specification process, all potential explanatory variables had a backing from either or both economic theory and previous empirical studies. First, I generated a correlation matrix including all the potential variables to check for possible correlation between the variables. Different model specifications were then estimated and compared before settling done on the best.

The model was cleared from any multi collinearity suspicions by executing the variance inflation factor (VIF)[10] test. To check for model misspecification the Ramsey RESET[11] test was executed for all the OLS models. All OLS models were also tested for heteroskedasticity using the White test[12]. None of our models had heteroskedasticity issues. Since our explanatory variables mainly included demographics and no choice variable, endogeneity was not deemed as a possible problem in this study (Johnston et al., 2017). The models were also evaluated using the resulting adjusted R-squared or the Pseudo R-squared. Models with higher adjusted R-squared have a higher explanatory power and these are better (Pearce et al., 2002). In addition, the AIC and the BIC values are assessed. Models with lower AIC and BIC values are deemed as better models (Dziak et al., 2020)

Four OLS models were estimated; the first two used the raw PC and interval midpoints WTP values as the dependent variables, while in the other two the WTP dependent variable was log transformed. The log transformation is recommended since from previous studies, the WTP distribution is often skewed (Cameron & Huppert, 1989). In the log transformed OLS models, log (WTP+1) was used as the dependent variable. A log transformation of the income was also applied, log (Income+1). It is important to note that during data collection, income data was collected in intervals. To convert the categorical income data into a continuous variable the midpoints of the income ranges were calculated and used as the income variable. Notice that +1 is added in the log transformations. This caters for instances where either WTP or income may have been stated as 0 since the log of zero is not defined.

In our data, 4 households responded "Don't Know" when asked their average monthly income while one household was not willing to answer. These five observations were dropped in the regression. Our model results are therefore based on 195 observations.

5.7.1 OLS Models: Log Transformed WTP

In the OLS model using the log PC values, log of income and happiness were statistically significant at 10 percent and one percent significance levels respectively for system one. Having log transformed WTP and income values, help us obtain the income elasticity of WTP. We can

[10] See attachment A.6 in the appendix for the VIF test results.
[11] See attachment A.4 in the appendix for the Ramsey RESET test results of the OLS log transformed models.
[12] See attachment A.5 in the appendix for the White test results of the OLS log transformed models.

therefore see that, holding all other factors constant, a percentage increase in income would lead to a 0.45 percent increase in the WTP levels for system one. This is the income elasticity of WTP. In the case of happiness, a unit increase in the happiness level would lead to an expected 25 percent decrease in the WTP level for system one, ceteris paribus.

In the case of the logged midpoint OLS model for system one, happiness and income remain the two statistically significant variables. In this model the significance level for log (income+1) is stronger at 5 percent while the significance level for happiness is maintained at 1percent. From the coefficients, we see that a unit increase in the happiness level would lead to a 3.8 percent decrease in the WTP level, all else unchanged. For income, a one percent increase in the household's income level would result in a 0.09 percent increase in the WTP for system one, all else unchanged.

For system 2 in both the logged PC and logged midpoint OLS, only income is statistically significant at a 0.01 significance level. For the logged PC OLS, a 1percent increase in income will see a 1.12 percent increase in the WTP whereas in the midpoint OLS, a 1percent increase in income will see a 0.27 percent increase in the WTP for system two while holding all other factors constant. The income elasticity of WTP is generally higher for system two as compared to system one in both OLS models.

System three is the most expensive system of the three. In both the PC OLS and midpoint OLS models, income is highly significant at one percent significance level. Based on the PC values, a one percent increase in the household's income would result in a 1.17 percent increase in the WTP for system three while holding all other factors constant. When based on the midpoints, a one percent increase in the household's income would result in a 0.34 percent increase in the WTP for system three while holding all other factors constant. The number of children in a household is also statistically significant at five percent and 10 percent significance level for the PC and Midpoint OLS models, respectively. In the PC OLS model, a unit increase in the number of children in a household would result in a 23.9 percent decrease in the WTP for system three, holding all other factors constant whereas in the midpoint OLS model, a unit increase in the number of children in a household would result in a 5.5 percent decrease in the WTP for system three.

The explanatory power of the log OLS models for system one and system three are quite low, less than 0.1, showing that there is a considerable amount of unexplained variation in the respondent's preference that these models are not able to capture. The log OLS models have a higher than 0.1 adjusted R-squared for system two. The log transformed interval midpoint OLS models have lower AIC and BIC values compared to the log transformed PC values OLS models. This means that the log transformed interval midpoint OLS models are better models compared to the log transformed PC values OLS models.

Table 14: OLS models with log-transformed PC and Interval Midpoint Values

Variables	System 1		System 2		System 3	
	Logged PC	Logged Midpoint	Logged PC	Logged Midpoint	Logged PC	Logged Midpoint
Sex: 1=female	0.873	0.160	0.371	0.118	-0.242	-0.063
	(0.557)	(0.104)	(0.585)	(0.133)	(0.730)	(0.185)
Education						
Base: No schooling						
Primary School	0.340	0.106	-0.854	-0.138	-0.308	-0.102
	(0.613)	(0.114)	0.643	0.146	0.804	0.203
High Sch. and above	0.115	0.129	-0.671	-0.042	-0.996	-0.224
	(0.742)	(0.138)	0.779	0.177	0.973	0.246
Household head age	0.020	0.003	-0.020	-0.005	0.003	-0.002
	(0.018)	0.003	0.019	0.004	0.023	0.006
Number of children	-0.071	-0.017	-0.063	-0.020	-0.239**	-0.055*
	(0.092)	0.017	0.096	0.022	0.120	0.030
Log (Income+1)	0.450*	0.087**	1.124***	0.268***	1.169***	0.337***
	(0.253)	0.047	0.265	0.060	0.332	0.084
Happiness	-0.248***	-0.038***	0.118	0.028	-0.065	-0.024
	(0.086)	0.016	0.090	0.021	0.113	0.028
Env. Awareness	-0.022	-0.008	0.036	0.016	-0.061	0.003
	(0.062)	0.012	0.065	0.015	0.081	0.020
Observation	195	195	195	195	195	195

Adjusted R2	0.033	0.038	0.100	0.135	0.040	0.059
AIC	977.472	322.475	996.202	418.951	1083.054	546.465
BIC	1006.93	351.932	1025.659	448.408	1112.511	575.922

Standard errors in parentheses

*10% sig. level **0.05 sig. level *** 0.01 sig. level

From table 15 below, we can spot that there is an increasing income elasticity of WTP from the cheapest system, system one, to the more expensive ones, system two and three, which is quite reasonable.

Table 15: Income elasticities comparisons

Model	Income elasticity of WTP for system 1	Income elasticity of WTP for system 2	Income elasticity of WTP for system 3
PC Value OLS	0.45	1.12	1.17
Midpoint Value OLS	0.09	0.27	0.34

5.7.2 Interval Regression and Interval Midpoints

The interval regression results for system one yielded happiness as the only statistically significant variable at the 10 percent significance level. For system two, income is highly significant at the one percent significance level. System three, on the other hand, has income and number of children in a household as statistically significant variables at one percent and 10 percent, respectively. For every additional child, the household's predicted WTP for system three decreases by Ksh 68, all else unchanged.

We can draw some similarities between the interval regression results and non-log midpoint OLS. In the non-log midpoint OLS the dependent variable WTP is not log transformed. The direction of the change for the explanatory variables is consistent in these two models. In addition, the level of significance for the significant variables is the same and the magnitudes of the coefficients are somewhat close to one another.

The explanatory power of the non-log midpoint OLS model as shown in table 16 is higher compared to the logged midpoint OLS model, shown in table 15. With a 15 percent explanatory power, system two's non-log midpoint OLS model has the highest explanatory power among the three. The interval regression models also have lower AIC and BIC values compared to the non-log midpoint OLS model. This implies that the interval regression model in this case is better model.

Table 16:Interval Regression model and OLS model with original interval midpoint values

Variables	System 1		System 2		System 3	
	Interval Regression	Midpoint non-log OLS	Interval	Midpoint non-log OLS	Interval	Midpoint non-log OLS
Sex; 1=female	164.062	172.788	186.395	185.114	-117.095	-112.939
	(104.987)	(112.904)	(172.125)	(175.845)	(267.646)	(273.421)
Education						
Base: No Schooling						
Primary School	132.67	136.055	-98.117	-94.3973	-137.867	-137.528
	(115.704)	(124.261)	(187.981)	(193.534)	(295.185)	300.924
High Sch. and above	211.532	225.562	122.619	128.541	-173.301	-179.73
	(139.915)	(150.397)	(228.123)	(234.241)	(357.295)	364.219
Household Head age	0.784	0.866	-6.094	-6.214	-4.774	-4.701
	(3.342)	(3.583)	(5.431)	(5.581)	(8.492)	(8.678)
Number of children	-18.140	-18.435	-30.153	-31.808	-73.086*	-72.868*
	(17.311)	(18.622)	(28.241)	(29.004)	(44.138)	(45.099)
Log (Income+1)	76.453	82.828	320.949***	327.258***	567.463***	561.747***
	(47.840)	(51.267)	(77.886)	(79.848)	(121.678)	(124.155)
Happiness	-27.826*	-29.866*	39.721	40.311	-29.480	-31.101
	(16.218)	(17.424)	(26.447)	(27.138)	(41.364)	(42.197)
Env. Awareness	-14.006	-13.559	23.955	23.664	31.755	31.014

	(11.640)	(12.511)	(18.939)	(19.486)	(29.608)	(30.299)
Observations	195	195	195	195	195	195
AIC	479.601	3048.936	595.839	3221.733	831.467	3393.881
BIC	512.331	3078.393	628.569	3251.19	864.197	3423.338
Adjusted R^2		0.042		0.15		0.099
lnsigma	6.231***		6.753***		7.222***	
	(0.06)		(0.055)		(0.052)	

Standard errors in parentheses

*10% sig **0.05 sig. level ***0.01 sig. level

5.7.3 Tobit Model and PC Value OLS

The results presented in this section are for the tobit and the PC value "non log" OLS models. The PC "non log" OLS model refers to the OLS model estimated where the original PC values have not been log transformed. The coefficients of the tobit model are interpreted in the same way as the OLS coefficients. However, since in a tobit model we have a latent variable, the effect is explained to be on the unobserved latent variable and not the observed outcome (UCLA: Statistical Consulting Group). In our case true WTP is the latent variable.

For systems one, sex, income and happiness are statistically significant. Both sex and income are statistically significant at 10 percent. While happiness is statistically significant at one percent. For the variable sex, we can see that while holding all other factors constant female headed households have a Ksh. 235 higher WTP for system one than their male counterparts. Finally, for the variable happiness we can see that a unit increase in the happiness level results in a Ksh. 51 decrease in the expected WTP levels, all else unchanged.

For system two, income is the only statistically significant variable at a one percent significance level. Number of children and income are statistically significant at 10 percent and 1 percent significance levels respectively, for system three. For every additional child, the true WTP level for system three reduces by Ksh. 159, holding all other factors constant.

For the PC values "non log" OLS model, the coefficients are interpreted as the effect on the observed WTP, unlike the tobit model where the effect is on the unobserved latent variable. In this study, the results for these two models seem to have a similar pattern. All statistically significant variables in one are equally statistically significant on the other and the signs of the variables are alike too.

Only the adjusted R-squared for system 1, in the non-log OLS model, is less than 0.1 As for the Pseudo R-squared all the three models have a value less than 0.1. The tobit models have lower AIC and BIC values compared to the non-log PC values OLS models.

Table 17:Tobit Model and OLS model with original PC values

Variables	System 1 Tobit	PC "Non-log" OLS	System 2 Tobit	PC "Non-log" OLS	System 3 Tobit	PC "Non-log" OLS
Sex; Female=1	235.103*	180.742*	203.97	173.943	-237.47	-129.44
	(139.447)	(111.305)	(215.279)	(169.17)	(529.007)	(273.778)
Education:						
Primary	156.793	128.52	-213.5	-107.12	-272.08	-118.76
	(156.369)	(122.501)	(239.733)	(186.186)	(584.439)	(301.317)
High Sch. above	205.361	194.431	14.293	105.632	-423.28	-120.06
	187.604	148.267	287.206	225.348	702.433	364.695
HH head age	2.845	1.267	-8.609	-5.701	-5.883	-4.286
	4.532	3.532	7.073	5.369	17.189	8.6897
Number of children	-23.955	-18.446	-35.417	-27.895	-158.78*	-73.725*
	23.172	18.359	36.796	27.903	92.651	45.157
Log (Income+1)	116.61*	83.013*	437.928***	309.629***	997.749***	573.925***
	64.549	50.541	101.237	76.816	242.135	124.317
Happiness	-51.431**	-33.502**	51.392	40.009	-25.958	-20.89
	21.936	17.177	33.431	26.108	81.908	42.251
Env. Awareness	-15.378	-13.646	25.129	21.440	18.229	31.513
	15.698	12.334	24.244	18.747	59.1	30.338
Observations	195	195	195	195	195	195

Adjusted R2		0.041		0.142		0.105
Pseudo R2	0.005		0.015		0.012	
AIC	2494.73	3043.37	2572.08	3206.64	1941.63	3394.39
BIC	2527.46	3072.83	2604.81	3236.1	1974.36	3423.85

5.7.4 Positive and Zero WTP Comparison

The logit model is applied to analyse what determines a household's decision to pay or not to pay. I will use the term positive WTP to mean that a HH is willing to pay an amount above zero. For system one, at a one percent significance level, happiness is the only statistically significant variable. It's co-efficient can be interpreted to mean that, holding all other factors constant, we will see a 26 percent decrease in the odds of a positive WTP for system one, for a unit increase in happiness level, since exp(.233)=1.262.

Just as in the other regression models, income is the only statistically significant variable in the decision of whether to pay or not to pay for system two. It is highly significant at a one percent significance level. For system 3, we see that income and number of children are statistically significant in the household's decision of whether to pay or not to pay. Income is highly significant at 0.01 significance level. Number of children on the other hand is statistically significant at a 5 percent significance level. All else unchanged, we will observe a 15 percent decrease in the odds of a positive WTP for a unit increase in the number of children in the household, exp (142)=1.153.

Finally, we notice that, unlike system two and three, income levels do not affect the probability of being willing to pay anything for system one. This is not surprising given that, system one is the cheapest and smallest system. In all the three models, the Pseudo R^2 is less than 0.1.

Table 18: Logit models

Variables	System 1	System 2	System 3
Sex; 1= female	0.843	0.259	-0.168
	(0.552)	(0.518)	(0.403)
Education			
Primary	0.190	-0.892	-0.254
	(0.512)	(0.552)	(0.444)

High School and above	-0.0713	-0.7136	-0.6319
	(0.654)	(0.687)	(0.539)
Household head age	0.02	-0.011	0.006
	(0.016)	(0.015)	(0.013)
Number of children in HH	-0.064	-0.054	-0.142**
	(0.079)	(0.074)	(0.068)
Log (Income+1)	0.270	0.758***	0.544***
	(0.221)	(0.218)	(0.190)
Happiness	-0.233***	0.094	-0.035
	(0.077)	(0.074)	(0.063)
Env. Awareness	-0.056	0.003	-0.064
	(0.053)	(0.052)	(0.044)
Observations	195	195	195
Pseudo R2	0.074	0.099	0.053
AIC	210.889	214.025	273.627
BIC	240.346	243.482	303.084

Standard errors in parentheses

*0.1percent sig. level **0.05 sig. level ***0.01 sig. level

6 Discussion

In this chapter I will first discuss how the results of this study compare to results of other previous studies. Secondly, I will evaluate how the WTP compares to the market prices of solar home systems in Kenya. Thirdly, I will evaluate the validity of this study and finally I will evaluate to see how well our research questions were answered in this study.

In terms of gender differentials, the results of this study are similar to those of a study in Bangladesh by Khandker et al. (2014) assessing the WTP for SHSs. In both studies women had a higher WTP for solar home systems. Abdullah and Jeanty (2011), Entele (2020), Mutua (2015) and Ugulu and Aigbavboa (2019) are among some studies that affirmed the expected positive relationship between income and the WTP for renewable energy sources. The results of this study too showed that income and WTP had a positive significant relationship. Results from Grimm et al. (2019) and Gunatilake et al. (2012) imply that households with more children would have a higher WTP for solar home systems and for multiple electricity connections respectively. In this study, household's WTP was decreasing with the number of children. This may be attributed to the fact that more children in a household in turn means lower income per capita for households. Montazer Hojat et al. (2019) and Sulemana (2016) found that happier people had a higher WTP. The results from this study show that happiness and WTP have a negative relationship for the cheapest system. I cannot conclusively determine whether this difference is because of the attributes of the cheapest system.

6.1 Willingness to Pay Versus Market prices

It is interesting to find out how market prices compare to the mean WTP. Throughout the study I have presented the monthly WTP. In this part of the discussion I have derived the total WTP, based on the interval midpoint mean WTP, over the three-year period. Given that the total WTP is over a three-year period, it is necessary that the monthly WTP is discounted to get the Present Value (PV). Whereas individuals may have a higher discount rate, for the purpose of this study I have used a 10% discount rate. This is the rate used in cost benefit analyses (CBA) undertaken in Kenya (Hafner et al., 2019, p. 54). The indicative market prices on the other hand, have been adopted from Mangoo Marketplace (n.d), a platform that shows prices for solar products in Africa and Asia.

Small solar home systems, within the tier one energy access category, seem to cost between $80 and $600 (Ksh 8000-Ksh 60000). Medium SHSs ranging from 50 Watts to 199 Watts, tier two energy access category, seem to range between $450 and $ 1300 (Ksh 45000-Ksh 130000) and lastly, systems of 200 watts and above seem to cost at least $1970. Assuming a 10% percent discount rate, the total WTP over three years for system one, system two and system three was approximately $357 (Ksh 35764), $513 (Ksh 51383) and $529 (Ksh 52933), respectively.

From my comparison above, we can see that small systems would be a popular choice for Kilifi residents. The total mean WTP, $357, is considerably higher than the lowest price found, $80. Solar home systems offering tier two energy access level could also be a realistic consideration among some residents of Kilifi County given that the WTP lies within the price range of tier two SHSs. It is however important to note that in this case, the total WTP for system two, $513, was just slightly above the lowest price for tier two SHSs, $450. For system three, the largest system, the total mean WTP does not fall within the present price range of systems above 200 Wp. Solar home systems offering tier three energy access are likely not to be a popular or affordable choice for Kilifi County households. In this study only 49.5% of the households had a positive WTP for system three.

6.2 Validity

"Content validity, construct validity and criteria validity" (Johnston et al., 2017, p. 371) are the three recommended validity assessments for stated preferences studies. In this study, I analyse both content validity and construct validity. The criteria validity of the study is not analysed since I did not find similar studies that I can compare the estimates of this study with.

6.2.1 Content Validity

The content validity of a study is anchored on the implementation procedures of the study (Johnston et al., 2017, p. 353). This study closely follows the guidance given by Johnston et al. (2017) on how to conduct stated preferences studies. To enhance the content validity of the study, a pilot survey was conducted as discussed in chapter three. Following the experience from the pilot, the payment card values were amended to include daily payment rates. It was important for us that the respondents could relate with what they were being asked.

6.2.2 Construct Validity

Construct validity involves assessing the quality of a study by analyzing the “performance” of the hypotheses (Johnston et al., 2017). In this part I will look at how the results compare with the different hypotheses. I will analyse the hypotheses and the findings, system by system considering only the statistically significant variables.

6.2.2.1 System one

In the different models that were estimated for system one, happiness was statistically significant in all models. Income was statistically significant in the log transformed OLS models and the PC value “non log” OLS. Finally, sex was statistically significant in the tobit and the PC value “non log” OLS. Happiness showed a negative relationship with the WTP level for system one, income had a positive relationship with WTP, while in assessing gender differentials, women had a higher WTP for system one.

From our earlier formulated hypotheses, we can see that the findings of this study and expected sign for the variable, income match. In assessing the WTP gender differentials our hypothesis did not have a definite sign. The findings of this study show that female headed households have a higher WTP than male headed households, for system one. This is the same as the findings by Khandker et al. (2014). Happiness and WTP for system one had a negative significant relationship. This is different from our hypothetical expectation. It is difficult to conclude whether the negative relationship has anything to do with the attributes of system one, especially because happiness is not statistically significant in the other two systems.

Table 19: Hypothesis and results comparison for system one

Variable	Expected direction of effect with respect to WTP	Results
Sex	ambiguous	+
Income	+	+
Happiness	+	-

6.2.2.2 System two

Income dominates the WTP for system two. It is the only significant variable in all WTP estimated models for system two and it shows a positive relationship with the WTP level. It is also good to note that in our case income also determines the purchase decision for system two since it is statistically significant in the logit model. We cannot comment about the other explanatory variables since they are not statistically significant.

Table 20: Hypothesis and results comparison for system two

Variable	Expected direction of effect with respect to WTP	Results
Income	+	+

6.2.2.3 System three

Number of children and income were statistically significant in the models estimated for system three. The results for income matched the hypothesis. Number of children had a negative relationship with the WTP levels. System three was the most expensive of the three systems. The negative relationship between the number of children in a household and WTP could be because the per capita income of a household decreases with an increase in the household composition and this may have negative effects on the household's WTP level.

Table 21: Hypothesis and results comparison for system three

Variable	Expected direction of effect with respect to WTP	Results
Number of Children	+	-
Income	+	+

6.3 Research Questions Versus Results

6.3.1 Research Question One: What is the willingness to pay levels for SHSs?

To answer the first research question, the mean WTP for the three different SHSs was estimated. In all three systems, we had three estimated mean values; based on the PC values, based on the interval midpoints, and lastly based on the unconditional interval regression. System one, the smallest system among the three, had a mean monthly WTP of Ksh. 793 based on the PC values, Ksh. 1154 based on the interval midpoints and Ksh. 1153 based on the unconditional censored interval regression.

System two on the other hand had a mean monthly WTP of Ksh 1228 based on the PC values, Ksh 1658 based on the interval midpoint and Ksh 1643 based on the unconditional censored interval regression. Finally, for the largest system, system three the mean WTP was Ksh 1283 based on the PC values, Ksh 1708 based on the interval midpoint and Ksh 1706 based on the unconditional censored interval regression.

We notice that the WTP is increasing from the smallest to the largest SHS. Moreover, 77.5 percent of the households have a positive WTP for the cheapest system, 75% for the medium system and only 49.5 percent for the most expensive system. The residents of Kilifi County seem to be more willing to pay for the small or medium sized systems.

6.3.2 Research Question Two: Which demographic factors affect WTP for SHSs?

In this study, different demographic factors were assessed to evaluate if they affected the WTP levels for households. Gender was only found to affect the WTP for system one, with female headed households having a higher WTP. Age and level of education were statistically insignificant in all three systems' models. Household size was not included in the final estimated models due to its high correlation with the number of children in the household. This was not unusual since we expect that an increase in the number of children in a household reciprocates to the household been larger.

Number of children in a household was found to inversely affect the WTP for system three. Households with more children had a lower WTP for system three. In all models, WTP and income increase significantly for systems two and three, and in most models for the smallest and cheapest system, system one. The income elasticity of WTP was also increasing from the cheapest and smallest system, system one, to the largest and most expensive, system three.

6.3.3 Research Question Three: Does environmental awareness affect WTP for SHSs?

From our results, environmental awareness did not affect the WTP for any of our solar home systems.

6.3.4 Research Question Four: Does happiness affect WTP for SHSs?

From our results, happiness levels only affected the WTP levels for the smallest and cheapest system, system one. Contrary to our hypothesis expectations, household heads with higher happiness levels had lower WTP levels for system one.

7 Conclusion

The results of this study have confirmed that residents of Kilifi County have a positive WTP for SHSs with the mean WTP being Ksh 1154 Ksh 1658 and Ksh 1708 for system one, system two and system three, respectively. We also see a positive relationship between WTP and income across all the three systems. Younger household heads also demonstrate a higher WTP for SHSs. Female headed households also have a higher WTP, evident from the regression results of system one. Taking number of children as a proxy for household size, results from this study show that larger households, households with more children, have a lower WTP for SHS. Lastly, from the results, happiness and WTP demonstrate a negative relationship between the two.

7.1 Limitations of the Study

This study, like other empirical studies, was not without its limitations. First, due to time and budgetary constraints it was only possible to capture responses from 200 households. Having a larger sample size improves the sample representativeness. Secondly, we had to rely on local knowledge to identify and stratify the villages not connected to the grid since we did not find any official registers of such villages. This makes the identification process a bit challenging and for a larger survey it would easier if official registers are available.

7.2 Policy Recommendations

Willingness to pay studies, such as this one, may be prioritized to assess the economic viability of policies geared towards achieving universal access of electricity in Kenya (Blimpo & Cosgrove-Davies, 2019). The off-grid sector in Kenya also has a lot of private stakeholders and understanding the WTP levels may enable policy makers to evaluate whether financial incentives are necessary, for these players to start providing electricity to the citizens living without electricity.

To evaluate whether subsidies are necessary for these systems, a CBA would have to be performed. The CBA would compare overall social benefits to the costs of the system. Overall social benefits include external benefits of the solar home systems that is not captured by the households´ assessment of their private benefits in terms of their WTP. Performing a CBA would determine the socially optimal uptake level of these systems, by households, and thus determine the optimal subsidy needed.

Figure 8 below illustrates what would be the society's optimal uptake level and thus the required subsidy level. Subsidies are provided to reach social optimality. As we can see the marginal social benefits are higher than the individual private marginal benefits. Point a is an individual's optimal level whereas point b is the society's optimal level. To reach societal optimality subsidies equivalent to P_1-P_0 need to be provided by the government.

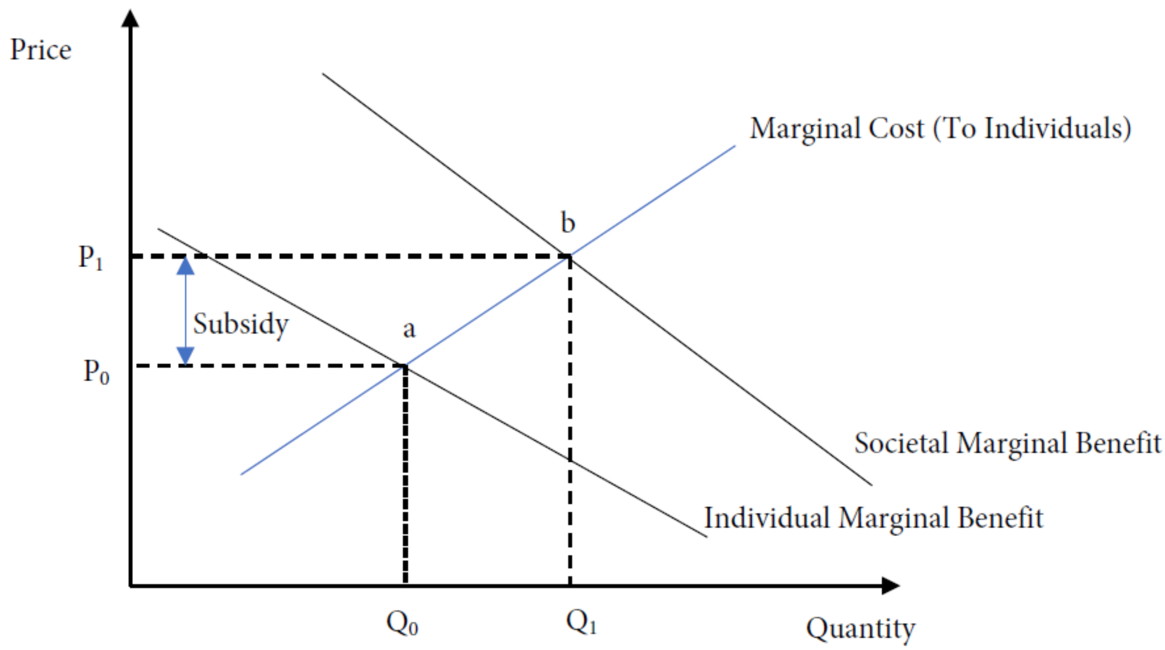

Figure 8: Social Optimality

Overall, we see that it will be important to additionally assess the external benefits of solar home benefits and the costs to be able to assess the necessary government support that is needed in Kilifi County. It is also important to note that I have assumed that the option to extend the grid in this area would have a lower Net Present Value (NPV). The NPV of the option to extend the grid would need to be assessed in the CBA as well.

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A Appendix

A.1 Questionnaire

Date: ___________

Sub-County: __________ Village: _________ Distance to the grid: _______

Interviewer code: ____ Beginning Time: _____ Ending time: ______________

A.1.1 Introduction

Hello, my name is (*interviewer's name*). I am conducting this survey on social well-being and public services as part of a master's thesis. The questions asked in the survey cover day to day issues and there are no right or wrong answers. Responses in the survey are recorded anonymously and the results will be presented in a way that cannot be traced back to individual respondent, so please give your honest opinion on each response. Kindly allow us 30 minutes of your time.

A.1.2 Part I: Attitudes to different Public Services

1. In your opinion, how important or unimportant do you think it is to address these public issues in your local area?

Show card 1-1 and read each of the public issues and record the answer in the table.

Card 1-1

Public issue no	1. Very Important	2. Somewhat Important	3. Somewhat Unimportant	4. Not Important at all	5. Don't Know
1. Improving Primary and Secondary Schools					
2. Extending the grid to your area					
3. Stricter enforcement of restricting access to the forest to collect firewood.					
4. Improving access to health facilities.					

5. Making private solar equipment more affordable.					
6. Improving security					

A solar home system is a package that can be used for producing electricity in a household. Usually it comes as a kit and its main components are a solar panel and battery.

2. Does your household own a SHS?
   1. Yes
   2. No
   3. Don't know

(To Interviewer: If respondent answers yes to Q2, ask Q3-Q6, if otherwise proceed to Q7)

3. If yes above, how many watt (W) is the solar panel? ____ W 2. Don't know *(The interviewer may assist by checking how many watts the solar panel is.)*
4. What is the average number of hours of light you get from the SHS daily? ______ hours/day
5. If yes, above how much did you pay for it? ________Ksh 2. Don't know
6. If you are still paying for it, how much do you pay per month and how much in total will you have paid for it before you can fully own it?

(*The interviewer may assist in calculating total costs based on the monthly payment and total number of months paid.)*

a. _____ Ksh. per month

b. ______Ksh. in total for all payments made

A.1.3 Part II: Energy Use

Now I am going to ask you some questions about which energy sources your household used for different tasks during the last month.

(To interviewer: Show card 7-1 with the list of energy sources (1-9), read each task (1-8), and tick off all energy sources used for each type of use. For "other"; record the energy source and/or task).

Card 7-1

7. For (task 1) what did your household use last month?

(To Interviewer: Read out the tasks one at a time)

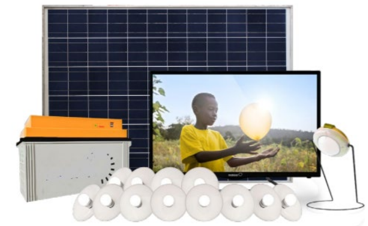
Tasks:	1. Electricity from Solar	2. Gas	3. Kerosene	4. Diesel	5. Charcoal	6. Firewood	7. Dung	8. Battery	9. Other; please specify
1. Lighting									
2. Cooking									
3. Mobile Charging									
4. Television and/or Radio									
5. Refrigeration									
6. Cooling									
7. Farming									
8.Other; Please Specify									

A.1.4 Part IV: Willingness to Pay

Now I am going to describe to you 3 different types of solar home systems. Please take a look at this card.

(To Interviewer: Show Card 8-1 showing all three systems in a table with a photo on top, and a list of uses. Read the description below of each system to the respondent).

Card 8-1

Uses	System 1	System 2	System 3
			
Lighting	Approximately 5.5 hours of light for 4 bulbs each with a brightness equivalent to 10 candles or 10 kerosene wick lamps	Approximately7 hours of light for 4 bulbs each with a brightness equivalent to 15 candles or 15 kerosene wick lamps,	Approximately 11 hours of light for 12 bulbs each with a brightness equivalent to 47 candles or 47 kerosene wick lamps
Portable Radio	4.5 hours	5 hours	8 hours
Portable Torch	6 hours	7 hours	11 hours
Mobile Charge	1.5 full charge	1.5 full charge	2.5 full mobile charge
Tv	No TV use	3.5 hours	5.5 hours

System 1

This first system allows you approximately 5.5 hours of light for 4 bulbs each with a brightness equivalent to 10 candles or 10 kerosene wick lamps, 4.5 hours of using a portable rechargeable radio, 6 hrs of light for a portable rechargeable torch and one and a half (1.5) full mobile charge for a basic phone.

System 2

The second system allows you approximately 7 hours of light for 4 bulbs each with a brightness equivalent to 15 candles or 15 kerosene wick lamps, 5 hrs of use for a portable rechargeable radio.

7 hrs of light for a rechargeable torch, one and a half 1.5 full mobile charge and 3.5 hours of TV.

System 3

The third system allows you approximately 11 hours of light for 12 bulbs each with a brightness equivalent to 47 candles or 47 kerosene wick lamps, 8 hours of use for a portable rechargeable radio, 11 hours of light for a rechargeable torch, 2.5 full mobile charge for a basic phone and 5.5 hours of TV

8. I want you to think about how much the services the solar home systems provide is worth to you and your household. What is the most, if anything, your household is certainly willing to pay per month over 3 years to have system 1? Please take a look at this card (8-5) and state the highest monthly amount, if any, you certainly are prepared to pay for System 1. Do the same for System 2 and System 3.

(Interviewer hands over the payment card- Cards 8-5)

Card 8-5

Daily	Ksh 0	Ksh. 28	Ksh 48	Ksh 77	Ksh 117	Ksh 140	Ksh 167	Others, Please Specify	Don't Know
Monthly	Ksh 0	Ksh 833	Ksh 1,450	Ksh 2300	Ksh 3,500	Ksh 4,200	Ksh 5,000		
Yearly	Ksh 0	Ksh 10,000	Ksh 17,400	Ksh 27,600	Ksh 42,000	Ksh 50,400	Ksh 60,000		
In 3 years	Ksh 0	Ksh 30,000	Ksh 52,200	Ksh 82,800	Ksh 126,000	Ksh 151,200	Ksh 180,000		

To interviewer: Record the answers for Systems 1, 2, and 3

System 1: ____ Ksh _ Don´t Know

System 2: ____ Ksh _ Don´t Know

System 3: ____ Ksh _ Don´t Know

To Interviewer: If the respondent chooses 0 Ksh for System 1, ask them to state why they are not willing to pay anything.

9. A. What is your most important reason for not being willing to pay anything for the solar home system 1? You can only choose one alternative; the most important one. *(To Interviewer: show card 9 with the alternatives, and read them aloud to the respondent)*
   1. I cannot afford it
   2. I do not trust solar home systems
   3. I do not think I need any electricity at home.
   4. I am better off waiting until the grid is extended

5. I do not own my house and cannot have it up in a rented house
6. I only need a smaller system.
7. Other, please specify_____________________

To Interviewer: If the respondent chooses 0 Ksh for System 2, ask them to state why they are not willing to pay anything.

9B. What is your most important reason for not being willing to pay anything for the solar home system 2? You can only choose one alternative; the most important one. *(Interviewer shows card with the alternatives, and read them aloud to the respondent)*

1. I cannot afford it
2. I do not trust solar home systems
3. I do not think I need any electricity at home.
4. I am better off waiting until the grid is extended
5. I do not own my house and cannot have it up in a rented house
6. I only need a smaller system.
7. Other, please specify_____________________

To Interviewer: If the respondent chooses 0 Ksh for System 3, ask them to state why they are not willing to pay anything.

9C. What is your most important reason for not being willing to pay anything for the solar home system 3? You can only choose one alternative; the most important one. *(Interviewer shows card with the alternatives, and read them aloud to the respondent)*

1. I cannot afford it
2. I do not trust solar home systems
3. I do not think I need any electricity at home.
4. I am better off waiting until the grid is extended
5. I do not own my house and cannot have it up in a rented house
6. I only need a smaller system.
7. Other, please specify_____________________

To Interviewer: If the respondent states the same or lower amount for system 3 as for system 1, ask Q. 9D

9D. Why do you pay the same for the system __ and __.

1. I cannot afford to pay more
2. I don't need the extra time and services provided by the other system
3. I don't see the difference
4. Larger solar home systems have higher probability of failing
5. Other; Please specify

10. When buying a Solar Home System, which of these payment options would be the best for you?
    1. I prefer making a one-off payment for a SHS without a service agreement
    2. I prefer having a one-off payment with a service agreement included.
    3. I prefer leasing a solar home system and finally owning it after my leasing period (3 years) is over.
    4. I prefer leasing a SHS, without finally owning it as I wait for the grid
    5. Others, please specify.
    6. Don't know

To Interviewer: If the respondent chooses option 2 above, ask them to state how much they are willing to pay for the service agreement

11. What is the most, if anything, your household is certainly willing to pay per month over 3 years to have the solar home system serviced? _____Ksh. 2.Don't know

A.1.5 Part V: Knowledge and Attitudes towards SHSs

12. To what extent do you agree or disagree with the following statements?

(To Interviewer: Show card 12-1 and read each of all statements and record the answer in the table)

Card 12-1

Statement no:	Strongly Agree	Agree	Disagree	Strongly disagree	Don't Know

1. In 3 years time, the grid will reach our village.					
2. I would retain a private solar system even after the grid reaches the village					
3. A solar home system is sufficient for my household's electricity needs.					
4. I prefer not to own but to lease a solar home system and stop the lease once the grid reaches us.					
5. Solar Home Systems can be income generating.					
6. Solar Home Systems can power appliances.					
7. Solar Home Systems power DC appliances.					
8. Solar home systems vary in size and capacity.					

A.1.6 Part VI: Environmental Awareness

13. Kindly state to what extent you agree or disagree with the following statements?

(To Interviewer: Show card 13-1 and read each of all statements and record the answer in the table.)

Card 13-1

Statement no:	Strong Agree	Agree	Disagree	Strongly disagree	Don't Know
1. I try my best not to cut down trees					

2. I am aware that plastics are not good for the environment					
3. I plant trees at least once a year.					
4. I try to keep my compound smoke free					
5. I am careful on my water usage					
6. I prefer to use manure than fertilizers					

A.1.7 Part VII: Happiness

14. How satisfied or dissatisfied are you with life in general as whole on a scale of 1 to 10 with 1 being Not at all satisfied and 10 being extremely satisfied?

(To interviewer: Show Card 14-1, showing the scale below).

Record the number the respondent states here: _____ __Don´t know

Card 14-1

Not at all satisfied Extremely satisfied

1 2 3 4 5 6 7 8 9 10

A.1.8 Part VIII: Demographics

15. Marital Status of Household head:
    1. Never Married-:
    2. Married-:
    3. Divorced-:
    4. Separated-:
    5. Widowed-:
16. Age of Household head: ______

17. How many people live in the household including yourself? (State 1 if you live alone) _____
18. How many children (under 18) live in the household if any? _________ *(To interviewer: If none, record zero)*
19. How many people in the household have paid work? ____ *(To interviewer: Write zero if n*one)
20. Which is the highest level of education that you have completed?
    1. Primary school
    2. High school
    3. Vocational training/ Certificate
    4. Diploma
    5. University
    6. Other (please specify) ______
    7. No schooling
21. What is your occupation type?
    1. Self-employed
    2. Part-time
    3. Full-time
    4. None
22. On average how much if any is your expenditure on school fees per term, if any? ______ Ksh
23. On average how much is your household's monthly food expenditure? _____Ksh/month __Don't Know
24. On average how much if any is your expenditure on house rent per month, if any? _____Ksh/month __Don't Know
25. What is your average monthly household expenditure on other goods and services? ________Ksh
26. Which of these items does your household own, if any?

(To interviewer: Read the items and circle those the household own)

1.	Radio
2.	TV

3.	Mobile Phone
4.	Bicycle
5.	Motorbike
6.	Car

27. During the last month, did you yourself receive any income?
    1. Yes
    2. No
28. How regular do you receive your income?
    1. Daily
    2. Weekly
    3. Bi-weekly
    4. Monthly
    5. It varies
    6. Don't Know
29. On average, what is your household approximate monthly net income (after taxes)?

(To Interviewer: Tick from the ranges below)

1.	Less than 3000 Ksh/month
2.	3000-10,000 Ksh/month
3.	10001-20,000 Ksh/month
4.	20,001-30,000 Ksh/month
5.	30,001-40,000 Ksh/month
6.	40001-50,000 Ksh/month
7.	50,001-60,000 Ksh/month
8.	60,001-70,000 Ksh/month
9.	70,001-80,000 Ksh/month
10.	80,001-90,000 Ksh/month
11.	90,001-100,000 Ksh/month
12.	Above 100,000 Ksh/month
13.	Would not like to answer

14. Don't Know

30. Do you own or rent the house you live in?
    1. Owner:
    2. Rented:
    3. Other, please specify
31. Do you have any other comments and feedback on the survey? Kindly feel to say what you would love improved.

To Interviewer: For Q32-35 record and not ask

32. Sex of Household head *(Interviewer to record; not ask)*
    1. Male:
    2. Female:
33. Type of house: (*Interviewer to record; not ask*)
    1. Permanent
    2. Semi-Permanent
    3. Temporary
    4. Other, please specify
34. Type of roof: (*Interviewer to record; not ask*)
    1. Thatched
    2. Iron Sheets
    3. Tiles
    4. Other, please specify
35. Type of floor: (*Interviewer to record; not ask*)
    1. Ground:
    2. Concrete:
    3. Tiles:
    4. Other, please specify

Thank you very much for your time, have a good day!

A.2 T-test

Tables 22, 23 and 24 below are the t-test results assessing whether there are statistical differences between the mean WTP values for the three systems. The mean WTP is based on the original PC cards.

Table 22: t test result for mean WTP for system one and system two

Variable	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]	t-value
WTP 1	200	792.9	41.88918	592.4025	710.2963	875.5037	-7.722
WTP_2	200	1227.775	67.00893	947.6494	1095.636	1359.914	

Table 23: t test result for mean WTP for system one and system three

Variable	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]	t-value
WTP_1	200	792.9	41.88918	592.4025	710.2963	875.5037	-4.662
WTP 3	200	1283.39	106.1207	1500.773	1074.125	1492.655	

Table 24: t test result for mean WTP for system two and system three

Variable	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]	t-value
WTP 2	200	1227.775	67.00893	947.6494	1095.636	1359.914	-0.6
WTP 3	200	1283.39	106.1207	1500.773	1074.125	1492.655	

A.3 Skewness Test

Table 25 below, shows the skewness test results for the WTP distribution, using the original PC values and the interval midpoints, for system one, system two, and system three

Table 25: Skewness Tests results for PC Value WTP and Interval midpoint WTP

Variable	Obs	Pr (Skewness)	Pr (Kurtosis)	Joint	
				adj chi2(2)	Prob>chi2

WTP_1	200	0.0000	0.0000	34.38	0.0000
mid_1	200	0.0000	0.0000	44.12	0.0000
WTP_2	200	0.0240	0.4167	5.66	0.0590
mid_2	200	0.0285	0.0054	10.96	0.0042
WTP_3	200	0.0000	0.0026	20.80	0.0000
mid_3	200	0.0004	0.0000	46.78	0.0000

A.4 Model Specification Test

Tables 26, 27 and 28 below represent the results of the Ramsey RESET test for the OLS models of system one, system two and system three. In all the three, we fail to reject the null-hypothesis and we can conclude that there exists no model misspecification.

Table 26: System one model specification test results

Ramsey RESET test using powers of the fitted values of WTP_1

Ho: model has no omitted variables

F(3, 183) = 1.06

Prob > F = 0.3668

Table 27: System two model specification test results

Ramsey RESET test using powers of the fitted values of WTP_2

Ho: model has no omitted variables

F(3, 183) = 0.31

Prob > F = 0.8155

Table 28: System three model specification test results

Ramsey RESET test using powers of the fitted values of WTP_3

Ho: model has no omitted variables

F(3, 183) = 0.79

Prob > F = 0.5026

A.5 Heteroskedasticity Test

Tables 29, 30 and 31 below show the results of the White test for the log transformed OLS models for all the three systems. In all the three values the p-values is greater than 0.05, we therefore fail to reject the null hypothesis. The null hypothesis in the white tests implies homoskedasticity. We can therefore conclude that these models have no heteroskedasticity problems.

Table 29: System one White test results

Cameron & Trivedi's decomposition of IM-test

Source	chi2	df	p
Heteroskedasticity	52.11	40	0.0951
Skewness	101.22	8	0.0000
Kurtosis	2.37	1	0.1235
Total	155.71	49	0.0000

Table 30: System two White test results

Cameron & Trivedi's decomposition of IM-test

Source	chi2	df	p
Heteroskedasticity	37.87	40	0.5667
Skewness	73.54	8	0.0000
Kurtosis	2.66	1	0.1028
Total	114.06	49	0.0000

Table 31: System three White test results

Cameron & Trivedi's decomposition of IM-test

Source	chi2	df	p
Heteroskedasticity	48.01	40	0.1800
Skewness	26.96	8	0.0007
Kurtosis	9.02	1	0.0027
Total	83.99	49	0.0014

A.6 Multi-Collinearity Test

As a rule, VIF values greater than 10 are viewed to potentially have a multicollinearity problem (Alin, 2010). From the VIF test results below none of the variables appear to potentially have a multicollinearity problem.

Table 32: VIF test results

Variable	VIF	1/VIF
Sex	1.08	0.923245
Education		
Primary School	2.18	0.459533
High Sch. and above	2.79	0.358129
Household head age	1.17	0.853643
Number of children	1.23	0.812477
Log (Income+1)	1.21	0.826754
Happiness	1.10	0.913005
Env. Awareness	1.06	0.939680
Mean VIF	1.48	

A.7 Other Descriptive Tables

Table 33:Sizes of Solar Home Systems Owned in Watts

SHS (Watt)	Freq.	Percent	Cum.

Don't know	2	2.33	2.33
6	1	1.16	3.49
15	3	3.49	6.98
16	2	2.33	9.30
30	3	3.49	12.79
40	48	55.81	68.60
50	4	4.65	73.26
60	5	5.81	79.07
70	1	1.16	80.23
80	4	4.65	84.88
120	12	13.95	98.84
150	1	1.16	100.00
Total	86	100.00	

Table 34: Preferred payment options

Payment Options	**Freq.**	**Percent**	**Cum.**
I prefer a one-off payment without a service agreement	4	2.00	2.00
I prefer a one-off payment with a service agreement	11	5.50	7.50
I prefer leasing and finally owning after the 3 years leasing period	175	87.50	95.00
I prefer leasing and without finally owning	7	3.50	98.50
Don't Know	3	1.50	100.00
Total	200	100.00	

Table 35: Marital Status

Marital Status	**Freq.**	**Percent**	**Cum.**

Never Married	21	10.50	10.50
Married	158	79.00	89.50
Divorced	7	3.50	93.00
Separated	8	4.00	97.00
Widowed	6	3.00	100.00
Total	200	100.00	

Table 36: Household head's Education Level

Household head Education	**Freq.**	**Percent**	**Cum.**
Primary	104	52.00	52.00
High School	45	22.50	74.50
Vocational training/Certificate	12	6.00	80.50
Diploma	4	2.00	82.50
University	3	1.50	84.00
No Schooling	32	16.00	100.00
Total	200	100.00	

Table 37: Household head's Occupation Status

Household head Occupation	**Freq.**	**Percent**	**Cum.**
Self-employed	94	47.00	47.00
Part Time	58	29.00	76.00
Full Time	32	16.00	92.00
None	16	8.00	100.00
Total	200	100.00	

Table 38: Income Frequency

Income frequency	**Freq.**	**Percent**	**Cum.**
Daily	58	29.00	29.00
Weekly	11	5.50	34.50
Bi-weekly	3	1.50	36.00
Monthly	35	17.50	53.50
It varies	84	42.00	95.50
Don't know	9	4.50	100.00
Total	200	100.00	

Table 39: Average Monthly Income in Categories

Average monthly income	**Freq.**	**Percent**	**Cum.**
less than 3000/month Kes	12	6.00	6.00
3000-10000 Kes/month	56	28.00	34.00
10001-20000 Kes/month	60	30.00	64.00
20001-30000 Kes/month	24	12.00	76.00
30001-40000 Kes/month	22	11.00	87.00
40001-50000 Kes/month	9	4.50	91.50
50001-60000 Kes/month	6	3.00	94.50
60001-70000 Kes/month	4	2.00	96.50
70001-80000 Kes/month	1	0.50	97.00

90001-100000 Kes/month	1	0.50	97.50
Would not like to answer	1	0.50	98.00
Don't Know	4	2.00	100.00
Total	200	100.00	

Table 40: House Ownership Status and Housing Conditions

House Ownership	**Freq.**	**Percent**	**Cum.**
Owner	181	90.50	90.50
Rented	19	9.50	100.00
Total	200	100.00	
House type	**Freq.**	**Percent**	**Cum.**
Permanent	51	25.50	25.50
Semi-permanent	99	49.50	75.00
Temporary	50	25.00	100.00
Total	200	100.00	
Roof type	**Freq.**	**Percent**	**Cum.**
Thatched	85	42.50	42.50
Iron Sheets	115	57.50	100.00
Total	200	100.00	
Floor type	**Freq.**	**Percent**	**Cum.**
Ground	143	71.50	71.50
Concrete	49	24.50	96.00
Tiles	8	4.00	100.00
Total	200	100.00	

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