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ADDIS ABABA UNIVERSITY
COLLEGE OF DEVELOPMENT STUDIES
CENTER FOR ENVIRONMENT AND DEVELOPMENT

ANALYSES OF HOUSE-HOLD WILLINGNESS TO PAY FOR OFF-GRID
ELECTRICITY SERVICE KOFTU MINI-GRID AKAKI DISTRICT OROMIA
REGION, ETHIOPIA.

BY

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ACRONYMS

AfDB-Africa Development Bank ATP- Ability to Pay
ADELE-Access to Distributed Electricity and Lighting in Ethiopia Programme
BAU-Business-as-Usual (scenario)
CRGE-Climate Resilience and Green Economy
CSP-Concentrating Solar Power
CVM- Contingent Valuation Methods CAPEX-Capital Expenditure
CO₂-Carbon Dioxide
CO_{2e}-Carbon Dioxide Equivalent
DBDC- Double Bounded Dichotomy Choice
DREAM-Distributed Renewable Energy-Agriculture Modalities Project
DCM- Decentralized Mini Grid
EEA- Ethiopia Electric Authority
ESMAP-Energy Sector Management Assistance Program
EEPco-Ethiopian Electric Power Corporation
EEU-Ethiopia Electric Utility EEP-Ethiopia Electric Power
FDG- Focus Group Discussion
FAO-Food and Agriculture Organization
HOMER-Hybrid Optimization of Multiple Energy Resources
IEA - International Energy Agency
IPCC- Intergovernmental Panel on Climate Change
IRENA- International Renewable Energy Agency
GHG- Greenhouse gases (mainly CO₂, N₂O, and methane)
GTP- Growth and Transformation Plan
GoE- Government of Ethiopia
KII- Key Informant Interview
KIAT-Korea Institute for Advancement of Technology
KWh-Kilowatt hour of electricity
LCOE- Levelized Cost of Energy
LUCF-Land Use Change and Forestry
LPG-Liquefied Petroleum Gas
MES- Mini-Grid Electric Service
MGE-Mini Grid Electricity
MoWE- Ministry of Water Electricity and Energy

MDB-Multi Donors Banks
MTF-Multi-Tier Framework
Mt- Megatonne (i.e., million metric tons)
NASA- National Aeronautics and Space Administration
NDC-National Determinate Contribution
NGTP-National Growth and Transformation Plan
NPV- Net Present Value
NEP- National Energy Policy
Opex- Operating Expenditure or Cost
RET- Renewable Energy Technology
SBDC- Single Bounded Dichotomy Choice
SSA-Sub-Saharan Africa
SDG- Sustainable Development Goals
SHS- Solar Home systems
PV- Photovoltaic
TCM- Travel Cost Methods
TWh- Terawatt hour of Electricity (Tera = one trillion)
WTP/WTA- Willingness to Pay/Accept
UEAP- Universal Electric Access Project
UNEP- United Nations Energy Program
UNDP- United Nations Development Programme

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ABSTRACT

Satisfying the ever-growing energy demand, but at the same time reducing greenhouse gas emissions and mitigating climate change are some of the most challenging and ardent issues for the policymakers around the world. Renewable energy is perceived as an effective way to cope with the dual nature of these challenges, usually topping the list of meaningful changes that our society can implement. Mini-grids play a critical role in providing electricity to remote, off-grid communities in grid option is not feasible. However, success of mini-grid projects can be hindered by poor cash flows and limited revenue returns. A clear understanding of off-grid household's preferences for electricity services is a prerequisite for mini-grid stakeholders to set tariff structures and stimulate income-generating power demand to scale up mini-grid deployment. The purpose of this paper is to determine to what extent the rural population is willing to make financial expenses for development of renewable energy. We also explore what lifestyle and socio-demographic factors influence willingness to pay. A contingent valuation methods were applied to 380 households from the rural populous and willing to pay is 355 birr (USD 6.57) per month. However, the empirical model reveals that the rural household's WTP value alone is insufficient to cover the cost of electricity. The total willingness to pay (TWTP) falls significantly short of the proposed project costs, covering only about 57% of the running costs and 39% of the total monthly costs. Investing in a decentralized mini-grid (DMG) with these characteristics would result in a capital loss over the system lifetime, necessitating subsidies to avoid financial losses. Our results also show that the creation of new jobs, household income, family size, age, basic education level, gender of the household head, occupation (particularly farming), and marital status, significantly impact household's WTP for renewable mini-grid services in the study area. Additionally, asset ownership, particularly land access, also significantly influences household WTP for these services. The study is useful in the design of adequate fiscal and renewable support policies and serves companies by identifying willingness to pay influence factors, as well as by demonstrating a market segmentation procedure. Additionally, creating an enabling environment by improving access to low-cost financing, implementing regulations that minimize project-related risks and fostering collaborative partnerships through a mix of public and private investments should be key policy objectives. These measures will facilitate the deployment of renewable hybrid mini-grid systems and help achieve targeted electrification ratios in a sustainable manner.

Keywords: *Renewable energy; Willingness to pay; Mini-grids; Bouble bound dichotomous choice; valuation methods.*

CHAPTER ONE: INTRODUCTION

1.1. Background of the study

The realization of universal access to low-carbon, affordable, reliable and modern energy services by 2030 is a key target of Sustainable Development Goal 7 (SDG7), the Sustainable Energy for All Initiative and the 2015 Paris agreement on climate change (Bruce & Vinuales, 2021). Yet despite significant progress towards this target in recent years, the current pace of electrification is considered insufficient to meet it and has been further exacerbated by the global socio-economic and political tension. The promotion of global goals, such as poverty reduction, sustainable development, and climate change mitigation, is primarily driven by off-grid renewable energy (REN21, 2013; UN, 2018; Johnston, 2016) and offers notable benefits such as improved access to clean cooking solutions, reduction of energy poverty, promotion of gender equality, and creation of sustainable employment opportunities. The desires of developing countries in the clean energy transition are twofold, apply low-carbon energy for profitable growth, and achieve universal energy access, and ameliorate human development. These binary objects can be getting a conflict in consummation because energy for growth must be low cost to support competitive products of goods and services.

Access to reliable electricity in Sub-Saharan Africa remains a significant challenge, with over 70% of the population lacking access to electricity, leading to extreme poverty (Butu et al., 2017; Blimpo and Davies 2019). This situation affects more than half a billion people in the region. The reliance on biomass, particularly in countries like Ethiopia, contributes to a significant increase in energy-related greenhouse gas emissions (World Bank Group, 2017). The World Bank Group (2017) shows the negative impact of this energy poverty on the region, and per capita energy consumption remains low across SSA, with the decline of Ethiopia rates below the regional average (MoWIE, 2012 and IEA, 2020). Addressing these challenges requires an effort to improve access and commitment to the region.

Nevertheless, off-grid Renewable energy systems are decentralized and technologically very different from traditional ones in terms of governance which creates unique challenges to their sustainable development or operation (Ma and Urpelainen, 2018; Nnafie, 2021; IRENA, 2019). However, progress is hindered by some factors such as policy inadequacies, institutional structures, technological barriers, cost-effectiveness issues (Frame, 2011; IRENA, 2019), capacity constraints, and public awareness concerns. The private sector's ability to provide affordable renewable energy products and services is often hindered by the absence of local manufacturing and service industries, as well as high initial costs and risks (Nnafie, 2021).

The expansion of off-grid renewable energy solutions poses a significant challenge for countries with numerous households without electricity. Lower adoption rates and higher connection fees are contributing factors to these challenges (Blimpo and Cosgrove-Davies, 2019). The practicality, reliability, and affordability of modern renewable energy (Trotter et al, 2018; Feron, 2016) are also disputed. Off-grid RE projects, particularly those facilitated by private actors, encounter several obstacles, such as unclear regulations, bureaucratic hurdles, and inadequate government backing, which are major contributors to the high rates of failure (Terrapon-Pfaff et al., 2014; Faron, 2016; Urpelainen, 2018; Dauenhauer et al., 2020). These issues can only be resolved through policies that are clear on all relevant matters, simplified procedures, and increased government support to improve the success rate of off-grid renewable energy projects.

Improving access to electricity is crucial for the development of rural communities, as it provides essential energy services, empowers local businesses, and improves the lives of residents. The provision of affordable and dependable electricity to remote regions can be achieved through off-grid energy production, which can also promote economic progress and sustainable infrastructure development (Lahimer et al., 2013; Baurzhan, & Jenkins, 2016; Poudel, 2020). To achieve universal access to electricity by 2030, it is essential to accelerate rural electrification projects. Small grids are seen as affordable and adaptable solutions for sparsely populated areas, offering different service levels at lower costs. However, these systems face sustainability challenges, particularly in terms of demand constraints and cost-reflective rates. Despite the benefits of low energy, its use is limited, especially in remote rural communities. Understanding the factors influencing rural electrification adoption and encouraging adoption is critical to economic empowerment and private sector participation (Blimpo et al., 2020).

The main strategic objectives of the Ethiopian government in the energy sector are focused on achieving global energy, improving energy efficiency, and promoting external energy production through the use of renewable energy technologies. To achieve universal access to electricity by 2030, rural electrification projects must be accelerated. Small grids, affordable and adaptable solutions for sparsely populated areas, can play an important role in this process (Light Power Africa, 2017). These specialized systems, with different designs and capacities, can achieve different service levels (ESMAP, 2015) and provide electricity to isolated communities at lower costs. Since 2012, there has been a significant increase in the number of small-scale projects in Ethiopia (Rahima, 2020). However, these systems face significant

sustainability challenges, especially due to demand constraints requiring cost-reflective rates (Pedersen et al., 2020). Despite the advantages of mini-grid electricity, adoption remains low, especially in rural off-grid communities. Understanding the factors influencing rural electricity adoption and incentivizing uptake is critical for financial feasibility and private sector involvement (Blimpo et al., 2020).

The Ethiopian government's strategic priorities in the energy sector focus on achieving universal electrification, improving energy efficiency, and promoting decentralized off-grid power generation using renewable energy technologies. To achieve total electricity access by 2030, accelerating rural electrification initiatives is essential. Mini-grids, adaptable and cost-effective solutions for low-population-density areas, can play a significant role in this endeavor (Light Power Africa, 2017). These independent systems, varying in design and capacity, can cater to different service levels (ESMAP, 2015) and offer energy access to isolated communities at reduced costs. Since 2012, there has been a significant rise in the installation of solar mini-grid projects in Ethiopia (Rahima, 2020). However, these systems face considerable sustainability challenges, particularly due to demand constraints that necessitate cost-reflective tariffs (Pedersen et al., 2020).

There is a notable gap in research regarding the willingness of off-grid customers in Ethiopia to pay for decentralized mini-grid electricity. This study seeks to fill that gap by examining household willingness to pay for electricity access. It utilizes empirical data gathered from community energy surveys conducted in selected solar mini-grid areas. This information is essential for accurately modeling rural household demand for renewable electricity and establishing optimal tariffs to ensure the commercial viability of the off-grid sector. It will provide insights into the correlation between customer WTP and their ability to pay (ATP), reflecting their financial capacity based on income.

1.2. Statement of the problem

The financial sustainability of the power sector has long been considered a prerequisite for ensuring universal access to affordable, dependable, and sustainable electricity and the transition toward clean energy (WB and IEG, 2016; Huenteler et al., 2018). However, the chronically poor financial performance of energy utilities remains widespread in developing countries due to factors such as low prices, excessive losses, and difficulties in collecting bills. These problems have long caused a lack of investment, inadequate infrastructure maintenance, electricity shortages, and poor supply quality (Huenteler et al., 2017). Electricity subsidies, necessary to sustain overwhelmed utilities, have significant macroeconomic, fiscal, and social implications. They divert fiscal resources away from other essential public services, including

clean water, education, health, and social protection (Saavalainen and Ten Berge, 2006; Komives et al., 2007; and Sdravovich et al., 2014). Moreover, the underpricing of electricity contributes to higher pollution levels and other environmental impacts (Huenteler et al., 2020).

Several stumbling blocks hinder the adoption and effective use of off-grid energy sources, in areas without grid connections. These challenges include affordability issues for the poor and overall low demand for electricity, which also affect grid connectivity efforts (Lee et al., 2014; Blimpo et al., 2020; and Sylvia M., 2021). As a result, recently electrified regions experience a low adoption of off-grid solutions due to the significant financial burden on households (Lenz et al., 2017; Urpelainen and Richmond et al. 2019).

While recent years have seen the rapid growth of off-grid solar power, ten per cent of the world's populations, the majority in sub-Saharan Africa, still lack access to electricity. Research shows that while off-grid solutions are preferred for remote areas, the willingness of the poor to pay does not cover the necessary costs (Blimpo et al., 2020; Grimm et al., 2020). The limited financial capacity to invest in the development, production and distribution of electricity adds to the problem. The limited ability of consumers to pay for the electricity consumed results in insufficient funds for suppliers. Current tariff structures fail to generate sufficient revenue to cover electrification costs, potentially leading to financial losses for off-grid providers if consumption levels and prices do not increase (Blimpo et al., 2020). Affordable systems or basic tariffs, even if they are socially acceptable, often do not provide enough energy for economic growth, thus perpetuating energy poverty. Utilities struggle to recover costs at low costs due to consumers paying tariffs below average production costs (Dye, 2023), a long-standing concern for service providers.

In spite of Ethiopia expanding population and economy, approximately 45% of its inhabitants, equating to 81 million individuals, lack access to an electric grid, and those connections often face unreliable service (World Bank, 2020; Getachew, 2020). The existing grid infrastructure fails to meet the escalating demand, resulting in an electricity access deficit that hampers economic growth and societal development. Off-grid solutions such as renewable off grid mini grid are emerging as potential solutions. However, the acceptance of off grid energy solution amongst off- grid communities and the households' willingness to pay (WTP) for such systems, which is a crucial determinant of viability, warrants further exploration.

In Ethiopia, depriving of access to clean, efficient and environmentally sustainable modern energy services significantly hinders economic growth and sustainable development. The availability of infrastructure services, such as electricity, plays a crucial role in long-term

economic growth (Guta, 2014). Admitting the vital role of the energy sector in economic growth and development, the Government of Ethiopia (GoE, 2016) has initiated large-scale energy projects aimed at rising renewable and sustainable energy sources. Significant investments have been made in energy infrastructure, including electricity generation from hydro, wind, solar, and geothermal sources (Guta et al., 2015).

The transition to renewable energy sources is essential to improve the livelihood of people in rural areas (Babayomi et al., 2022). However, about 80% of the rural population does not have access to electricity, in stark contrast to the electrification rate of 90% in urban areas in Ethiopia. This inequality significantly affects living standards and contributes to high levels of poverty in rural areas. Addressing this disparity is essential to economic equality. In response, the Ethiopian government implemented the National Energy Policy (NEP 2.0) in March 2019.

NEP 2.0 aims to make more than a third of electricity connections from off-grid solutions, including solar mini-grids with local low-voltage networks by 2025. The establishment of off-grid power plants in Ethiopia has encountered challenges, which have a limited impact on rural development. Despite the launch of twelve mini-grid pilot projects in 2019, many remain in the pilot phase. Furthermore, the rural mini-grid electrification initiative, including the Koftu solar mini-grid model, has failed to deliver sustainable electricity in line with Ethiopia's national strategy. Research indicates that project failure often emerge from beneficiaries in ability to pay' insufficient institutional and financial capacity to manage and sustain these power plants, leading to reduced community willingness to pay for electricity and cover maintenance costs.

Regulation of electricity prices based on customers' willingness to pay can ease financing problems. Although private investment and incentives have been encouraged for the renewable hybrid mini-grid sector, Ethiopia has not had significant success in decentralizing electrification as an alternative to expanding the network in rural and remote off-grid areas. Moreover, it has not yet introduced mini-grid tariffs that are consistent with those of customers connected to the grid. The significant costs associated with setting up and running mini-grids mean that private-sector developers will only invest if they foresee profitability.

Therefore, setting electricity prices based on consumers' willingness to pay can help solve financing problems. Although several empirical studies have examined the willingness of Ethiopian households to pay for electricity, none have specifically addressed the sustainability of off-grid mini-grid systems in the case of off-grid lines. This study aims to fill this gap by using the contingent valuation method to estimate the willingness of rural households to pay for mini-grid electricity. It takes into account various factors, such as socioeconomic conditions,

electricity reliability, perceptions of renewable energy, and environmental awareness. The results are intended to inform decision-making processes to ensure the long-term financial sustainability of rural electrification and to understand how different factors affect the demand for energy services.

1.3 Objective of the study

1.3.1. General objective

The primary objective of this study is to analyze household's willingness to pay for Koftu solar mini-grid off-grid renewable electricity supply in the Akaki district of Oromia Regional State.

1.3.2. Specific objective

1. To measure household willingness to pay (WTP) for off-grid solar-powered mini-grid electric service provision using contingent valuation methods.
2. To investigate determinants of household's WTP for off-grid solar-powered mini-grid electric service in rural settings.
3. To analyze household WTP values recovery cost of electricity service in off-grid renewable electric service.

1.4. Research questions

Within mind the research problem afore mentioned above this study addresses the following questions:

1. How much does a household pay for a renewable mini-grid electricity service in a rural off-grid setting?
2. What are the determinant factors that influence household's WTP for off-grid renewable energies mini-grid rural electrification?
3. Does the household willingness to pay (WTP) value cover the cost of service in mini-grid energy service project?

1.5. Significance of the Study

This research aims to identify the factors that influence the sustainable operation of renewable energy -based mini-grid systems. The findings will be valuable for researchers, stakeholders, and especially those working in the energy sector, as they provide insights into how to effectively disseminate renewable energy technologies, such as mini-grid solar energy, to rural households.

Importantly, the results of this study can serve as a crucial input for rural electrification programs, helping to focus on the identified factors during the promotion of these technologies.

The study is expected to inform policymakers about the amount an average rural household is willing to spend to access renewable mini-grid electricity services. This information will guide not only tariff adjustments but also support the development of comprehensive business strategies for off-grid, renewable energy electrification services. Overall, the findings will be instrumental in shaping policies and strategies to enhance the adoption and sustainability of renewable energy solutions in rural areas.

1.6. Scope of the Study

The study focused on household's willingness to pay for solar off-grid electricity access, specifically examining the case of the Koftu mini-grid.

1.7. Limitation of the Study

Due to time and financial resource constraints, only one mini-grid was selected as a case study. As a result, the ability to generalize the findings to other mini-grids is limited. Moreover, methodological limitation of WTP approach since hypothetical market scenario presented for respondent is not realized.

1.8. Organization of the thesis

The structure of the thesis is critical organized, beginning with Chapter One, which provides an introduction and an overview of renewable energy, with a particular focus on mini-grid electricity. This chapter also addresses the key issues in depriving the development of renewable energy. Chapter two look into the existing body of knowledge through a comprehensive analysis of various articles, journal policy documents on mini-grid and renewable energy policy issues in Ethiopia, as well as books and other credible sources obtained from the internet.

A crucial section of the thesis is the methodology, presented in Chapter Three. This chapter outlines the research approach used to address the identified problems related to renewable energy, specifically focusing on the willingness to pay for non-market environmental services. Chapter Four is dedicated to the presentation of data, findings, and the analysis of major results.

Finally, Chapter Five summarizes the findings based on the data analysis, draws conclusions, and offers recommendations for future actions to improve energy access in rural communities.

CHAPTER TWO: RELATED LITERATURE REVIEW

In this section, we look into the literature on the economic valuation of non-market goods. We specifically examine the theoretical underpinnings of the methods developed by economists to evaluate the value of public environmental resources.

2.1. Concept and Theoretical Literature Review

Electricity can be regarded as a normal good (service) and, thus, higher disposable income is expected to increase consumption through greater economic activity and purchases of electricity- using appliances in both the short- and long-run. On the other hand, a rise in electricity prices *ceteris paribus* will lead to a fall in quantity demanded. Economic theory suggests that electricity purchases will depend on the prices of its substitutes such as fuel oil. The independent influence of alternate fuel prices is rather small because of the response by suppliers and the constraints faced by consumers in fuel switching. However, fuel oil prices could be taken as an alternative measure of prices. Valuation: it is the process of putting monetary values on goods and services, many of which have no easily observed market prices. Willingness to pay (WTP) is the maximum sum of money the individual would be willing to pay for rather than do without an increase in some good such as an environmental amenity. This sum is the amount of money that would make the individual indifferent between paying for and having the improvement and forgoing the improvement while keeping the money to spend on other things (Freeman et al., 2014)

Willingness to accept (WTA) is the minimum sum of money the individual would require to forgo voluntarily an improvement that otherwise would be experienced; it is the amount that would make a person indifferent between having the improvement and forgoing the improvement while getting extra money (Freeman et al., 2014). It is designed to ask for an individual's minimum willingness to accept compensation for a decrease in the quality or quantity of the resource (Othman et al., 2016).

2.1.1 Utility Theory

The objectives of this research are grounded in the theory of demand and utility functions, which underpin the understanding of consumer behaviour in contingent valuation studies (Pearce et al., 2002). This study employs the theories of utility and demand to explain individual appraisals of an asset (Carson & Hanemann, 2005). Given 'q' as an asset and 'x' as other market goods, utility can be defined as $u = (x,q)$. The indirect utility function is denoted as $v(p,q,y)$, where 'p' represents the price vector for other market goods and 'y' denotes the

individual's income (Audu & Adamu, (2022). Utility is compared across two scenarios: "with q" (q_1) and "without q" (q_0), with the difference between these situations determining the Hicksian measures, Compensating Variation (C), and Equivalent Variation (E) (Carson & Hanemann, 2005). These measures serve as value indicators for the change in 'q'.

Given the focus of this study on WTP rather than willingness to accept (WTA), it's worth noting the absence of individual property rights on the asset under consideration (Mitchell & Carson, 1989). This study specifically measures the Hicksian consumer surplus measure of compensating variation for improvements.

A number of theories have been developed to measure people's willingness to pay to ensure the sustainability of publicly funded goods and services. The contingent valuation method (CVM) is an example of the stated preference methods whereby hypothetical markets are created for a non-marketed commodity and individuals are asked to state how much they would be willing to pay for the commodity if the market really existed. It draws upon economic theory and survey research to elicit directly from consumers the values they place upon commodities or services (Carson & Hanemann, 2005; Mitchell & Carson, 2009). In a contingent study, the proposed improvement (or damage) in the provision of the commodity is presented in a hypothetical market and the individual is then asked to express his or her maximum (minimum) willingness to pay (or accept) to benefit (lose) from the consumption (destruction) of the commodity (Seip & Strand, 1992). Both Bowen and Ciriacy-Wantrup saw that a typical feature of these goods was that, while individuals would have their own distinctive demand curves for these goods, the aggregate demand curve is obtained by adding the marginal rate of substitution (expressed in money) of the various individuals at each possible quantity of the social good.

2.1.2. Non-Market Goods Valuation

Economists have developed several techniques to estimate the value of public environmental goods that are not traded in markets. These methods are generally categorized into two types: revealed preference methods and stated preference methods (John Loomis, 2005). Additionally, hybrid methods that integrate both market-based and non-market valuation approaches are used to assess the value of public environmental services, such as green electricity. The indirect approach estimates the unobservable demand and value of environmental goods and services by analyzing the observable demand for related marketable goods and services.

Economists analyze market transactions for private goods to infer the demand for environmental goods (Freeman, 1993; Tietenberg, 2003). The indirect method includes the travel cost method (TCM), hedonic pricing method (HPM), averting expenditures, and production functions. The great advantage of the revealed preference method is its dependence

on the actual behavior (Bockstael et al 2005, P.538). The Travel Cost Method (TCM) is used to determine the value of environmental amenities by examining the travel expenses incurred by individuals to access these sites. By studying how people allocate their time and resources to visit natural areas, economists can estimate the value they place on these visits (Saúl Torres-Ortega, 2018).

The hedonic Pricing Method (HPM) examines the relationship between property prices and environmental attributes. By analyzing real estate transactions, economists infer the value that individuals place on features like clean air, proximity to parks, or scenic views.

2.1.2.1. Stated preference methods (The direct method)

The stated preference methods are the direct valuation methods used to solicit value measures by asking individuals hypothetical questions. In the stated preference techniques individuals are directly asked to state their willingness to pay (WTP) and/ or willingness to accept (WTA) compensation for change in public environmental resources from a hypothetical market scenario (Frey et al. 2004, p.1).

The Contingent Valuation Method directly asks individuals hypothetical questions about their willingness to pay (WTP) or willingness to accept (WTA) compensation for changes in environmental resources. It involves creating a hypothetical market scenario and eliciting respondent's stated values.

Choice Experiment Method, respondents choose between different program alternatives, each with varying attributes and costs. By analyzing these choices, economists estimate the marginal valuation of each attribute. These valuation techniques play a crucial role in understanding the economic value of non-market goods, even when direct market transactions are absent.

2.1.2.2. Choice methods

Choice modeling (CM) is another SP method that can take three possible forms: Discrete Choice experiment, contingent ranking (CRN) and contingent rating (CRT). The basic designing of the alternatives is the same in each approach and the respondents must decide which of mutually exclusive multi-attribute alternatives they prefer. Choice Experiments, also known as comparative analysis, involve asking respondents to select between two programs (A and B), each with different attributes and associated costs, or to reject both options (Dibaba et al., 2022). This allows marginal valuation of each attribute (Rahnama, 2018).

2.1.3. Contingent Valuation Method

Contingent valuation (CV) is a well-established valuation method used to estimate people's willingness to pay for public or non-market goods and services. It involves creating

hypothetical markets where individuals are asked how much they would pay for a good or service that does not currently exist in the market. This survey-based method is commonly used in environmental economics and impact assessments to estimate non-market and non-use values.

Despite its widespread use, CV has faced criticism regarding accuracy and reliability. Some challenges include:

Hypothetical Bias, the use of hypothetical scenarios can introduce bias, as respondent's preferences may differ from real-world market behavior.

Strategic Biases when respondents might understate their true WTP (free riding behaviour) or overstate it to influence service provision.

Scenario Influence, the information and scenarios provided to respondents can impact CV results positively or negatively.

However, researchers like Whittington (2004) and Carson et al. (2001) argue that careful study design and implementation can address these issues. CV remains informative for eliciting passive or bequest values, which are often overlooked in expert judgments. For example, individuals might be willing to pay for reliable electricity services not just for their own direct benefit, but also out of moral considerations. They may believe it is morally right to ensure that others have access to better services, even if they do not expect to benefit directly themselves (Taale and Christian, 2016). Regarding WTP studies for electricity, common CV methods commonly applied include:

Single-Bounded Dichotomous Choice (SBDC): Respondents are asked whether they would pay a specified amount for a good or service (YES or NO). The bid value differs among respondents, resembling a bargaining process (Dahal et al., 2022).

Double-Bounded Dichotomous Choice (DBDC): In this method, respondents make two consecutive YES or NO choices. If the first choice is YES, the second bid value is higher; if the first choice is NO, the second bid value is lower. The dichotomous choice format offers two main benefits over the open-ended question format when eliciting willingness to pay (WTP): it is easier for respondents to understand and it minimizes the likelihood of strategic responses (Bateman et al., 2000). Double-bounded contingent valuation is preferred by many scholars since it increases efficiency and avoids many of the biases inherent in CVM. DBDC is preferred by many scholars due to increased efficiency and reduced biases (Oseni, 2012; Abdullah and Jeanty, 2022).

Other CVM studies use different elicitation methods.

Open Ended: Respondents provide a point estimate of their WTP. For instance, the question might be phrased as, what is the maximum amount you would be willing to pay for an off-grid solar system? Currently, the open-ended contingent valuation (CV) elicitation format is less commonly used because respondents often struggle with the payment question; leading to numerous missing values (Popping, 2015). Bidding Game: Participants engage in a sequence of questions and answers until they identify either a maximum estimate or reach a point estimate of their Willingness to Pay (WTP). However, this method may suffer from lack of incentive compatibility and starting point bias. For example, it is worded as "What are the most you would be willing to pay for off-grid solar system?" now days open-ended CV elicitation technic is not usually seek to employed as result of challenging costumers to respond payment question and exposed to too much missing values or outlier(Popping, 2015).

Payment Cards: Respondents choose a WTP point estimate (or a range) from a list of values on a payment card. This approach lists possible values and asks customers to select the best representation of their WTP. Some criticism exists, as respondents may limit their announced WTP to the listed values. This approach involves presenting customers with a card that displays a range of possible values. They are then asked to select the value that most accurately reflects their minimum willingness to pay (WTP) and another value for their maximum WTP. This approach is also criticized on the ground that the respondents might limit their announced WTP to the values listed on the (Kerr, 2001).

2.1.3.1. Bid value and Elicitation method

The choice of elicitation format is crucial because different formats yield varying estimates. Currently, the dichotomous choice format, accompanied by one or two follow-up questions, is preferred over other alternatives. It is widely used for eliciting willingness to pay (WTP) and has proven effective even in developing countries (Dalal, 2000). This format mirrors people’s behavior in regular markets, where they decide whether to buy or decline a purchase. By reducing cognitive burden, it ensures more accurate responses from survey participants.

In this study, the elicitation question follows the double-bounded dichotomous choice format. Respondents answer with either —yes (indicating acceptance of paying for access and consumption fees for the new service) or —no (refusal to pay). If a person refuses, an open ended question explores the reasons behind their protest bid.

Table 1: Mini grid power generation capacity and daily energy demand of study interest

Plant power capacity (kwp)	Area solar irradiance(kwh/m2/ /per day	Daily average energy generated for sale kWh	Commercial daily demand	Community daily Power load
250	5.81	1162	429 kwh	1.045(29)

Operation Cost of mini grid

For the plant to run well, it requires upkeep, tending to any specialized issues, and periodical substitution of parts such as batteries and inverters. To calculate the toll of supplanting components, costs of person and sun-oriented components were utilized to come up with the sum of cash required to supplant these components after their life span exhaustive assessment amid vitality venture advancement to decide reasonable OPEX costs and vitality duties inside the nearby socio-economic setting which characterizes the supportability of an off-grid framework. It must be clear at this point that the calculation displayed does incorporate not any taken toll of capital as the extent was 100% grant-funded. For a plant to be operationally maintainable, income created from the deal of sun-based vitality ought to be able to meet all the OPEX costs. Yearly vitality produced can be assessed utilizing the everyday vitality produced values from the (WB and Kang, 2020).

Table 2: Estimated sustainable tariff

Sustainable tariff using Investment cost of the project		Annualized cost	monthly
Total system capacity(kwp)	250		
Annual solar irradiation in the area(kwh/m2/day)	5.81		
Energy Generated daily kwh	250×5.81		
Annual energy generation kwh	530162.5		
Net energy assuming after 20% energy loss kwh	530162.5×0.88		
Annual energy sold 80% kwh	1163	424130	35344
System life period in years	25		
Initial CAPEX	USD125,0000	50000	
Replacement cost	140300	5612	467.3
O&M cost CAPEX 2%	25,000\$	1000	83.3
overhead cost	2449800	97992	8166
contingency 5%	62500	2500	208.3
total OPEX	2,677,600	107104	8925
tariff per kwh	0.25\$ kwh per month		

Source: own computation, 2023.

Given that the leadoff capital cost was comprehensively funded by an allocation, the cost-reflective tariff is estimated to be the minimum reference tariff that yields a positive Net Present Value (NPV > 0). The minimum reference tariff is estimated to be around 0.25 US\$ kWh which is equal to 7 birr. This tariff will be set as a threshold checked to bring sufficient gain on a yearly root to cover the cost of constituents (innovators, batteries) as well as operation expenditure in the life span of design. The assumed service stoner will cover all OPEX costs of design grounded on the estimation given in the above table also the following shot value will be proposed on the basis of per kWh energy demand to know the ménage

amenability to take operation cost of design. In this regard, the original cost (400, 500 600, and 700) with high and low follow-up bid price is proposed.

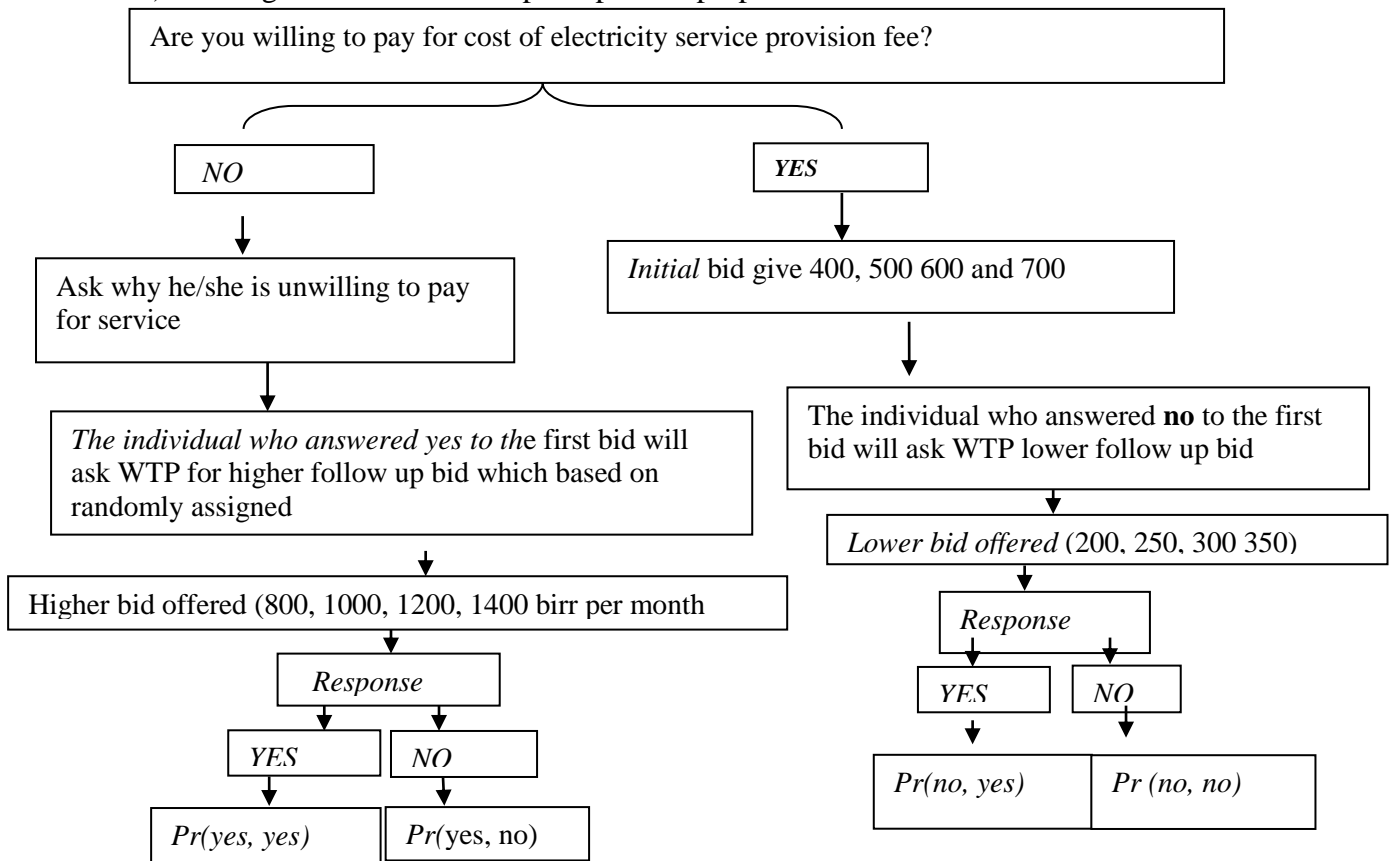


Figure 1: Conceptual framework of CVM-DBDC Elicitation

Source own constructed, (2023).

2.1.3.2 Payment Vehicle Selection

The selection of payment vehicles is often study-specific and will always require careful pretesting to understand how respondents view the payment vehicle. In the context of this study, where customers are newly connected to electricity services, the utility bill serves as the payment vehicle. It's important to note that there is no standardized tariff for off-grid services, as the national tariff structure typically extends to grid-connected areas. Consequently, the cost may not accurately reflect the economic demand of rural low-income communities. Developing feasible policy options and considering payment schedules are crucial factors in ensuring affordability and sustainable service provision (Whittington, 2010). For this study, a customer is newly connected to an electricity bill fee i-e the utility bill is set to determine the household to offer service so the household will ask WTP for access to mini-grid electricity as there is no standardized tariff since the national tariff for the grid is extended to off-grid which might not cost reflective.

Ethiopia's commitment to investing in environmentally friendly renewable energy is promising. Still, the advanced installation costs of renewable power plants compared to conventional energy sources pose challenges. Ethiopia aims to reduce environmental pollution and dependence on foreign energy by investing in renewables. This aligns with global trends toward sustainable energy systems (IEA, 2012). Beyond government enterprise community steal-theft is pivotal for the sustainability of renewable energy investments. People willing to pay (WTP) plays a vital part in backing intimately funded goods and services. WTP is a theoretical concept that reflects the maximum price a consumer is willing to pay for given a product or service in this case, maximum cost pay to access electricity service. Factors impacting WTP include income situations, electricity prices, electrification status, indispensable energy vacancy, perceived value, and being electricity expenditure (TERI, 2017). While advanced countries have sustainable electricity access, understanding WTP becomes critical when transitioning from grid-connected systems to out-grid or original micro grids. Whether for a low-carbon energy system or decentralized results, WTP informs decision maker to invest.

In general, balancing affordability, environmental pretensions, and community engagement is essential for Ethiopia's renewable energy trip. Understanding consumer's amenability to pay (WTP) is pivotal for new product development, pricing strategies, and competitive positioning. WTP measures involve three main procedures Direct Open Format Question Repliers are directly asked about their WTP for increased consumption of a specific good or service. List Model Actors are presented with colorful value options, and they indicate the quantum they would pay for each listed value. Vote Model Actors express whether they're willing to pay a specific quantum for the good or service. These approaches give precious perceptivity for decision-making and help knitter immolations to consumer preferences (Breidert et al., 2006). Grounded on the data collection system, WTP checks can be divided into two major orders revealed and expressed preferences.

Revealed preference data are derived from individuals' responses to price changes or new product cost. In the case revealed preferences can be inferred from the charges of the original population for indispensable sources of energy, similar as kerosene for lights or candles, and for charging phones. On the other hand, expressed preference data deduced from checks are constantly appertained to as stated preferences or the contingent valuation methods (CVM). In this case, consumers are asked to reveal the maximum quantum they're willing to pay for an academic service or product that's created by a request experimenter. According to USAID, & NRECA International, Ltd (2019), the styles produce a realistic script that offers a rational rate

of electricity service that's also attainable for the electricity design. therefore, the end of this thesis increase our understanding of the WTP for out- grid electricity to be suitable to estimate how numerous people are willing to satisfy their electricity consumption through a mini-grid connection.

Another profitable principle used is the Ability to Pay (ATP), which states the quantum of plutocrat that a person can pay relative to income and wealth. It's about Affordability which refers to the factual capability of a ménage to pay for goods services and it can be distinguished between the affordability for access and the affordability for consumption (Estache et al., 2002), consumption is examined in this study where access is addressed. Although its primary function is for taxation purposes (Koritnik and Podlipnik, 2017), in this thesis, the term will be used to assess the income effect that leads individuals to pay more than their willingness to pay (WTP). Income status plays a crucial role in determining WTP; Venkatachalam (2004) found a significant correlation between WTP and the income status of respondents in developing countries. Therefore, the ability to pay (ATP) should be considered alongside WTP.

2.1.4. Sub-Saharan Africa country Energy Trends

Underdeveloped Sub-Saharan African countries were the home to over 950 million people, face significant challenges to basic services mainly electricity access (Avila et al., 2017). Nearly more than half a billion individuals lack access to electricity, whereas millions more are connected to an unreliable grid source of electricity that fails to meet their daily energy needs as a result of inefficiency. Moreover, accounts for 80% of the global population lacking electricity access are found in this region which indicates serious deprivation. Despite efforts to extend access, recent crises related to geopolitical events have hindered progress, pushing the number of people without electricity back to 2019 levels. It's crucial to address these disparities and work toward universal access to sustainable energy in Sub-Saharan Africa.

Electricity access in Africa has significantly improved, with the number of individuals gaining access doubling from 9 million between 2000 and 2013 to 20 million between 2014 and 2019, outpacing population growth (IEA, 2020). This progress has significantly minimized the number of people without electricity from 610 million in 2013 to 580 million in 2019, predominantly as a result of all-embracing electrification programs in the region (IEA, 2020).

The majority of residents in Sub-Saharan countries have shown nearly a 20% improvement in electricity access (Abimbola and Ajagun et al., 2024). The average annual electricity consumption per person in the residential sector of Sub-Saharan Africa is 488 kilowatt hours (kWh) much less in comparison with others. A 35% surge in electricity demand was noted from 2000 to 2012, with reports indicating a total of around 352 terawatt-hours (TWh). A 4%

annual increase in the energy demand trend is anticipated (Avila et al., 2017). The prevailing energy scenario in SSA necessitates immediate actions for the expansion and enhancement of power grids. The ongoing pace of electrification endeavors falls short of achieving the objective of "electricity for all" by 2030. At this pace, over half a billion individuals will remain without electricity by 2040, requiring at least 40 more years to realize the target (Avila et al., 2017).

The role of Africa continent in global GHG release has been relatively emanates and it is reported to only contribute 2% of global CO₂ emissions from energy-related sources. Despite the continent's growing economies, it is projected that Africa's cumulative CO₂ contribution will only increase to 3% by 2040. Whereas the contribution of electricity to climate change is minimal as compared to other regions since most of the energy source was derived from renewable sources. In 2017, Africa's fossil fuel emissions represented just 3.6% of the global total, even though the continent is home to nearly 17% of the world's population. However, Africa is highly vulnerable to the impacts of climate change (Abimbola and Ajagun, 2024).

A significant number of people, approximately 700 million, live in areas where the average daily temperature exceeds 25 degrees Celsius (Abimbola and Ajagun, 2024). Even due to the high poverty rate in the region, most individuals could not access the cooling device. By 2040, this situation is anticipated to deteriorate as average temperatures increase due to climate change. Furthermore, Africa's population is expected to reach 1.2 billion by that time. Thus, it is very indispensable to allocate resource to the development of modern and efficient power systems to pull out Africa's renewable energy potential and alleviate dependency on fossil fuels (Abimbola and Ajagun, 2024). Despite a significant portion of the population lacking access to electricity, Sub-Saharan Africa (SSA) possesses diverse energy resources that can meet the continent's current and future electricity needs. These resources encompass abundant solar potential across nearly all Sub-Saharan African countries, geothermal capacity in Eastern Africa, hydropower resources in Central, Western, and Eastern Africa, coal in Southern Africa, and oil and gas in Eastern, Southern, and Western Africa (Xavier et al., 2021). Sub-Saharan Africa boasts a vast renewable energy resource potential, with an estimated 525 GW of solar PV capacity and 475 GW of concentrated solar power. These solar energy resources are distributed throughout the region.

2.1.5 Energy sector in Ethiopia

The development of the economy and livelihoods is heavily reliant on access to modern energy sources, as highlighted by (Mondal, 2018). In Ethiopia, the energy sector faces challenges due to limited access to modern energy and a significant dependence on traditional biomass

sources, as noted by (Mondal, 2018). Ethiopia primarily generates electric power from hydro sources, with only 23% of the population connected to the national grid in 2012, according to the World Bank (2015). Urban areas have higher electricity access at 92%, while rural regions lag significantly at about 5% (WB, 2015). Biomass is the main energy source in Ethiopia, constituting 91% of energy consumption (MOWIE, 2005). The heavy reliance on biomass for cooking and heating in rural areas poses health and environmental risks, as highlighted by various studies (Guta et al., 2015; Guta, 2012). In 2006, biomass energy accounted for 89% of the total national energy consumption (Benti et al., 2021).

Urban households and small industries are the main consumers of electricity in Ethiopia, with consumption increasing over the years but still lower compared to other African countries (Asres et al., 2021). Petroleum fuels and electricity meet a small percentage of the national energy consumption. Just 7.6% and 1.1% of the country's energy needs were satisfied by electricity and petroleum fuels, respectively. With 89% of gross energy consumption in 2006 coming from the residential sector, Ethiopia's energy industry is typified by its dominance. The majority of the energy needed for domestic use comes from wood, animal manure, and agricultural waste. Of the approximately 16 million families, 81% utilize firewood, 11.5 percent cook with leaves and dung cakes, and 2 percent use kerosene.

One of the nation's most fortunate to have access to a variety of renewable energy sources is Ethiopia, including hydro, photovoltaic, wind, and biomass. Potential energy sources include 45 GW for hydropower, 10 GW for wind, 5 GW for geothermal and 4.5 kWh/m² to 7.5 kWh/m² for solar radiation each day (Mengistu, 2015). Ethiopia now has roughly 2 GW of hydropower capacity in use, and over the next few years, work is being done to increase this amount fivefold. The Ethiopian Electric Power Corporation (EEPCO) describes how it plans to significantly increase its hydropower capacity over the next few decades in its 25-year growth plan (Rahima, 2021). Accordingly, the development of renewable energy technologies to enable decentralized off-grid power generation, energy efficiency enhancement, exporting electricity to neighboring countries, and universal electrification access are the Government of Ethiopia's strategic priorities in the energy sector (Mondal, 2018). The current generation is predicted to rise five times to 30 TWh, per the nation's growth and transformation plan for 2015 (MoWE, 2011). To carry out the plan, work has already begun on the Grand Renaissance Dam on the Blue Nile and the Gibe III dam, which has an 8000 MW specified power capacity. Five further hydropower stations, with a combined installed capacity of 1500 MW, are currently in the development stages. They are called Chemoga Yeda, Geba, Halele Werabesa, and Genale Dawa III and IV. Their capacities range from 250 MW to 400 MW. It is also anticipated that

wind power output will rise to 866 MW. A total of 150,000 solar home systems (SHS) are intended to be given to rural areas and institutions, despite the fact that solar energy is still untapped, according to several data sources, including national databases (MoWE, 2011).

The Ethiopian government has several ambitions, some of which include producing renewable energy, electrifying the entire country, and exporting extra electricity to its neighbors. With the intention of granting access to electricity to everyone by 2025, Ethiopia initiated the "Light to All" National Electrification Program in November 2017. By providing grid access to 65% of the population and mini-grid and solar household systems (SHS) to the remaining 45%, NEP 2.0 seeks to achieve 100% electrification by 2025 (Bekele, 2024).. According to MoWIE (2019), the NEP 2.0 policy has the following primary objectives and intentions. On-grid Access: By 2025, 65% of people living 2.5 km or less from the grid will have grid access. This corresponds to about 15 million homes. It also includes homes that are already linked to the grid. A short-term off-grid electricity strategy is being implemented for a group of people who will gain access to power in the latter half of 2025. Until then, solar home systems will provide electricity to these families

Long-term off-grid access: By 2030, it is anticipated that households more than 254 kilometers away from the grids will not have access to grid connections. Mini-grids and solar-powered household systems will be available for electrification up until that point. Mid-term electrification: By 2025–2030, homes 2.5–25 kilometers from the grid should have access to electricity. They will be electrified by using mini-grids or off-grid solar system (Rahima, 2021).

2.1.6 Electrification projects of Ethiopia

The Ethiopian government is actively pursuing the goal of providing affordable power to all citizens by 2030. The Ethiopian government and Ethiopian Electric Power Corporation (EEPCo) have launched a number of development initiatives to meet Ethiopia's increasing energy needs. Ethiopia's National Growth and Transformation Plan (GTP) include several initiatives.

Nonetheless, Ethiopia's low rate of energy access continues to be a major obstacle to development and the eradication of poverty. In June 2015, the Energy Sector Management Assistance Program (ESMAP) adopted a multi-tier framework (MTF) technique to assess the state of energy access. Using this framework, families are divided into various groups according to the degree of electrical access. From Tier 0 (no access) to Tier 5 (full access), there are six tiers in all. The MTF offers insightful information that helps policymaking organizations understand the nation's energy position. Ethiopia hopes to increase energy

availability for all of its population and support sustainable development by tackling these issues (Rahima, 2021).

2.1.7 Rural electrification in Ethiopia

Ethiopia has carried out a number of projects and programs to improve access to energy. The government launched the Rural Electrification Project in 1999, marking the beginning of the first significant rural electrification project. The project's main objective was to expand the electrical network to large towns and Woreda (district level) towns that were adjacent to substations or existing distribution lines. Rural electrification is one of Ethiopia's biggest issues right now. Financial constraints, ineffective distribution networks, and limitations on grid extension initiatives are some of the obstacles to electrifying isolated rural areas. Metropolitan households receive less priority than rural ones from state distribution businesses, which already operate at a loss throughout the majority of Ethiopia. This difference can be explained by the fact that rural communities have less demand for power and have less financial means than their metropolitan counterparts. Government programs to promote rural electrification have been implemented in the past and present, but issues with technical, institutional, and social factors still need to be addressed.

Ethiopia has historically placed a great deal of emphasis on hydropower and maintained extremely low subsidized electricity tariffs, such as EEU and EEP, which have historically operated at a loss and added to the nation's debt load while operating poorly and not significantly improving access to electricity in rural areas. The situation has been evolving in recent years due to multiple tariff increases (Hassen et al., 2022). The government designated access to energy as a high-level policy goal at the same time as these policy adjustments. Although the nation's overall access rate has been increasing (to 48% as of 2020), more work must be done to reach the national target of universal access by 2025 (IEA et al., 2021). Over 90% of people currently have access to cities, but guaranteeing rural access, particularly in mountainous or remote areas, is more difficult.

2.1.8. National electrification program

NEP was introduced in 2017 sets a strategy for achieving universal access by 2025, with the goal of providing off-grid options to 35% of the population. Along with, Ethiopia is expanding its hydro-dominated installed generation mix to include solar, wind, and geothermal in order to achieve a more climate-resilient power system and economic development goals (MoWE, 2015). The MoWE is now in charge of the new energy policy, which outlines a plan to diversify the country's energy sector and seek all exploitable renewable energy resources.

According to Lighting Africa (2018), governments anticipate that by 2025, 65% of the population will be connected to the grid, with a significant focus on expanding connections in areas within short-term reach of the grid. The remaining 35%, or approximately 7.7 million households, will need an intermediate off-grid solution. Most of these households currently rely on kerosene and spend about 4.5% of their total household consumption on lighting. While waiting for grid expansion or even as a permanent solution in very remote areas where grid connectivity will remain prohibitively expensive and logistically challenging, off-grid solutions are essential. One of the main challenges that developing countries like Ethiopia face in achieving universal energy access is the substantial capital investment required to establish and expand grid infrastructure to off-grid (rural and remote) areas. The majority of Ethiopia's population lives in widely dispersed rural communities, and studies have shown that providing traditional grid electricity to most rural households is currently a costly endeavor for Ethiopia (Ecofys, 2016).

Even after Ethiopia's Grand National Electrification Program is completed, only 65% of the population will have access to power by 2025. This means that 35% (12 million households, primarily in rural/off-grid regions) will remain without electricity (Lighting Africa, 2019; Lakew, 2017). Solar energy continues to provide significant benefits compared to other renewable energy sources. For example, wind turbines produce noise during operation and require large spaces for installation, whereas solar cells can be easily installed on rooftops or open spaces for micro-grids and require less maintenance. Hydroelectricity, while renewable, requires the construction of dams, which are expensive and can affect aquatic life and ecosystems.

In Ethiopia, solar mini-grids are used in off-grid areas for lighting and income-generating activities, such as powering social institutions (health centers, schools, and farmer training centers), households (including running TV and radio), telecom towers, and town water supply systems (Khader, 2016). Ethiopia employs solar energy in off-grid areas due to population growth, low investment costs, stable power supply, and the creation of local employment and income opportunities. With about 79% of the population living in rural areas without access to grid electricity, Ethiopia serves as an excellent case study for researching the challenges of clean energy access and the development of domestic renewable energy technologies.

NEP 2.0 is one of the most visible instances of an electricity access strategy that provides a comprehensive perspective on grid and off-grid options. According to this strategy, by 2025, off-grid solutions will account for more than one-third of all power connections, adding 6

million household connections to standalone solar systems and mini-grids. The NEP 2.0 off-grid initiative highlights the importance of speed, nationwide coverage, increased service (going beyond Pico- lights), commercial feasibility and affordability, and an enabling ecosystem of laws. Ethiopia's off- grid industry is in its early phases, with two projects recently launched: the Access to Distributed Electricity and Lighting in Ethiopia (ADELE) programme and the Distributed Renewable Energy- Agriculture Modalities (DREAM) project (AfDB, 2022; World Bank, 2022). The programs work together to mobilize public, private, and philanthropic funding to increase access to electricity services for households, commercial and industrial users, and social institutions, as well as to improve smallholder farmer productivity through solar-powered irrigation and other services. The federal government recognizes the difficulty in its NEP 2.0, a forward-thinking policy document that emphasizes the importance of off-grid alternatives (MoWIE, 2019). The appropriateness of each of these modalities is determined by geographical least-cost electrification analysis, and plans are being developed to link many of the 5 million off-grid households to the grid.

The newly built off-grid concept is projected to cost approximately \$2.5 billion to implement. These investments demonstrate the need of providing access to services in tandem with and complementing grid development. By 2025, around 35% of the population is estimated to have access to mid-term pre-electrification or long-term off-grid options. The vast majority of these recipients will be linked to the grid after 2025, while a tiny portion (about 1 million) is unlikely to receive a grid connection in the foreseeable future. Furthermore, around 3.3 million beneficiaries are considered candidates for short-term pre-electrification solutions, as they are scheduled to be linked through the grid program only during its latter stages of completion (by 2025), and are thus candidates for interim solutions. These beneficiaries could then use the off-grid solar systems as a back-up solution-as is already happening in several urban and peri-urban areas of the country-in case of grid unreliability.

Overall, the NPE off-grid initiative aims to provide off-grid access to approximately 9.2 million beneficiaries by 2025, divided into three segments that serve diverse purposes: short-term pre-electrification, midterm pre-electrification, and long-term off-grid access. The implementation of the NEP off-grid initiative was crafted with a focus on best practices and insights from recent experiences, both positive and negative, in the off-grid sector (MoWE, 2019). This approach has led to a thorough evaluation of the country's challenges and opportunities, along with a detailed analysis at each phase of the off-grid solution market. The investment needs and program support activities are based on a professional assessment of the critical actions required to rapidly address the demands of the Ethiopian market.

According to World Bank estimates, Ethiopia's population will be around 115 million in 2020. The Government of Ethiopia (GOE) intends to boost energy access from 26% in 2014 to 60% by 2040 (Singh, et al., 2017). Improving the efficiency of existing energy sources is another goal. The vast majority of rural people work in agriculture. Due to extremely low electricity access of approximately 5% (Singh, et al., 2017), the rural population is forced to rely on kerosene/diesel generators or traditional biomass energy sources for cooking and heating. Dependence on this type of energy generation is tough to afford in the long run because fuel costs are rising by the day. Furthermore, biomass resources like firewood are increasing deforestation and soil degradation because major environmental effects (Tilahun et. al, 2017). Most of these rural areas are either scattered in large areas or are located at a long distance from the national grid. Hence high cost of transmission and low load factor makes it economically impossible to provide energy through it. To change these circumstances, The Ministry of Water, Irrigation and Energy (MoWIE) of Ethiopia has recognized PV-wind hybrid, PV-diesel generator hybrid, micro-hydro and other renewable energy-based mini-grids as the only suitable solution.

However, the deployment of small grids has proven to be highly difficult, and many projects have failed after installation. Mini grids' long-term performance is frequently hampered by financing, management, business models, sustainable operations, maintenance, and socioeconomic situations rather than technological constraints. Each community is defined by a complex collection of features and interests that guide technological and strategic solutions based on local financial, social, and environmental considerations. As a result, designing acceptable technology requires taking into account the local context. There is also a need for a model that can assess community energy demands, expectations, and opportunities, as well as readiness to pay for electricity, income, and productive activities.

2.1.9. Climate Resilient green Economy Strategy

In addition to livestock and LUCF, the energy sector holds significant mitigation potential in the revised NDC. Renewable energy constitutes the majority of grid-connected electricity generation. Moreover, the reduction in biomass energy emissions has already been incorporated into LUCF. The energy sector is projected to account for 5% of total BAU emissions by 2030. Policy measures in this sector are expected to reduce emissions to 9.5 Mt CO₂eq under the conditional pathway, representing a 52.5% reduction (10.5 Mt CO₂eq) compared to baseline emissions. The unconditional pathway aims to lower emissions to 15 Mt CO₂eq, a 25.5% reduction in sectorial emissions. BAU emission by 2030 (-5.1) Policy interventions in the energy sectors investments in energy efficiency (economy-wide improvements of energy

efficiency of appliances, machinery, and other capital assets) by the Ministry of Water, Irrigation and Energy (MoWIE, 2019).

Expanding electricity generation from renewable sources for local and regional markets is one of the Strategy's four pillars. One of the strategy's key goals is to prevent the use of traditional fossil fuels, which cause a significant increase in GHG emissions and unsustainable use of natural resources. According to the strategy, if existing practices continue, greenhouse gas (GHG) emissions will more than quadruple from 150 Mt CO₂e in 2010 to 400 Mt CO₂e in 2030 (E.P.A, 2011). The power industry is classified as a low-carbon emitting sector in the strategy since it generates electricity mostly from renewable energy sources, primarily hydropower. Regarding electrical access, the strategy targets to expand the electricity grid network of the country to nearly 100% not measured in household electricity connection. In general, even though Beyene (2018), asserts that the strategy puts the expanding electricity network as one of the main objectives it gives less attention to how to enhance the sustainability of electricity schemes and access in the country particularly how to meet global climate change reduction target and national determination contribution through using locally accessible renewable energy source like mini-grid power.

2.1.10 Ethiopia Renewable Energy Resource Development

Ethiopia's current development and energy strategies are aimed at promoting climate-resilient economic growth. With ample renewable energy supplies, clean power generation is critical for achieving national energy and industrial development goals. However, the primary problem in Ethiopia is to harness these resources in an efficient and cost-effective manner. Ethiopia has a potential of 4 PWh per year from wind energy (Rahima, 2021). Potential varies by geography. According to the global wind energy categorization, Ethiopia's average wind energy is rated as class 1 (Tucho, 2016). There are extremely few locales that fall within the good to exceptional (above class 4) category. All sections of the country are unsuitable for the construction of wind energy projects or grids. Agricultural, forested and built-up lands are not considered at all. Wind-powered mini-grids are not the greatest option for electrifying rural areas where the majority of people work on agricultural properties. Other problems that limit wind energy-based mini-grids include infrastructure, altitude, distance from main power, transportation, installation, and operational costs, which can be very high at times.

Furthermore, the availability of technical personnel in a remote location poses a considerable constraint. Thus, a wind-powered mini-grid is not a long-term answer for rural electrification. Ethiopia, an agricultural economy, has the capacity to create around 50 Mtoe of biogas (IEA, 2020). Biomass resources are plentiful in rural locations. Crop leftovers, mainly cereals,

account for nearly 60% of the overall potential, while animal manure and municipal solid waste are used for most of the remaining energy potential (IEA, 2020). The literature review shows that 7,000 digesters were installed between 2008 and 2013. However, only about 40% of the bio-digesters are now operational due to a lack of local capacity. Thus, indicating that bioenergy is not a suitable and productive solution for electrification.

In terms of solar energy resources, Ethiopia receives between 4.5 and 7.5 KWh/m² per day, which varies. During the summer months, highland locations receive the least amount of irradiation. Sites in the extreme north, from the eastern border to the southern rift valley regions, have been shown to get the greatest irradiation per day, reaching the value of 7.5 KWh/m² (IEA, 2019).

2.1.11 Solar Power contribution of Sustainable Energy

The development of renewable energy sources is required for any country's sustainable growth due to decreasing fossil fuel reserves, rising fossil fuel prices around the world, and, more recently, pressure to reduce emissions levels. Among the numerous renewable energy-based technologies, photovoltaic technology for power generation is thought to be particularly well-suited for distributed power generation (Jamil et al., 2012). The widespread adoption of PV systems may substitute or postpone the expansion of conventional central power plants, while investment in grid reinforcement has a beneficial overall economic benefit. The PV system's electric power is valuable when it corresponds with peak demand, such as during the summer afternoon peak caused by the use of air conditioning equipment, solar photovoltaic systems can also increase the reliability of the system to which they are connected, can also reduce transmission and distribution losses as they generate the electricity close to the point where it is consumed.

Cutting greenhouse gas emissions is especially important for the developing countries, as climate change threatens to destabilize the weakest economies and disadvantage the poorest people. Tens of millions of people who live in low-lying areas could be displaced as sea levels rise in response to expected temperature rises. With climate change, the weakest economies will confront new challenges, such as preventing the spread of vector-borne diseases. According to the International Energy Agency, (2011) 1.5 billion people, or 22% of the world's population, did not have access to electricity in 2008, with rural areas accounting for 85% of the total. According to the IEA, if current policies remain unchanged, 1.2 billion people will still lack access to power by 2030.

Even in Sub-Saharan Africa, the number of people without access to electricity will increase. The 2.4 billion people who rely on conventional biomass fuels for energy must collect and burn straw, manure, and wood scraps to prepare their meals. They frequently go without fridge, radios, and even lights. According to the International Energy Agency, in order to meet the SDG poverty- reduction target, an additional 700 million people will need access to modern energy services by 2030 (Flavin et al., 2015). In recent decades, impoverished people's energy demands have been supplied most often through the use of petroleum-based liquid fuels and the expansion of the electricity grid, which is mostly powered by fossil fuels and hydropower. These alternatives benefited from government subsidies and are widely available on World markets. However, conventional energy systems are often inaccessible for people in remote areas, and even in urban slums, they can be prohibitively expensive for the poorest residents.

Furthermore, many developing countries import the majority of their fuel and technology. Of the 47 poorest countries, 38 are net oil importers, while 25 rely entirely on imported oil. This energy future for the poor is unacceptable. It is possible to attain universal access in the near future, and current Renewable Energy Technologies can play an important part in making this happen. However, technology alone is insufficient for universal access, which necessitates long-term operations and economic models, political activities, and targeted public backing. The significance of energy, especially electricity, is vital for growth. Access to modern electricity decreases hunger while also improving access to safe drinking water via food preservation and pumping systems (Guta et al., 2015). It promotes education by providing light and communication tools, improves gender equality by relieving women of fuel and water collection tasks, and reduces child and maternal mortality as well as disease incidences by enabling medication refrigeration and access to modern equipment. Finally, providing access to energy using environmentally friendly technologies directly contributes to global environmental sustainability. Energy alone is insufficient to alleviate poverty, but it is undoubtedly vital, and significant development progress will not be possible unless a rising proportion of people get sustained access (Guta et al., 2015).

2.1.12 Renewable energy and Sustainable development goals

The 2030 Agenda for Sustainable Development provides essential guidelines for international efforts to foster a comprehensive, global transformation towards sustainability. Extensive range of development agendas was addressed SDGs comprise 17 topics like poverty, hunger, health, water, energy, education, gender equality, reduction of inequalities, economic development, and biodiversity and climate action (Bhandari, 2019). Renewable energy like mini-grid consumption contributed to SDG7 which targets affordable and clean energy since mini grids

enable access to electricity from renewable energy sources to some of the most vulnerable and marginalized people. In this sense, mini grids provide an essential infrastructure for economic development and human well-being, a core element of SDG9. Innovative digital technologies have the potential to enhance the sustainability and reliability of these infrastructures, thereby improving the services they provide. Additionally, when mini grids are powered by renewable energy sources, they support not only SDG7 by ensuring access to affordable, reliable, sustainable, and modern energy, but also SDG13 by promoting climate change mitigation (Aljaghoub et al., 2022).

2.1.13 Power sector reforms and Private sector participation

Policy and strategy reform in energy sector demand to be tailored in comprehensive framework aimed at delivering modern energy services to foster poverty alleviation and economic growth (Besant-Jones, 2006). Governments face crucial decisions in reforming their power sectors, including determining the roles of public and private sectors in providing power services, governance and reform of public enterprises, restructuring to introduce competition (such as unbundling and developing power markets), and regulatory reforms (World Bank, 2004). Energy reform of low developing world country manifested through in hamstrung, poor institutional performance and null involvement of private entities. According to the World Bank and USAID (2004), there are four major drivers for reform in emerging markets of renewable energy.

Lack of Private Sector Investment: Historically, developing country governments financed their largely state-owned power utilities and supplemented their capital needs with multilateral development bank loans. However, these sources are insufficient to meet future power sector investment needs. To bridge the gaps of financial problem of energy sector involving private actors will be seen as ultimate solution (Laimonas, 2024). **Higher Financial Returns:** The private sector requires higher financial returns than those needed by MDBs or governments. It is expected that efficiency gains from private sector involvement will offset the higher cost of capital. **Economic Inefficiencies:** Many developing countries power sectors suffer from high technical losses, lack of cost recovery pricing, poor maintenance, low equipment reliability, high staff levels, low productivity, corruption, non-payment issues, and mounting debt. These factors contribute to the commercial unsustainability of the power sector, making it unattractive for private investment.

State Subsidies: If the power sector cannot charge consumers the full cost of power, the public must cover the difference through direct or indirect taxes that support subsidies. These subsidies have become an unsustainable burden for many developing countries (Aljaghoub et

al., 2022). Reforming the power sector to attract the necessary private investment is a significant challenge, but it is essential for achieving sustainable development and economic growth.

2.1.14 Mini grid system

Mini grids are the middle ground between the central grid and independent power systems. They usually work in rural areas, because they are isolated and not cheap to connect to the main grids, but there is a high demand and a variety of loads that need to be connected. It is an alternative to a centralized power grid such as the main or national grid. There will be more than one source of energy generation. This includes energy sources, storage systems, for example batteries and a small transmission system that distributes power to a small number of consumers. A mini grid is not connected to the main system and can work independently. But for power sharing purposes, it can be connected to another network. Mini grids can work differently depending on the technical requirements and the size of the electricity production (see 4Africa, 2019).

2.1.15. Types of mini grids

There are multiple ways to categorize sub-grids, such as being connected to the grid and requiring maintenance that can be turned on or off depending on location and requirement. Mini-grid based on renewable energy: powered by renewable energy sources. It is also possible to combine several generation sources connected together, sometimes with diesel engines as well. Depending on the capacity, micro-engines produce 5-100 kW; while Nano-engines are less than 5 kW (Pellegrino, 2018). Many areas have seen competition with diesel systems through the use of grid-grids and micro-hybrid, resulting in reduced operating costs. Most regions in Africa have seen lower electricity prices for renewable energy and hybrid solutions compared to generators, as per Energy Month 2017 pricing. Generation technologies for small grids have become less expensive (including significant cost reductions for some renewable technologies) and reliability has increased, resulting in lower capital, operation, maintenance, and maintenance costs (Numminen & Lund, 2019).

2.1.16. Mini-Grid Delivery Model

Ownership of mini-grids can vary significantly from project to project. This variation can depend on several factors, including the funding sources, the stakeholders involved, and the specific goals of the project. In this regards many mini-grids bestowed in the hand of and run by private companies, whereas some others can be managed jointly by community, cooperatives or public entities. In some cases, a hybrid ownership model involving both public and private sectors may be employed to leverage the strengths of each. There are three main

actors that can own, install, manage, operate and maintain the system: local communities, governments/utilities or private entrepreneurs. Different models are used according to local institutional arrangements and regulation. The four most common ones are Community-based, private-sector, utility-based and hybrid.

Under community-based models, the mini-grids are owned by the local community which also takes care of tariff collection and operation and maintenance. Often, the system is designed and installed by an outside organization, while a public entity or donor provides grants or financial assistance. After the installation the community takes control, often creating local jobs for community electricity cooperatives or other local organizations. Although enforcement and ensuring payment can be challenging, communal ownership can sensitize the beneficiaries, facilitating proper management and delivery of high-quality service. Community based ownership models are favorite where private companies and utilities do not have the incentive to electrify remote communities since tariffs may not be enough to cover investment costs. This model is more likely to succeed when enhanced electricity access support income generating activities and local businesses, increasing community members revenues. Gradually, the demand for and the ability to pay for electricity increased, thereby enhancing the financial sustainability of the mini grid (USAID, 2020).

Community self-management of mini grids can face challenges such as improper management, financial instability due to low tariff levels, and corruption, which can divert resources and reduce community support. Despite these issues, there are successful examples worldwide. By 2016, communities in West Bengal owned and operated over 23 mini-grids. In Indonesia, the Green PNPM program involved local villagers in operating and maintaining micro-hydro projects (USAID, 2015).

In the private-sector model, a private investor is responsible for the installation, operation, and maintenance of the mini-grid. Funding typically comes from private equity and commercial loans. At present; there are only a few instances of models that are fully financed by private sources. Private investors typically get involved in countries with supportive policies and simple licensing procedure. In these countries, it is easier for entrepreneurs to access credit, financing, subsidies and technical assistance. In a supportive environment, concessions and output-based subsidies can be provided as government incentives. Improvements in technology, innovations in finance and development of customer-management platforms have contributed to an increasing focus on private sector operating mini-grids (IRENA, 2016). In Tanzania, the government is actively encouraging private investment in mini grids by establishing a comprehensive framework that includes policy, regulatory, legal, and financial support

mechanisms for the private sector. This framework has successfully implemented cost-reflective tariffs and boosted the capital provided by local banks (IRENA, 2016). Thomas Otieno (2018) highlights government regulations on mini grids can have both positive and negative impacts on ownership models. In regulated countries private actors must meet technological, financial and quality requirements. Although these requisites may increase the quality of the projects, transaction costs can get too expensive deterring the participation in mini-grid markets. Apparently in case when country not any regulation mini grids market, the lack of transaction costs can make projects financially viable (Thomas Otieno, 2018). In Cambodia, effective deregulation has fostered a favorable environment for private mini-grid operators. However, the lack of regulations can lead to higher costs for investors if private companies operate without constraints. In Somalia, where the sector is mostly unregulated and private companies set their own tariffs, consumers often face very high electricity prices (USAID, 2015).

Over the utility-based model, mini-grids are owned by traditional a state-owned utility, which operates in the same way as the national grid, but on smaller scale. Sometimes utilities contract with local ESCOs to manage part of the project. Even though costs are higher for rural mini-grids clients, utilities often use the same tariff as in the national grid, covering the remaining costs with subsidies. Utilities possess robust technical expertise, effective maintenance capabilities, and strong financial management systems (Thomas Otieno, 2018). They often have good access to legal services and system to manage regulations. Finally, if the investment is sustainable, they can scale up operations connecting other villages and eventually the national grid. Nonetheless, Utilities need to engage local communities and promote a sense of local ownership to avoid lack of trust, payments and sometimes failure. Inclusion of mini-grids development in government national electrification strategies facilitates the utility owned model. For example, India's Rural Electrification Policy describes where utilities should use distributed generation instead of grid extension to achieve rural electrification objectives (USAID, 2018). In Kenya, the utility-based ownership model is commonly used for mini-grids and The Rural Electrification Authority is responsible for developing mini-grid sites across the country, while Kenya Power, the national utility, handles the management, operation, and maintenance of these mini grids (WB and USIAD, 2020).

According to Alliance for Rural Electrification (2011), in appropriate contexts, hybrid ownership can be an effective approach. A combination of the three principal actors (local communities, private investors and utilities) collaborate to manage, operate and maintain the mini grid, taking advantage of the strengths of each partner. One common solution is for a

utility to install and own a mini-grid and give the management responsibility to a community-based organization, with technical maintenance provided by a private company.

Moreover, several companies have created innovative business models. The use of digital finance, enhanced connectivity, and smart technologies can help address some of the challenges associated with deploying mini-grids. For example, Power hive developed a cloud-based software platform, called Honeycomb automates account management tasks, remotely monitors and controls mini-grid operations, and runs real-time data analytics. Honeycomb communicates with any mobile money service for customer payment processing and remotely connects or disconnects a customer's electricity depending on the account status. A smart meter is installed in every client, allowing energy measurements, flexible tariffs and pricing, load balancing and performance monitoring. This solution guarantees a better efficiency and reliability of the system and an accurate analysis of the evolution of power demand.

2.1.17. Mini-grids Tariff

Deploying renewable mini grids involves navigating complex tariff challenges. Factors such as high capital costs, low-capacity factors, and financing limitations, lack of economies of scale, remote locations, and low demand contribute to the higher generation costs of mini-grids compared to the national grid. These considerations require careful policy frameworks and sustainable business models to ensure viability and affordability. In the past, governments have heavily relied on donor support, while private sector participation has been relatively limited (PWC, 2016). As a result, the emphasis has primarily been on socio-economic and technological aspects of mini grids, often overlooking the development of sustainable business models (Safdar, 2017). Many existing mini-grid systems still depend on subsidies and external assistance. The regulatory frameworks governing tariffs play a crucial role in ensuring the financial sustainability of mini-grid projects. Striking the right balance with tariffs is crucial. They must be affordable for customers while also generating sufficient revenue to cover operational costs, maintenance, and ideally, the capital investment. Achieving full commercial viability often depends on finding this delicate equilibrium. When regulated tariffs mandate that electricity generated by mini grids be sold at the same rates as the central grid, despite differing generation costs, government subsidies become essential for the financial viability of such projects. These subsidies, whether in the form of direct financial support or incentives, must align with the operator's requirements and be provided promptly.

Private sector mini-grids often set higher tariff rates compared to government-sponsored ones. This is because private operators rely on equity or investments that demand higher returns. As a

result, private mini grids typically operate in areas where customers have greater ability to pay, allowing tariffs to cover production costs (Safdar, 2017). Mini grids located near larger population centers tend to have better economic prospects. These areas often benefit from more robust economies and the potential for higher profits. In rural areas, revenue collection for energy services faces greater challenges due to lower demand and affordability constraints. Additionally, political considerations often impact tariff settings, sometimes resulting in excessive subsidies. In example, the local electricity monopoly in Indonesia charges for electricity at a flat rate much lower than the willingness to pay, hindering the investments the development of mini grid-based solutions and, at the same time, providing a low-quality supply.

2.1.18 Mini grids in Ethiopia

Mini-grids were introduced in Ethiopia in 2012 (GoE, 2018). Most of them were used for pilot studies and their failure has helped the country to get useful experience in terms of management and operation model (GoE, 2018). In Ethiopia mini-grid concept is supported by policies, strategies, and standards. Key policies and standards that support mini-grids include; the National energy policy 2018, Ethiopia Renewable Energy Strategy, Regulatory framework for mini-grids, among others.

The main objective of the National Energy Policy for Ethiopia is to increase access to affordable, reliable, sustainable, efficient, and modern energy for people in the country (GoE, 2018). In one of its policy statements, the government expresses its commitment to supporting small-scale renewable energy initiatives led by communities or entrepreneurs. This is done by developing appropriate regulations and reviewing tariffs to accommodate mini-grids (GoE, 2018). Ethiopia Renewable Energy strategy sets the target of a minimum of 25 operational Mini-grids sites by 2025 (MoWE, 2018). These mini-grids will include those for self-consumption and those selling excess power to the communities and the grid (MoWE, 2017). A regulatory framework for mini-grids was developed to provide guidelines for mini-grid development and operation in Ethiopia ((EERA, 2019)). It helps in the mini-grid development solicitation process and provides requirements for approval of the mini-grid project (EERA, 2019).

2.1.19. Cost Recovery Tariffs

Tariff setting is often a politically sensitive issue for governments in developing countries. Regulations related to tariffs can significantly impact the viability and sustainability of mini grids by directly affecting the selling price of electricity generated by these systems.

Tariff setting is a politically sensitive issue for governments in developing countries, especially when it comes to mini grids. These regulations directly impact the viability and sustainability of mini-grid projects by influencing the selling price of electricity. Balancing Affordability and Investment governments must strike a delicate balance keeping tariffs affordable for end-users while ensuring they don't discourage potential investors. Some small-scale mini-grid operators have the flexibility to negotiate tariff levels with local communities. However, for larger systems, formal mechanisms are preferred to prevent future disputes. Standardized methodologies, such as the cost-plus method, enhance transparency and provide potential investors with more certainty (SVMG, 2016). Policy and Regulation for Mini-Grids in Sub-Saharan Africa indicated that if tariffs above the national rate for grid-connected consumers are not allowed, government financial support becomes necessary otherwise, private sector revenues may fall short.

ESMAP study in Ghana revealed that aligning electricity rates with local affordability would require subsidies covering over 50% of the capital expenditure (CAPEX). Setting tariffs at the national level would necessitate 100% subsidy coverage. This highlights the disconnect between government equity concerns and the expected financial returns for potential private actors. To enhance profitability, private mini-grid operators can consider several measures. Permitting mini-grid operators to set tariffs higher than the national rate can attract investment. Cross-Subsidization-Implementing cross-subsidies among different customer groups balance affordability and financial viability. Increasing operator freedom in negotiating power sale contracts with corporate customers can enhance profitability. Allowing mini-grid operators to design tariffs that align with their technology and business models ensures sustainability. Thus, addressing tariff-related challenges is crucial for achieving equitable access to electricity while maintaining financial attractiveness for private sector investments.

2.1.20. Sustainability of mini-grid project

Indeed achieving universal electrification by 2030 is a significant thing, but it requires substantial investment. According to the International Energy Agency (IEA), in 2017 an estimated \$ 52 billion in fresh periodic investments will be demanded unanticipated, about 50 of this investment will be directed toward mini-grids still, financing universal electrification systems remains demanding monetary institutions and lending agencies over and over find the transaction volume associated with mini-grids too low to be cost-effective. Also, multi fold large realities may not show interest in this request, indeed if design aggregation is tried. likewise, the lack of adverse profit channels through power purchase or deals agreements,

coupled with limited understanding within the financial sector, makes investing in mini- grids serious (Bhattacharyya, 2018).

The profitable assessment of implicit mini- grid systems is critical for assessing long- term sustainability. Private companies and investors must precisely dissect design- related capital costs, functional and conservation (O&M) costs, and anticipated earnings color profitable parameters help forecast cash overflows over the system's continuance. The Levelized Cost of Electricity (LCOE) estimation allows comparison of different strategies and business models. To ensure funding flow and increase private sector engagement, risks associated with mini- grid projects need mitigation. A Risk Sharing Facility could benefit the mini-grid market. Similarly, a co-developer fund, raised from multiple sources, could absorb risk to a greater extent. Small companies often participate in the mini-grid sector due to project size, but their financial needs differ, and the risk of failure can be high due to narrow profit margins. The growth of financial institutions is essential for closing financial gaps and aiding in risk mitigation efforts (Bhattacharyya, 2018). Walls to mini- grid growth include delicate investment processes, lack of affordable backing options, underdeveloped private sector engagement, and perceptivity to cost-reflective tariffs. Especially, utmost communal areas electrified through public grids profit from high allocations, performing in public homes paying lower than \$ 0.05/ kWh for electricity. VERITAS Consulting, (2020), outlines that pastoral populations anticipate similar support for on- grid connections.

In Ethiopia, although tariffs for mini- grids are not yet established, grid tariffs for homes are roughly \$ 0.01/ kWh for the first 50 kWh, making them indeed less precious than in other countries (SouthSouthNorth, 2020). An Establishing and operating mini- grid involves high costs, and private- sector designers invest when they believe they can earn a profit. According to Ethiopia's nonsupervisory report, 2019, icing sustainability requires furnishing homes with a like grid rates and securing marketable tariff rates coincidentally.

Full profitable sustainability implies continued profitability and viability, that is, the mini- grid should be suitable to induce enough profit to meet all its functional expenditure (OPEX) throughout the continuance of the design while still generating an respectable rate of return on the original investment (Stritzke, 2021). Presently, solar mini- grids are far from full profitable sustainability, primarily due to low income and the capacity to pay for the pastoral people constantly an annuity is handed in CAPEX with the contemplation that the mini- grid has OPEX viability. In mini-grid, the anticipated trade of electricity can be used to calculate financial pointers analogous as anticipated return on equity and payback times. These values give the base on which investment opinions can be made (Takouleu, 2019). Social

sustainability implies having an affordable and fair tariff plan, guest satisfaction, and vacuity of electricity 24/7 (Stritzke, 2021). As a result either using electricity beyond domestic consumption or continuing with allocations is a need policy decision. Specialized sustainability signifies the robustness of the system, the use of good quality and satisfactory factors, and proper planning and sizing, inferring that the mini- grid should be suitable to meet the energy demands of the community without interruption at the least possible life cycle cost of the workshop including reserves and form, in a secure, predictable and fair manner (Strike, 2021).

As an illustration, the Solar Electrification by Concession Approach in Limpopo Province and Eastern Cape in South Africa (USAID, 2017), faced multi fold difficulties because it did not consider original community conditions, prospects, and capacity at its baseline. After the deployment of 6,000 SHS, further than three- diggings of them were taken back by the supplier because of missing payments by the users. Miscommunication about the capacity of the bias left the stoners unsatisfied and, therefore not willing to pay.

2.2. Empirical literature review

The body of literature on energy demand estimation and household willingness to pay is expanding significantly, encompassing studies from both developed and developing nations. This growing research highlights the increasing interest and importance of understanding how households value and are willing to pay for energy services across different economic contexts.

The reviewed literature indicates that CVM can be used in different areas when market prices are missing and CVM is a better environmental valuation method, for it can capture both use and non-use values. In this section, we review the most relevant empirical literature that can help us to identify the potential socioeconomic, demographic and environmental factors that can explain willingness to pay for the good under consideration.

Bhandari and Jana (2010), investigated consumer preferences for various types of solar photovoltaic (PV) electricity sources in rural India. By comparing standalone solar PV for individual houses with mini-grid solar PV for a few households, the study highlighted behavioral differences based on flexibility and cost factors. Interestingly, higher household expenditure on kerosene correlated with greater willingness to adopt solar electricity connections.

Twerefou (2014), Using a contingent valuation method, this study assessed willingness to pay (WTP) for improved electricity supply in Ghana. Respondents were willing to pay an average of GHC 2.7 per kilowatt-hour, which was higher than their existing payments. The study

considered starting bias by asking respondents to estimate WTP based on electricity consumption. The results indicated that households are willing to contribute to the improvements in the services. An econometric analysis of the factors that influence households WTP for uninterrupted electricity supply suggested that household income, sex, secondary as well as the tertiary level of education of the household head, and household size are significant factors that affect households WTP for improved electricity. The study finally recommended that government shall invest in infrastructure in the power sector and increases tariffs as households are willing to pay more than what they are paying now when there is an improved electricity supply. Unlike most of the prior research on the subject, the researcher included the effect of family size but ignored the effect of job type and electric status of the household head on willingness to pay for improved electricity.

Tadele (2022), study is to estimate households' willingness to pay for improved electricity applied a dichotomous choice contingent valuation survey with follow-up questions, the results show that household heads whose jobs and income depend on electricity quality, married household heads, and those who have a positive attitude on the existing electricity supply are more willing to pay than others. However, those who can read and write are less willing to pay than illiterate households mainly due to job differences and income deficiency. In all circumstances, as the bid price increases, a smaller proportion of people are willing to pay the amount to achieve improved electricity service.

Wakjira (2022), conduct study aims to analyze households' preference for reliable electricity services using primary data collected from 210 sample households in Hosanna and Durame towns of Southern Ethiopia. The households' preferences were analyzed using the choice experiment valuation technique. The study used both Conditional and Mixed Logit models to estimate the mean and marginal Willingness to Pay (WTP) for the attributes. The result suggests that households are willing to pay 230.84 ETB (\$8.34), 229.34 ETB (\$8.2), 2230 ETB (\$8.3), and 230 ETB (\$8.26) per month for improvement scenario one, two, three and four respectively in addition to the current monthly charge. It implies that households' WTP for improved electricity service increases with a decrease in the frequency of outage, duration of the outage, night time outage and additional costs, respondents are WTP 88 and 86 cents per kWh for reducing the frequency of outages from current to five times and three times per month respectively. Respondents also WTP 85 cents for reducing unannounced outages that occurred during the night-time, 70 and 56 cents to reduce the duration of outages from the current to three and 2h per month respectively.

Using panel data obtained in 2004 and 2006 Mekonnen and Kohlin, (2008), investigated the factors of urban household fuel choice in Ethiopia's main cities. The multinomial logit model was used to study the factors of household energy consumption choices. The findings revealed that as households' total expenditures rise, they use more fuels and spend more money on the fuels they use, even in metropolitan locations. Furthermore, this research demonstrated the importance of fuel stacking (the use of several fuels) in urban locations in Sub-Saharan Africa. According to the findings of this study, while income is a significant factor, other factors such as family size, home location, and level of education are also significant determinants of household fuel choice in Ethiopia.

Abdullah and Mariel (2010) investigating improved electricity services in Kenya, this study found that household size, age, and bank account ownership influenced willingness to pay for reduced power outages. Income also played a significant role.

Gunatilake et al. (2012) Household's willingness to pay for electricity services is influenced by factors such as home business ownership, perceived benefits of reliable electricity, per capita household income, and the number of school-age children in the household. Preez et al. (2021), this study explored the impact of age and environmental awareness on attitudes toward paying for electricity from renewable sources. Flemish households were willing to pay approximately €190 per year, but the specific green electricity sources were not identified.

Lay et al. (2013) have investigated the driving force of household choices of fuels in Kenya. The result revealed that the adoption of solar energy was significantly determined by socioeconomic variables of households such as income and level of education. But, this study confined only to solar energy system, a thorough studies on analysis of households WTP for use of mini grid source of energy for multiple purpose.

Amador et al. (2012) Conducted in the Canary Islands, this contingent valuation study found that customers who had experienced serious power outages in the past were more willing to pay for reliable electricity supply. Highly educated respondents and those concerned about greenhouse gas emissions also showed greater willingness to pay.

Hobman and Frederiks (2014); Claudy et al. (2012); Dupont and Bateman (2012), these authors emphasized that willingness to pay for reliable electricity services are both a moral and political issue. While individuals value reliable electricity and prefer environmentally friendly sources, they may resist energy sector reforms that increase household charges. Some households feel they already pay high tariffs for social utilities and expect reasonable rates. Income Constraints

are another determinant factor affecting willingness to pay. Consumers with irregular income sources (e.g., agricultural activities or loans) may face time constraints in payment schedules, affecting their ability to pay (ATP) even if their true willingness to pay (WTP) is high.

For instance, Danlami et al., 2015, analyzed a number of empirical studies on the factors that influence household energy consumption and choice in developing nations. The findings revealed that the majority of studies on household energy choice and consumption were narrow in scope, covering only some characteristics and dimensions of household energy consumption while ignoring the others. Furthermore, due to the average degree of development in the energy sector, variations in socio-economic, environmental, and cultural factors, not all factors have equal importance in shaping the pattern and behavior of household energy use for different places.

In Uttar Pradesh, a rural Indian community, one study analyzed the determinants of awareness and the willingness to pay for a solar home system (Urpelainen and Yoon, 2015). The study underlined the role of income, education level, and age of the household head in predicting the household's awareness regarding a solar home system. Moreover, the study indicated that the willingness to pay was high in households that have electricity compared to those households with no access to electricity.

Mugamba (2023), this study investigates the socio-economic factors influencing the adoption of hybrid solar electricity among households on Bujumba Island, located in Lake Victoria, Uganda. Utilizing a cross-sectional research design, the study employed binary logistic regression analysis to identify key socio-economic determinants of hybrid electricity adoption. The findings indicate that factors such as the sex of the household head, education level, monthly income, tenure status, and the materials used for walls and floors were statistically significant in influencing adoption decisions. However, variables including age, household size, marital status, and primary occupation were found to be insignificant. These insights provide a critical foundation for policymakers to develop more effective and equitable strategies aimed at promoting clean energy adoption.

Considering the actual circumstances of rural households in Ethiopia, where most rely on non-renewable energy sources like firewood and kerosene, and the government's strong promotion of alternative renewable energy development, this study investigates rural household's willingness to pay for mini-grid solar electricity services. Analyses of the factors influencing household's willingness to pay for electricity reveal that demographic, socioeconomic, and

institutional factors vary across different regions. However, in the study area, no research has been conducted on household's willingness to pay for electricity use.

2. 2. 1 Literature Gap

Despite the wealth of literature, there exists a gap regarding the valuation of electricity services specifically for off-grid households in Ethiopia. Prior research has primarily focused on urban populations and their willingness to pay (WTP) for grid lines, with a significant volume of work exploring topics such as solid waste and environmental management, water services, improved healthcare services, and soil and forest resource management. While these studies have provided valuable insights into the valuation of various services in Ethiopia, there is a dearth of research specifically addressing the valuation of electricity services for off-grid households. To address this gap, the present study focuses on the dynamics of WTP, factors influencing WTP decisions, and overall valuation of electricity services in the off-grid sector. By concentrating on off-grid households, we hope to expand the existing knowledge base, providing useful insights for policymakers, energy service providers, and other stakeholders to develop tailored interventions and investment strategies, enhancing electricity access and affordability for off-grid communities.

In their 2017 study, Arega and Tadesse examined the factors influencing household's willingness to pay for green electricity in urban area of Tigray region. They discovered that variables such as proximity to alternative energy sources, gender, and income significantly affect the amount households are willing to pay each month. Notably, the study revealed that participants were willing to pay more than their current monthly electricity bills.

Reta (2020) conducted a study in Hexosa (Harbe) and Boset (Xiyyo) rural districts of Ethiopia to analyze households' preference for electricity service connections and estimated potential WTP for the grid-line services and solar PV electricity. This study found that households preferred grid lines over solar electricity services, regardless of the payment scheme. Households' willingness to pay for connection of electricity service is also influenced by households' income level, level of education, age, location, and amount of initial bid prices. The study suggested the provision of electricity service that is suitable and preferred by the rural households and the community shall get various options of payment modalities. However, these findings cannot be generalized to rural and off-grid communities, which underscore the need for additional research in these underserved areas.

In conclusion, while several studies have examined various aspects of service valuation in Ethiopia, there is a distinct gap in the literature concerning the valuation of electricity services for off-grid households. This study seeks to fill this gap and offer valuable insights to help policymakers and stakeholders improve energy access and affordability for these communities.

2.3. Conceptual literature review

The current investigation builds upon the existing body of literature that explores renewable energy off-grid solar powered demand and households' willingness to pay (WTP) (Marschak, 1959; McFadden, 1980; Thurstone, 1927). Notably, decision-making process, influenced by factors such as rationality, the availability of information, cognitive biases, and external variables (Bazerman & Moore, 2009; Simon, 1955; Gilovich et al., 2002), plays a significant role. Particularly, the behavioural concept of sunk costs may crucially impact WTP (Arkes & Blumer, 1985; Just & Wansink, 2011; Ho et al., 2013). Furthermore, consumer perception and expectations feature prominently in decision-making (Kahneman & Tversky, 1979; Baddeley, 2013).

Theories in behavioral economics, like the nudge theory, demonstrate how decision-making can be subtly directed towards more sustainable choices. Additionally, societal norms, peer effects, and environmental consciousness can shape consumer behavior (Kollmuss & Agyeman, 2002). However, gaps persist in understanding the impact of sunk costs on WTP, and the correlation between perception, expectation, and WTP. This research seeks to fill these gaps by providing comprehensive insights into consumer behavior concerning off-grid solar systems.

Therefore, in this framework, the likelihood of household's willingness to pay for electricity usage is influenced by various factors-individual and situational factors which can be categorized into socio demographic psychological and contextual and structural factors. Institutional factors encompass elements such as the initial bid price, and energy consumption costs.

Socio-economic characteristics influencing willingness to pay for electricity includes educational level, income, and the current cost of electricity. Demographic characteristics encompass age, gender, and household size. Additionally, factors such as the initial bid price and subsequent bid price significantly impact WTP for electricity usage. This variation in areas and determining factors makes it hard for one to develop a general model of willingness to pay for electricity use with specific determinants and hypotheses that can be universally applied across different locations and situations. Depending on this the conceptual framework present

below describes the variables expect to influence willingness to pay for solar mini-grid electricity use in the koftu kebele.

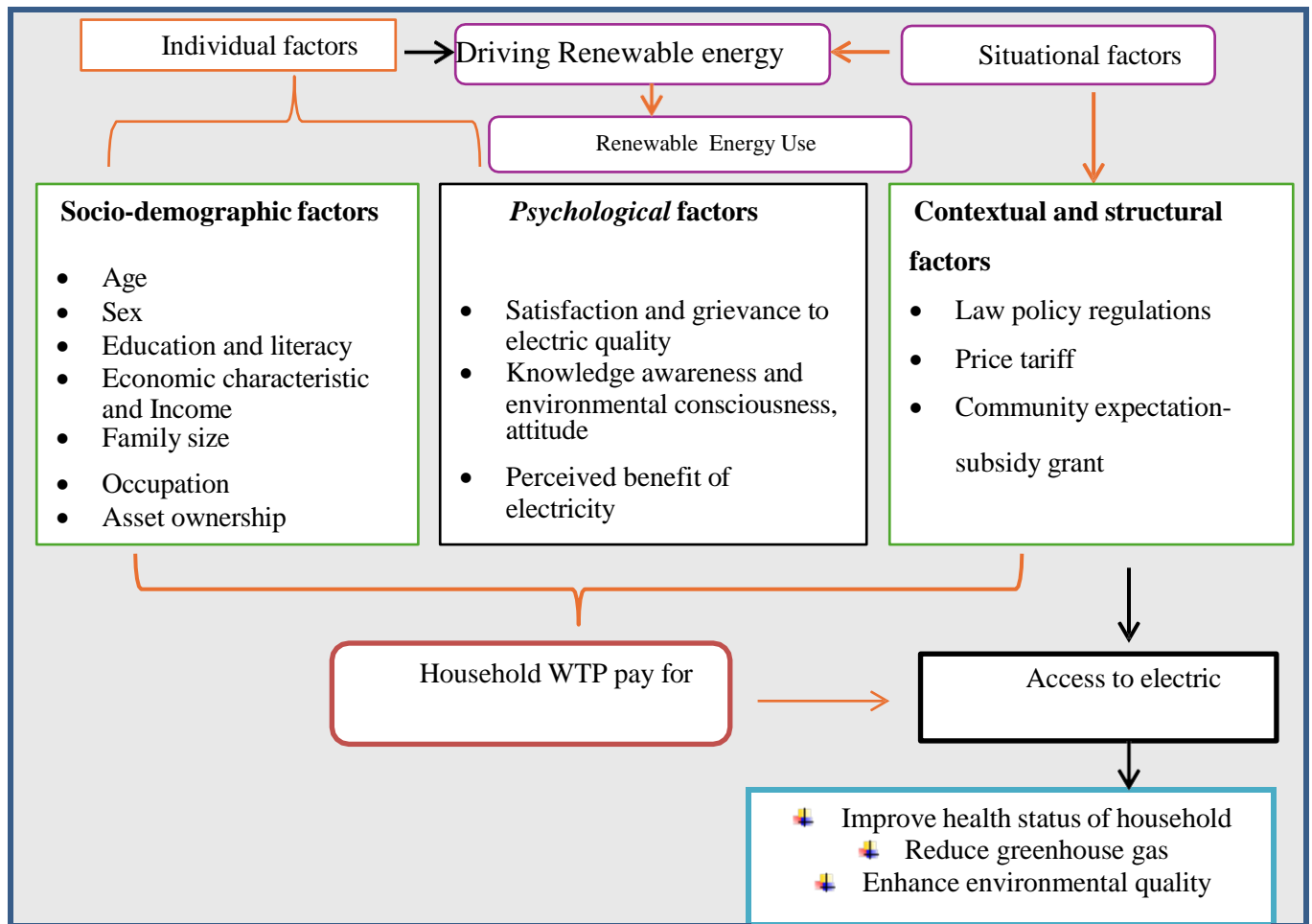


Figure 2: Conceptual framework

Source: own constructed, (2023)

CHAPTER THREE: RESEARCH METHODOLOGY

3.1. Description of study Area

The scope of this study is confined to the Koftu Model Mini-Grid Site. Located 40 km southwest of Addis Ababa and 20 km west of Dukam town, the Koftu plant was established as a model project with support from the Korea Institute for Advancement of Technology (KIAT) and completed in 2019. The project was as part the Universal Electric Access Project (UEAP) run by Ethiopia electric utility (EEU).

The site receives solar radiation of 5.81 kW/m²/day, with solar panels inclined at 50 degrees. The mini-grid can supply 400 households, meeting a power demand of 100 kW and a workload of 151 kW with eco-friendly energy. The selected panels are 320 W each, requiring a total of 630 panels to achieve a 250 kW capacity. The optimal design was created using HOMER software. Koftu comprises two sites: Site A, which includes two 100 kW AC/DC conversion units (PCS) connected to batteries, and Site B, which operates a 50 kW inverter directly connected to batteries and solar panels. A 30 kW backup diesel generator is available but has not been used yet.

Geographically, Koftu is situated at latitude of 1.23456°N and a longitude of 9.87654°E, with an elevation of 1950 meters above sea level. The population of the study area is 3,985, including 1,853 males and 2,029 females, with 830 households. The site was selected based on its 10 km distance from the main grid, in line with Ethiopian policies and the economic activities in the area. The mini-grid aims to address the prevalent issue of electricity access.

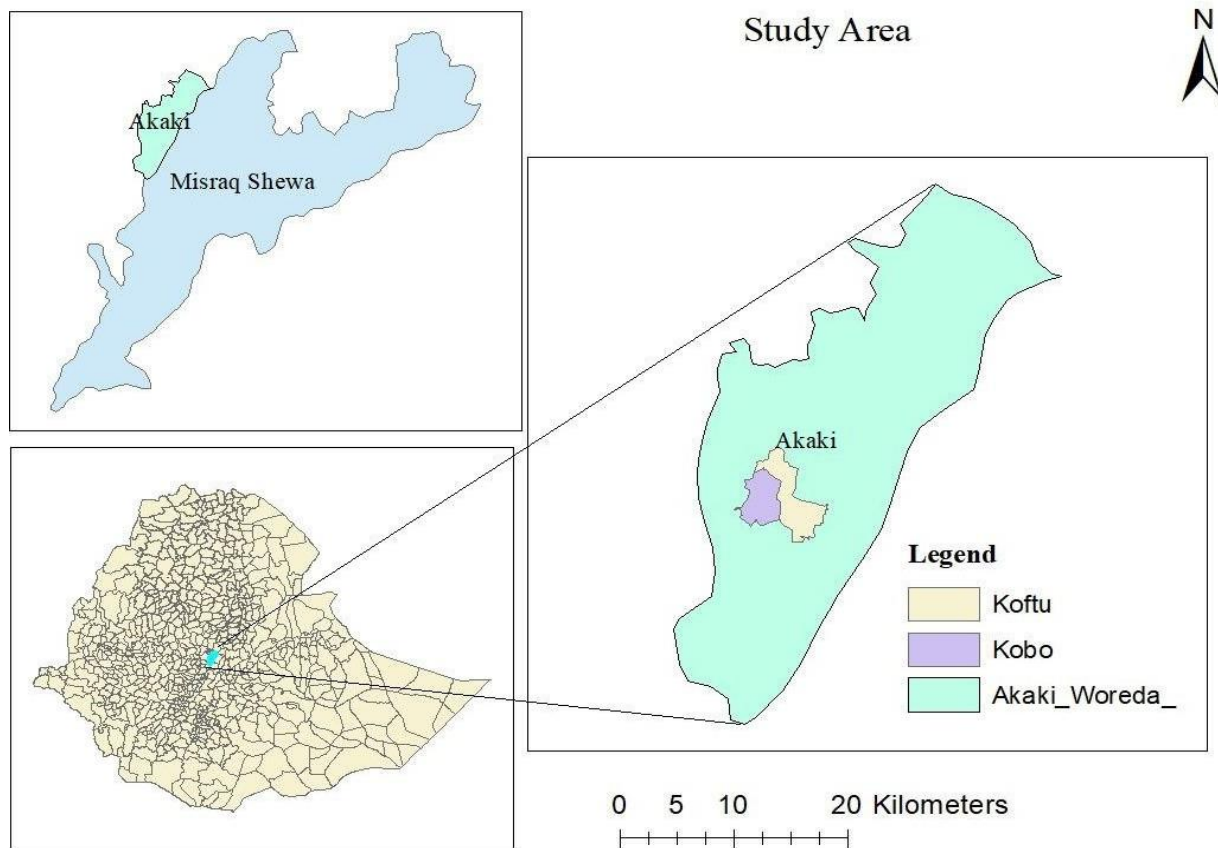


Figure 3; Map of study area

Source: Researcher own sketch, (2023)

3.2. Overview of Research Design

The research study is designed to investigate the demand for solar photovoltaic systems in off grid rural communities in koftu village, oromia regional state, Ethiopia, with a special focus on assessing household willingness to pay (WTP) for such systems. Given the multifaceted nature of this issue, the research utilizes a mixed-methods approach, combining elements of both qualitative and quantitative research methodologies. This strategic approach allows for a broad and nuanced understanding of the research question by enabling data triangulation.

3.3. Data Sources

Data for this research was collected via three primary modes: structured questionnaires, KII interviews, FDG and secondary data sources. To meet objective of the present study primary sources of data was employed to gather reliable and valid information from household unit those who was connected and not connected to mini-grid electric service.

3.3.1. Survey methods

The structured questionnaires, designed in line with stated preference studies' guidelines Johnston et al., (2017), aimed to collect quantitative data on WTP and demographic information. The study used a questionnaire to collect data from the respondents. The questionnaire contained open and close ended questions (Appendix I), which sought the views, attitudes, and opinions of the respondents concerning mini grid solar energy. Most importantly, the willingness to pay data is generated, using dummy variables (yes/no), based on valuation scenario presented to the respondents. In that case Contingent valuation methods DBDC elicitation followed.

3.3.2. Focus group discussions (FGDs)

To supplement the survey questionnaire data, FDG conversation were conducted with community helped gather information about socio-economic factors, community attitudes, and potential barriers to related mini grid electricity service. Two focus group discussions were held separately. One involved twelve aged 18 years and above and the other involved ten no- electrified community aged 18 years and above. These were organized discussions facilitated by the researcher to gather more information from participants who use solar powered mini grid electricity and who not in their homes to get consensus on issues emerging from the structured interviews. FGD participants were selected based on their willingness to engage in the group discussion. At the end of the discussions, the data collected used to investigate willingness and ability challenges awareness and benefit concerning mini grid electricity access.

3.3.3. Key informant interviews

The KII interviews were conducted with community leaders, women and Energy Service office representatives and expert focused on exploring socio-cultural factors affect WTP, Customer satisfaction to the electricity, market dynamics, pricing strategies, and viable payment plans.

These were face-face conversation with selected key informants who the researcher interacted with such as two community leaders at the koftu village, three managerial level and five experts. A key informant interview guide (Appendix II) was used to guide the process. The

key informants were selected professionals from the leaders and expert from MoWE, EEU who related to off-grid energy and Galan branch electric service utility level who interact frequently with the residents at site level, including chief operator cash collectors‘ managers, community leader and women rural group leader. Finally, to strengthen, the result of the study, secondary data of different source review of documents, books, journals, published and unpublished article, reports, and websites etc. has been used.

3.4. Populations and Sampling Procedures

The target population of this study is households who have access to electricity and no to it. That means those are electrified by any mini grids electrification and non-electrified households. The study population which is the subset of these target population are households that were selected from two kebeles, Kuftu and Kobo. These Kebele were purposively selected by the researcher. The main reason of selecting only these two kebele is that solar Mini grid electric supply Oromia Shagar city mainly targeted this area to improve the household’s infrastructural services. Then after, samples had drawn randomly from each selected kebeles. By means of lottery methods, chance, 263 samples was drawn from 830 households.

The formula that used computes this sample size is the one that developed Kothari (2009). It was proposed to calculate the final sample size in case when the population is finite which is given as:-

$$n = \frac{Z^2 pqN}{(e^2(N-1) + Z^2 pq)}$$

Where,

n is the required Sample size. This is total sample that would be required in this study.

- p = probability that respondents belong to classes of desired study population a given outcome (success). Based on Kotari (2004), this study used $p=0.5$. The corresponding probability of failure is denoted q , $q = 1 - p = 1 - p=0.5$).
- N is the total number of households in the selected kebeles. In the selected Kebeles two 830 households.
- e is the desired level of precision (i.e. the acceptable error), $e =$ the desired level of precision 0.05

- $Z = Z$ - Score associated with appropriately chosen level of confidence (95%) with the table value of 1.96.

Then based on the above information, desired sample size would be

$$n = \frac{1.96^2 * 0.5 * 0.5 * 1830}{0.05^2 (830-1) + 1.96^2 * 0.5 * 0.5} \cong 263$$

However, to obtain the desirable estimation results of the methodology chosen for the purpose of this study, the researcher scaled up the number of sample size 380. This is just what practiced by existing empirical studies (Reta, 2020).

Lastly, the study used proportional sampling methods to draw the number of samples from each Kebele and according to their electric status, which is electrified and non- electrified. Based on the data from Gelen town electric district office, 157 household were connected but most of them are not started to pay bill and willingness to pay is limited and reluctant the reason for this study.

In selecting the estimated sample households, the study employed simple random sampling techniques because of its superiority over other families of sampling techniques in assuring equal chance for the population. A complete listing of households in the selected project was taken from data available at kebele administrations and Galan utility center. $n = N/n$ techniques will seek to use for choice respondents.

Table 3: Sample distribution across study kebeles

Kebele	Electricity status	Population	Sample	Proportion
Koftu	Connected	157	50	19%
	Not connected	279	88	34%
	Total	436	138	53%
kobo	Not connected	394	125	47%
	Total	394	125	47%
Total		830	263	100%

Source: Author owns computation-based data from Akaki district Economic and finance development office.

3.5. Data collections methods

3.5.1. Design of Survey Questionnaire and Valuation Techniques

A total of two-focus group discussion with a group of 5-6 individuals and pretest survey was conducted with 15 selected household heads to set up the starting point bids which were used to elicit WTP. To consider the range of bid values, the pretest survey was undertaken in open-ended questionnaire format and response were failed between 200 and 1000 whereas only limited person shows willing to pay one thousand birr per month during the per pretest interview. In addition, selected bid values were evaluated by Galan district electric service provider expert who closely knows behavior and ability of their customers. After the focus group discussion and pilot survey and expert evaluation, among most frequent called bid values four initial start bid value (400, 500, 600 and 700 Birr per month) were identified for the double bounded dichotomous choice format and distributed proportionally to the formal survey questionnaire. Then, sets of follow up bid values (200, 250, 300, 350) and (800, 1000, 1200, and 14000 birr per month) was determined based on the respondents -yes/ or -no/ response of the initial bid value.

The study used closed ended questionnaires format. The questionnaire format consists of three main components and further classified in four steps data gathering (i) introductory questions on energy service; (ii) WTP questions on the off grid renewable sources of electricity service connection; and (iii) questionnaires seeking respondents' information on socioeconomic and demographic characteristics and further extended to different steps as aforementioned above.

The substance of the data for this study was collected using quantitative data gather methods. This household survey was used to collect quantitative data. The face-to-face interviews intend to use as a technique for eliciting data. According to Kwak et al. (2007), face- to-face interview is the preferred technique to ensure high response rate and recognizing rural literacy rate as it provides the greatest scope for detailed questions and answers. Data will be collected mainly focus on WTP for mini-grid electricity, determinates of WTP regards to energy consumption. Questionnaire is developed and pre-test has been taken from same households. Input obtained from pretest is incorporated particularly to set initial bid. Data will be collected mainly focus on WTP for off grid green energy, determinates of WTP regards to

energy consumption, current status electric supply, benefit of mini grid in reducing climate change, socio economic, demographic characteristics of household, energy consumption and awareness of renewable energy, among others.

Based on the finding from the pre-test (pre-survey, FGD and Key informant interview), the draft questionnaires were prepared and reviewed. For instance, some refinement was made by incorporating the key informant comments. After incorporating the feedback from pre-questionnaire and have prepared the final questioners which were presented in four sections. To obtain the above-mentioned data through the field survey the target-oriented questionnaire finalized considering the socio-economic conditions of the non-electrified and electrified rural household of study area. This final questionnaire contained four specific steps to serve the purpose. These are:

Step 1: To facilitate the interview process, the scope and objectives of the study will be briefly explained to the respondents. Once respondents are ready to answer the questions data regarding socio-economic age sex income house type land size will be noted.

Step 2: At this stage respondent were ask about current energy source. Based on their response for the purpose of this study household respondent was classified as non-electrified and electrified based on their level of access mini grid electricity. To make more clear households in the study area may classified into two ideal group based on their level of access namely household already connected to mini grid, household who have access but not connected for reason. This is aimed to evaluate whether there are significant differences in WTP values for renewable mini grid electricity services across already electrified communities and un-electrified rural locations. Besides to this assess perception of electrified community to mini grid electricity will also note. And then on the electrification status of the households, respondents will be asked different sets of questions at this stage. Respondents connected to mini grid are considered as electrified households. On the other hand, respondents using firewood, kerosene, Solar Home Systems (SHS), pre charged battery or solar lamp etc. classified as non-electrified households. Through specific target questions at this stage, households (both electrified and non-electrified) source of energy usages and monthly costs for used energy will estimate and mini grid electric user are asking specific question about cost, and reliability of mini grid electricity access.

Step 3: At this stage of the interview, respondents will be asked to share their awareness of electricity's environmental impact and their plans for using it in business activities. Non-electrified households will also be asked to indicate their preference for switching to mini-grid (MG) based energy supply. Besides perception towards solar electricity, benefit, and access electricity noted at this stage of the interview.

Step 4: At this crucial stage of the interview all respondents will be asked specific questions to find out their willingness to pay (WTP) for the proposed electricity supply form mini grid. The second part that will be the main aim of the thesis is valuation cost of supplying improved off grid renewable electric supply for rural electrification thus, valuation scenario that describes the service which is being valued given in detail. While offering different valuation bid prices (0.25 per kWh) and (400, 500, 600 and 700) to the respondents, further analysis of WTP is value corresponding to unit bid values whereas unconnected respondent offered different bid value about on connection and monthly payment. This is to be estimating the revealed demand for off grid reliable electricity and predicting the demand in not connected areas. Then, every respondent asked if they are ready to pay for an electric service for the access electricity supply. Respondents, who not connected and answered yes, are further investigated if they are ready to pay either as one off or installment.

3.6. Data Analysis methods

In this study, the collected data was analyzed using the descriptive and inferential statistics. To provide insights enabling researcher to understand characteristics of the respondents, mean, frequency and standard deviation are used to describe the data. Constructive description, summary of data points in a way that indicates patterns, data distribution, and the detection of types and outliers. The researcher was used the statistical software package, STATA, for the analysis of data. In addition, data transformation has been made on generate some variables. Importantly, the researcher facilitated the analysis by reducing the dimension of instrument items categories by factor analysis.

Principal component analysis (PCA) is the most important and common statistical which is used by most of the researcher. PCA is dimension-reduction tool that can used to reduce a

large set of variables to a small set that still contains most of the information in the large set. Indexes, the result of PCA is quantitative measures, would be used for regression analysis. So, this method was used to create index measure the variables that were employed in this study numerically. Finally, the determinants of willingness to pay has been using econometrics model as detailed under. By using STATA, different econometrics model has been used to examine the determinants of WTP.

3.6.1. Econometric Model Specification

3.6.2. Contingency valuation modeling (CVM)

The CVM is the method used to analysis is the need to be placed monetary values on non-marketed goods and services. It implies asking to a sample of the population about their willingness to pay. Despite ongoing debates about its validity, contingent valuation is widely utilized in environmental economics research (Lopez-Feldman, 2013). One of the most prevalent methods to elicit willingness to pay (WTP) is through the use of dichotomous choice questions. In the simplest case the individuals are asked whether they are willing to pay or not for energy usage. Thus, dichotomous answer ($y_i = 0$ if the individual answers no and $y_i = 1$ if the answer is yes), given a question about paying a previously determined amount (t_i , that varies randomly across individuals), allows us to estimate the WTP. Based on the previous study, it is possible to estimate the WTP assuming that it can be modeled as the following linear function:

$$wtp_i (z_i ; u_i) = z_i\beta + u_i-----[3.1]$$

Where z_i is a vector of explanatory variables is a vector of parameters and u_i is an error term. It is expected that the individual will answer yes when his WTP is greater than the suggested amount, that is when $WTP_i > t_i$. As different socio-economic and demographic factors (age, gender, income, and frequency of income, size of household, electrification status, and expected consumption) are related to respondent’s willingness to pay, the mean willingness to pay for the proposed electricity supply calculated by estimating the parametric model allowing inclusion of attributes of renewable electricity as major determinants into the WTP

function. The inclusion of these factors enhances the validity and reliability of contingent valuation method (CVM) results, thereby increasing their acceptance (Alam, 2017).

According to Lopez-Feldman (2013), equation (3.1) can be estimated using the single bounded because the initial bids and the responses to the first question are included discrete choice variable. Based on the above concepts and the variables defined in Table 2, we have following practical specification.

$$wtp_i (\text{bid1 reponse1}) = f(z_i\beta) = f(\beta[\text{sex, age, education, } \dots]) \text{-----} [3.2]$$

3.6.3 Univariate Probit model

The study aimed to analyze the household willingness to pay for Mini grid electric services. In addition, the discrete choice model, probit regression model has employed. The univariate probit employed here would be used to estimate willingness to pay per day bidding prices of 5, 6, 7 8, and 9. With some modification, the current model will be specified as in the case of the previous model [3.1] using the dichotomous choice model.

According to Baltagi et al., (2005) in the probit model which depends on the standard normal distribution, the dependent variable is a discrete random variable since it takes only two values, either 0 or 1. It assumes that the conditional mean function for the dependent variable (say Y) is given by;

$$P(Y/z_i) = F(z_i\beta) \text{-----} [3.3]$$

The mean of the dependent variables(Y) is given by Expected value of (Y) =P, where P is probability and variance =P (1-P). Therefore, in this study average willingness to pay is measured in probability (P), which has limited value between 0 and 1.

Based on the above concepts and the variables defined in Table 2, we have following practical specification.

$$wtp = \beta_0 + \beta_1 \text{bidday} + \beta_2 \text{gender} + \beta_3 \text{marital} + \beta_4 \text{occupation} + \beta_5 \text{landown} + \beta_6 \text{Famsize} + \beta_7 \text{education} + \beta_8 \text{benefit} + \beta_9 \text{age} + \beta_{10} \text{I4} + \beta_{11} \text{a cost} + \beta_{12} \text{inv} + \beta_{13} \text{fueldistance} + u_i \text{-----} [3.4]$$

3.6.4. Double bounded model

The single bounded model developed by López-Feldman has limitation regarding its efficiency. According to Hanemman et al. (1991), there is a problem with this method is that individual provides very few information with respect to her WTP. As the alternative to single bounded model, the double-bounded model or dichotomous question with follow-up has been developed, which improve efficiency of the estimation.

In double bounded model, respondents are offered with two levels of bid where the second bid is contingent upon the response to the first bid. If the individual answers yes to the first question he is asked about his willingness to pay for a higher amount. López-Feldman (2013a) suggests that if the respondent answers “No” to the initial question, a lower amount is subsequently offered. If the individual responds —yes to the first bid, the second bid (as follow up) is an amount greater than the first bid would be offered to the respondent. If we denote the first bid by $bid1$ and second by $bid2$. The concept of double bounded evaluation is that $bid1 < bid2$. In this scenario, there are four possible outcomes:

Let’s look more carefully at the information that is gathered with this strategy. Let’s call the first bid amount $bid1$ and the second one $bid2$, and then everyone will be in one of the following categories:

- a) both answers are —yes [yy]. In this case, infer that $bid2 \leq WTP < \infty$
- b) both answers are —no;[nn]. We infer that $0 < WTP < Bid2$.
- c) a —yes followed by a —no;[yn]. In this case we can infer that $bid2 > bid1$ and $bid1 \leq wtp < bid2$
- d) a —no followed by a —yes. [ny]. In this case, $bid1 > bid2$, we infer $Bid2 \leq WTP < Bid1$.

Let’s define $response1$ and $response2$ as the dichotomous variables that capture the response to the first and second closed questions, then the probability that an individual answers yes to the first question and no to the second can be expressed as:
 $Pr(response1= 1; response2/z) = Pr(s; n)$.

Under the assumption of normality and given (3.1), the probability of observing a given the values of the explanatory variables is given by:

Probability of yy response: $\Pr(s; n) = \Pr(wtp > bid1, WTP > bid2) = \Pr(z_i\beta + u_i > bid1, z_i\beta + u_i > bid2)$
 Probability of nn response $\Pr(s; n) = \Pr(0 < WTP < Bid2) = \Pr(z_i\beta + u_i < bid1, z_i\beta + u_i < bid2)$
 Probability of ny Response: $\Pr(s; n) = \Pr(bid1 \leq wtp < bid2) = \Pr(bid1 \leq z_i\beta + u_i < bid2)$
 Probability of yn response: $\Pr(s; n) = \Pr(Bid2 \leq WTP < Bid1) = \Pr(Bid2 \leq z_i\beta + u_i < Bid1)$

At the end of the day, we can specify the doubled bounded model as in the following.

$$Wtp(bid1 \text{ bid2 response1 response2}) = f(z_i\beta) = f(\beta[\text{marital2, occupation2, Famsize landown1, dhouse2, inv, benefit, education1, I4, age2, fueldistance}]) \text{ ----- [3.5]}$$

3.6.5. The bivariate probit model

In comparison with double bounded, this study used the bivariate probity regression model. According to Areal and Marcleod (2006), the nonlinear model using bivariate probity produces accurate result than the double bounded model. In a bivariate probit model, unlike the ordinary probit model, we have two binary dependent variables and two latent variables (Areal and Marcleod, 2006)

The bivariate regression model has become a general parametric modeling approach for the double-bonded CV method. It is the best match for analyzing the data generated by CVM (Cameron and Quiggin, 1994). Therefore, it used to examine factors that influence a household's willingness to pay for solar mini-grid electricity service. The difference between this model and the double bounded dichotomous choice model is that, in later case respondents present with two levels of the bid where the second bid price is depend upon the response to the first bid or the second bid price is endogenously determined.

The estimation of the coefficients using bivariate probit model includes two related models, which can be expressed as:

So, the latent dependent variables Y_1^* and Y_2^* are modeled as linear functions of the independent variables:

$$Y_1^* = \beta_1 X_1 + \epsilon_1 \text{ and } Y_2^* = \beta_2 X_2 + \epsilon_2 \dots \dots \dots [3.7]$$

Here, $X = [X_1, X_2, \dots, X_k]$ are vectors of independent variables, $\beta = [\beta_0, \beta_2, \dots, \beta_k]$ are vectors of coefficients, and ϵ_1 and ϵ_2 are error terms. The error terms are assumed to follow a bivariate normal distribution with zero means, unit variances. The Coefficients, $\beta = [\beta_0, \beta_2, \dots, \beta_k]$ indicate the effect of the independent variables on the latent variables Y_1^* and Y_2^* , respectively. Positive coefficients suggest that an increase in the corresponding independent variable increases the likelihood of the latent variable being positive, thereby increasing the probability of observing a 1 in the corresponding binary outcome.

The parameters of the bivariate probit model β 's are typically estimated using maximum likelihood estimation (MLE). The likelihood function involves the joint probability of the observed outcomes Y_1 and Y_2 , which depends on the cumulative distribution function (CDF) of the bivariate normal distribution

Likelihood Function

Given two binary outcomes Y_1 and Y_2 , the probability of the four possible combinations of outcomes is needed:

$$\begin{aligned} \Pr(Y_1 = 1, Y_2 = 1) &\Rightarrow \Pr(Y_1 = 1, Y_2 = 1) = \Phi_1(\beta_1 X_1, \beta_2 X_2) \\ \Pr(Y_1 = 1, Y_2 = 0) &\Rightarrow \Pr(Y_1 = 1, Y_2 = 0) = \Phi_1(\beta_1 X_1, -\beta_2 X_2) \\ \Pr(Y_1 = 0, Y_2 = 1) &\Rightarrow \Pr(Y_1 = 0, Y_2 = 1) = \Phi_1(-\beta_1 X_1, \beta_2 X_2) \\ \Pr(Y_1 = 0, Y_2 = 0) &\Rightarrow \Pr(Y_1 = 0, Y_2 = 0) = \Phi_1(-\beta_1 X_1, -\beta_2 X_2) \end{aligned}$$

Where Φ_1 denote the bivariate normal cumulative distribution function (CDF). The log-likelihood function for a sample of n observations is given by;

$$\begin{aligned} (\beta_1, \beta_2) &= \sum_{i=1}^n \\ Y_{1i} Y_{2i} \ln \Phi_1(X_{1i} \beta_1, X_{2i} \beta_2) &+ Y_{1i} (1 - Y_{2i}) \ln \Phi_1(\beta_1 X_1, -\beta_2 X_2) + \\ (1 - Y_{1i}) Y_{2i} \ln \Phi_1(-\beta_1 X_1, \beta_2 X_2) &+ (1 - Y_{1i}) (1 - Y_{2i}) \ln \Phi_1(-\beta_1 X_1, -\beta_2 X_2) \end{aligned}$$

Therefore, the coefficients β_1 , and β_2 are estimated by maximizing the log-likelihood function. This is typically done using numerical optimization methods, such as the Newton- Raphson algorithm or other iterative optimization techniques. Once the bivariate probit model is estimated, it can be used to calculate the individual's willingness to pay. This is typically done by deriving the expected willingness to pay (E [WTP]) from the estimated parameters. The E [WTP] can be calculated as;

$$E[WTP] = \Phi(\beta_1'X_1 / \sqrt{(1 + \beta_1'Var(X_1)\beta_1)}) * E[y_2|y_1 = 1]$$

Where: ' $\Phi(\cdot)$ ' is the cumulative distribution function of the standard normal distribution, ' $Var(X_1)$ ' is the variance-covariance matrix of the explanatory variables in the willingness to pay equation and ' $E[y_2|y_1 = 1]$ ' is the expected value of the purchase decision, given that the individual is willing to pay.

In general, bivariate probit model cases, we have two binary dependent variables, Y_1 and Y_2 , and a set of explanatory variables X_1 and X_2 that are potentially correlated. In the present study Y_1 =response1, Y_2 =response2, X_1 =bid1 and X_2 =follow up bid (bid2). Thus, the predicted probabilities can be calculated as follows:

$$\begin{aligned} \text{For the first outcome variable (Y1): } P(Y_2 = 1 | Y_1 = 1) &= \Phi_2(X_1\beta_1, X_2\beta_2, \rho) / \Phi(X_1\beta_1) \\ \Rightarrow P(\text{response2} = 1 | \text{response1} = 1) &= \Phi_2(\text{bid1_01}\beta_1, \text{bid2_01}\beta_2, \rho) / \Phi(\text{bid1_01}\beta_1) \\ \text{For the second outcome variable (Y}_1 = 1 | Y_2 = 1) &= \Phi_2(X_1\beta_1, X_2\beta_2, \rho) / \Phi(X_2\beta_2) \\ \Rightarrow P(\text{response1} = 1 | \text{response2} = 1) &= \Phi_2(\text{bid1_01}\beta_1, \text{bid2_01}\beta_2, \rho) / \Phi(\text{bid2_01}\beta_1) \end{aligned}$$

Where: - $\Phi(\cdot)$ represents the cumulative distribution function (CDF) of the standard normal distribution and $\Phi_2(\cdot, \cdot, \rho)$ represents the CDF of the bivariate normal distribution with correlation ρ , β_1 , β_2 are the coefficients for the covariates in the first and second equations.

3.6.6. Mean and Aggregate WTP

One of the main objectives of estimating empirical WTP model based on the CV survey response is to draw central measure or mean and median of the willingness to pay distribution (Hanemann, 1984). Two options such as the mean and the median can be used to calculate the average willingness to pay (AWTP) across respondents (Perman et al., 2003). So far, there is no consensus on the choice between the mean and the median as the better and appropriate measure of welfare. The median is affected less by a few very high WTP responses that are known as outliers. The mean WTP is the theoretically correct measure and is relevant in the case of cost-

benefit analysis. Whereas, the median is important in the case of public choice or the economic analysis of political decisions due to its more weight on the majority (Pearce & Ozdemiroglu, 2002). Therefore, this study used mean WTP to estimate AWTP of respondents from the responses of both open-ended and double-bounded value elicitation formats since the proposed project is related to cost benefit analysis.

The mean willingness to pay is computed using predicted probabilities for a bivariate probit model (Greene, 2012; Wooldridge, 2010; Cameron & Trivedi, 2005). Then, the mean willingness to pay from a bivariate probit model can be computed as follow; first estimate the bivariate probit model. This will involve specifying the model, estimating the parameters, and obtaining the parameter estimates. Then, use the estimated coefficients to calculate the predicted probabilities for each outcome. In a bivariate probit model, in fact have two equations, each representing the probability of a specific outcome. After this, compute the mean willingness to pay using the predicted probabilities from the bivariate probit model. Finally use the predicted probabilities to compute the expected value of willingness to pay for each individual and take the mean of these expected values across all individuals in the sample.

Thus, to calculate the mean WTP from the double bounded discrete value elicitation format, the “doubleb” command created by (Lopez-Feldman, 2012) is used. Since the “doubleb” command directly estimates, β^{\wedge} the WTP formula is simply $z^{\wedge}\beta^{\wedge}$. In case with no control variables WTP is simply the constant. With the inclusion of the covariates, the WTP evaluated using the average values for the explanatory variables.

Then after estimating (3.5), mean willing to pay can be computed from Probit model result.

Lopez-Feldman (2012) proposes the following to estimate the mean WTP;

$$\text{Mean WTP} = \frac{-(\beta_0 + X\beta)}{\delta} \quad [3.8]$$

Where β_0 is estimated value of constant term, X is the scalar computed from each

explanatory by subtracting actual values from its means, X is a vector of explanatory variables included in this study and β is a vector of estimated coefficients of each explanatory variable and lastly δ is the coefficient of bidding variable. In short, the purpose of estimating a different mean WTP from the summary statistics is to obtain a consistent and adjusted mean WTP controlling other characteristic of the respondents.

After the estimation of mean WTP value, the next step is converting mean WTP to the total population level. This step is an aggregation of WTP by multiplying the mean WTP by the relevant total population (Perman et al., 2003). The relevant total population for this study is the total number of households living in the two kebele covered by mini-grid design. Hence, the total or aggregate WTP is mean WTP multiplied by the total number of households (N).

$$\text{Total WTP} = \text{Mean WTP} * N \text{-----} \quad [3.9]$$

3.6.7. Valuation Scenario

An initial capital investment cost of the project was estimated to be 125000 US\$ with 25 years life span which covered by grant and not included in this valuation. The total operation cost of valuation mini grid is estimated to 2,677,600US\$ with COE of 0.25 US\$ per kWh equal to 78426904 ET. Birr. Of this maintenance cost is about 2% of CAPEX which is estimate to be 25,000US\$ annual in life span of project, battery and inventor needs to be replaced which cost about 140200US\$ and 6338US\$ after 10 and 15 years of the system was commissioned. Another cost is overhead expense to run the project routinely that has been estimated 2449800US\$, besides 5 percent (62500 US\$) contingency included to perceive future continuity of project. Thus, annually and monthly cost of project to generate 424130 kWh is estimated about 107104US\$ and 8925US\$ respectively to electrify village with COE 0.25US\$/ kWh. This cost is excluding connection fee like metering, wire cable and electric appliance. In this regards government envision to electrify rural household like you through optimal cost effective renewable energy in public-private partnership and estimate of

the average amount of money required per household to run the plant operationally sustainable so it needs to pay for service cost of electricity.

Imagine electricity allows you to illuminate your house, use for entertainment, information and communication service appliance- radio, TV and mobile phone charging, cooking service -stove, electric mitad, fridge and also enjoy for business activity-Poultry and agricultural processing as well as for different social service so you spend certain amount money from your income on electricity pay monthly based on power consumption.

Despite electricity benefit, there are also homes like yours with no having electricity connection and instead uses alternative fuels like fire wood, crop residual, cow dung and charcoal for cooking, heating, and firewood, candles, kerosene and paraffin for lighting purposes, further deprive welfare gain resulting from using electricity. This, option are expensive and inconvenient when used, not healthy and environmentally unfriendly. Thus, the tariff you pay for the electricity you consume-mini grid supply, as well as any damage due to voltage fluctuations and interruptions to supply. You may also incur for alternative energy source in cases of no access, which can be far more cost to per kWh and unfriendly to use than mini grid supply. Paying for electricity will result in: reliable, uninterrupted regular 24 hour electricity supplies to your home. The bill payment will be collected monthly based on agreement with Ethiopia electric utility institution responsible for electricity distribution and selling with improved customer service.

Now we want to find out how much access to improve electric service by EEU is worth to you.

I would like to know what the development of the electricity mini grid in order to provide more reliable and stable services is worth to you. Please consider the chosen amount as your current basic monthly electricity tariff based on your consumption of power counter in kWh if, to make more clear 1kw is encourage to use for 3 bulbs 13w for 6h/d is 0.078kW, radio 3w for 4hours is 0.012kwh/d, 3chargers for 2 hours is 0.03 6kWh/d and if you have a plan to use it for TV 65w for 7h is 0.77kWh/d at least if you

use this appliance which is count 1 Kwh that will cost you 7 birr per Kwh. When you consider the monthly fee, please take into account: your household real income, which means your revenue and all expenses that you have to expense each month. Please note that your answer will have no effect on the price at which this service will be offered but, still might use as information to do so.

So are you willing to pay ---this amount monthly base?

3.7. Diagnostics testing

Most importantly, the above econometrics model is subject to collinearity, validity of the overall result, goodness of fit and specification error. The study would examine collinearity problem using variance inflation factors (VIF). If mean of value of VIF would less 5, we detect no collinearity problem (Gujarati, 2012). To examine the validity of overall results, the study used Wald test. In this test must be rejected for the estimated result to be acceptable. So, smaller probability value would expect. The other test for violation of assumption is goodness of fit which can be detected using Pearson chi-square. In these cases, the test would better if not rejected to justify good fit. So we need larger probability of value of greater 5%. Model Specification error is also series issues that must be examined and corrected. According, linkest command would be used to produce the result of squared predicted value. It is desirable if the test fails to reject this test hypothesis as well.

3.8. Reliability Test

Reliability refers to the consistency of a measure. A measuring instrument is reliable if it provides consistent results (Heale & Twycross, 2015). Reliable measuring instrument does contribute to validity, but a reliable instrument need not be a valid instrument. For this study, the formal test for reliability of measurement is —Cronbach’s alphas, which always used in many literatures. Note that a reliability coefficient of 0.7 or higher is considered —acceptable in most social science research situations (Cronbach, 1955).

3.9. Description of study variable

Households' Willingness to pay (HWTP) binary choices for renewable source of electricity service connection is the dependent variable of the model in this study. It is assumed that WTP is determined and explained by different household energy consumption pattern, socio economic and demographic characteristics. In the context of this study, the value that household places to get electricity services is indirectly measured by the amount they are willing to pay (WTP) for it

Dependent variables

Willingness to pay: In this study household willingness to pay is the outcome or dependent variable which measured using discrete dummy variable. It is the indirectly measured from the utility of household from using mini grid electricity. The key idea is that, if the expected utility of household greater 0, household has willingness to pay for additional services, not otherwise. Depending on the type of methods employed we have different dependent variables as measure of willingness to pay for MG electric services.

- a) Binary response one (response1): in discrete choice model, particularly single bounded model, this is the dummy variable which captures 1 if household are willing to for initial bid (first question) and 0 otherwise.
- b) Binary response two (response2): Similarly, it is a dummy variable=1 if the households are willing to pay for the second bid (second question) and 0 otherwise. Here it is important to note that, in case the univariate probit model is estimated, response1 is the only dependent variable. In that case, $response1 = \begin{cases} 1 & \text{if } wtp \\ 0 & \text{otherwise} \end{cases}$ for(5,6,7,8,9),

Other dependent variables in case of bounded discrete choice models

- c) Initial bid (bid1_01): this is the first bidding prices offered to the respondents. It includes (400, 500, 600 and 700). These are discrete values representing initial questions.

d) Second bid (bid2_01): likewise, this is the second bidding prices offered to the respondents. Bid1_01 includes values of (200, 250, 300 and 350) as the lower bidding prices if the respondent said no the first question and bid1_01= (800, 1000, 1200, 1400) as bidding prices if the respondents say yes to the first questions. . These are discrete values representing initial questions.

However, the Initial bid (bid1_01 and Initial bid (bid2_01) would not dependent variables under in the case of bivariate probit model. Rather these would be included as repressors with expected sign of negative. The expected negative sign reflects the higher bidding prices, the lower willingness to pay for it. Moreover, when the single bounded model is estimated, the only dependent variables are response and Initial bid (bid1_01).

Independent variables (1): Socioeconomic and Demographic factors

1. **Age of the household:** like previous studies, this study used age as one of factors determining willing to pay. It measured in years and expected increase WTP. As age increase, the studies believe that household has more understanding of public services and are willing to pay for such services. Some literature revealed that older household heads are less likely to adopt solar home system compared to younger ones. That means it has a negative influence on the household's willingness to adopt a solar energy technology (Anteneh, 2018; Legesse, 2016). But other studies found that households__age has a positive influence on solar home system adoption because it might be related to the fact that older household heads may be wealthier as they accumulate more productive resources that enable them to invest in the solar energy technology (Guta, 2018). In this study age of households head is hypothesized to affect solar energy adoption either positively.
2. **Sex of the household:** The study included sex, being female and male, in studies which also expected affect wtp for mini grid electric services. The study includes this variable as being female as dummy variables and being male as reference category. Studies have indicated that women participate in environmentally friendly technologies more than men. For instance, one study indicated that support for new renewable energy development was supported by about 90% of women as compared to 60% of men

(Patrick, 2007). By contrast, one study showed that males were more likely to adopt new technologies compared to female (Bollinger and Gillingham, 2012). In rural Ethiopia, the male is considered to be strong, resourceful, and autonomous decision maker in deciding the adoption of modern technologies, but women are most affected by the lack of access to clean energy. Therefore, the effect of the household head's gender on PV solar technology adoption is indeterminate. Empirical studies concerning demographic variables are inconclusive and still debatable. Regarding gender of household head, there are two contrasting groups, which means the first group argued that male-headed households are more likely to adopt solar for instance (Anteneh, 2019), and in the other side, female headed households are more likely to adopt solar home system (Guta, 2018; Partick, 2009). Therefore, in this study gender of the household head is expected to have either a positive or negative influence on solar energy technology adoption.

3. **Education level:** The study measure household education level by four categorical variables including having normal education, attaining primary school, secondary school and tertiary education. This has been done based on the previous studies (Muiruri, 2020; Toleshi & Teshome, 2022). In addition, the researcher reduces the categories for these variables in to two, having no formal education and otherwise by means of data transformation technique. Hence, having no formal education was entered in the regression. Household head that are more educated tend to acquire a greater awareness regarding the benefits of solar energy technology; these benefits include health, environmental, economic, and social welfare. However, regarding the effect of education, there is mixed evidence in the literature. In developed countries, a study found a positive effect of education on household solar panel adoption (Rahut et al., 2017; Kwan, 2012). On the contrary, another study found no positive effect of education of renewable energy (De Groote et al., 2016). However, in the case of low-income household differences in educational status is an important determinant of how people acquire and use information on solar PV technology and its benefits. Individuals who are less educated may lack awareness about the benefits of solar PV technology. Therefore, the model is controlled for the educational level of the household head, and it is proposed that positively influence the household's decision on solar energy technology adoption. Regarding education, studies revealed that the education level of household heads has a positive

effect on solar powered renewable energy (Abera, 2019; Guta, 2018; Anteneh, 2019). This is because of the reason that education enhances individual's health and environmental awareness that helps them to choose clean and modern energy sources. Thus, in this study, the educational level of household heads is expected to positively influence the household willingness to pay for off-grid renewable energy provision.

4. **Family size:** the number of family size in household is the other important demographic factors driving wtp. The study expected that as number of household increase, WTP would be increases, if another thing kept constant. This means that larger family size requires more energy consumptions for their daily ordinary activities. Previous studies have indicated that larger households are more likely to adopt solar PV because they are larger consumers of electricity and they can spread the fixed cost over the members of the household (De Groote et al., 2016) The negative effect is likely related to the fact that with an increase in the household size, it is expected that expenditure on various commodities may increase. The other study also revealed that household size has a positive effect on solar energy technology adoption (Guta, 2018). The variable expected to have either a positive or negative effect on solar PV adoption. Likewise, family size is expected to have either a positive or negative influence on solar energy adoption. Studies indicated that family size has a negative effect on solar energy technology adoption (Gitone, 2014; Anteneh, 2019; Abera, 2019). This is because households with large family sizes spend more resources in upholding their children rather than investing in a solar energy technology.
5. **Marital status:** The study categories this variable in to three, single married and widowed. Then after, it has included in the model with a dummy variable to get reliable and precise results. The generated dummy variables represent binary values of 1=married household and 0=otherwise. A study stated that married household heads are more likely to adopt a solar energy technology than either single or divorced household heads (Anteneh, 2019). The variable expected to have a positive influence on HH WTP.
6. **House condition (dhouse2):** though classified into several categories, the researcher used wall mud iron sheet roof as dummy for house condition. The reason why such dummy is created to avoid dummy variable trap and collinearity issues. The variables

that are particularly important for rural households in determining their willingness to pay include household house type, as it is a prerequisite for installing an electric meter.

7. **Land access** it captures asset of the household which crucial variables influencing WTP of the households. It measured by categorical variables that is with yes/no response. The larger the household landholding, the greater their agricultural output, which in turn augment income to enhance ability to pay for renewable energy technology. Guta (2018), studies show that having large landholding size increases the probability of adopting solar energy technology. Annual crops such as grain are grown in the area, and thus the households who have large land may grow these crops (Toleshi & Teshome, 2022). The more likely the household have their own land, the more likely that they will be able pay for services.
8. **Income:** one of the most important determinants determines wtp is logarithm of the annual agricultural income received by households measured in Ethiopia birr (ETB). With regard to the households income variables, the study used the gross estimated farm=2 revenue as a proxy for household income. Those household with higher income would expected have more willingness to pay. In this study, income is measured by total annual income. However, the researcher transformed the income data into logarithmic form. This transformation was done because the values of the other independent variables and outcome variables are relatively small compared to total income. So, using total income in regression might generate spurious regression. It constitutes income from crop production, fruit, vegetable, animal and animal products and income from different services. Household income is one of the socioeconomic factors that could affect the adoption of a solar energy technology. Findings in the empirical studies are inconclusive and contrasting. Some studies found a positive effect of income on the decision for household solar energy adoption (Abdullah and Mariel, (2010); Twerefou, 2014; Smith and Urpelain, 2014), but other studies revealed a negative wealth effect (Willis et al., 2011). In the case of rural Ethiopia, a study showed that modern energies (e.g., kerosene, solar, and electricity) are luxury goods (Guta, 2012). Moreover, studies on East Africa countries have revealed a positive effect of wealth on solar panel adoption (Smith and Urpelainen, 2014). This study controlled for a household productive assets (e.g., landholding size and the number of cattle), which are expected to influence a household

willingness to pay for renewable energy technology positively. Thus, in this study household income is expected to have a positive influence on WTP for solar powered mini grid electricity service. Consumers with irregular income sources (e.g., agricultural activities or loans) may face time constraints in payment schedules, affecting their ability to pay (ATP) even if their true willingness to pay is high.

Independent variables (2): Alternative characteristics

9. Distance to fuel: Distance of household access and collect firewood measured in Km and expected to be positively related with WTP. The longer the distance in Km from households to fuel means higher cost. Transportation cost and related issues encourage searching for alternative energy sources, which is most probability MG electricity pay. In their 2017 study, Arega and Tadesse, examined the factors influencing household's willingness to pay for green electricity. They discovered that variables such as proximity to alternative energy sources, gender, and income significantly affect the amount households are willing to pay each month.
10. Average cost of fuel: Cost of the fuel is another important factor influencing willingness to pay for MG electric services. For those household, who use it higher fuel cost mean less demand for fuel energy. That is households might be interested ad pushed by cost of fuel to pay for MG. Bhandari and Jana (2010), higher household expenditure on kerosene correlated with greater willingness to adopt solar electricity connections.
11. Environmental awareness (inv): inv variable is generated from three questions about importance of MG electricity in reducing pollution, reducing deforestation and reduction of fuel expanders using PCA. In this study, it captures household's awareness about their environment. Du Preez et al. (2012), environmental awareness on attitudes toward paying for electricity from renewable sources. Highly educated respondents and those concerned about greenhouse gas emissions showed greater willingness to pay.
12. Reliability of MG (ralmg): This variable is also scoring values computed from respondent perception about reliability of the MG. It expected in such that the more reliable the MG electricity, the more households are willing to pay. It measured using information from electrified households only. Gunatilake et al. (2012), Household's willingness to pay for electricity services is influenced by factors such as home business

ownership, perceived benefits of reliable electricity, per capita household income, and the number of school-age children in the household. Amador et al. (2012) found that customers who had experienced serious power outages in the past were more willing to pay for reliable electricity supply.

Hobman and Frederiks, (2014); Claudy et al., (2012); Dupont and Bateman, (2012) these authors emphasized that willingness to pay for reliable electricity services are both a moral and political issue. While individuals value reliable electricity and prefer environmentally friendly sources, they may resist energy sector reforms that increase household charges. Some households feel they already pay high tariffs for social utilities and expect reasonable rates. Wakjira (2022) household's WTP for improved electricity service increases with a decrease in the frequency of outage, duration of the outage, night time outage and additional costs.

13. Satisfaction from MG electricity (starmg): Just like ralm, the extent of household Satisfaction of from electricity can influence their willingness to pay, for electrified household. The score index is computed from the opinion of the respondents using relevant question offered. It measures respondent grievance towards quality of current electric supply.
14. Current cost of electricity (cec): Electricity cost is expected be negatively related with wtp. The higher cost of using electricity, the fewer users are willing and able to pay for it. The variables are measured in monetary terms (in Birr).
15. Electric consumption per KW (ceckwh): in this study, Electric consumption is measured in terms of kw per hour. It expected to increase wtp if the consumption increases by one unit.
16. Benefit from electric services (benefit): Perceived benefit from utilizing electricity is expected increase wtp. The more perceived benefit derived, the more respondents are wtp.
17. Perception toward current electric services: This variable measures individual's attitudes, opinions, and satisfaction levels regarding the quality, reliability, affordability, and overall performance of the existing electric services they receive. The summary of variables and its description is as shown below in Table 4.

Table 4: Description of the study variables summary

variable name	value label	Description	Sig n	Reference
WTP1	Numerical	First bid	-	(Reta, 2021; Tadale, 2022)
response1	Dummy	1=yes to the first question, 0= no to the first question		
WTP2	Numerical	second bid offered		
response2	Dummy	1=yes to the second question, 0= no to the first question		
fdistance	Numerical	Distance in Km to all fuel	+	(Arega and Tadesse, 2017
Famsize	Numerical	Number of family	+	Mekonnen and Kohlin (2008)
age2	Numerical	Age of the household in years	+	Abdullah and Mariel, 2010; Du Preez et al. 2012; Reta 2021)
dhouse2	Dummy	1==wall_mudiron_sheet_roof,0= otherwise	+	
landown2	Dummy	2=own land, 1= no own land	+	(Guta, 2018; Toleshi & Teshome, 2022; Reta, 2021)
lnincome	Numeric	Log of income	+	(Arega and Tadesse, 2017; Twerefou, 2014; Mekonnen and Kohlin, 2008)
marital2	Dummy	1 = Married, 0 =otherwise,	+	(Reta, 2021)
education1	Dummy	1==have_no_any_formal_education, 0=otherwise	+	Mekonnen and Kohlin,2008;Reta 2021)
education2	Dummy	2==attained_primary_school__0_8, 0=otherwise	+	
education3	Dummy	3==attained_secondary_school__9_12, 0=otherwise	+	
education4	Dummy	4==attained_tertiary_educationabove12, 0=otherwise	+	(Twerefou,2014; Lay et al.,2013; Amador et al. 2012)
gender2	Dummy	2 if male , 0 otherwise	+	(Arega and Tadesse, 2017; Twerefou, 2014)
benefit	Score	Scores for component 1	+	Gunatilake et al. (2012)
perception	Score	Scores for component 1	~ 68	(Tadale, 2022)
acost	Numerical	Average cost of fuel	+	Bhandari and Jana (2010)
cec	Numerical	Current cost of electricity	+	(Tadale, 2022)
ceckwh.	Numerical	electricity consumption inkwh	-	(Tadale, 2022)
inv.	Score	Environment awareness	+	(Du Preez et al. 2012; Danlami et al., 2015)
realmg.	Score	Reliability of mini grid	+	Amador et al. (2012)
starmg.	Score	Satisfaction from mini grid electricity	+	(Tadale, 2022)

Source: Own survey, (2023)

3.10. Ethical Considerations

The main objectives of the research, guarantee of anonymity of the respondents and confidential treatment of the data obtain explained to participants that the information provide by them only used for the study purpose. The letter of permeation was written from Addis Ababa University College of development studies from center of environment and sustainable development to ensure that the study is only for the academic purpose. Moreover, it ensures confidentiality by making the participants anonymous to eliminate the problems of ethical dilemma and facilitate smooth flow of information between data that collected and respondent. Then following this, it needs to obtain a consent and willingness to participate in the survey. Finally, the studies also assure that there is no used material without source citation or appropriate credit is given for any use of another person's idea or word, or no improper paraphrasing of materials.

CHAPTER-4

4.1. RESULTS AND DISCUSSIONS

This chapter shows the data analysis, presentation and interpretation of the results on the analysis of household willingness to pay for mini-grid solar powered electricity in the study area. The chapter is divided into different sections featuring the research objectives which were: the first objective determine household willingness to pay value; the second analysis factors affect household willingness to pay for solar powered mini grid electricity; finally and the 3rd objective evaluate the extent to which total WTP value is cover cost of electricity service provision to ensure sustainability of mini- grid energy in rural area.

The research instruments comprised of both structured and unstructured questions aimed at drawing relevant information for this study. Descriptive techniques were used to analyze the data, mainly socio-demographic factors and energy consumption pattern of respondent were entertained. The data obtained was analyzed by using STATA- version 14. The frequencies percentages, and mean scores are computed and presented. The information and data obtained were presented in form of frequency tables for easy interpretation by the readers. The main sections covered include reliability analysis, validity and demographic information.

4.1.1 Descriptive Statistics for Dummy Variables

Table 5: presents household's characteristics using frequency distribution. The result shows that 271(71.3%) and 109(28.7%) of the respondents were male and female, respectively. Regarding household's education level, 223(58.7%) of the respondents attained informal education, while the remaining 90(23.7%), 48(12.6%) and 19(5.0%) attained primary, secondary and tertiary educations, respectively. It indicates that most of the respondents are male.

According to the result in table 5, of 380 respondents, 43(11.3%) are single, 234(61.6%) are married and 103(27.1%) are widowed. On the other hand, when we look at the occupation of the respondents, 119(31.37%) are engaged in off farm, and 261(68.7%) engaged in farming activities. The result also revealed that most of the result own land as asset. From the result, it is clear that about 225(59.2%) have their own land, while the remaining not.

Table 5: Socio-demographic characteristics of household

Variables	Categories	Frequency	Percent
Sex	Male	271	71.3%
	Female	109	28.7%
	Total	380	100.0%
Education	No formal education	223	58.7%
	Primary school	90	23.7%
	Secondary school	48	12.6%
	Tertiary education	19	5.0%
	Total	380	100.0%
Marital status	Single	43	11.3%
	Married	234	61.6%
	Widowed	103	27.1%
	Total	380	100.0%
Occupation	off farm	119	31.3%
	Farmer	261	68.7%
	Total	380	100.0%
Land Access	No	155	40.8%
	Yes	225	59.2%
	Total	380	100.0%
House condition	Other	138	36.3%
	Wall mud iron sheet roof	242	63.7%
	Total	380	100.0%

Source: survey results (2023).

Table 6 revealed the estimated result of measures of association between demographic characteristic of the household and status of access to electricity. The aim here is to compare whether the two groups, electrified and non-electrified, are independent of specific demographic factors. Accordingly, the result shows that their land owing, education level and sex are independent of the electric status. The test result is significant at 1% and 10% respectively. This mean being electrified household or not has associations with attaining certain level of education, having own land and being male or female. That implies that even though there is electricity access in their area and it is basic thing some households were unreflecting to connect to get service due to aforementioned.

However, the result shows that house condition, occupation, and marital status have association with being electrified or not. The hypothesis would be accepted at 5% for each. The implication is that being farmer or not matter having access to electricity or not, being

married or not is also issue and living standard house does not have relation with being electrified household or not.

Table 6: Chi-square test for association two categories

Variables	Categories	Non electrified (160)	Electrified (220)	Total	Pearson chi2	P
Land access	No	46	109	155	16.586	0.000
	Yes	114	111	225		
House condition	Otherwise	65	73	138	2.219	0.136
	Wall mud iron sheet room	95	147	242		
Occupation	off farm	55	64	119	1.2025	0.273
	Farmer	105	156	261		
Marital status	Single	18	25	43	0.744	0.689
	Married	95	139	234		
	Widowed	47	56	103		
Education	Have no any formal education	86	137	223	7.4014	0.060
	Attained primary school	49	41	90		
	Attained secondary school	18	30	48		
	Attained tertiary education	7	12	19		
Sex	Male	106	165	271	3.4669	0.063
	Female	54	55	109		

Source: Author survey (2023).

4.1.2. Descriptive statistics of continuous variable

Table 7 shows the summary descriptive statistics for continuous variables that describes household characteristics in the study area. The finding shows that on average the number of family was 5.83, with minimum and maximum value 1 and 11 respectively. The family size varies with a standard deviation of 2.2. On the other hand, the distance from household to all fuel is 25.80 Km on average, with 8.676 km variation between the household as it measured by standard deviation. The finding indicates there is high variation among the households.

Table 7: Description of the Characteristic of the households (continuous variable)

Variable	Obs	Mean	Std. Dev.	Min	Max
tincome	380	45,349.47	35497.07	10000	180,000
Famsize	380	5.823684	2.211261	1	11
Fdistance	324	25.75926	8.676009	9	50
age2	380	44.37105	10.77139	28	73
Accost	164	250.122	289.1387	60	2400
Benefit	220	-0.2720341	0.977011	-1.77064	2.434624
Cec	220	108.5343	50.77559	55.9	199.875
Ceckwh	220	74.08364	43.51196	0	182
Perception	376	-1.82E-09	1	-1.33172	2.028867

Source: Author survey, (2023).

In this study, the household income is measured by birr and computed based on annual basis. These measurement represents total income earned from all sources. Result in Table 6 revealed that the household average income in this study is about 45,349.47 Birr per annual. In this case, there also is high variation among households regarding their income as indicated standard deviation, with minimum income of 10000, and maximum 18, 0000.

The cost of kerosene is among the key determinants of household demand for solar energy. According to the result in Table 6, the average cost of kerosene is 250.122, with 289.1387 variations among the household. In this study, the higher the cost of kerosene, the more demand for solar energy would expect to be.

Table 8 reports the t test result for comparing mean of Electrified and non-electrified households based on socioeconomic characteristics. Here the key points is that mean of total income (tincome), age of the respondents, family size, distance to all fuel, perception, benefit and environment awareness (Environment) factors were compared for the two groups and found to significant. The result shows that there is difference between the two groups based on their income, family size, distance to all fuels, perceived benefit and awareness they had on environment. The estimated mean for these variables is statistically significant at 1%, 10%, 1%, 1% and 1% respectively.

Result of interview with District Electric Power Office expert, due to high tariff levels, customers could only use electricity for low-end tier services (such as lighting, phone charging, and TVs) at a cost lower than alternative energy sources like kerosene firewood. The tariff levels did not allow customers to use electricity for high-end tier energy services (e.g., welding or milling, poultry). Lighting a house with a light bulb

is cheaper than using a kerosene lamp. Consequently, the tariff model with high per kWh tariffs was effective because people used few kilowatt hours per month. A low-end consumer used approximately 1-2 kWh per month, while a high-end consumer used about 4-8 kWh per month. Higher levels of consumption (for example, for cooking) would quickly become unaffordable. The use of 1 kWh is equivalent to using one 11W light bulb for three hours per night for one month.

Variables	Non-electrified (160)	Electrified (220)	t	P
tincome	38242.76	50517.99	-3.3735	0.0008
age	245.19375	43.77273	1.2708	0.1023
Famsize	6	5.695455	1.3269	0.0927
Fdistance	27.41353	24.60733	2.8966	0.002
Perception	0.020053	-0.01422	0.327	0.7438
Benefit	0.216181	-0.15722	3.6518	0.0003
Environment	-0.76264	0.554646	-16.6841	0.000
Bidday	7	7.109091	-1.1495	0.2511

Table 8: T-test for mean difference among Electrified and non-electrified households

Source: Author survey (2023).

4.1.3 Household Energy Use in the study Area

By Energy use pattern of household means that level of energy consumption and its condition as it would be described by frequency distribution and percent.

The result in Table 9 presents the main source of energy consumed by the households. From the table Electricity (MG), fuel wood, kerosene, crop residual, charcoal, dung, Biogas, SHS and solar interim are the main source of energy used by the households. Among these sources electricity, SHS and solar interim are used by 55%, 52.7% and 48.6% respectively.

Table 9: Household use source of energy

Main Source of energy	No		Yes		Total	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Electricity (MG)	99	45.0%	121	55.0%	220	100.0%
fuel wood	294	77.4%	86	22.6%	380	100.0%
kerosene	328	86.3%	52	13.7%	380	100.0%
Crop residual use	336	88.4%	44	11.6%	380	100.0%
charcoal	335	88.2%	45	11.8%	380	100.0%
dung	352	92.6%	28	7.4%	380	100.0%
Biogas	345	90.8%	35	9.2%	380	100.0%
SHS	104	47.3%	116	52.7%	220	100.0%
solar interim	112	51.4%	106	48.6%	218	100.0%

Source: survey result (2023).

The analysis starts with identifying access to electricity. Table 10 revealed the presents the distribution of household according to their access to electivity in the study under the consideration. It shows that more than half of the respondents have access to electrify, which about 220(57.07%) and, about 160(42.11% of the household have no access to electricity. The number of households lack access to electricity very huge even though more than half of them have access to it.

Table 10: Access to electricity

Access	Frequency	Percent
No	160	42.11
Yes	220	57.89
Total	380	100

Source: Author survey (2023)

According to table 11, 160 households have no access to electricity, while of them are from Kobo Kebele. In this kebele, on other hand, of 179, 19 household have access to electricity. Of 220 household with access to electricity, 201 of them are from Koftu kebele.

Table 11: Access to electricity by kebele

Kebele	Access to electricity		
	no	Yes	Total
Koftu	12	189	201
Kobo	160	19	179
Total	160	220	380

Source: Author survey (2023)

Table12: respondent asked about current electric access only 19.47(74) has been connected while 80.53(306) were unable to connected.

Table 12: Household current electricity statues

Connected	Frequency	Percent
No	306	80.53
Yes	74	19.47
Total	380	100

Source: Author survey (2023)

From table 13 respondent were asked whether they like to switch to new renewable energy or stick to their current source of energy which is biomass. As see from the table below 90 (230) ere say yes while 25 (6.58) were willing to maintain status quo with current source of energy

Table 13: Household willing to switch to mini grid

Freq.	Percent	
Yes	230	90
No	25	6.58
Total	255	100.00

Source: Author survey, (2023).

Table 14 presents the possible Reason for not being connected to electricity. The result revealed that no electricity access, grass house significant problems that limited connection to electricity while others summited and waited connection are most. With lack of having access to electricity higher reason 34(87.18%), Summited and waited connection issue is lowest observed reason 2(5.13%).

Table 14: Possible reason for not being connect to electricity

Reason for not connected	Frequency	Percent
No electricity access	34	87.18
others grass house	3	7.69
Summited and waited connection	2	5.13
Total	39	100

Source: Author survey, (2023).

As table 15 outline current purpose of using power from the mini grid project. Accordingly, the most important purpose identified from the respondents is Business, Cooking, Lighting, Cooling and Heating. From the result, the mostly using mini grid utility for cooling is the dominant frequency (50%), which followed by for lightening (49.95%) and then business purposes (47.11%). Using mini grid electricity for cooking the least frequency (30.53%).

Table 15: Purpose of using power from the mini grid project

Statement of Purpose/ reason for using	Frequency	Percent
Business	179	47.11
Cooking	116	50.53
Lighting	186	80.95
Cooling	190	.50
Heating	176	46.32

Source: Author survey, (2023).

Table 16 indicates that most of the respondents have no interest to create business if electricity access is improved to them. According to the survey result out of 380 household's

respondents, 275 (72.35) percent) household have not an interest to create their own business and the remaining 105 (22.34 percent) have eager interest to create a business whether they are connected to electricity or not. This is one of the key factors contribute to low willingness to pay in the study area since most people were not awareness how generate business using electricity energy.

Table 16: Does your household need to use electricity for business activities

Business activity	Freq.	Percent
no	275	72.35
yes	105	27.63
Total	380	100.00

Source: Author survey, (2023).

Table 17 shows possible problem of electricity faced by the households. According to the result, supply shortage not enough hours of electricity, high voltage problems or voltage, unpredictable interruptions, too expensive unaffordability cost, Maintenance service problems, Unpredictable bills, social problems limited interaction are key problems observed in the study area. The leading problem is social problems limited interaction (47.89%), followed by high voltage problems or voltage (46.32%). While too expensive to afford the cost is the least observed problem (20.26%).

Table 17: Most possible problem of mini grid solar powered electricity

Problems	Frequency	Percent
Supply shortage not enough hours of electricity	163	42.89
high voltage problems or voltage	176	46.32
Unpredictable interruptions	140	36.84
Too expensive affordability cost	77	20.26
Maintenance service problems	132	34.74
Unpredictable bills	131	34.47
Social problems limited interaction	182	47.89

Source: survey result (2023).

The public mini-grid in Koftu village faced several issues despite being designed to operate as a solar-powered diesel hybrid. However, it has not successfully functioned as a hybrid system. The mini-grid operators highlighted the major problems as a lack of expertise in using renewable energy as a hybrid source, inadequate maintenance in case of technical problems,

and a shortage of trained manpower. This failure has led to issues with cost-efficiency, reliability, and quality.

Although the cost of diesel does not directly affect households since the selling price remains unchanged, it imposes a significant financial burden on the government, decreasing the system's sustainability. Additionally, the low reliability and quality have indirectly increased household costs. As households experience frequent blackouts, many have opted to purchase Solar Home Systems (SHS) or lanterns as backups and shift to alternative energy sources (Koftu mini grid operator, 2023).

Table 18 reports the result of overall satisfaction of the household from the solar energy. According to these results, majority of the respondents, which account 320(84.21%), are not satisfied from the overall from the current utilities of the energy system in the study area. This finding may due the fact that the status of energy utilities in the study area is not well established and not available to the extent that the household need to use it.

Table 18: Overall satisfaction from mini grid electric services

Overall satisfaction	Frequency	Percent
No	320	84.21
Yes	60	15.79
Total	380	100

Source: Author survey (2023)

The study attempted identifies the reason behind not satisfying from the current mini grid electricity services. According to the views of the respondents, among other reasons, Access problem, Unavailability problem and Cost issues are driving reason behind. The result in Table 19 reports the extent of these reasons.

Table 19 Reason for not satisfying from mini grid electric services

Main reason	Frequency	Percent
Access problem	41	10.8%
Unavailability problem	40	10.5%
Cost issues	2	0.5%

Source: author survey, (2023).

4.1. 4. The Contingent Valuation Method Result

To address the first objective of the paper, researchers estimate the household's willingness to pay for renewable off-grid solar-powered electric service for both sets of respondents. Accordingly, 121(almost 75.63%) of the respondents do have willingness to pay to connect to the MG electrical network if it extended to your area. The other 39(24.37%) do not have willingness to pay. Those households who are willing to be connected about 96(79.34%) are ready to accept 4500 Birr proposal, while 25(20.66%) are not willing pay 4500 birr. In addition, majority of the households, 52(54.17%) preferred to pay the bill on monthly basis, while 27(28.13%) prefer two times year and 17(17.71%) prefer another schedule.

Table 20: WPT elicitation for un-electrified household desire to connect

Statement	Response	Frequency	Percent
Do you paid to connect to the MG electrical network if it extended to your area?	Yes	121	75.63
	No	39	24.37
	Total	160	100
If yes, would you be prepared to pay 4500 birr to connect?	Yes	96	79.34
	No	25	20.66
	Total	121	100
If you accept proposed bid what schedule you preferred to pay your bill?	Monthly based	52	54.17
	two times a year	27	28.13
	Others	17	17.71
	Total	96	100
Do you have any preference for the power supplier?	Government owned company	36	22.5
	Private company	10	6.25
	Cooperative	12	7.5
	Hybrid	44	27.5
	I don't care	58	36.25
	Total	160	100

Source: Author survey (2023).

Table 21 shows respondent willingness for electricity provision. The respondents were asked if they have willingness to pay or not. As shown in Table 16, about 25(6.58%) of the household are not willing to pay and 355(93.42%) are willingness. The main reason, according to their opinion, why they are not willing to pay is lack of ability to pay for such utilities.

These findings align with those of Birara Endalew (2019). Those who failed to express willingness to pay (WTP) were considered to have a true zero WTP, possibly due to economic reasons.

The mini-grid in this village was produced and delivered by a KOICA. It has been operating in the village for two and a half years, and 157 households were connected during my visit in November 2023. After interviews with 2 of the households connected to this mini-grid, blackouts and other issues with the systems was common. Both connected households being interviewed were dissatisfied with both quality and reliability of the system. Several of these households had been using kerosene firewood and solar lantern previously, but had changed after the mini-grid got installed in the village mainly due to the scarcity of fuel resource. They wanted a higher reliability of electricity so that they could have lights, phone charging, TV/radio and sometimes cooking stove, for instance. The households confirmed that high power electric appliance would not be possible with their previous system, but also, that using mini-grid as electricity supply was more expensive than using a SHS. They did however choose to switch to the mini-grid despite the increase in costs instead of using alternative energy.

Table 21: frequency distribution of willingness to pay of electricity provision

Willingness to pay	Frequency	Percent
Unwilling	25	6.58
Willing	355	93.42
Total	380	100

Source: Author survey (2023).

Those, unwilling household heads reported that they couldn't afford to pay money for the proposed electricity (Table 22). This suggests that the given scenario is supported by about 93% of households. These results did not indicate a willingness to pay because, as Gebremariam (2021), outlines the economic reason may be considered as having a true zero WTP.

Interactive bid Game

Table 22 the extent of household's willingness to pay for MG electricity per day. Accordingly, 166(43.68%) of the households have now willingness to pay per day for the standard bids of 7 Birr, while 214(52.32%) of the households have willingness to pay.

Table 22: Willing to pay for per day bidding prices

Response for bid per day	Frequency	Percent
No	166	43.68
Yes	214	56.32
Total	380	100

Source: survey results (2023)

As table 23: shows that extent of household's willingness to pay a per day prices for MG electric services. According, 25(6.58%) of the household can pay 5-birr, 40(10.53%) can pay up to 6 Birr, 233(61.32%) 7-birr, 50(13.16%) birr 8 and 32(8.42%) of the household can pay up birr 9. The result indicates that majority of the respondents can pay 7 birr per day prices for MG.

Table 23: Willingness to pay for per day bidding prices

Bidding price (per days)	Frequency	Percent
5	25	6.58
6	40	10.53
7	233	61.32
8	50	13.16
9	32	8.42
Total	380	100

Source: survey result (2023).

Bid Price and Proportion of Responses: The theory of demand states that as the price of commodity increases, the quantity that households purchase decreases. Similarly, in the case of the contingent valuation model, the proportion of households choosing -yes decreases as the proposed bid price increases. In the literature, this is known as the implied demand curve.

Table 24 shows that about 40.53% of the sample households were willing to pay for the initial bid. More than half (59.4) of the sample, households were not willing to pay the initial bid. The follow-up bids were doubled for those households who were willing to pay the given initial bids and halved for those households that were not willing to pay the initial bids.

Therefore, given the randomly assigned follow-up bids, 28.95% of households said "yes" or they are willing to pay the second bid and 71.05 % of households said "no" or they are not willing to pay the second bid. Proportional results in the line with economic demand which states that inverse relationship between the price of product and quantity of demand. The

number of households‘ who were willing to pay the second bid is less than those households‘ who were willing to pay the initial bid by about 11.58%.

Table 24: Summarize the initial bid (wtp1) and second bid (wtp2)

Offered bid	Response	Frequency	Percent
WTP1	No	226	59.47
	Yes	154	40.53
WTP2	No	270	71.05
	Yes	110	28.95
Total		380	100

Source: survey result, (2023).

Hoyos et al., (2010) outline efficiency within the elicitation of WTP may be increased if repeated questions are used. Following this, double-bounded CVM followed by an open-ended question was used for this study. Households were also categorized supported their joint responses to the primary and therefore the second bids as we discussed in the methodology part if a household responds —Yes to the first bid he/she could be asked for an increased amount of the first bid and also the discounted amount for those that respondl No‘ to the primary bid. Accordingly, the joint responses of respondents are Yes-Yes, Yes-No, No-Yes, and No-No.

Table 25 depicts the joint response of sample households for the first and also the next high or low bids. Therefore, the descriptive statistics revealed that among 380 sampled households, 27.1 % of them accepted both the initial and the second higher follow up bid (yes-yes), 14.7% accepted the initial offered bid but rejected the second higher follow up bid (yes-no), 9.7% of the households rejected the initial bid but accepted the second lower follow up bid (no-yes), and the remaining 48.42 % rejected both the initial and the second lower follow up bid (no-no). A notable result obtained in this study is that nearly half (48.42 %) of the respondents not accepted both the initial bid and the follow-up bids while only about 27.1 % of the respondents accepted both bids. This is because respondents in the study area claimed that the projects were supplied by NGOs, and they were not willing to participate.

Table 25: Distribution of response to the double bounded willing to pay for electricity use

Joint responses of households' WTP	freq	Percent
yy	103	27.11
yn	56	14.74
yy	37	9.74
nn	184	48.42
Total	380	100

Source: survey result, (2023).

4.1.5. Estimation of household mean willingness to pay

One of the objectives of this study is to estimate the average willingness to pay of household for MG electric utilities. This is achieved estimated using mean. The estimate would be obtained after estimating different models including probit, discrete choice bounded model and bivariate probit. Accordingly, Table 26 reveals the estimated per day average willingness to pay using univariate probit model. The result shows that, the estimated mean Willingness to pay for MG electricity (1 kW per days). As it can be seen, the mean WTP for is 7.47 for non-electrified household, 7.30 for electrified households and 7.28 in full sample households (overall mean).

Table 26: Estimated mean Willingness to pay for MG electricity (1 kW per days)

Model	Coefficient	Std. Err.	z	P	95% Confidence Interval	
					Lower	Upper
Non-electrified	7.474068	0.175092	42.69	0.000	7.130894	7.817243
electrified	7.303395	0.130907	55.79	0.000	7.046821	7.559968
Full sample	7.283789	0.112238	64.9	00.000	7.063807	7.503771

Source: Author survey (2023)

There are three approaches involved in estimating mean WTP, namely through double bounded, single bounded and bivariate probit analysis. The calculated mean values are listed according to models estimated using different approaches in Table 26. Moreover, one can also estimate the mean monthly willingness to pay using the discrete choice model and bivariate model. Therefore, the average willingness pay was measured after estimating contingency valuation model and the probit model is presented in table 26. Here it is important to note that probit model is a probability estimate, while CVM models are not. In addition, the full model

captures the estimates of all household in the study area including electrified and non-electrified.

Accordingly, from the double bounded model the average WTP is Birr 380, 339 and 358.1 for non-electrified households, electrified households and full model respectively. Using single bounded model, on the other hand, the average willingness to pay is Birr 430.6, 481.5 and 466.7 respectively. The result shows the estimated is WTP higher for single bounded model than double bounded and finding with consistent with other authors (Tadale, 2021). Similarly, the estimated result of WTP which obtained using bivariate probit is 351.9, 389.009, and 355.070 for non-electrified household, electrified house-hold and full model respectively. The finding from bivariate probit model indicates that electrified household has higher mean willingness to pay than non-electrified household.

The results from the table (27) indicated that rural households are willing to pay an average of about 355.07 (USD 6.6) per month for off grid renewable electricity services. The surveyed households are thus willing to pay around 9.4% of their discretionary incomes for electricity. These finding confirms with Taale & Kyeremeh (2015), shows that, on the average, households were prepared to pay more, relative to the mean monthly electricity bill in the sample, to improve electricity services. Though they did not examined for both groups, this finding confirm with previous study (Birku, 2020; Tadele, 2021; Toleshi & Teshome, 2022).

Table 27: Estimated average willingness to pay for solar energy

Model	Estimates	Non-electrified	Electrified	Full model
Double bounded	Coefficient	380.0***	339.0***	358.1***
	Standard error	-55.02	-57.83	-40.18
Single bounded	Coefficient	430.6***	481.5***	466.7***
	Standard error	-65.69	-26.9	-26.5
Bivariate Probit	Coefficient	351.9151***	389.0096***	355.0704**
	Standard error	126.2897	200.496	80.94358

Note: The asterisks ***, **, and * indicates the coefficient is significant at 1%, 5% & and 10% respectively.

Moreover, some important factors that influence household's decision are highlighted by key informants; even there was an interest to use electricity within the community, many of

the households unable to afford the cost due to their low financial capacity, due to the failure of systems and lack of awareness. Both connection and power cost of mini grid also doesn't reflect the purchasing power of the households. Many households need solar to adjust as per their financial capacity to pay, since majority of resident are rural agrarians. But utility supply energy power with the same cost as urban counter parts which are beyond the capacity of most of households (Key informants from koftu village and kobo kebeles community leaders, 2023).

Furthermore, discussion with key informants helped to dig additional factors related to government and institution; there are governmental and institutional factors mainly costumer service affecting willingness to pay for installed mini grid system in the study area. We observed that there were conflicts in the village resulting from the divide between those who could and could not afford electricity. For example, PV inverters were abounded no can be responsible to maintain on time since the satiation faraway from sub-district, and there were fights at a local milling. There is less organized management system of installed solar mini grid due to this its malfunction for many week even more month. As result they get back to use polluting energy like firewood and kerosene. These conflicts occurred because not all villagers were satisfied with the fact that wealthy households created a larger gap in the social system by using electricity as a status symbol. As indicated in an interview with an expert in district, electricity access has a profound impact on individual social status. Thus, it may be implied that villagers wish to improve their social status by bringing others' attention to the electrical devices.

4.1.6 Determinants of households' Willingness to pay

In this section, the second objective of the study is addressed, examining the determinants of household willingness to pay for MG electric services in the study area. To this extent, the researcher estimated several models using three econometrics methods. In addition, per day WTP and month based WTP has been examined and identified respectively. As per knowledge of this study, previous study did not identify the WTP variation among the two types of households. Particularly, per daily bidding prices proposals have not been considered in previous. So, this study believes that the finding of WTP for per day bidding price is unique. To ensure the validity of the result, several diagnostics testing has also been carried to examine whether a relevant assumption were satisfied or violated. In case violation of

assumption is detected, the relevant remedial measure has been taken. The analysis is started with presentation of univariate probit model, followed by presentation and analysis of the dichotomous choices model and then finally concluded the analysis by bivariate probit model. In doing this critically forward and backward model selection has been made. Use such methods to take the advantage of each respective model comparing the robustness of the results.

Univariate Probit model

The result of univariate probit regression model and the associated average willingness to pay is presented (see Annex-6). Three probit models have been estimated to capture factors affecting household's willingness to pay (wtp) a different bidding prices per day. As it can be seen from the result, the study examined factors determining willingness to pay for electrified and non-electrified households separately. In addition, since coefficients of probit cannot be directly interpreted, the researcher computed the marginal effects each explanatory variable.

Accordingly, the result shows that **bidding price** (bidday) has negative significant effect on household's willingness to pay at 1% level in all models. The finding confirms with what expected in this study and in line with previous studies. The finding implies that, holding other factors constant, an increase in bidding price would reduce willingness to pay. Specifically, for one Birr additional increase in bidday, the willingness to pay would be reduced by 0.444, 0.933 and 0.524 for non-electrified, electrified and in full sample respectively.

Income of the households: In this study income of the household included in the model in log form. Using probit model, this found to be significant variable in influencing only electrified households wtp the per kWh bidding prices at 10. It determines the daily household willingness to pay for first and second bids follow up bid prices. The alternation implication of this result is that increasing income is positively associated with willingness to pay. This finding is consistency with the single bounded results. The finding is in accordance with what expected in this study and confirmed with previous studies (Muiruri, 2020; Tadele, 2021).

On the other hands, the estimated coefficient of **sex** (female) is statistically significant for non-electrified households and electrified households at 5% level. The result shows that for non- electrified households, willingness to pay would be more likely in households headed by female than male, another thing reaming constant. That is, the estimated marginal effect of female is positive 0.179(17.9%) implying being female would increase the willingness to pay for Mini grid electric services by 17.9% more likely than being male. But, as it can see form the result, estimated coefficient of female, for electrified household, is negative. This finding implies that for electrified households, being female would reduce the probability of willingness to pay by 0.201(20%) than being male, keeping all other things constant. The possible reason could be there may be more electrified who are connected and may have no willingness to pay for additional prices for additional services. Sex of the household head becomes statistically and positively significant for transition fuels, hydro power, and solar energy.

The probability of using modern sources of energy is proportional to female headed households than male headed. The implication was that female headed households have preferred the improved energy services more than male headed households. This was due to traditionally; collecting fire wood, cooking, baking, and domestic works at large is exclusively left for females and they are exposed to be conscious about the health and environmental impact of using traditional biomass and the time devoted in collecting fire woods. They knew using modern source of energy is cost effective and faster for cooking, lightning, and heating than solid fuel. These results are inconsistent to Mekonnen and Kohlin (2008); Ogwumike et al., (2014); Deshmukh et al. (2014), findings of female headed household choose the traditional sources of energy due to high prevalence rate of poverty for such households. Hence, the study suggested that there is a need to create awareness to male headed households so that they can take their parts in achieving proper energy uses as they have accounted for substantial number in the study area.

Occupation of the households: measured by dummy variable which being farmer, occupation of the household found to be significant variables in affecting willingness to pay for MG electric services. Based on the univariate probit model, the estimated effect of occupation (being farm) on WTP a daily bidding prices is negative, for electrified households

and in full sample model. The estimated coefficient of household occupation (farm) is statistically significant at 1% level, but with negative sign, for electrified households and in full sample model. The finding implies that, holding all other thing constants, being a household who engaged in farming activities would reduce WTP for Mini grid electric services more likely than those households having other occupations. The marginal effect of being farmer would on WTP is negative 0.314(31.4%) and 0.171(17%) for electrified households and in sample households respectively. The possible reason is that farmer has may have less awareness than other type of households and have subsistence living condition to pay for electrified services.

Family size: Using univariate probit model estimation result, number family is found to be significant determinants of non-electrified households. The finding implies that additional increase in family size would reduce wtp by 0.0410(0.4%). This practically true that larger the number of households, there a probability of dependency and household income being allocated for food consumption and like, which by no means reduce ability of the household to pay for electric services. The effect is positive and is in line with previous studies. Birku (2020) stated that married families are more likely have children and large family size thereby exhibiting more responsibility to possessing renewable source of electricity service connection compared to their counterparts. This responsibility initiates them to have more willingness to pay for electricity service connection.

Education level: measured by having no formal education as dummy, education level of the respondent is also found to be the significant determinants of willingness to pay. Based on the probit model, the finding implies that, all other things being constant, for household with no formal education the marginal effect on wtp for mini grid electrify would increase by 16%. This finding aligns with the literature, as highly educated consumers are found to be more eco-conscious and hence, they support RES (Birku, 2020; Arega and Tadesse, 2023). According to Islam, (2019), an alternative way of comparing the estimated coefficient for education level, those individual with tertiary education level are more likely to pay for better improved living standard.

Satisfaction: Further, Satisfaction from MG electricity (starmg) is significantly influenced electrified household's willingness to pay at 5% level. This finding contract with the theory that increases in satisfaction could increase wtp. In this study, this satisfaction score factor is a

perceived satisfaction which constructed from household's opinion. So, the finding implies that satisfaction of household perceived negatively, which could lead to reduction wtp. The computed marginal effect of perceived satisfaction toward electricity usage is negative 0.10. So, the implication of this finding could be used with caution. That is a policy recommendation can be made by looking into each component that forms generate satisfaction. Usually, customer's willingness to pay for a product increase as their level of satisfaction is positive and they experience less levels of dissatisfaction (Hensher, 1972). In most cases, the dissatisfaction emanates from the quality of the services provided by the institution. Moreover, households may become dissatisfied with the mode of bill payment or frequency and the duration of electricity outages. It is expected that those households that faced fewer and shorter outages are more satisfied compared to those that experienced more frequent and longer outages.

Electric cost (Cec): The result (see Annex-6) also revealed that current of cost of electricity (cec) is important determinants of electrified household's willingness to pay for mini grid electric services at 10% level significance. The estimated marginal effect of cec is 0.00148. The finding implies that for one additional increase in cost of electricity, wp would reduce wtp by 0.148%, another thing reaming constant. This is confirming what expected in this study. This is confirming what expected in this study and confirm with (Tadale, 2020).

Using electricity for **business purpose** (Busin): The probit model estimation result shows that, using electricity for business (busin2) purpose is important factor determining electrified household willingness to pay and in full sample at 5% level. The estimated marginal effect of busin2 is 0.195 and 0.166 for electrified and in full sample respectively. The results show that being a user of electricity for business would increase WTP by 19.5% than user of electricity for other purposes and then result is align with (Reta, 2020).

Finding from KKI indicated that no out of women interviewed had a business. Two of these were started after gaining access to electricity. If there is suitable access to reliable electric access there is huge opportunity to engage in poultry framing activity with utilizing electric.

Likewise, the estimated marginal effect of **perceived benefit** is positive and statistically at 1% level. This finding aligns with what expected in this study and implies that a one-unit additional increase in perceived benefit would lead WTP for Mini grid electric service by 12.9%. This result shows, this is only true for electrified households. Lastly, the estimated

coefficient of dummy for education level (educ1= have no formal education) has significant effect on non- electrified households WTP at 10% level. This implies that, all other things being constant, for household with no formal education the marginal effects on WTP for Mini grid electrify would increase by 44.4%.

Focus group discussion result indicate that women are agreed benefited from using mini grid electricity by expending less medical expenses due to respiratory infections and eye related problems using more modern cooking system. They all agreed that children had better opportunity to do more studies in evening and family unity had enhanced due to entertainment, by television to gathers.

The rural women leaders from villages had this to say:

Women have benefited from extended hours in their small businesses because they have extra income that they use to improve their children's diet, upkeep for the family and have also experienced less medical attention since they can afford modern cooking and heating methods.

Choice models results

Table 28 reports the estimated result of discrete choice model using L'opez-Feldman (2012) framework. The result presented here was selected after carried several model selection criteria. That is backward and forward method estimated method has been done to select the desirable results. Based on this, then after, the first three results, under column 2 through 3 are estimated using for single bounded regression model. In addition, the study estimated factors affecting non- electrified, electrified and full sample separately. Accordingly, from the single bounded estimation results indicate that marital status (marital2), income (lnincome), environmental awareness index (inv) and distance fuel (fueldistance) are significant factors influencing willingness to pay for MG grid electric services. The estimated coefficient of these variables as expected in this study and confirms with previous studies. However, though results for single bounded model have been presented and interpreted, conclusion of this study would not depend on result from single bounded model. This is because the model lacks efficiency (L'opez- Feldman (2012)). Instead, the double bounded estimation result would be used due to its efficiency over the single bounded model. Thus, the result under the last three columns 5 through 7 of Table 28 are presented for the double doubled. Thus, the interpretation made hereafter has to be given high emphasis for the conclusion will be based this.

Accordingly, marital status(marital2), own asset in terms of land (landown2), fueldistance, inv and ceckwh are the most significant factors influencing household willingness to pay for MG electric services in the study area.

Therefore, the first variables that found to influence willingness to pay are marital status (marital2) for all types of households. As it can be seen from result in Table 28, the estimated coefficient for marital2 is positive and statistically significant, at 10% level in cases. The finding implies that being married household would increase probability of willingness to pay for MG energy by 193.9, 195.9 and 153.1 for non-electrified household, electrified and of all types of households as whole respectively. This just as expected in this study and confirm with existing studies. This could be due to the fact that married couples were more likely to have their own children and corresponding increased energy needs. Previous study conducted by Korzhenevych and Owusu, (2021) Renewable Mini grid Electrification in Off-Grid Rural Ghana found similar results, which showed that married couples are more likely to pay for electricity connection services relative to the unmarried.

Land access: The other socioeconomic factor affecting wtp is asset (Land use). Likewise, having own land is statistically significant factors influencing electrified households wtp at 5% level, but not significant in other cases. Based on the double bounded choice model, having own land is statistically significant factors influencing electrified households wtp but not significant in other cases. Its effect on daily wtp is estimated to be 211.6 birr, if the other things kept constant.

Distance to fuels: Moreover, the result of the double bounded estimation in Table 28 shows that for non-electrified households, distance to fuels (fueldistance) has significant effect on willingness to pay for MG electric services at 5% level. The estimated effect is positive 15.47 which indicate that as distance to fuel increase by 1 Km; it would lead to the willingness to for Mini grid energy this magnitude, other things being constant. This confirms with what expected in this study.

The finding indicates that increasing to fuel wood increase the willingness to for Mini grid solar energy, other thing being constant. This confirms with what expected in this study. The finding also consistent when estimated using bivariate probit model that Distance to fuel as measured by, fueldistance, significantly and positive determine willingness to pay. For Non-electrified household the longer the distance to fuel the high willingness they must pay for

first and second as well. The same is true in full sample that the estimated effect of willingness to pay for first and second bid in full sample. It also confirms with the finding of (Arga and Tadase, 2017, Islam, 2019).

Electric consumption (Cekwh): Nonetheless, current electric consumption (ceckwh) has significant influence on willingness to at 5% level for electrified household. The estimated effect is found to be positive 2.368 which imply that as electric consumption increases by 1 KW, the willingness to pay increase 2.368 units, other thing being constants. This also what expected in study and in line with previous studies. This also what expected in study and in line with previous studies. This is consistent with the result of bivariate probit model, in which an increase in current electric consumption by 1 Kw per hour would lead wtp to increase by 0.00397 (0.400%), other things being constant. In the whole sample access to electricity has important implication for willingness to pay for MG energy, most importantly in determining household willingness to pay the first bidding scenario. This finding is consistent with (Korzhenevych and Owusu, 2021).

Finally, household attitude toward role of MG electric services in environmental (Inv): The result of double bounded shows that, having awareness about the importance of MG electric services in helping to maintain environment (measured by inv) is significant at 5%, with negative estimated effect. This finding contradicts with what expected in this study. The result might be due to many reasons. The first possible reason could be the variable inv is an index which constructed from the opening of household. So, the household might have less aware of about the importance of MG energy in reducing pollution, and deforestation.

Discussion with key informants clarified some attitudinal issues that households feel towards solar energy technology; since the solar energy technology is new for the local community; most of the households hesitate and become slow to adopt the technology until they see electricity in use in the house of their relatives or neighbors due to fear of high tariff. This is mainly resulted from information gap about renewable solar energy and further awareness is required to bring attitudinal change. Some portion of the rural society has been aware of solar energy either in formal or informal way. But it needs still more and more awareness to make them the beneficiary of the technology (key informants from Gelan district).

Table 28 Estimated results of discrete choice model

Variables	Single bounded			Double bounded		
	Non-electrified	Electrified	Full	Non-electrified	Electrified	Full
gender2	-58.32 (91.71)	-10.17 (66.16)	-43.88 (55.60)	-60.28 (120.5)	101.9 (127.8)	-19.14 (86.00)
age2	4.315 (5.399)	1.981 (3.105)	1.605 (2.558)	7.382 (6.623)	-6.298 (6.239)	-1.943 (4.041)
marital2	173.7* (105.1)	66.01 (60.96)	112.3** (55.17)	193.9* (116.5)	195.9* (117.4)	153.1* (81.19)
occupation2	-92.16 (90.45)	-42.02 (62.53)	-74.30 (54.62)	-138.2 (112.5)	-72.66 (121.3)	-123.1 (83.35)
Famsize	-21.28 (22.24)	-1.180 (16.38)	-6.512 (13.00)	-13.35 (28.01)	18.26 (32.12)	7.626 (20.65)
landown2	48.69 (92.55)	8.833 (64.03)	48.34 (55.66)	-39.90 (122.7)	211.6* (124.1)	105.6 (85.47)
housetyp2	-37.76 (85.52)	3.938 (56.86)	-19.56 (49.46)	-76.56 (113.4)	-66.98 (111.5)	-50.19 (77.16)
educ1	-21.59 (81.01)	62.78 (56.71)	38.93 (48.71)	-156.3 (109.6)	136.6 (108.3)	-2.129 (76.24)
lnincome	11.48 (35.71)	34.14** (15.34)	30.43** (12.94)	-9.532 (42.08)	26.11 (29.02)	28.29 (19.11)
perception	47.23 (41.60)	-13.20 (27.87)	15.74 (24.37)	15.36 (54.50)	-10.76 (54.54)	
firewodist	12.36* (6.983)			15.47** (7.781)		
Accost	-0.488 (0.456)			-0.396 (0.571)		
Inv	22.17 (71.35)	-62.78* (37.51)	-60.13* (33.31)		-136.7** (66.92)	-67.83 (50.13)
Cec		0.435 (0.573)			-0.437 (1.149)	
busin2		-67.93 (61.23)	-80.13 (67.84)		-144.1 (112.6)	-143.1 (103.9)
Realmg		-7.526 (28.48)			-2.549 (54.81)	
daccess2			135.6* (77.58)			160.8 (112.1)
ceckwh					2.368* (1.369)	
Constant						
Observations	156	220	376	156	220	380

Note: Robust standard errors in parentheses. The asterisks ***, **, and * indicates the coefficient is significant at 1%, 5% & and 10% respectively.

Seemingly unrelated bivariate Probit model

The results from the seemingly unrelated bivariate probit model (SUBP) revealed that coefficients of the initial and the follow-up bids are negative and statistically significant as expected. This shows that higher initial and follow-up bids lead to lower probability of accepting the offered bid. In addition, the correlation coefficient (ρ) is negative and significantly different from zero. However, this correlation is not perfect. The correlation coefficient being less than one indicates that the random component of willingness to pay for the first question is not perfectly correlated with the random component from the follow-up question (See Annex-5).

The test against the null hypothesis is that the two equations can be independently estimated or the correlation between the two error terms is close zero can be checked by looking at the Likelihood-ratio test of the correlation coefficient (i.e. $\rho=0$). The result is significant at 1 % level of significance, showing that the two equations can be estimated simultaneously.

The coefficients of both the initial and second bids are statistically significant at 1%. The coefficients show that as the price offered to a household increases the demand for electricity decreases keeping another factor constant. The marginal effect of full model for both Bid1 and Bid2 is significant at 1% level of significance. As Bid1 increase by one unit, WTP decrease by 0.032%; and as Bid2 increase by 1-unit WTP decrease by 0.022%.

The estimated results of factors determining willingness to pay using bivariate model is also presented (see annex-7). The result is estimated using seemingly unrelated bivariate probit model, which used when two equations are to be estimated and the dependent variables are significant correlation. As it can be seen from the result, six models have been estimated based on household access to electricity. Accordingly, the first two result is for non-electrified household, the next two for electrified and the last two for full sample. Thus, the bidding variables, bid1 (first bid) and bid2 (follow up bid) are included as regression as repressors and found to be significant at 1% level of significance. The estimated coefficients are negative, and it is as expected in this study. The finding implies that increase bidding price would decrease the willingness to pay for MG electric services. Particularly, for non-electrified household an increase first bid by one birr decreases wtp by 0.194% and further

increase in the second bid by one birr decrease wtp by 0.147%. likewise, for electrified households, an increase first bid by one birr decrease wtp by 0.323% and but further increase in follow up bids by 1 birr would have no effect on wtp. Also, in the full sample, increase in first bids by one birr would decrease wtp by 0.234%, while follow up bids decrease by 0.114%.

Sex: In addition, the result shows that sex of the households (gender2) has significance influence on electrified household willingness to pay on second bidding scenario, but insignificant in the other cases. The estimated effect of wtp is 0.447 for gender dummy (female) and the finding shows that being female would increase the probability of paying second bid for electrified households. The finding of these studies corroborated with (Arega and Tadesse, 2020).

Marital status: The other demographic variable, marital status (marital2) has also significant effect on non-electrified and electrified household's willingness to pay. For non-electrified households, being married household is significant to pay for the first bidding prices, which is estimated to be about 0.507 (50.7%) effect. While this effect is 41.3% and 32.3% for electrified households and in full sample and is statistically significant at 10% and 5% level in cases of the for first and second bidding prices scenario respectively. Based on the double doubled model and bivariate probit estimation results, household marital status (marital2=married) found to influence willingness to pay for all types of households. Thus, for electrified and in the whole samples of the household, being married household is significantly associated with willingness to pay for MG electric services. The implication of this finding is that for willingness to pay married household is more likely than other marital status. This confirm with (Reta, 2020; Tadele, 2021). According to Reta (2020), married families are more likely have children and large family size thereby exhibiting more responsibility to possessing renewable source of electricity service connection compared to their counterparts. It further stated that, such responsibility initiates them to have more willingness to pay for electricity service connection.

Age of the households: The other demographic that determines household willingness to pay for MG is age. Using the bivariate probit this study found that age of the household found that has negative effect on electrified household willingness to pay for second bids at 5%. The

finding shows that increase age of the household would decrease the probability of willingness to pay for MG energy by 3%. The implication is that as willingness to pay would decrease with increase in age. This finding also confirms with Reta (2020) and Islam (2019). According to Reta (2020), the estimated marginal effect coefficient of this variable shows that it has negative and significant influences on households' willingness to pay for both types of electricity service connection. This result may reveal that older people may have less willingness to accept a change from their status quo may be due to fear of change, or because they do not trust both the government and the provider. Because of this behavior, the older the household head gets the lesser the willingness to pay for electricity service connection irrespective of payment type.

The result also confirms with results investigated by, Mekonnen and Kohlin (2008) and Deshmukh et al. (2014) indicated that older head of the households inclined to traditional fuel than younger does. However it is inconsistency with study conducted by (Eshetie, 2021) the result indicate older respondents live in the study area long than younger one so that they have observed the previous and current poor energy services practices and may easily compare the effect of inadequate energy options and the proposed one. Moreover, they might be opted to leave a quality and healthy environment to their offspring.

The study found that land access (dummy variable landown2) has strong significant effect on electrified household willingness to pay for second bidding scenarios, the effect is estimated 0.859 (85.9%) at 1 significance level. That means having own land increase the likely of willingness to pay by 85.90%. From the estimated result of bivariate probit model, having own land is one of the important factors that expected influence household's willingness pay for Mini grid electric services. This study found that own land (dummy landown1) has significant effect on electrified household willingness to pay for second bids. The study found that own land (dummy variable landown2) has strong significant effect on electrified household willingness to pay for second bidding scenarios, the effect is estimated 0.859 (85.9%). That means having own land increase the likely of willingness to pay by 85.90%. This finding is what expected in this study and confirmed with (Toleshi & Teshome, 2022). Moreover, for non-electrified households distance to all fuel (fueldistance) is statistically and significantly wtp for MG electric services at 10% level. This result implies that increase in

distance to all fuel by 1 KM would increase wtp by 0.0269(2.69%). Likewise, current electric consumption as measured by per KW is significant determinant of electrified household willingness to pay at 10% level. The finding shows that an increase in current electric consumption by 1 Kw per hour would lead wtp to increase by 0.00397 (0.400%), other things being constant. In the whole sample access to electricity has important implication for willingness to pay for MG energy, most importantly in determining household willingness to pay the first bidding scenario.

In addition to sample household respondents, Key informant interviewees also explained some reasons that are considered to be driving factors for WTP; the improvement of community consciousness and a need for change to acquire better living condition is one reason of accepting offered bid. In addition most parts of the study area are off grid where no electricity access still. Because of this many households considered offered solar powered energy as the only and the best way to solve their problems of energy sources for lighting cooking and even for productive activities. Furthermore, its environmental value is high. Because it substitutes other lighting energy sources that could affect health of family members and environment including non-rechargeable dry cell that can be used as lighting energy source and its remnant also pollutes the environment while dropped out after usage (key informants from energy office, 2023).

Using solar energy technology is economically feasible than other energy sources. For instance if households use dry cell/battery as source of light for their home, they have to buy dry cells within at least two weeks interval. The cost to be incurred for it in every two weeks is difficult for low income families. But for those households who use solar mini grid electricity, it is not required to cost more money after ones they invest on it (key informants from energy office, 2023).

In full sample, as it be seen from the result, the dummy variable (daccess2) is statistically significant at 10% level implying that compared to household with access to electricity, the wtp would increase more likely by 0.388(38.8%). This finding confirms with what normally expected and practically happening in real situations.

Income generating activities

The connection to solar mini grids facilitated the emergence of new income generating activities and enhanced those already existing, both at the household and business levels. Families and businesses are engaging in previously unavailable ventures, contributing to the socio-economic wellbeing of households. This finding is in line with the findings of the World Bank study conducted which revealed that home businesses were more active and productive in areas with electricity (World Bank, 2008). This observation highlights the role of sustainable energy in fostering economic diversification. Further, the shift from traditional income sources to new opportunities, such as small businesses powered by solar energy highlights the transformative potential of solar energy in enhancing economic activities.

Finally, though statistically significant in previous studies MG related factors such as Reliability of MG services and environmental awareness is not in this study. This does not mean that this variable not important in determining WTP in this study area. Rather it necessitates that something strongly driving WTP of the household than these variables. Such thing may be low- quality electricity service current tariffs and rural household with subsistence economic condition (Deutschmann et al., 2020).

Awareness, perceptions and user expectations regarding use, benefits and impact of clean energy is a prerequisite for uptake and sustained use. Renewable energy solutions offer several benefits to consumer including income and fuel savings. A question that need to be asked is does the consumer understand the triple benefits (economic, social and environmental) including their role in household health, livelihoods, local environmental quality and regional climate benefits? The proposers of renewable energy solutions must bring out this message at a level that the customers can identify with. We have to look at the benefits from consumers'' perspectives and not providers. Consumers seldom adopt innovations without good reasons (KII result with energy expert).

4. 1.7. Estimated Total Willingness to Pay

As indicated in Table 29, one amongst the last objectives of WTP contingent valuation study is to calculate or estimate the aggregate WTP of the goods valued or the analysis of welfare measures using the value of total WTP obtained from the sample households to the whole population within the access to mini-grid electricity service. For a valid analysis, the advantages and various biases of the sample design in a contingent valuation study must be minimized, and protest zero responses should be excluded from the data (Carson & Mitchell, 1993). Lastly, as indicated in Table 29 and supported by the NOAA panel guidelines, protest zero households are excluded from the aggregation, ensuring that none of the various biases affect the analysis.

One of the study's objectives is to explore whether the investment cost of electricity services can be recovered through estimating household willingness-to-pay (WTP). To achieve this goal, we must determine the total WTP and mean WTP for electricity service connections. In the contingent valuation method, specific steps are followed to estimate the economic value of natural and environmental resources. These steps were previously discussed in the paper. The final step involves aggregating the results or calculating average estimated values.

The total household's WTP for mini-grid electricity use can be estimated by taking the entire number of beneficiary households less the protest zero bidders and total power generated from mini-grid plant. In line with data source obtain project design was 250 kWh. Consequently, the total amount of willingness to pay for the mini-grid project was calculated by multiplying the mean WTP value obtained from seemingly bivariate Probit regression model. The valid number of households was obtained after deducting the expected protest zero responses from the total population. In the sections mentioned, the mean estimated WTP for improved off-grid mini-grid electric service provision in the study area is 355 Ethiopian Birr (ETB) per month and 7.28 ETB per kilowatt-hour (KWH). Measuring the total economic cost using the mean WTP is crucial for benefit aggregation (Alemu, 2000).

Table 29 Total wtp estimation from mean

Name of kebel	Total HH kebele	Sample HH valid response	Sample HH invalid response	Proportion of invalid response	Expected total invalid response	Expected HH total valid response	Mean HHWTP	total WTP
Koftu	436	197	4	0.0199	8.7	427	355.07	151615.0608
kobo	394	158	21	0.1173	46.2	348	355.07	123564.5
total	830	355	25	0.1372	54.9	775	355.07	275,179.56

As discussed overhead, the survey covered 380 sample households and only 355 were valid out of 830 total user households within the study area. The results of the study show that about 93.42% of the households were willing to pay for electric service use system. Based on the sample mean and willing-to-pay permits, we can generalize the estimates for the entire population's aggregate willingness to pay and the amount of money that will be collected to ensure sustainable electric service. Using the sample mean and willingness-to-pay estimation, we can generalize the estimates for the entire population's aggregate willingness to pay and the total amount of money that could be collected to ensure sustainable electric service. According to our estimation, a total of 755 households ($830 * 0.1372 = 755$) are willing to pay for the proposed off-grid electric service project (as shown in column 7 of Table 29). Which is calculated from the total sample of about 93.42% of households that were willing to pay for off grid solar Mini grid project and proportionally applied for the entire target population size.

As outlined above, the mean WTP from bivariate Probit model (355.07 ETB/month, multiplied by the corresponding number of household's willing to pay. Finally, the total willingness to pay (TWTP) was obtained in each Kebele (column 8 and 9). The households TWTP are estimated, based on the double-bound elicitation method, amounts to 275,179.56 Ethiopian Birr (ETB) per month (approximately \$5,096) (column 9), and calculations are also performed from individual Kebeles (local administrative areas). The total WTP across sample of Kebeles were also calculated and result indicated significant amount of difference. The TWTP of the Koftu were 151615.0608 and 123564.5ETB per month, respectively, from double bound elicitation method (column 9).

To achieve the specific objective of this research, it is essential to determine whether the willingness to pay value is sufficient to cover the project's costs when compared to the overall expenses incurred. This involves a detailed analysis of the WTP data in relation to the financial requirement of the project. The key factor in the formation of mini grid the power system with the required size, which determines the initial investment function of CAPEX, OPEX. The required revenue on an annual basis for the mini grid provider can be defined using the function for net present value (NPV). A project is financially feasible, if the NPV is at least zero.

Where Revenue = (monthly fee household*number of household use) for a time periods. The result of this study indicates that calculated TWTP values is much lower than the amount of project cost 225000(\$4167) capital cost and 481950(8925) running costs respectively as compared to (275,179.56 ETB/month) total WTP estimation results from bivariate probit. Accordingly it's observed that calculated total willingness to pay from survey results falls significantly short of the proposed project costs. In this regards, the calculated TWTP only covers about 57% of the running costs and 39% of the total costs per month. In applying assumptions to the Discounted Cash Flow Model (DCF), the NPV under current conditions is negative at -3,599,605.77 birr. Investing in a decentralized mini-grid (DMG) with these characteristics would result in a capital loss after the 25-year system lifetime, necessitating subsidies to avoid losses. Applying the assumptions to the DCFM described above, the NPV under current conditions is negative at - 3599605.77 birr. Therefore, an investment in MG electricity with those characteristics will lead to a capital loss of 3599605.77 birr after the 25 years of system lifetime have elapsed, and subsidies in the same amount are required to run this MG without making losses. A study by ESMAP in Ghana highlights that keeping the electricity rate equal to the ability to pay of the local people would require subsidies for more than 50% of the CAPEX. Finally, while a customer is willingness to pay for electric services, bridging the gap between ability to pay and project costs remains a challenge. Policymakers may need to explore additional funding mechanisms to ensure sustainable energy access for rural community.

4.4.5. Diagnostics testing

After estimating econometrics model the next step in the process of regression 888 is to examine whether assumptions are satisfied or not. To this extent, the study examined all relevant assumptions and corrected where the violations happened. In addition, the researcher examined the pre-estimation tests such detection of outliers, and influential observation. For scores factors computed using principal component analysis, reliability test has been conducted using Cron Back alpha method. According to Cronback (1985), Scale reliability coefficient of greater than .7 or 70% would better. The result in Table 30 shows reliability test for perceived benefit, perception, environmental awareness, reliability of mg, and satisfaction from Mini grid electric services. The result shows Scale reliability coefficient for all scores greater than .7, which indicates reliable to incorporate in regression analysis.

Table 30: Reliability test (Cronback alpha)

Variables	Number of items in the scale	Scale reliability coefficient
Benefit	5	0.9113
Perception	6	0.9967
Environment awareness	3	0.7229
Reliability of MG	6	0.7178
Satisfaction	4	0.8730

Source: survey results, 2023

The post estimation test, most importantly assumption violation, has been carried before processing to interpreting the result. The first assumption, which is about multi-collinearity, has been examined using variance inflation factors (VIF). Based on Gujarati's (2012) guidelines, a mean Variance Inflation Factor (VIF) of less than 5 is considered acceptable. Therefore, the data does not exhibit any significant collinearity issue as see in below table-31.

Table 31: Collinearity Diagnostics

Variable	VIF	Sqrt VIF	Tolerance	R-Squared
bid1_01	4.09	2.02	0.2447	0.7553
response1	32.71	5.72	0.0306	0.9694
bid2_01	29.94	5.47	0.0334	0.9666
response2	1.2	1.1	0.8306	0.1694
gender2	1.13	1.06	0.8826	0.1174
marital2	1.18	1.09	0.8475	0.1525
occupation2	1.13	1.06	0.8881	0.1119
Famsize	1.98	1.41	0.5044	0.4956
landown1	1.67	1.29	0.5982	0.4018
age2	1.7	1.3	0.5891	0.4109
education1	1.12	1.06	0.8953	0.1047
I4	1.74	1.32	0.5737	0.4263
Starmg	1.14	1.07	0.8781	0.1219
Realmg	1.09	1.04	0.9209	0.0791
Perception	1.07	1.04	0.933	0.067
Cec	1.27	1.13	0.7892	0.2108
Ceckwh	1.36	1.17	0.7359	0.2641
Fueldistance	1.3	1.14	0.7714	0.2286
Benefit	1.3	1.14	0.7709	0.2291
Inv	1.29	1.14	0.7761	0.2239
dhouse2	1.15	1.07	0.8688	0.1312
Mean VIF	4.31			

Source: Own computation model result, (2023)

Furthermore, overall validity of the result, goodness of fit and specification test had been examined as post estimation for violation for the assumption. As the result, the study found no violation of assumption. To obtain efficient, the study estimated and reported the robust results

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

Estimating the value of renewable source of electricity service in the rural household of Ethiopia is of paramount significance for an optimal investment decision for institutions involved in rural electrification program. Using a hypothetical scenario with double bounded dichotomous contingent valuation formats, the value of electricity service in the rural, off-grid communities of Akaki district koftu model solar mini grid was estimated. The result of the empirical model indicates that the rural households' willingness to pay alone is not sufficient to recover the cost of electricity provision. The mean willingness to pay is about 355 (USD 6.57) per month for off grid solar-powered mini grid electricity services. Estimated project cost 225000(\$4167) capital cost and 481950(8925) running costs respectively, by using this cost as a benchmark as compared to (275,179.56 ETB/month) total WTP estimation results the household WTP cost is not sufficient to cover investment cost of the project. Variables household income, family size, age basic education level gender of household head occupation (being farmers) and marital status of respondents are noted to be significant factors at different confidence level that impact household willingness to pay for renewable mini grid services in the study area. Another factor socioeconomic factors influence household willingness to pay for provide service is asset ownership among which land access is significantly influence house WTP.

Another important finding is that household electric demand is critical influence WTP. In this case households that do not have enough electrical capacity to meet all their current and potential energy needs are willing to pay more for renewable-powered electricity services. The benefits that come with electricity access are evident to all the mini grid-connected communities, as even households without adequate electrical capacity indicated their readiness and willingness to pay offered price for the mini grid electricity services. This should serve as a major signal to the policy makers: first of the household's readiness to embrace new forms of alternative energy sources, and second, of the need to fast-track access provision for the energy have-nots and under-served areas, bringing into sharp focus the importance of the mini grid business model.

In conclusion, addressing the issue of improving access to electrification and, in particular, ameliorating the rural electrification gap, is an essential component of assisting in energy poverty reduction and sustainable development. The Ethiopian case is extremely relevant given its size and economy. Ethiopia has the potential to serve as an example for developing countries around the globe on how to address the issue of limited access to electricity and bridging the energy poverty divide. The current effort of the government to pull the country out of darkness through building range of electricity projects on off grid electricity in this regard will have a paramount role and should get national support.

5.2. Recommendations

Understanding households' demands behavior and WTP is crucial for welfare measures as well different stakeholders who want to invest in the sector. To advance the renewable energy sector in Ethiopia, several policy recommendations must be implemented to address the existing challenges and harness the available opportunities. Although the study gives insightful policy implications with regard to rural household electricity service payment in remote rural Ethiopia, it has some limitations. For instance, the study exclusively focused on one mini grid electricity supply which were the only potentially feasible options at a time of the study; i.e. 2023. However, at this time and in the future, sources of electricity generation could be diversified based on the country's economic needs. Based on the consumers' source of electricity preferences and level of willingness to pay, the government and other electricity-supplying stakeholders will have proper and effective plan.

Recommendations based on the findings, the following recommendations are proposed:

1. **Market Development:** Encourage private sector participation to foster competition, improve quality, and drive down costs, thereby aligning the price of renewable energy access with the WTP of households. Creating proper enabling environment by improving access to low cost financing, placing proper regulations that minimize the risk related to the projects, and creating collaborative partnership by making use of a combination of public and private investments should be a major policy objective in order to facilitate deployment of renewable hybrid mini-grid systems and to achieve targeted electrification ratio in a sustainable manner.
2. **Policies and Subsidies:** Develop and implement policies that incentivize the uptake renewable energy. This can include subsidies to reduce the initial high costs associated

with investment cost, tax incentives for providers, or the creation of low-interest financing schemes for consumer. Along this line, financial/fiscal incentives such as provision of subsidies and soft loan with flexible repayment schemes for rural solar powered mini grid can help increase the use to adopt. Innovative financing sources such carbon pricing (petroleum levies) and public bond rising could help the government raise funds for subsidizing renewable energy resources. In addition, Access to credit plays a vital role in maintaining adequate energy services. Rural farmers were unable to invest on costly electric appliance-refrigerators, baking stove. Thus, any concerned body should facilitate credit opportunities for rural farm households to easily adopt better energy technologies instead of solely use electricity for lighting purpose.

3. Consumer Awareness: Any concerned body should encourage intensive public awareness of the advantages of proper energy services. Intensify efforts in educating the populace about the benefits of renewable energy access. While acceptance is high, there is a need to further enhance the understanding of the economic prospects of Renewable energy off-grid access. Moreover, a policy intended for expanding green electricity should be supported through consideration of household motivation and willingness to pay. Increasing the awareness of local communities about renewable energy and its benefits could help increase and sustain the market. To that end, we suggest that the private sector in determining the actual price for electricity, consumption factors such as consumer's location, job type, and marital status could be considered as important factors and providing by develop various formal and informal awareness creation and knowledge sharing platforms.

Overall, policy makers need to consider household willingness to pay for improved electricity while determining the tariff rate. This is crucial to complete already initiated mini, medium, and mega projects, and also to expand and start a new project.

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ADDIS ABABA UNIVERSITY
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House-hold survey questionnaire on willingness to pay for solar mini-grid electricity: case of Koftu Solar Mini grid, Dukam town, Oromia National Regional State, Ethiopia.

My name is Kifilu Getachew, this interview is used for the research Master of Arts in Development studies at Addis Ababa University for requirement of partial fulfillment to the award of MA degree in Environmental and Sustainable Development. I conduct a survey which focuses on your households Willingness to pay for solar mini-grid electricity use. Now you are randomly selected and asked to give information about your demographic, socio economic characteristics, your experience in fuel consumption and satisfaction, electricity demand load awareness of renewable energy and willingness to pay for the improved service of the electricity supply. The result of this study will help different stakeholders and policy makers to make appropriate measures on electricity use development in the future.

I would like to have your full cooperation and participation in this study by freely responding to the questions I will ask. This study is meant for academic purpose and not otherwise. I therefore ensure the anonymity and confidentiality of the higher standard. The responses given under this study will remain a secret between you and me as a researcher. Then you are cordially requested to provide genuine responses.

Would you agree to participate in the interview? If yes proceed to section I, if no change the respondent.

Yes

No

Annex 1. Household survey Questioner

PART I DEMOGRAPHIC AND SOCIOECONOMIC PROFILE

SECTION 1: A). Demographics and socioeconomic features						
Household (respondents) code			Region/town/Kebele Code			
(1) Respondent relationship	(2) Sex	(3) Age	(4) Marital statues	(5) family size	(6) school age: 7-15 years	(7) Level education
(8) houses type	(9) numbers of rooms			(10) main occupation		
<p>1. 1=Husband 2=Wife 3=Daughter 4=Son 5=Relatives 6= Others</p> <p>2. 1= Male 2. Female</p> <p>4 1=Married 2=Single 3 =divorced 4=Coupled 5==other</p> <p>7. 1= Have no any formal education 2= Attained Primary school (0-8)3=Attained secondary school (9-12) 4=Attained tertiary education (above12)</p> <p>8. 1= Thatched 2= advanced finished floor 3=finished roof/Corrugated Iron Sheets 4=Advanced finished walls 5. Temporary structure 6=Advanced finished house</p> <p>10. 1=Farmer (crop production) 2=Employed 3= others if. 2 enter salary_____</p>						

B). Seasonal income What is your total income from farm production of the last year i.e. 2013/14 (total production minus seed used) per year?

a). farm product	Quantity	Price per 100	Total value	Inputs used	Farming come (farm)	
1						
2						
Others_____						

4) What is your total income from livestock or poultry and their products of the year 2013/14? (It include own

consumption and sold). source of income from livestock sector							
b).Type	of	Total unit	Price per unit	Total value	Inputs /cost of	Farm revenue	
1							
C). Sales of industrial products _____birr /month _____ birr / year _____birr / season D).Services, repairs, etc. _____birr /month _____birr / year							
E).Dou you received remittance during the last year? 1=yes 0=no							
F). Transfers from family members (remittances) _____birr /month_____birr / year							
G). Pensions of retiree(s) _____birr /month _____birr year							
H). Other (specify) _____birr/ month							

5) Please give us your best estimate of the total monthly expenditures of your household (include all kinds of expenditures)

1=nutrition: __2= education: __3=farming activity: __4=transport: __5=health __others ____

c. asset ownership

6) Do you have land 1= 0= No

7) Land size in he_____

SECTION 2. HOUSEHOLD SOURCE OF ENERGY

A) Fuel source

1) Which of the following energy source is mostly used for house-hold purposes?

1=Electricity 4=Kerosene 2=Fuel wood 5=Crop residual
3= Charcoal 6=Dung 7=Biogas 8=Other

2) What type (s) of energy source do you often use in your home for lighting? (Multiple response)

1= Electricity 2=Kerosene 3=Candle 4=Firewood 6=SHS 7 =Solar lantern

8= Electricity Charged Battery 9=Rechargeable Battery Lamps 10= Biogas

11= No alternative 12= Other (Specify)

3) What type of electricity supply are you using?

1=Mini grid 2= Solar home system 3= Solar lantern
4=Diesel generator 5=No connection

12). Are members of your household able to charge all their mobile phones as often as they need inside your dwelling? 1= Yes 2= No 3=I don't know

13). How many members of your household usually have to go to charge your mobile phones outside your dwelling? ___in km and ____in minute/hour

14). How many members of your household usually have to go to charge your mobile phones outside your dwelling? ___in km and ____in minute/hour

15). How much does your household spend each month (in total) on charging the mobile phone(s) outside your dwelling? ___in (Eth birr)

16). Overall, how satisfied are you with the service provided by the main solar device?

What is the most serious problem you experience with the solar device use?

1= Duration of service too short

2=Breaks too often

3=Too expensive

4=cannot power large appliances

5= Quality of light

6=Battery problems

7= No problems

8=Maintenance and availability of spare parts

9=other, specify

17). what was your main source of lighting/electricity when it was not a solar device?

1=Rechargeable battery and storage devices

2= Kerosene lamp

3= Fuel -based lighting

4=Candle

5=Dry -cell (non-rechargeable) battery/Torch/Flashlight 6=Firewood 7=No substitutes 8.Other, specify _____

19). Over all how are you satisfied to the solar device use? 1=Very satisfied 2=somewhat satisfied 3=Neutral 4= Unsatisfied 5=Very unsatisfied

20). Do you like to switch to mini grid? 1=Yes 0=No

C) Detailed usages and cost for individual non-electrified households-based fuel gas

21). If your household uses fuel gas in the last 12 months, what type of fuel gas you use?

1=LPG

2=Kerosene

3= Biogas

5= Candle

6=Others

22). For what purpose does your household use fuel gas?

1= Lighting

2=Cooking/igniting

3=Lighting

4=Agriculture activity

5. = Heating

6=

Others

23). Are you use kerosene a main fuel source for lighting 1. Yes 0. NO

24). in average how much you household buy kerosene per month? _____in lt

24.1. Household Average cost of kerosene in month? ___birr

24.2. Average usage of kerosene in liter per day? ___ per day

24.3. Numbers of lighting unit use for kerosene lighting. ___Lighting unit

24.4. Average hours use kerosene per day ___ av. Hours per day

25. Did you have problem with gas fuel/kerosene supply of your household use

- | | | |
|--------------------|--------|------|
| 1. Unavailability | 1=Yes | 2=no |
| 2. Inaccessibility | 1= Yes | 2=No |
| 3. High-cost | 1=Yes | 2=No |

26). What don't you like most about using the fuel gas/kerosene? 1= Lantern too expensive 2= Fuel too expensive 3=Fuel not available 4= Accidents can happen 5= Bad for health 6=Time spent to collect fuel 6= other, specify 7= No problems

27). Overall, how satisfied is you with the service provided by the fuel gas for lighting?

1=Very satisfied 2=somewhat satisfied 3=Neutral 4= Unsatisfied 5=Very unsatisfied

28). Are you willingness to switch to MG electricity use? 1=Yes 2=No

30) If you use biomass for what purpose do you often you use?

- | 1=Agriculture residual | lighting | cooking | others |
|------------------------|--------------|-----------|-------------|
| 2=Fire wood | 1= yes 0. No | 1= yes no | 1= yes 0=no |
| 3=Dung | 1= yes 0. No | 1= yes no | 1=yes 0= no |
| 4=Charcoal | 1=yes 0. No | 1= yes no | 1=yes 0=no |

31) Is fire wood is main source of fuel for lighting 1. Yes 0. No

32) Over all how would you satisfied with the biomass use? 1=extremely significant
2=Significant 3= neutral 4= less significant 5= insignificant

33) Do you willing to switch to mini grid electricity 1= yes 0=No

HOUSEHOLD CONNECTED TO MMINIGRID

A) Electricity consumption and billing system

1. How many years have you had this mini-grid connection? _____
2. What type of power counter meter do you use? 1=Pre-paid 2= Postpaid 3= Smart metering 4= I don't know
3. Are you sharing the electricity meter with another household? 1= Yes 2= no
4. How many households are sharing the meter? _____
5. Were you involved in setting the tariff for the mini-grid? 1=Yes 2=No
6. How were you involved in the tariff setting?
1=Community meeting

2=Contacted by mini-grid developer

3=Member of electricity committee

4=Member of cooperative

5=other, specify-----

7. Do you think the current mini grid electricity tariff is ...:

1= underpriced 2= fairly priced 3= Very High/over-priced

8. Ask if the respondent pays the electricity or has a record of the electricity payment, ask to see the electricity bill/invoice and use it for 10 and 11.

1=Respondent has energy bill and shows it
show it or could not locate it

2=Respondent has energy bill but refuses to

3=Respondent does not have an energy bill

9. In the last month, how much did you spend on the electric bill? _____birr

10. In a typical month, how much did you spend on electricity? _____birr

11. In the last month how much electricity did your household use? Calculate the consumption from the last bill. _____in kwh

12. Do you think you are paying more than the electricity units you consume? 1=Yes 2= No 3=I don't know

13. How frequently do you make your payment?

1= By Week 2=Every 2 weeks... 3= Monthly.... 4= Every 6 months... 5=other, specify

14). How do you make your electricity bill payment?

1=Cash direct to EE 2=Vouchers from local store 3= Credits using mobile money /connected with bank system 4= Credit, using other ways/ electronic payment system 5= other, specify

15). Do you problem of paying your electricity bill 1. Yes 2. No if yes specify _____

16). Do you use electricity for all purpose? 1. Yes 2 No

17). which of the following ways does your household use power from the mini grid project for?

(Check all that apply)

1=Lighting 2= Cooking 3=Heating 4= Cooling 5= Business activity 6=other (specify_____)

18). If no what is the main reason electricity why not use for domestic purpose?

1= electric appliances (stoves andll mitad) are expensive 2= Cost of electricity is high tariff

3= Problem of electric meter

4=Outage of electricity is high

5= other (specify) -----

19). What do you use electricity for now? (Multiple responses) Please tick appropriate answers.
(Multiple response)

1=Light bulb 2= Radio/cassette 3= TV 4 =Refrigerator 5= Cell phone/charger
6=Injera mitad 7= Improved coking stove 8=Heater 9= others

b. Mini grid electric reliability

20. Is the current electric supply from mini grid is good? 1=Yes 0. =No, if yes
specify_____

21. Is there a limit for the load and/or appliances you are allowed to power from this mini-grid?
1= Yes 2= No

22. Is the quality of electricity service the same all the year? 1. Yes 2. No

23. What is the worst season/time for service from the mini-grid?

1=Do you experience 2=flickering lights 3=Brown Lights 5=Other_____

24. _____
How many times do you experience surges or dips in voltage in a day/week/month?

25. Do you use any other form of energy during power failure for cooking? If yes
specify_____

26) Do you receive information about a —load shedding|| schedule (load shedding is the set hours
of electricity not available from the mini grid)? 1. Yes 2. No

27) Dou you experience outages 1. Yes 2. No

28) How many blackouts occur in a day/week/month? Frequency of outages in per d_____

29) How long do these outages usually last in average?

1=Less than a minute 2=several minutes 3= One hour 4= 8 hours 5=12-24 hours
6=More than 24 hours 7=Variable and unpredictable

30) What is your main back-up source of lighting during outages/blackouts of the mini grid?

1=Rechargeable battery 2=Solar Lantern 3= Solar Multi-Light Product 4= Solar Home
System 5=Kerosene/paraffin lamp 6 =Dry-cell (non-rechargeable) battery/ Torch/ Flashlight 7.
=Candle 8=other, specify 9= Firewood 10. =No back-up source

31) How much cost incur on buck-up source of electricity?__in month.

c. Satisfaction of the current supply of electricity from the mini-grid project to your home

32) Do you think the concerned authorities have done enough to solve or at least deal with the problems of providing reliable and quality mini grid electricity supply? 1=Yes 0= No

32. What do you think the power services from the mini-grid project to your household?

1=Very poor 2.=Poor 3= Satisfactory 4= Good 5=Very good

33) Quality system can adequately supply the energy demand (appropriate level of voltage and/or no- fluctuating or stable current): is it enough to satisfy power demand

1=Excellent 2= Very good 3= Good 4=Poor 5=Very poor

34). Reliability system can provide power consistently? Is it available all over day?

1=Excellent 2=Very good 3=Good 4=Poor 5=Very poor

35). I perceive that the price of our electricity bill is

1) Very low 2) Low 3) Moderate 4) High 5) Very high

36). How do you rate Prior notification given before an outage happen?

1=Excellent 2= Very Good 3= Good 4=Poor 5=Very Poor

37). Have there been improvements in power supply quality over last year? 1. Yes 2. No If yes explain. _____

38). what are the most serious problems you experience with your mini grid electricity? Multiple responses are possible.

1. Supply shortage/not enough hours of electricity
2. Low/high voltage problems or voltage fluctuations
3. Unpredictable interruptions
4. Too expensive unaffordability/cost
5. Maintenance/service problems
6. Unpredictable bills
7. Social problems (limited interaction, inequality)
8. Other, specify
9. No problems
10. No problems

38). Please indicate how much you agree or disagree with the following statements

	Reaction to Mini grid	1	2	3	4	5
1	Current power supply is sufficient					
2	Maintenance response from the utility is fast					
3	Readers read the counter correctly and timely					
4	When I have an appeal, I get polite response					
5	The current monthly tariff rate is fair compared to the service					
6	The current mode of monthly bill payment mechanism is suitable					
7	Current monthly payment schedule is not suitable					
8	I prefer using a prepaid card system to the traditional way					

9	Electricity saves money than alternative energy sources					
10	Electricity is safer for health than alternative energy sources					
11	Electricity saves time than alternative energy sources					

39. Over all do you satisfied to current mini grid electricity service

1. Very satisfied 2.Somewhat satisfied 3.Neutral 4. Unsatisfied 5.Very unsatisfied

d Perceived Benefit of off grid energy supply						
42) Please indicate how much you agree or disagree with the following statements:						
The mini grid service benefit		1	2	3	4	5
1	---- Mini grid project is beneficial to my household					
2	----project increase my household income					
3	- ---Life in the community is better with the project					
4	- -----it is help full in the reduction in environmental pollution					
5	- -----brought about more job and business opportunity					

43) Do you think your household welfare would improve if you access to electricity services, MG?

1=.Yes 0=No

40) Which of the following are the benefits of the mini-grid project to your community?

(Check all that apply). 1=Support petty trading 2= Reduction in deforestation 4=Reduction in youth migration 3=Access to clean water 4=Reduction in burden of women 5=Access to improved health care 6= Improvement in business activity 7=Improvement in education 8. reduce fuel expanders 9=Job opportunities 10=Reduction in air pollution from burning wood 11= Improvement in entertainment and access to information 12=others

41) Which of the following are the benefits of the mini-grid project to your community? (Check all that apply).

1=Support petty trading 2=Reduction in deforestation 3= Access to clean water

4=Reduction in burden of women 5= Reduction in youth migration

6=Access to improved health care 7=Improvement in

business activity 8=Improvement in education 9=reduce fuel

expenders 10=Job opportunities 11=Reduction in air pollution from

burning wood 12= Improvement in entertainment and access to

information 10. others_____

42) Please rank the following benefits of the mini-grid project to your community. (1 is the most important and 3 is the least. Choose only 1 item per number)

benefit of mini grid	1	2	3
----------------------	---	---	---

1. Livelihood diversification
2. Environmental protection
3. Improvement in access to social service

e. Household expected electricity load demand for future Potential

43) Does your household have an interesting to use electricity for productive use? (e.g., copier shop, hair salon and carpenter shop) 1. Yes 0. No

47) Which income opportunities would do you enjoy at household level? _____

48) Would you be interested on using Mini grid electricity for agricultural activities? 1= Yes 0=No

49) If the answer for Q 44 is yes, in which agricultural activities are you interested to enjoy?

1=Water pump 2=Packing 3= Draying 4=Milling 5= others

44) Are you Owen/planning to purchase/use following electrical appliances in the next one year?

(Multiple responses)

1=Refrigerator 2=Hair Dryer 3=Electric stove& baking 4=Television (Flat screen) 6= Computer

5=Electric heater/boiler 7=Air conditioner 8= Bread Maker 9= Phone charger 10= Electrical hair clipper Iron 11=Television LCD

PART III: CONTINGENT VALUATION WILLINGNESS TO PAY

QUESTIONS KOFTU SOLAR MINIGRID ELECTRICITY



1. Do you pay for electricity service fee? 1= yes 0=no

If no description of mini grid solar electricity.

The main system components of the MG include PV modules, converters (solar direct current (DC) to alternating current (AC) inverters, and battery DC/AC inverters), battery energy storage system (BESS), MG monitoring and energy management system (MEMS), a diesel generator (DG), a distribution panel. The koftu solar mini grid site capacity to stastify energy demand of 509 house hold by the power demand 100kw of load power and 151work load with eco-friendly energy. To elaborate more main part of the system as show on picture below and was commissioned in December, 2019 one part of national electrification program.



320w solar panel was used and the total panel required for 250-kw is 630 panels.

	<p>Inverters are central components in the communication with the SCADA system; it has AC/DC conversion unit PCS (power conversion unit) 100kw each. Both they are bi lateral and connected to the battery. On the other side site is operating inverter 50kw bi lateral PCS directly connected to the battery and the solar panel.</p>
	<p>A battery is a device that stores Direct Current (DC) electrical energy in electrochemical form for later use. It contains Energy storage system that used to keep the demand and supply energy balance stable, enables the excess produced energy from renewable sources to store for later uses. It also help to minimize power outage avail power as solar power reduced</p>

An initial capital investment cost of the project was estimated to be 125000 US\$ with 25 years life span. Maintenance cost is 2% of CAPEX which is estimate about 25,000US\$ in life span of project, during life period of battery and inventor needs to be replaced that cost about 140200US\$ and 6338US\$ overhead cost to run the project with 10 percent contingency perceive future replacement of project to be sustainably. Thus, overall cost of project to generate 250 kWh is estimated about 1563691.8US\$ to electrify village with COE 0.147US\$/ kWh. This cost is excluding connection fee like metering, wire cable and electric appliance. Government plan is electrify rural household like you through optimal cost effective renewable energy in public-private partnership and estimate of the average amount of money required per household to run the plant operationally sustainable so it needs to pay for service cost of electricity.

Imagine you if electricity allows you to illuminate your house, use for entertainment information and communication service appliance- radio, TV and mobile phone charging, cooking service - stove, electric mitad, fridge and also enjoy for business activity-Poultry and agricultural processing as well as for different social service you spend certain amount on energy pay monthly based on power consumption. And the tariff you pay for the electricity you consume-mini grid supply, as well as any damage due to voltage fluctuations and interruptions to supply. You may also incur for alternative energy source in cases of no access, which can be far more

cost to per kWh and unfriendly to use than mini grid supply. Paying for electricity will result in: reliable, uninterrupted regular 24 hour electricity supplies to your home. The bill payment will be collected monthly based on agreement with Ethiopia electric utility institution responsible for electricity distribution and selling.

WPT elicitation for un-electrified household desire to connect

- 1.1. Do you paid to connect to the MG electrical network if it extended to your area? 1=Yes 0=No
- 1.2. If yes, would you be prepared to pay at least 4500 birr to connect? 1=Yes 0=No
- 1.3. If yes are you willing to pay 6500 birr to connect? 1=yes 2=no
- 1.4. If yes what is the maximum amount you willing to pay to be connected to the network? _____birr
- 1.5. What is the minimum amount you pay to get connecting to electricity?
- 1.6. If you agree to pay for connection fee? 1=One off 0= Installment based
- 1.9. If you like to pay in installment what timeframe you preferred?
1= Sixth month 2=One year 3=More than one year

Now we want to find out how much access to improve electric service by EEU is worth to you. I would like to know what the development of the electricity mini grid in order to provide more reliable and stable services is worth to you. Please consider the chosen amount as your current basic monthly electricity tariff based on your consumption of power counter in kWh. When you consider the monthly fee, please take into account: your household real income, which means your revenue and all expenses that you have to expense each month. Please note that your answer will have no effect on the price at which this service will be offered but, still might use as information to do so. So are you willing to pay this amount monthly base?

2. Are you willing to pay for this service provision fee? 1=Yes 0=No If you answer No, please respond to questions #2; otherwise answer question #33. If your answer for question No. 1 is No, Could you tell me the reason why you do not want to pay anything for electricity use?
1= I cannot afford it 2=Cost of electricity is increase3= I am not satisfied with mini grid the electricity service 4 = There is no electricity at all/ low power supply 5= the outage of electricity is very high. 6=Others _____
3. Are you willing to pay for electricity use (400/ 500/ 600/ 700) birr per month?

1) =Yes 0) =No If the answer for question No. 3 is yes, go for question No.4 and otherwise go to question No. 5.

3. Are you willing to pay for electricity use (800 1000 1200 1400) birr per month? 1=Yes
0= No

4. Are you willing to pay for electricity use (200/250/300/350) birr per month? 1= Yes 0= No

5. For these say yes would you state the maximum amount that you are willing to pay for electricity use per month? _____

6. What is the main reason for the maximum amount of willing to pay for electricity use per month?

1= I can afford more 2=I believe that electric service will be improved income

3=No other energy sources 4= other energy sources is expensive than electricity 5). Others_____

7. Would you state the minimum amount you are willing to pay for electricity use per month? _

Follow up question (reason for protest) for no-no response

8. What is the main reason for the minimum amount of willing to pay for electricity use?

1. Electricity tariff is too high
2. do not have enough income to pay for electricity services
3. if it not requires any additional payment
4. Electricity service is not a priority use income for other household exp.
5. Oppose electricity services regardless of whether it costs you anything
6. Government should provide funds for electricity service.
7. Others (specify)

9. If you accept proposed bid what schedule you preferred to pay your bill?

1. Monthly based
2. Two times a year -seasonal along with income source
3. Others

Annex: 2 FDG Guide Questions

1. What are the major factors that influence solar technology/renewable energy adoption of the household?
2. Cost of use compared to the situation before? (electricity bills etc)
3. Increased income which has enabled more savings?
4. Diversification of the household income sources?
5. How is the community view/perception towards solar energy technology?
6. In Education impact? Longer hours of lighting for reading? Other impacts? Increase in employment opportunities?
7. Does the household have any livelihood goals?
8. If yes, has the electrification by the solar-mini grid helped people to achieve those goals?
9. Does the solar-mini grid help the household to take different livelihood strategies and fulfill certain goal that was impossible before?

Annex: 3 KII Local Communities

1. Is there an observed benefit and life improvement from using solar home systems in your village?
2. What is the main challenge to use solar mini-grid energy systems in the village?
3. How do you benefited from solar mini grid electricity as you as well as community?
4. Any suggestion for improvement in the system?
5. Is there a demand for additional solar power system in the village?
6. How do you think to improve adoption of solar powered mini grid electricity?
7. In your view what are the barriers to the up take off- grid electricity like mini grid electricity

Annex: 4 KII for Energy Expert

1. Could you please explain the role of your ministry in renewable energy dissemination?
2. What is the ministry plan to increase solar power implementation in rural part of Ethiopia?
3. Is there any experience sharing mechanism with those countries who have pioneering in solar Power generation and distribution?
4. What are challenges faced from the rural population to implement the Government's strategy in renewable energy capacity growth?
5. Is there a Government body who that supports Solar Energy Companies to come and invest in the country?
6. What information would you like to share sustainability of mini- grid energy in rural areas?
7. What do you think should be done to enhance the sustainability of mini- grid energy in rural areas in Ethiopia?

Annex: 5. bivariate probit model specification result

Variables	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
Response1						
bid1_01	-0.0024	0.000619	-3.88	0	-0.00361	-0.00119
Constant	1.066383	0.34329	3.11	0.002	0.393548	1.739218
response2						
bid2_01	-0.00111	0.000356	-3.13	0.002	-0.00181	-0.00042
Constant	0.194609	0.273189	0.71	0.476	-0.34083	0.73005

Bids	dy/dx	Std. Err.	z	P>z	[95% Conf.	Interval
bid1_01	-0.00032	0.00008	-3.96	0	-0.00047	-0.00016
bid2_01	-0.00022	9.22E-05	-2.39	0.017	-0.0004	-4E-05

Annex: 6. Estimated probit regression result

Variables	Non-electrified		Electrified		Full sample	
	Probit	Marginal	Probit	Marginal	Probit	Marginal
bidday	-1.200*** (0.268)	-0.444*** (0.0907)	-2.342*** (0.550)	-0.933*** (0.220)	-1.345*** (0.246)	-0.525*** (0.0939)
gender2	0.482** (0.245)	0.179* (0.0920)	-0.505** (0.254)	-0.201** (0.101)	-0.00544 (0.166)	-0.00212 (0.0648)
marital2	0.131 (0.291)	0.0487 (0.108)	-0.0604 (0.232)	-0.0241 (0.0926)	0.0418 (0.168)	0.0163 (0.0655)
occupation2	-0.260 (0.240)	-0.0963 (0.0891)	-0.787*** (0.258)	-0.314*** (0.103)	-0.454*** (0.161)	-0.177*** (0.0630)
Famsize	-0.111* (0.0610)	-0.0410* (0.0226)	-0.0921 (0.0760)	-0.0367 (0.0303)	-0.0711 (0.0465)	-0.0278 (0.0181)
landown2	-0.134 (0.270)	-0.0496 (0.100)	0.304 (0.283)	0.121 (0.113)	0.149 (0.178)	0.0580 (0.0694)
age2	0.0158 (0.0129)	0.00585 (0.00476)	-0.0106 (0.0148)	-0.00421 (0.00591)	0.00676 (0.00959)	0.00264 (0.00374)
lnincome	-0.0297 (0.213)	-0.0110 (0.0789)	0.370* (0.206)	0.148* (0.0821)	0.136 (0.125)	0.0530 (0.0487)
starmg			-0.256** (0.116)	-0.102** (0.0461)		
realmg			0.0795 (0.111)	0.0317 (0.0442)		
busin2			0.488** (0.246)	0.195** (0.0981)	0.429** (0.199)	0.168** (0.0776)
perception	-0.0449 (0.123)	-0.0166 (0.0455)	0.0757 (0.108)	0.0301 (0.0429)	0.0156 (0.0741)	0.00609 (0.0290)
cec			-0.00372* (0.00218)	-0.00148* (0.000870)		
firewodist			-0.00915 (0.0136)	-0.00364 (0.00543)	-0.00842 (0.00977)	-0.00329 (0.00382)
benefit			0.323*** (0.104)	0.129*** (0.0413)	0.0983 (0.0752)	0.0384 (0.0294)
inv	0.238 (0.205)	0.0880 (0.0759)	-0.177 (0.127)	-0.0703 (0.0506)	-0.0765 (0.0992)	-0.0299 (0.0388)
housetyp2	-0.147 (0.241)	-0.0543 (0.0895)	0.231 (0.245)	0.0920 (0.0976)	0.00350 (0.158)	0.00137 (0.0617)
educ1	0.434 (0.265)	0.161* (0.0974)	-0.315 (0.220)	-0.125 (0.0875)	0.00846 (0.160)	0.00330 (0.0626)
acostfuel	-0.00124 (0.00120)	-0.000458 (0.000445)				
daccess2					-0.151 (0.231)	-0.0591 (0.0899)
Constant	9.422***		14.98***		8.809***	

	(3.170)		(4.376)		(2.234)
Observations	156	156	220	220	

Note: Robust standard errors in parentheses. The asterisks ***, **, and * indicates the coefficient is significant at 1%, 5% & and 10% respectively.

Annex: 7 Estimated results of bivariate probit regression Model

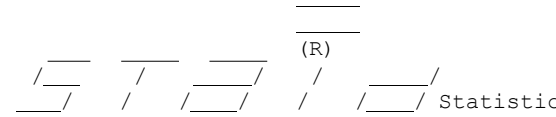
Repressors	Non-electrified		Electrified		Full model	
	(1)	(2)	(3)	(4)	(5)	(6)
bid1_01	-0.00194*		-0.00323***		0.00234***	
	(0.00105)		(0.00108)		(0.000703)	
bid2_01		0.00147***		0.000416		0.00114***
		(0.000400)		(0.00162)		(0.000406)
gender2	-0.251	-0.166	-0.0287	0.447*	-0.156	0.0626
	(0.252)	(0.240)	(0.217)	(0.242)	(0.155)	(0.153)
marital2	0.507**	0.278	0.247	0.413*	0.323**	0.199
	(0.241)	(0.232)	(0.195)	(0.225)	(0.147)	(0.141)
occupation2	-0.292	-0.240	-0.0652	-0.110	-0.207	-0.178
	(0.217)	(0.207)	(0.204)	(0.221)	(0.149)	(0.142)
age2	0.00545	0.00538	0.000893	-0.0300**	-0.000105	-0.00948
	(0.0137)	(0.0138)	(0.0106)	(0.0125)	(0.00749)	(0.00708)
Famsize	-0.0277	0.0327	0.0151	0.0587	0.00879	0.0493
	(0.0558)	(0.0604)	(0.0564)	(0.0617)	(0.0383)	(0.0368)
landown2	0.0834	-0.231	0.144	0.859***	0.195	0.205
	(0.252)	(0.245)	(0.226)	(0.254)	(0.156)	(0.147)
busin2			-0.197	-0.147	-0.207	-0.179
			(0.191)	(0.222)	(0.188)	(0.181)
	(0.227)	(0.216)	(0.193)	(0.209)	(0.138)	(0.131)
educ1	-0.0423	-0.484**	0.175	0.279	0.0677	-0.0604
	(0.223)	(0.231)	(0.184)	(0.201)	(0.137)	(0.132)
lnincome	-0.292	-0.296	-0.0942	-0.0185	-0.151	-0.0667
	(0.193)	(0.188)	(0.161)	(0.176)	(0.113)	(0.108)
perception	0.0996	-0.0785	-0.0394	0.0258	0.0393	-0.0445
	(0.111)	(0.116)	(0.0933)	(0.103)	(0.0685)	(0.0675)
inv			-0.193*	-0.106	-0.155	-0.0193
			(0.114)	(0.142)	(0.105)	(0.0981)
realmg			-0.0150	0.0441		
			(0.0938)	(0.0998)		
cec			-0.000103	-0.00222		
			(0.00196)	(0.00211)		
ceckwh			0.00397*	-0.000696		
			(0.00236)	(0.00329)		
acost	-0.00151	-0.000580				
	(0.00118)	(0.00120)				
firewodist	0.0242*	0.0176				
	(0.0154)	(0.0149)				
location2					0.388*	0.0854
					(0.215)	(0.209)
Constant	3.333*	3.138*	2.067	-0.120	2.265*	0.985
	(2.023)	(1.884)	(1.764)	(2.124)	(1.222)	(1.202)
Observations	156	156	220	220	376	376

Note: standard errors in parentheses. The asterisks ***, **, and * indicates the coefficient is significant at 1%, 5% & and 10% respectively.

Annexx:8 Estimation model use stata

June 17 15:01:26 2024

Page 1



User: Thesis
Project: Willigness to pay project

```
name: <unnamed>
log: D:\Kifile\Kifile Log files.smcl
log type: smcl
opened on: 17 Jun 2024, 14:53:28
```

```
1 . do "C:\Users\bati\AppData\Local\Temp\STD02000000.tmp"
2 .
3 . *****
3 . probit answr bidday gender2 marital2 occupation2 Famsize landown2 age2 lnincome hc2 educ1 /
> perception acost inv if access ==1 ,r
```

```
Iteration 0: log pseudolikelihood = -104.8255
Iteration 1: log pseudolikelihood = -67.602321
Iteration 2: log pseudolikelihood = -66.732361
Iteration 3: log pseudolikelihood = -66.731513
Iteration 4: log pseudolikelihood = -66.731513
```

```
Probit regression                               Number of obs   =          156
                                                Wald chi2(13)   =          38.77
                                                Prob > chi2     =          0.0002
Log pseudolikelihood = -66.731513             Pseudo R2      =          0.3634
```

answr	Coef.	Robust Std. Err.	z	P> z	[95% Conf. Interval]
bidday	-1.199727	.2683125	-4.47	0.000	-1.725609 - .6738438
gender2	.4818182	.2450011	1.97	0.049	.0016249 .9620114
marital2	.1313817	.2905641	0.45	0.651	-.4381134 .7008768
occupation2	-.2598342	.2398906	-1.08	0.279	-.7300111 .2103427
Famsize	-.110683	.0610266	-1.81	0.070	-.2302929 .0089269
landown2	-.1337954	.2695609	-0.50	0.620	-.6621251 .3945344
age2	.0157815	.012861	1.23	0.220	-.0094255 .0409886
lnincome	-.0297302	.2131171	-0.14	0.889	-.4474321 .3879717
hc2	-.1466023	.2411838	-0.61	0.543	-.6193139 .3261092
educ1	.4344643	.2646688	1.64	0.101	-.084277 .9532057
perception	-.04492	.1233299	-0.36	0.716	-.2866421 .1968021
acost	-.001236	.0011974	-1.03	0.302	-.0035828 .0011108
inv	.2375834	.2046566	1.16	0.246	-.1635362 .638703
_cons	9.421991	3.17028	2.97	0.003	3.208356 15.63563

```
4 .
end of do-file

5 . do "C:\Users\bati\AppData\Local\Temp\STD02000000.tmp"

6 . probit answr bidday gender2 marital2 occupation2 Famsize landown2 age2 lnincome starmg realm
> perception cec fueldistance benefit inv hc2 educ1 if access==2, r
```

Iteration 0: log pseudolikelihood = **-151.75519**
Iteration 1: log pseudolikelihood = **-91.362294**
Iteration 2: log pseudolikelihood = **-87.810435**
Iteration 3: log pseudolikelihood = **-87.522768**
Iteration 4: log pseudolikelihood = **-87.521379**
Iteration 5: log pseudolikelihood = **-87.521378**

Probit regression	Number of obs	=	220
	Wald chi2(18)	=	52.21
	Prob > chi2	=	0.0000
Log pseudolikelihood = -87.521378	Pseudo R2	=	0.4233

answr	Coef.	Robust Std. Err.	z	P> z	[95% Conf. Interval]
bidday	-2.342255	.5497829	-4.26	0.000	-3.41981 -1.264701
gender2	-.505122	.2536873	-1.99	0.046	-1.00234 -.0079039
marital2	-.0604469	.232387	-0.26	0.795	-.515917 .3950232
occupation2	-.7870362	.2577611	-3.05	0.002	-1.292239 -.2818336
Famsize	-.0921249	.0760399	-1.21	0.226	-.2411604 .0569106
landown2	.3041602	.2827699	1.08	0.282	-.2500585 .858379
age2	-.0105667	.0148273	-0.71	0.476	-.0396278 .0184944
lnincome	.3702674	.2060455	1.80	0.072	-.0335743 .7741091
starmg	-.2559133	.1158274	-2.21	0.027	-.4829308 -.0288959
realmg	.0794989	.1108448	0.72	0.473	-.1377529 .2967506
busin2	.4883571	.2461215	1.98	0.047	.0059678 .9707464
perception	.0756723	.1077114	0.70	0.482	-.1354381 .2867828
cec	-.0037192	.0021835	-1.70	0.089	-.0079989 .0005604
fueldistance	-.0091451	.0136227	-0.67	0.502	-.0358451 .0175549
benefit	.3227652	.1036178	3.11	0.002	.1196781 .5258523
inv	-.1765587	.1269948	-1.39	0.164	-.4254638 .0723465
hc2	.2309444	.2448568	0.94	0.346	-.2489661 .7108548
educ1	-.3147317	.2196738	-1.43	0.152	-.7452844 .1158211
_cons	14.98133	4.376159	3.42	0.001	6.404214 23.55844

```

7 .
  end of do-file

8 . do "C:\Users\bati\AppData\Local\Temp\STD02000000.tmp"

9 . probit answr bidday gender2 marital2 occupation2 Famsize landown2 age2 lnincome busin2 //
  > perception fueldistance benefit inv hc2 educ1 daccess2, r

Iteration 0: log pseudolikelihood = -257.289
Iteration 1: log pseudolikelihood = -174.89333
Iteration 2: log pseudolikelihood = -173.37534
Iteration 3: log pseudolikelihood = -173.37206
Iteration 4: log pseudolikelihood = -173.37206

Probit regression                               Number of obs   =          376
                                                Wald chi2(16)   =          52.36
                                                Prob > chi2     =          0.0000
Log pseudolikelihood = -173.37206              Pseudo R2       =          0.3262
    
```

answr	Coef.	Robust Std. Err.	z	P> z	[95% Conf. Interval]
bidday	-1.344948	.2461498	-5.46	0.000	-1.827393 -.8625033
gender2	-.0054397	.1660145	-0.03	0.974	-.3308221 .3199427
marital2	.0418275	.1676788	0.25	0.803	-.2868169 .370472
occupation2	-.4538148	.1613319	-2.81	0.005	-.7700196 -.13761
Famsize	-.071111	.0464506	-1.53	0.126	-.1621525 .0199306
landown2	.1485853	.177578	0.84	0.403	-.1994613 .4966318
age2	.0067614	.009589	0.71	0.481	-.0120327 .0255555
lnincome	.135758	.124759	1.09	0.277	-.1087651 .3802811
busin2	.4289986	.1990937	2.15	0.031	.0387821 .819215
perception	.0155937	.0741118	0.21	0.833	-.1296627 .1608502
fueldistance	-.0084206	.0097736	-0.86	0.389	-.0275765 .0107354
benefit	.098335	.0752118	1.31	0.191	-.0490775 .2457475
inv	-.0765195	.0992493	-0.77	0.441	-.2710445 .1180055
hc2	.0035045	.1578192	0.02	0.982	-.3058154 .3128244
educ1	.0084553	.1603605	0.05	0.958	-.3058455 .322756
daccess2	-.1512688	.2305414	-0.66	0.512	-.6031217 .300584
_cons	8.808586	2.234011	3.94	0.000	4.430005 13.18717

```

10 .
    end of do-file
11 . do "C:\Users\bati\AppData\Local\Temp\STD02000000.tmp"
12 . singleb bid1_01 response1 gender2 age2 marital2 occupation2 Famsize landown2 hc2 educ1 lni
    > perception fueldistance acost inv if access ==1 , noconst

```

```

initial:      log likelihood =      -<inf> (could not be evaluated)
feasible:     log likelihood =    -21685.255
rescale:      log likelihood =    -101.99249
rescale eq:   log likelihood =    -101.99249
Iteration 0:  log likelihood =    -101.99249
Iteration 1:  log likelihood =    -98.574774
Iteration 2:  log likelihood =    -94.808147
Iteration 3:  log likelihood =    -93.782446
Iteration 4:  log likelihood =    -93.752082
Iteration 5:  log likelihood =    -93.750832
Iteration 6:  log likelihood =    -93.750829

```

```

Log likelihood = -93.750829
Number of obs   =          156
Wald chi2(13)  =          131.35
Prob > chi2    =           0.0000

```

	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
Beta						
gender2	-58.31886	91.71187	-0.64	0.525	-238.0708 121.4331	
age2	4.314634	5.399004	0.80	0.424	-6.267219 14.89649	
marital2	173.6504	105.1143	1.65	0.099	-32.36989 379.6707	
occupation2	-92.16193	90.44813	-1.02	0.308	-269.437 85.11314	
Famsize	-21.27539	22.23677	-0.96	0.339	-64.85866 22.30789	
landown2	48.68739	92.55099	0.53	0.599	-132.7092 230.084	
hc2	-37.76085	85.51799	-0.44	0.659	-205.373 129.8513	
educ1	-21.59226	81.00547	-0.27	0.790	-180.3601 137.1756	
lnincome	11.4791	35.70596	0.32	0.748	-58.5033 81.46151	
perception	47.22678	41.60443	1.14	0.256	-34.3164 128.77	
fueldistance	12.36355	6.983293	1.77	0.077	-1.323457 26.05055	
acost	-.4880012	.456103	-1.07	0.285	-1.381947 .4059442	
inv	22.1656	71.34663	0.31	0.756	-117.6712 162.0024	
Sigma						
_cons	367.7231	131.7906	2.79	0.005	109.4183 626.0279	

```

Bid Variable:      bid1_01
Response Dummy Variable: response1

```

```

13 . outreg2 using scm2.rtf,replace
    scm2.rtf
    dir : seeout

```

```

14 .
15 .

```

```
16 . singleb bid1_01 response1 gender2 age2 marital2 occupation2 Famsize landown2 hc2 educ1 lninco
> perception cec busin2 inv realmg if access==2 , noconst
```

```
initial:      log likelihood =      -<inf> (could not be evaluated)
feasible:     log likelihood =    -19121.565
rescale:      log likelihood =    -143.88217
rescale eq:   log likelihood =    -143.88217
Iteration 0:  log likelihood =    -143.88217 (not concave)
Iteration 1:  log likelihood =    -140.05573
Iteration 2:  log likelihood =    -136.79031
Iteration 3:  log likelihood =    -136.28954
Iteration 4:  log likelihood =    -136.28635
Iteration 5:  log likelihood =    -136.28634
```

```
Number of obs      =      220
Wald chi2(14)      =      277.12
Prob > chi2        =      0.0000
Log likelihood     =    -136.28634
```

	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
Beta						
gender2	-10.17502	66.16285	-0.15	0.878	-139.8518 119.5018	
age2	1.980678	3.104717	0.64	0.524	-4.104455 8.065812	
marital2	66.0126	60.95739	1.08	0.279	-53.46168 185.4869	
occupation2	-42.01632	62.52743	-0.67	0.502	-164.5678 80.53518	
Famsize	-1.180323	16.37818	-0.07	0.943	-33.28097 30.92033	
landown2	8.832908	64.0334	0.14	0.890	-116.6702 134.3361	
hc2	3.937708	56.86411	0.07	0.945	-107.5139 115.3893	
educ1	62.78257	56.7128	1.11	0.268	-48.37248 173.9376	
lnincome	34.13709	15.33497	2.23	0.026	4.081098 64.19309	
perception	-13.20191	27.87178	-0.47	0.636	-67.8296 41.42578	
cec	.4352534	.5726851	0.76	0.447	-.6871887 1.557696	
busin2	-67.92658	61.2293	-1.11	0.267	-187.9338 52.08065	
inv	-62.78445	37.50862	-1.67	0.094	-136.3 10.73109	
realmg	-7.525853	28.47994	-0.26	0.792	-63.34551 48.2938	
Sigma						
_cons	308.0859	79.58986	3.87	0.000	152.0927 464.0792	

```
Bid Variable:      bid1_01
Response Dummy Variable:  response1
```

```
17 . outreg2 using scm2.rtf,append
    scm2.rtf
    dir : seeout
```

```
18 .
19 . singleb bid1_01 response1 gender2 age2 Famsize marital2 occupation2 landown2 hc2 educ1 lninco
> perception busin2 daccess2 inv ,noconst
```

```
initial:      log likelihood =      -<inf> (could not be evaluated)
feasible:     log likelihood =    -26291.261
rescale:      log likelihood =    -250.92455
rescale eq:   log likelihood =    -246.02623
Iteration 0:  log likelihood =    -246.02623 (not concave)
Iteration 1:  log likelihood =    -239.17901
Iteration 2:  log likelihood =    -237.91755
Iteration 3:  log likelihood =    -235.76203
Iteration 4:  log likelihood =    -235.71801
Iteration 5:  log likelihood =    -235.7179
Iteration 6:  log likelihood =    -235.7179
```

Log likelihood = **-235.7179** Number of obs = **376**
 Wald chi2(13) = **308.43**
 Prob > chi2 = **0.0000**

	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
Beta						
gender2	-43.87736	55.60349	-0.79	0.430	-152.8582 65.10347	
age2	1.605057	2.557917	0.63	0.530	-3.408369 6.618482	
Famsize	-6.511549	13.00112	-0.50	0.616	-31.99328 18.97018	
marital2	112.3334	55.16997	2.04	0.042	4.202262 220.4646	
occupation2	-74.29964	54.61541	-1.36	0.174	-181.3439 32.7446	
landown2	48.34373	55.65657	0.87	0.385	-60.74115 157.4286	
hc2	-19.55706	49.46172	-0.40	0.693	-116.5002 77.38613	
educ1	38.93141	48.70799	0.80	0.424	-56.53449 134.3973	
lnincome	30.42798	12.93873	2.35	0.019	5.068535 55.78742	
perception	15.74339	24.37199	0.65	0.518	-32.02484 63.51162	
busin2	-80.12927	67.83538	-1.18	0.238	-213.0842 52.82564	
daccess2	135.5899	77.58227	1.75	0.081	-16.46859 287.6483	
inv	-60.13292	33.31366	-1.81	0.071	-125.4265 5.16065	
Sigma						
cons	355.4726	76.16818	4.67	0.000	206.1857 504.7595	

Bid Variable: **bid1_01**
 Response Dummy Variable: **response1**

```

20 . outreg2 using scm2.rtf,append
    scm2.rtf
    dir : seeout
21 .
    end of do-file
22 . do "C:\Users\bati\AppData\Local\Temp\STD02000000.tmp"
23 .
24 . doubleb bid1_01 bid2_01 response1 response2 gender2 age2 marital2 occupation2 Famsize landown2 h
    > perception fueldistance acost if access ==1, noconst

initial:      log likelihood =      -<inf> (could not be evaluated)
feasible:     log likelihood = -9935.6885
rescale:      log likelihood = -235.76393
rescale eq:   log likelihood = -195.40157
Iteration 0:  log likelihood = -195.40157
Iteration 1:  log likelihood = -189.34288
Iteration 2:  log likelihood = -188.3929
Iteration 3:  log likelihood = -188.38064
Iteration 4:  log likelihood = -188.38063

Log likelihood = -188.38063      Number of obs = 156
Wald chi2(12) = 60.65
Prob > chi2 = 0.0000
    
```

	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
Beta						
gender2	-60.27568	120.4549	-0.50	0.617	-296.3629 175.8115	
age2	7.382424	6.622552	1.11	0.265	-5.59754 20.36239	
marital2	193.876	116.5032	1.66	0.096	-34.46606 422.2182	
occupation2	-138.2173	112.469	-1.23	0.219	-358.6525 82.21799	
Famsize	-13.34743	28.0076	-0.48	0.634	-68.24133 41.54646	
landown2	-39.89885	122.7395	-0.33	0.745	-280.4639 200.6662	
hc2	-76.55734	113.4144	-0.68	0.500	-298.8455 145.7308	
educ1	-156.2876	109.6178	-1.43	0.154	-371.1344 58.55931	
lnincome	-9.531923	42.0818	-0.23	0.821	-92.01074 72.9469	
perception	15.35688	54.49703	0.28	0.778	-91.45534 122.1691	
fueldistance	15.46599	7.781229	1.99	0.047	.2150566 30.71692	
acost	-.3959952	.5712239	-0.69	0.488	-1.515574 .7235831	
Sigma						
_cons	582.9411	60.43878	9.65	0.000	464.4833 701.399	

First-Bid Variable: bid1_01
 Second-Bid Variable: bid2_01
 First-Response Dummy Variable: responsel
 Second-Response Dummy Variable: response2

```
25 . outreg2 using scm2.rtf,append
    scm2.rtf
    dir : seeout
```

```
26 .
27 . doubleb bid1_01 bid2_01 responsel response2 gender2 marital2 occupation2 age2 Famsize landown2 h
    > cec ceckwh perception busin2 inv realmg if access==2 , noconst
```

```
initial:      log likelihood =      -<inf> (could not be evaluated)
feasible:     log likelihood =    -676.45658
rescale:      log likelihood =    -326.7742
rescale eq:   log likelihood =    -273.01469
Iteration 0:  log likelihood =    -273.01469
Iteration 1:  log likelihood =    -268.0061
Iteration 2:  log likelihood =    -264.03119
Iteration 3:  log likelihood =    -263.96619
Iteration 4:  log likelihood =    -263.96607
Iteration 5:  log likelihood =    -263.96607

Number of obs      =          220
Wald chi2(15)      =          57.04
Prob > chi2        =          0.0000

Log likelihood =    -263.96607
```

	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
Beta						
gender2	101.9361	127.8416	0.80	0.425	-148.6288 352.5009	
marital2	195.9458	117.4264	1.67	0.095	-34.20567 426.0972	
occupation2	-72.66272	121.3003	-0.60	0.549	-310.4069 165.0814	
age2	-6.29769	6.238772	-1.01	0.313	-18.52546 5.930078	
Famsize	18.25755	32.11757	0.57	0.570	-44.69173 81.20683	
landown2	211.5776	124.0909	1.71	0.088	-31.63616 454.7913	
hc2	-66.97778	111.4591	-0.60	0.548	-285.4337 151.4781	
educ1	136.6485	108.3323	1.26	0.207	-75.67887 348.9759	
lnincome	26.11404	29.02399	0.90	0.368	-30.77194 83.00002	
cec	-.4374588	1.148862	-0.38	0.703	-2.689187 1.81427	
ceckwh	2.367875	1.368917	1.73	0.084	-.3151532 5.050903	
perception	-10.76399	54.53993	-0.20	0.844	-117.6603 96.1323	
busin2	-144.14	112.5817	-1.28	0.200	-364.7961 76.51619	
inv	-136.6866	66.9178	-2.04	0.041	-267.843 -5.530103	

realmg	-2.548704	54.81089	-0.05	0.963	-109.9761	104.8787
Sigma						
_cons	692.5128	65.54989	10.56	0.000	564.0374	820.9882

First-Bid Variable: bid1_01
 Second-Bid Variable: bid2_01
 First-Response Dummy Variable: response1
 Second-Response Dummy Variable: response2

```
28 .
29 . outreg2 using scm2.rtf,append
    scm2.rtf
    dir : seeout
30 .
31 . doubleb bid1_01 bid2_01 response1 response2 gender2 age2 marital2 occupation2 Famsize landown2 h
    > inv busin2 daccess2 ,noconst
```

```
initial:      log likelihood =      -<inf> (could not be evaluated)
feasible:     log likelihood = -11470.203
rescale:      log likelihood = -491.76121
rescale eq:   log likelihood = -484.95246
Iteration 0:  log likelihood = -484.95246
Iteration 1:  log likelihood = -469.00735
Iteration 2:  log likelihood = -466.56826
Iteration 3:  log likelihood = -466.56762
Iteration 4:  log likelihood = -466.56762
```

```
Log likelihood = -466.56762
Number of obs   =      380
Wald chi2(12)   =      93.48
Prob > chi2     =      0.0000
```

	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
Beta						
gender2	-19.14419	86.00487	-0.22	0.824	-187.7106 149.4223	
age2	-1.943159	4.040717	-0.48	0.631	-9.862818 5.976501	
marital2	153.1459	81.19065	1.89	0.059	-5.984877 312.2766	
occupation2	-123.1184	83.34574	-1.48	0.140	-286.4731 40.23623	
Famsize	7.625949	20.65193	0.37	0.712	-32.85109 48.10299	
landown2	105.6433	85.47292	1.24	0.216	-61.88052 273.1672	
hc2	-50.18895	77.16052	-0.65	0.515	-201.4208 101.0429	
educ1	-2.129186	76.24034	-0.03	0.978	-151.5575 147.2991	
lnincome	28.29431	19.10918	1.48	0.139	-9.159002 65.74761	
inv	-67.8268	50.12626	-1.35	0.176	-166.0725 30.41885	
busin2	-143.1	103.938	-1.38	0.169	-346.8148 60.61482	
daccess2	160.7759	112.0507	1.43	0.151	-58.8394 380.3912	
Sigma						
_cons	654.1673	45.16735	14.48	0.000	565.641 742.6937	

First-Bid Variable: bid1_01
 Second-Bid Variable: bid2_01
 First-Response Dummy Variable: response1
 Second-Response Dummy Variable: response2

```

32 . outreg2 using scm2.rtf,append
    scm2.rtf
    dir : seeout
33 . *****
34 .
    end of do-file
35 . do "C:\Users\bati\AppData\Local\Temp\STD02000000.tmp"
36 .
37 . *****
38 . //////////////////////////////////////
> biprobit (response1 = bid1_01 gender2 marital2 occupation2 age2 Famsize landown2 hc2 educ1 lnincome //
> perception acost fueldistance , noconst)
> (response2 = bid2_01 gender2 marital2 occupation2 age2 Famsize landown2 hc2 educ1 lnincome //
> perception acost fueldistance , noconst) if access==1 ,robust

```

Fitting comparison equation 1:

```

Iteration 0: log pseudolikelihood = -108.13096
Iteration 1: log pseudolikelihood = -93.826168
Iteration 2: log pseudolikelihood = -93.800241
Iteration 3: log pseudolikelihood = -93.800238

```

Fitting comparison equation 2:

```

Iteration 0: log pseudolikelihood = -108.13096
Iteration 1: log pseudolikelihood = -89.735623
Iteration 2: log pseudolikelihood = -89.712886
Iteration 3: log pseudolikelihood = -89.712886

```

Comparison: log pseudolikelihood = -183.51312

Fitting full model:

```

Iteration 0: log pseudolikelihood = -183.51312
Iteration 1: log pseudolikelihood = -182.38873
Iteration 2: log pseudolikelihood = -181.81594
Iteration 3: log pseudolikelihood = -181.76429
Iteration 4: log pseudolikelihood = -181.76127
Iteration 5: log pseudolikelihood = -181.76126

```

```

Seemingly unrelated bivariate probit          Number of obs      =          156
                                                Wald chi2(26)         =           91.82
Log pseudolikelihood d = -181.76126          Prob > chi2           =           0.0000

```

	Coef.	Robust Std. Err.	z	P> z	[95% Conf. Interval]	
response1						
bid1_01	-.001796	.0009516	-1.89	0.059	-.003661 .0000691	
gender2	-.1718948	.2497422	-0.69	0.491	-.6613805 .317591	
marital2	.4450132	.2358425	1.89	0.059	-.0172295 .907256	
occupation2	-.2579737	.2159216	-1.19	0.232	-.6811721 .1652248	
age2	.0124479	.0132799	0.94	0.349	-.0135803 .0384761	
Famsize	-.0513094	.0559294	-0.92	0.359	-.160929 .0583102	
landown2	.0888042	.251515	0.35	0.724	-.4041562 .5817646	
hc2	-.1190564	.2255457	-0.53	0.598	-.5611178 .323005	
educ1	-.0421891	.2194566	-0.19	0.848	-.4723162 .387938	
lnincome	-.0166861	.0957845	-0.17	0.862	-.2044203 .1710481	
perception	.120546	.1098571	1.10	0.273	-.0947701 .335862	
acost	-.0012121	.0011575	-1.05	0.295	-.0034808 .0010565	
fueldistance	.0299817	.015304	1.96	0.050	-.0000136 .0599771	
response2						

bid2_01	-.0013833	.0004055	-3.41	0.001	-.0021782	-.0005885
gender2	-.0803272	.2444457	-0.33	0.742	-.5594319	.3987776
marital2	.2185324	.227911	0.96	0.338	-.228165	.6652299
occupation2	-.2061733	.2082783	-0.99	0.322	-.6143913	.2020447
age2	.01184	.0134699	0.88	0.379	-.0145606	.0382405
Famsize	.0121085	.0591652	0.20	0.838	-.1038532	.1280701
landown2	-.222494	.2521251	-0.88	0.378	-.7166502	.2716622
hc2	-.1217895	.2133945	-0.57	0.568	-.540035	.2964559
educ1	-.4859758	.2279853	-2.13	0.033	-.9328188	-.0391328
lnincome	-.0338502	.0851362	-0.40	0.691	-.200714	.1330137
perception	-.0662589	.1143254	-0.58	0.562	-.2903324	.1578147
acost	-.0003295	.0011601	-0.28	0.776	-.0026032	.0019443
fueldistance	.0227263	.0152835	1.49	0.137	-.0072289	.0526814

/athrho	.9811071	.4732876	2.07	0.038	.0534805	1.908734
---------	----------	----------	------	-------	----------	----------

rho	.7535448	.2045408			.0534295	.9569789
-----	----------	----------	--	--	----------	----------

Wald test of rho=0: chi2(1) = **4.29717** Prob > chi2 = **0.0382**

```

outreg2 using mypro.rtf,replace
      mypro.rtf
dir :biprobit (response1 = bid1_01 gender2 marital2 occupation2 age2 Famsize landown2 busin2 hc2
ed benefit inv realmg cec ceckwh,noconst)(response2 = bid2_01 gender2 marital2 occupation2 age2
Famsize landown2 busin
benefit inv realmg cec ceckwh,noconst) if access==2 ,robust
    
```

Fitting comparison equation 1:

```

Iteration 0: log pseudolikelihood = -152.49238
Iteration 1: log pseudolikelihood = -134.64328
Iteration 2: log pseudolikelihood = -134.61154
Iteration 3: log pseudolikelihood = -134.61154
    
```

Fitting comparison equation 2:

```

Iteration 0: log pseudolikelihood = -152.49238
Iteration 1: log pseudolikelihood = -111.91033
Iteration 2: log pseudolikelihood = -111.4047
Iteration 3: log pseudolikelihood = -111.40455
Iteration 4: log pseudolikelihood = -111.40455
    
```

Comparison: log pseudolikelihood = **-246.01609**

Fitting full model:

```

Iteration 0: log pseudolikelihood = -246.01609
Iteration 1: log pseudolikelihood = -246.01321
Iteration 2: log pseudolikelihood = -246.01316
Iteration 3: log pseudolikelihood = -246.01316
    
```

Seemingly unrelated bivariate probit	Number of obs	=	220
Log pseudolikelihood = -246.01316	Wald chi2(32)	=	125.75
	Prob > chi2	=	0.0000

	Coef.	Robust Std. Err.	z	P> z	[95% Conf. Interval]	
response1						
bid1_01	-.0029259	.0013779	-2.12	0.034	-.0056265 -.0002253	
gender2	-.0211872	.2143961	-0.10	0.921	-.4413958 .3990214	
marital2	.2415799	.1935087	1.25	0.212	-.1376902 .6208499	
occupation2	-.0835787	.2051737	-0.41	0.684	-.4857117 .3185543	
age2	.0051193	.0104589	0.49	0.625	-.0153797 .0256183	
Famsize	-.0076412	.0606675	-0.13	0.900	-.1265474 .111265	
landown2	.0511436	.2033105	0.25	0.801	-.3473376 .4496247	
busin2	-.196176	.1888046	-1.04	0.299	-.5662261 .1738742	
hc2	-.0327253	.1918597	-0.17	0.865	-.4087635 .3433129	
educ1	.1921963	.1874394	1.03	0.305	-.1751781 .5595708	
lnincome	.0799464	.0856122	0.93	0.350	-.0878505 .2477432	
benefit	-.0129359	.0905668	-0.14	0.886	-.1904436 .1645717	
inv	-.2107421	.1170902	-1.80	0.072	-.4402347 .0187504	
realmg	-.0335395	.0933879	-0.36	0.719	-.2165764 .1494974	
cec	.0001245	.0018945	0.07	0.948	-.0035887 .0038377	
ceckwh	.0043272	.0023532	1.84	0.066	-.000285 .0089395	
response2						
bid2_01	.0006628	.0022579	0.29	0.769	-.0037626 .0050881	
gender2	.4654877	.235421	1.98	0.048	.004071 .9269043	
marital2	.4342107	.2187461	1.98	0.047	.0054762 .8629452	
occupation2	-.0782313	.229045	-0.34	0.733	-.5271513 .3706887	
age2	-.0301842	.0116077	-2.60	0.009	-.0529348 -.0074336	
Famsize	.0514065	.0599164	0.86	0.391	-.0660275 .1688404	
landown2	.9603041	.2627446	3.65	0.000	.4453341 1.475274	
busin2	-.1224049	.2395395	-0.51	0.609	-.5918937 .3470839	
hc2	-.1230691	.2071579	-0.59	0.552	-.529091 .2829528	
educ1	.2526452	.2143424	1.18	0.239	-.1674581 .6727486	
lnincome	-.0476386	.1216866	-0.39	0.695	-.2861399 .1908627	
benefit	-.1792452	.1104009	-1.62	0.104	-.3956271 .0371367	
inv	-.131947	.1654447	-0.80	0.425	-.4562126 .1923187	
realmg	.0690435	.0992399	0.70	0.487	-.1254631 .26355	
cec	-.0025443	.0020247	-1.26	0.209	-.0065125 .001424	
ceckwh	-.0008946	.0038394	-0.23	0.816	-.0084198 .0066305	
/athrho	.0605842	1.113864	0.05	0.957	-2.122549 2.243718	
rho	.0605102	1.109786			-.9717365 .9777514	

Wald test of rho=0: chi2(1) = .002958 Prob > chi2 = 0.9566

```

outreg2 using mypro.rtf,append mypro.rtf
dir : seeout biprobit (response1 = bid1_01 gender2 marital2 occupation2 age2 Famsize landown2 hc2
educ1 lnin inv busin2 daccess2 , noconst)(response2 = bid2_01 gender2 marital2 occupation2 age2
Famsize landown2 hc2 ed, inv busin2 daccess2, noconst) ,robust
    
```

Fitting comparison equation 1:

```

Iteration 0: log pseudolikelihood = -263.39593
Iteration 1: log pseudolikelihood = -239.43881
Iteration 2: log pseudolikelihood = -239.40829
Iteration 3: log pseudolikelihood = -239.40829
    
```

Fitting comparison equation 2:

