Rural household preferences in transition from traditional to renewable energy sources: the applicability of the energy ladder hypothesis in North Gondar Zone

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ABSTRACT
Adequate, uninterrupted, and environment-friendly energy practices are indispensable for maintaining the quality environment and the health of the households in most developing countries, like Ethiopia. However, for the successful implementation of adequate energy options, the preferences of households should be taken into consideration. The main aim of this study was to analyze the determinants of rural household preferences in transitions from traditional to renewable energy sources and estimate the WTP for various energy alternatives. The study is based on the data collected in 2019 from 212 randomly drawn respondents living in the North Gondar zone. The key result from the descriptive statistics revealed that hydropower was the most preferred with the highest average WTP, 36.86 per month by households' followed by solar energy and transitional fuels. Therefore, the total average WTP of hydropower for the surveyed respondents becomes 93,771.86 per year in the study area. This considerable amount of money implies that households are willing to share the cost of providing renewable energy services. Results of the multinomial logit model revealed that the majority of the sampled households preferred and support the transition from conventional to cleaner energy sources. The results further indicated socioeconomic characteristics of the respondents such as age, family size; income, education, and credit facility were the determining factors of households' fuel choices to satisfy daily energy demand. In this study, an inconclusive result was investigated on the relationship between income and adoption of improved energy sources. Generally, the finding showed that analyzing households' preferences is very important to prioritize among alternatives for the implementation of good energy services. In closing, to achieve adequate energy options, it is recommended that any concerned body takes into account households’ preferences and WTP for the successful implementation of sound energy use practices and creates opportunities that can facilitate the use and advancement of better energy options.

1. Introduction and rationality of the study

Energy is a critical component, particularly at the home level and in terms of the country's long-term growth. It has the potential to boost economic and social advancement while also enhancing input productivity. It is extremely difficult to achieve any development goals without reliable, inexpensive, and long-term energy services. People, communities, and countries in terms of economic growth, social well-being, employment, health, education, security, and environment are proportionally related to energy services (UNDP, 2013; IRENA, 2019). As a result, adequate energy service is a vital component of long-term progress in all countries (UNDP, 2013; SE4ALL, 2013; IRENA, 2019). Households and companies benefit significantly from services like light, electricity, and heat, which provide job opportunities, a more efficient food chain, and greater production and revenue, particularly when modern energy is used (IRENA, 2019).

According to the WHO, if half of the world's households that currently use conventional fuels and stoves switch to suitable cooking sources, they will save $34 billion and produce an annual economic return of $105 billion over a ten-year period (UNDP, 2013). To reach agreed-upon climate objectives, renewables must grow six times faster than total final energy use. For carbon dioxide reduction, increasing renewable

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energy will be critical. Solar power would account for three-fifths of worldwide electricity generation by 2050; with 8500 GW installed capacity and wind power accounting for 6000 GW. Electricity usages in final-use industries will more than from current levels (IRENA, 2019). Energy efficiency and renewable energy supply can produce more than 90% of the desired reductions in energy-related CO2 emissions (IRENA, 2019).

Inadequate energy services in rural parts of developing countries, on the other hand, prompted an economic, political, social, environmental, and health crisis (UNDP, 2013). As a result, the provision of reliable and uninterrupted energy services has an impact on economic and social growth. Regrettably, most developing countries have critical and difficult challenges in terms of access to, reliability of, and efficiency of appropriate energy sources. The lack of universal access to energy, in particular, exacerbates gender disparities. Fuel collection and transportation, indoor air pollution, and time-consuming and dangerous cooking technology disproportionately affect women and children (SE4ALL, 2013; UNDP, 2013). Women often spend one to four hours a day collecting biomass for fuel, putting them at a greater risk of energy poverty and unpaid labor (World Bank, 2011). Fuel collection is also a dangerous duty that exposes women and children to violence, impacting the productivity and well-being of homes and communities (WFP, 2012).

Furthermore, the lack of adequate energy services is intimately linked to food poverty. The high cost of energy for cooking and lighting encourages low-income households to consume more firewood from the neighborhood. In consequence, it causes land degradation, decreasing biodiversity and the environment’s ability to maintain food production, resulting in an increase in food insecurity, particularly in Africa.

With a fast growing population and a significant shift from mainstream sources of energy, Africa is emerging as a major source of global growth for oil, natural gas, and renewable energy. Africa’s energy future is becoming increasingly relevant for global trends as it experiences the world’s largest urbanization. In Africa, and notably in Ethiopia, energy is critical to accomplishing development goals (IEA, 2019). Ethiopia’s government, according to Power Africa (2016), plans to become a middle-income country by 2025 under its most recent growth and transformation plan. Ethiopia’s opportunity to accomplish this lofty goal in agriculture and industry is hampered by existing energy-related challenges. Ethiopia has the potential to produce over 60,000MW of electricity from hydroelectric, wind, solar, and geothermal sources, but only has about 2,300 MW of installed generation capacity to serve a population of over 100 million people. Other important issues facing Ethiopia’s government in growing the country’s energy infrastructure include the need to rehabilitate an aging distribution system, ensuring more effective operation and maintenance of the expanded system, and deliver more power to the country’s off-grid population.

Traditional biomass fuels, which are utilized for a variety of purposes by Ethiopian homes, are a substantial source of energy. Excessive reliance on conventional biomass has a negative impact on the economy, the environment, and public health (Yonas et al., 2013; SE4ALL, 2013). As a result, modern energy resources are necessary for economic development (SE4ALL, 2015), as they are more accessible, cost-effective, and reliable than old rural electrification methods (Ethio-Resource Group, 2012). The task is therefore to provide access to contemporary sustainable energy services while also protecting the environment. The proposed solution in Ethiopia is to introduce and adapt renewable energy technology for home and industrial purposes (SE4ALL, 2013). This is due to the fact that Ethiopia is endowed with renewable energy resources: hydropower (45GW), wind (1,350GW), geothermal (5GW), bio-energy (96 million tons yield per year), and solar energy (5.5 kWh/m².d). Further, Ethiopia’s recognized reserves include coal and natural gas. The development of geothermal and wind renewable resources is now developing rapidly, although being below expectations. In reality, these are likely to contribute a significant portion of future energy needs (ibid). Despite the fact that Ethiopia is naturally endowed with a wide range of cleaner energy sources, both rural and urban Ethiopian households rely largely on conventional fuels to meet their competing energy needs (Yonas et al., 2013).

Ethiopia’s government recently issued a climate-resilient green economy policy to support initiatives that will lessen the country’s vulnerability to climate change while simultaneously reducing greenhouse gas emissions. This strategy’s major goal is to transition to cleaner, more current energy methods for cooking, heating, and other purposes. Furthermore, by increasing the use of appropriate energy sources for industrial, residential, and transportation purposes, this can prevent deforestation and forest degradation (SE4AIL, 2013). The interaction of the socioeconomic system and energy transformation, however, determines the outcome of any energy transition roadmap. Because of their differing transformation ambitions and socio-economic dynamics, the balance between benefits and less favorable results differs per location (IRENA, 2019).

The rate of energy transformation is continually increasing. While progress has been made in recent years, a larger acceleration is required, with a focus on renewable energy, electrification, and energy efficiency. A more prosperous and inclusive environment can result from such energy transformation. Indeed, the energy transformation is more than a basic energy sector transformation. It will also be a complicated change with far-reaching implications for economies and civilizations. It is an economic shift that would bring new opportunities and wealth while also enhancing city air quality, conserving the environment, and protecting the climate. As a result, the subject of energy transformation is multidimensional, incorporating technology, socioeconomics, institutional drives, and financial structures (IRENA, 2019).

Despite the relevance of household energy in most developing nations, rigorous empirical studies on the factors influencing household preferences and choice of domestic energy services are scanty available but slightly growing. This study explored the determinants of rural household preferences in transition from conventional to modern energy sources in the North Gondar Zone of Ethiopia. It examined the choices for different sources of energy and estimate households’ Willingness to Pay (WTP, hereinafter) for the switch from the prevailing to the proposed. More specifically, it was

➢ To assess the available alternative energy sources and the energy consumption pattern in the study area.
➢ To investigate the effects of socio-economic factors on households’ choice in switching to possible cleaner energy options.
➢ To estimate households’ WTP for various energy options.
➢ To analyse rural households perception of the prevailing energy consumption and its effect on the environment.

2. Related literature review

The role of income in determining household’s preference for various energy options are emphasized The energy ladder hypothesis emphasized. Household preferences in the transition from traditional to renewable energy sources, which are cleaner, more efficient, and convenient, are influenced by income. To put it another way, the hypothesis found that households with higher incomes employ secondary energy technologies such as biogas, natural gas, LPG, and hydropower, which are both environment friendly and expensive fuels. Meanwhile, low-income households employ conventional energy sources such as wood, dung, charcoal, and agricultural residues (Hosier and Dowd, 1987; Barnes and Floor, 1999; Helberg, 2005). Households move up the energy ladder, from traditional energy sources to advanced energy technology, as their income rises (Baldwin, 1986; Smith, 1987; Leach, 1992) for a variety of purposes.

So far, a large number of studies have been undertaken on the pattern and determinants of household energy consumption. It has been the focus of precursor studies with different tools of econometric analysis, depending on the dimensions of household energy consumption covered by a study. Here are the brief discussions of a handful of environmental
studies undertaken in different areas by different authors related to problems of inadequate energy services. Then they discovered that a household's energy source selection is influenced by the interaction of several factors that influence household energy demand. 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. Deshmukh et al. (2014) used a multinomial logit model to analyze factors that influence fuel choice for cooking and heating in a rural area of India's Buldhana region. The findings demonstrated that the size of the family, the age of the household head, the level of education, the size of the household for the type of fuel used, and the kind of dwelling status were the determining factors for the type of fuel used. Among mutually exclusive and highly distinct fuels for cooking and heating, the study found that fire-wood would be the most important fuel for the majority of homes in assessed communities. Finally, the study proposed that the impact of fuel pricing on fuel choice be considered, and that improving public knowledge would make shifting to cleaner fuels easier. Another study was conducted by Olushola et al. (2018) on households’ cooking energy choices and the determinants of transition to clean modern sources of energy in rural Nigeria. The finding indicated that household head's age and education, household size, income, residential status, and farmland possession are significant determinants of cooking energy choice and transition, probability of switching to cleaner sources of fuel. This result was consistent with the results investigated by Adeyemi and Adereluye (2016). Further, the study found that fuel-wood and charcoal remain the dominant cooking energy choice of the surveyed households. 63% of the rural households rely on fuel-wood as their primary cooking energy, about 21% of the population used kerosene, 12 percent using gas, while only 4 percent use electricity as their main source of energy for domestic cooking. The study suggested using cleaner cooking energy sources can achieve the development agendas. Lay et al. (2013) have investigated the driving forces 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 preference of households choice for various energy services such as lighting. Twerefou (2014) also, undertake a study on households’ WTP for improved electricity supply and the influencing factors of WTP using a contingent valuation survey in Ghana. 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.

During rural power shortages 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. Gebregeziabher et al. (2012) investigated the behavior of urban households to transit from traditional fuel based to better non-deplatable energy sources in Northern Ethiopia. The finding revealed that the transition energy rely on the adoption of appropriate stove technologies. One of the drawbacks of this study is the inability to identify to which modern electricity type respondents would like to transit from the prevailing conventional biomass.

Reta (2020) conducted a study in Hexosa (Harbe) and Boset (Xiyoo) 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. Among the two sources of renewable electricity services, the study found that households preferred grid line to solar electricity services, and monthly payment vehicle is more convenient for the rural household than a lump sum. 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.

2.1. Conclusion: lesson learnt and gaps identified

Various studies have proved the existence of energy poverty, and as far as secondary energy sources are concerned, households are willing to bear the cost of energy sector development on an average basis. In addition, they have placed a great emphasis on modern energy sources in order to alleviate the poverty of depletable energy, meet climate change targets, and maybe mitigate environmental concerns. Socioeconomic and demographic factors such as education, income, occupation, family size, age, household structure, and others have interesting effects on households' WTP for improved energy services.

To the best of the researcher's knowledge, no research has been done in the study area on the current alternatives for better energy services: lighting, cooking, heating, communication, and entertainment. As a result, a more comprehensive examination of the various factors influencing household decision-making may enable a more realistic integration of rural households’ attitudes, habits, and behavior into future policy and corporate development in the energy sector. As a result, this research adds to the growing body of knowledge about the factors that influence household choices and willingness to pay for the move from traditional to modern energy options.

Furthermore, the successful implementation of adequate, continuous, and environmentally friendly energy services should be based on trustworthy data on the types of energy sources used and their effects on residents' health and the quality of the environment. Unfortunately, such information is scarce in the research area, and setting appropriate energy policies is difficult without specific scientific data. As a result, gathering benchmark data on the current state of energy service systems in the area can aid in the development of appropriate energy services, service charge rates, and schedules, as well as the drafting of future concession agreements between the Zonal administration and service providers. Another aspect of this research is to examine the mismatch between what service providers can deliver and what the public prefers. Estimating WTP for better energy service options enables us to better understand the impact of effective energy option implementation. Thus, information obtained from this study can serve as an input for sound policy formulation to fill and reconcile the affordability of supply and public WTP for energy services offered.

3. Data and methods

3.1. The study area description

The data for this study is based on a cross-section survey of rural households in Dabat Woreda. Dabat is one of the 21 districts in Semien
Gondar Zone, Amhara Region of Ethiopia and bordered on the West by Tach Armachiho, on the south by Wegera, on the Northeast by Debark, and on the Northwest by Tegeda. Mount Ras Dejan is the highest peak, in this woreda and Ethiopia.

According to the 2007 survey of the Central Statistical Agency of Ethiopia (CSA), this Woreda has a total population of 145,509 reside in this woreda. However, the estimated total population in 2012 is 159,091, of whom 10.87% is urban dwellers and the remaining fraction lives in rural areas. A total of 31,111 households were counted in this Woreda, resulting in an average of 4.68 persons to a household. The majority of the dwellers are follower of the Orthodox Tewahido, with 97.7% reporting that as their religion, while 2.4% of the population said they were Muslim.

The high dependency of the district’s population on unclean traditional biomass and subsistence agriculture accelerates various human health and environmental challenges and the agri-environmental scheme is not practiced well yet. Production and consumption shall increase to meet the growing competing needs of the population which can, in turn, provokes over exploitation of the existing natural resources and dwindling of environmental view. Any economic activity uses resources as a source of inputs and economic development has major impacts on the environment by degrading soils, polluting water bodies, altering landscapes, and threatening biodiversity, in some cases driving species into extinction. Moreover, modern energy technologies which are efficient in many dimensions and environment friendly are rarely available. Thus, introducing and scaling up sustainable energy options can serve as a catalyst to leapfrog from energy poverty and can achieve sustainable development goals by creating a better future. Therefore, conducting a rigorous research plays a paramount relevance to arrive at sound natural resource management practices and better environmental intervention packages, green growth such as renewable energy source.

3.2. Data, sampling issues, and survey procedures

To achieve the research objectives, this study has deployed primary and secondary data sources. Primary data was garnered mainly through formal household survey (Structured questionnaire) on 212 randomly selected rural households covering the various sub-districts of Dabat Woreda, Amhara National State.

In so doing, this paper has reviewed criteria for determining a sample size and explains several strategies for determining the representative sample size. The size of the sample included under a study is influenced by a number of factors: including but not limited to the purpose of the study, population size, resources, the allowable sampling error, and the confidence level (Alpizar et al., 2001; Israel, 2013; Polonia, 2013). The target population is neither the individuals nor the total population rather household heads in Dabat Woreda. Two-stages stratified random sampling were employed to draw a representative sample of households and then to conduct a household survey, and collect a data using in person interview. The district administration is organized into 30 administrative sub-districts, the lowest administrative unit. Stage one involved random selection of nine local administrative units (Namely: Abtara, Wokin Zuria, Talak Mesk, Dara, China, Ajirje, Janora, and Charbita) out of 30 prevailing kebeles in the district.

In stage two, the sample farm households in the selected sub-districts were determined using a proportionate farmer’s population weights. Thus, the administrative list of farmers associations in selected Kebeles was used as a final unit of analysis for this study and proportionate simple random sampling technique was followed to draw representative sample farm households. Hence, considering the nature of rural households in terms of energy consumption pattern, the tradeoff between cost (due to financial, time, and personnel constraints), and precision level structured survey questionnaire was administered to a total of 212 rural households.

The questionnaire comprised of households’ socioeconomic characteristics, energy consumption patterns and preferences, and overall perceptions about the use of different sources of energy. Further, field observation and in-depth interviews from different local government offices were conducted as a complement to the main survey. Valuable information was also obtained from the office of energy, environmental protection, and natural resource conservations about the existing practices. After the required data was collected, it was coded, entered, and cleaned using Excel.

3.2.1. Ethical clearance

To make the respondents comfortable and protect their rights, the researchers tried to consider some ethical issues during data collection. The study passed two sets of clearance; the University of Gondar institutional review board and permission letter from direct responsible authority of the topic at hand.

3.2.2. Informed consent

Participants of this study were provided written information about the study and requested for their willingness to take part in the study. All participants had the opportunity to ask questions about the study. Due care was taken to ensure that potential participants provide individual informed consent providing them with opportunities to withdraw or to refuse to answer specific questions whenever they wish. With the help of trained data collectors, the literate participants were asked to give their written consent while participants who cannot read and write were confirmed consent verbally.

3.3. Model specification and its grounding

The likelihood of respondent n in selecting option i from a set of mutually exclusive energy sources in the study area will be estimated using the multinomial logit model (McFadden, 1974; Green, 2003).

\[
\text{Prob}(V_i=j) = \frac{\exp(V_{i,n})}{\sum_{j=0}^{4} \exp(V_{j,n})} = \frac{\exp(V_{i,n})}{\sum_{j=0}^{4} \exp(V_{j,n})}
\]

where: PR \( [Vin = j] \) from zero to four is the \( n \)th respondent likelihood of choosing any one of the following energy options: Solid fuel, 0 (Wood, agriculture residue, and animal dung) as a reference category, Transition fuels, 1 (Charcoal, kerosene, and petrol gas) for cooking stove and for lighting, Hydropower (2), Biogas production, 3 (Either underground or plastic tube biogas digester), and Solar energy (4) for lighting and charging.

The idea of consumer behavior best explains households’ preferences and consumption of alternative energy services. As a result, the theoretical framework of utility maximization serves as the foundation for our model specification. The random utility theory proposes that rational individuals choose the most preferred options that provide them with the greatest utility from a set of viable options (Adamowicz and Boxall, 2001; Varian, 2010).

The objectives of this paper is to see how changes in household socioeconomic variables affect preferences for switching from depletable to renewable energy services for a variety of purposes, including but not limited to cooking and lighting. The choice of a better source of energy services by rural households is treated as a dependent variable in this study. It has a value attached to it, and if a respondent selects one category of energy sources, the selected source will be assigned one value, while the remaining alternatives will be assigned zero. It is hypothesized that several socioeconomic and environmental awareness independent variables influence and explain household preferences for better energy options. The specified multinomial indirect utility function takes the form,

\[
V_{in} = ASC + \beta_1 S_1 + \beta_2 S_2 + \ldots + \beta_k S_k + \epsilon_i
\]

The number of socioeconomic variables of the respondent is assumed to be k. The vector of estimated coefficient \( \beta_1 \) to \( \beta_k \) is attached to socioeconomic characteristics of the respondent labeled by \( S_1 \) to \( S_k \). Where,
ASC is the Alternative Specific Constant (ASC), which represent the effect of systematic but unobserved factors that explains the individuals’ choices. Technically, ASC reflects the differences in the error terms and it captures the effect on utility of any socioeconomic variables that are not included in choice specific attributes (Biro1 et al., 2006). In a multinomial logit and nested logit with j options, it is possible to have J-1 ASC (Othman, 2002). Drawing from Greene and David (2002), we adopt the following multinomial logit model (Eqs. (1) and (2)) for the purpose of analyzing the determinants of selecting the various sources of energy.

\[
V_{in} = ASC + \beta_1 \text{Age} + \beta_2 \text{Sex} + \beta_3 \text{Ms} + \beta_4 \text{Fs} + \beta_5 \text{Educ} + \beta_6 \text{LF} + \beta_7 \text{Cred} + \beta_8 \text{NFA} + \beta_9 \text{Incom} + \epsilon
\]

where:
- \( V_{in} \) is the indirect utility function of various energy sources
- \( \text{Age} \) = age of the household head in years
- \( \text{Sex} \) = Sex of the household head: labeled by 1 if female, and zero otherwise.
- \( \text{Ms} \) = Martial status of the respondent: 1 if married, and zero otherwise.
- \( \text{Fs} \) = Family size of the household
- \( \text{Educ} \) = level of education by the household, 0, for illiterate, 1 for those who have attended any education: informal education or formal education.
- \( \text{LF} \) = Number of Labor force in the household, \( Cred = \) Access to credit service: 1, if yes, and zero otherwise.
- \( \text{NFA} \) = engagement in nonfarm activities: 1, if yes, and zero otherwise.
- \( \text{Incom} \) = average estimated annual income of the households from various sources, and \( \epsilon \) = Error term.

3.4. Methods of data analysis

The information gathered was examined using descriptive statistics including mean, percentage, and frequency. Instead of using standard regression analysis, the paper used discrete choice models to do the econometric analysis. This is because the model’s outcome variable is a qualitative response rather than a continuous variable. As a result, the classical regression assumptions will be broken, and the ordinary least square method may not be adequate for analyzing such discrete choice models (Woodridge, 2002; Baum, 2006; Cameron and Trivedi, 2009; and Greene, 2013). In order to investigate the determining factors of household choices and WTP for the deployment of enhanced energy technologies for multiple use services, a multinomial logit model was proposed (see Table 1).

4. Results and discussions

4.1. Descriptive statistics

For this study a total of 212 household heads were interviewed. The questionnaire was responded by the head of the household or a responsible and a representative adult in case their absence. Fortunately, except eight, all respondents answered the required questions, willing to participate for enhanced energy interventions. Thus, it avoids the problem of sample selection bias (Mekonnen et al., 2010).

The socioeconomic characteristics of the respondents are revealed in Table 2. The result showed a large proportion of respondents (52%) were female headed households. This was mainly because they were the only one found at home. Besides, even when both wife and husband found at home, the husband may prefer to send his wife to the interview indicating that women are more concerned and aware off about energy use in the vicinity. While, the remaining, 48% of respondents were male headed households. With regard to marital status, 86% of respondents reported they were married which may have a significant implication on the use and adoption of new energy technologies.

The education level of the interviewed household head was very low; more than 73% of the household heads did not read and write, have not attend any school education. About 24.2% of the respondents have attended basic level of education. Only 2.5% of the interviewee had attended formal school. Respondents were also asked about their main source of income. The result revealed that more than 90% of respondents’ source of income is emanated from rain feed agriculture. The remaining respondents’ source of income is from engagement in non-farming activities such as trade, daily work, renting farm inputs and house, and beef. About 37.68% of respondents reported that they got credit opportunity from formal financial institutions such as Amhara Saving and Credit Association for various purposes.

Results from Table 3 further showed that the average years of age a household has stayed in the study area was 38. The youngest respondent was 26 years and 77 years for the oldest respondent. The average family

| Table 2. Descriptive statistics for selected variables of the sample respondents. |
|-------------------------------|------------------|-----------|
| Qualitative Variables          | Labels           | Percentage (%) |
| Sex of the Hb. Head            | 1, if female, 0 otherwise | 52        |
| Marital status of the Hb. Head | 1 if single | 1.5           |
|                                | 2, if married | 86           |
|                                | 3, for any other | 12.5       |
| Level of education             | 1. Illiterate | 73.3           |
|                                | 2. Informal education | 24.2  |
|                                | 3. Formal education | 2.5       |
| Source of income               | 1. If agriculture 0 otherwise | 91.097   |
| Access to credit               | 1, if yes and 0 otherwise | 37.68    |
| Quantitative Variables         | Minim            | Average  |
| Age of the Hb. Head            | 26               | 34        |
|                                | 10.319           | 78       |
| Family size                    | 2                | 4.1       |
|                                | 7                | 4.750    |
| Labor force size               | 2                | 3.8       |
|                                | 6                | 8.907    |
| Annual income from timber, charcoal | 400        | 679.381   |
|                                | 7826             | 13.543    |
| Annual income from Dungs       | 156              | 495       |
|                                | 1350             | 8.946    |
| Annual Hh. Income from all source | 7612.10      | 14700     |
|                                | 40,000.00       | 16.789    |

Source: Author’s Computation using Limdep 10 Nlogit 5 from Field Survey Data, 2019.

| Table 3. Monthly willingness to pay for alternative sources of energy. |
|-----------------------------------------------|------------------|-----------|
| Sources of Energy                            | Willingness To Pay(WTP) |
| Minimum                                      | Average           | Maximum  |
| Transition Fuels                             | 0                 | 14.516   |
| Biogas production                            | 0                 | 6.367    |
| Solar Energy                                 | 6                 | 28.942   |
| Hydropower                                   | 12                | 36.86    |

Source: Author’s Computation using Limdep 10 Nlogit 5 from Field Survey Data, 2019.
size of the household was 4.1. Further, the maximum family size who is economically active was 6 and the average was 3.8 per household in the study area. Getting realistic information on gross household income from all sources was challenging. In cases, households became reluctant to elucidate their yearly income, their yearly expenditures on the consumption of various goods and services have been used as a surrogate. From the enlisted income source categories, the result indicated that a wide range of responses starting from ETB 5612 to 40,000 and the average was found to be 14,700. This showed a high degree of income inequality, where many are poor while very few people have high income (see Tables 4, 5, 6).

The key result from the descriptive statistics revealed that hydro power was the most preferred with the highest average WTP by rural farm households’ followed by solar energy and transitional fuels (See Table 3). Whereas, biogas source of energy was found to be the least preferred energy alternatives. The average WTP of respondents for hydro power energy services was 36.86 per month. Thence, the total average WTP of this option for the surveyed respondents becomes 93,771.86 per year in the study area.

The table below showed the estimated average quantity of energy produced and consumed during the study period. Larger proportion of energy production and consumption was mainly obtained from collecting firewood from forest and nearby community. It was followed by the production and consumption of agricultural residue: straw, dung and others. This indicated the traditional source of energy is the dominant form of energy sources in the study area. The implication of dependency on primary energy sources which are not environment friendly causes health problems, deforestation, carbon dioxide emissions, and intensified global climate change at large.

However, the attitude towards the adoption of solar energy is promising and slightly increasing indeed the supply is scanty available. About 63% of respondents stated that they have adopted non depletable energy sources, solar energy. Further, 3% of the respondents who are geographically suited in the outskirt of the towns revealed that they got benefit from electricity generated from hydropower services. Whereas, the study indicated that the geothermal and bio gas as alternative sources of energy were rarely available in the study area. The implication is that

Table 4. Estimated energy production and consumption for various sources in 2019.

| Source of energy                                  | N   | Ave. quantity (Multiple response is possible) |
|--------------------------------------------------|-----|---------------------------------------------|
| Collecting firewood from forest and nearby        | 212 | in Kg. per Month:370                        |
| Agricultural residue: Straw, dung and other       | 212 | in Kg. per Month: 250                       |
| Charcoal                                         | 212 | in Kg. per Month: 160                       |
| Petrol Gas Cooking stove, lighting & irrigation   | 212 | in litter per month:0.765                   |
| Biogas production                                | 212 | in litter per Month: 0                       |
| Solar energy for Lighting and charging            | 212 | **Yes I do have (%ge):63.06**               |
|                                                  |     | 1. Yes I have with 3 Ampoule (12.02%ge):    |
|                                                  |     | 2. Yes I have with 2 Ampoule (23.04%ge):    |
|                                                  |     | Yes I have with 1 Ampoule (28%ge):           |
|                                                  |     | No, I did not have(%ge):36.94               |
| Geothermal energy                                 | 212 | N.A                                         |
| On-grid electricity                               | 212 | 3%                                         |

Source: Author’s Computation using Limdep 10 Nlogit 5 from Field Survey Data, 2019.

Table 5. Rural farm households’ perception about the prevailing energy service practice & effect.

| Perceptions                                      | N   | Agree | Strongly Agree | Disagree | Strongly Disagree |
|--------------------------------------------------|-----|-------|----------------|----------|-------------------|
| There is natural resource exploitation.           | 212 | 33%   | 44.2%          | 21.3%    | 1.5%              |
| Problem of environmental degradation in your vicinity. | 212 | 53.6% | 23.1%          | 19.3%    | 4.0%              |
| To use traditional biomass is harmful for the health. | 212 | 39.5% | 40.5%          | 17.0%    | 3.0%              |
| Reading with electricity/solar on night is better than the usual for children. | 212 | 60.2% | 30.7%          | 8.0%     | 1.1%              |
| At the moment, it is easy to read at night in the home. | 212 | 12.0% | 4.8%           | 52.5%    | 30.7%             |
| Renewable energy sources makes life easy than traditional does. | 212 | 40.6  | 39.8%          | 16.2%    | 3.4%              |
| Local energy and development office provides awareness/training on the adoption renewable energy. | 212 | 24.2% | 5.9%           | 32.5%    | 37.4%             |
| I get news and information from radios and TV provides good information relevant about energy. | 212 | 12.5% | 4.0%           | 48.2%    | 35.3%             |

Source: Author’s Computation Using Limdep 10 Nlogit 5 from Field Survey Data, 2019.

Table 6. Results of marginal effect for MNL model for choices to improve energy services.

| Variables            | Transition fuels Coefficients (R.Se, P-value) | Hydro power Coefficients (R.Se, P-value) | Biogas production Coefficients (R.Se, P-value) | solar energy Coefficients (R.Se, P-value) |
|----------------------|-----------------------------------------------|----------------------------------------|-----------------------------------------------|------------------------------------------|
| Age of Households    | 0.0486 (4.596, 0.0000)                        | 0.0486 (4.596, 0.0000)                 | -0.964 (0.567, 0.032)                         | 0.341 (12.75, 0.17)                      |
| Sex of Households    | 0.520 (-1.24600, 0.001)                       | 0.520 (-1.24600,0.001)                 | 0.165                                         | 0.190 (3.25,0.074)                       |
| Martial Status       | 1.238                                         | 1.238                                  | 0.0041                                        | 0.0002                                   |
|                      | 0.284, 0.24                                  | 0.284, 0.93                           | 2.34, 0.27                                   | 2.58, 0.45                               |
| Family Size          | -0.05 (0.92, 0.34)                            | -0.05 (0.92, 0.34)                    | 0.68 (0.730, 0.000)                          | -0.240 (3.810, 0.003)                    |
| Level of Education   | 0.337 (0.649, 0.041)                          | 0.337 (0.649, 0.041)                  | 0.17 (0.142, 0.007)                          | 0.368 (5.684, 0.000)                     |
| Credit               | 0.0866 (4.696, 0.055)                         | 0.0866 (4.696, 0.055)                 | 0.193 (1.74, 0.074)                          | 0.821 (0.103, 0.0046)                    |
| Non-farming activity | 0.173 (7.970,0.000)                           | 0.173 (7.970,0.000)                   | 0.829 (4.972,0.137)                          | 0.625 (0.678, 0.000)                     |
| Yearly Income        | 0.427 (0.472,0.000)                           | 0.427 (0.472,0.172)                   | 0.210 (0.734, 0.000)                         | 0.610 (1.896,0.0000)                     |
| Intercept            | 1.438                                         | 1.424                                  | 0.258                                         | 0.624                                    |
| Likelihood ratio statistics | 1135.078                                     | 672.310                               | 500.017                                       | 128.11                                   |
| Probability of likelihood ratio | 0.0000                                    | 0.0000                                | 0.0000                                        | 0.0000                                   |
| Pseudo R²            | 0.015                                         | 0.463                                  | 0.381                                         | 0.428                                    |

Source: Author’s Computation using Limdep 10 Nlogit 5 from Field Survey Data, 2019.
rural farm households in Dabat Woreda are conscious about the benefit of secondary sources of energy especially for solar energy and the negative impact of traditional energy services practice on dwindling of the environment and the health of the resident. Thus, as far as the supply for renewable energy services do exist in suffice quantities at reasonable price, then households might be willing to switch or transit from traditional to non depletable energy sources such as solar energy, hydropower and others.

About 44.4% and 28% of respondents reported that they were strongly agree and agree respectively on the effects of the use of traditional source of energy on natural resource exploitation. As it is revealed from the table, majority of the respondents gave a positive answer about the adverse impact of inadequate energy services practice on health, resource depletion, and environmental degradation at large. On the other hand, majority of the respondent reported a negative answer about adequate training on the use of renewable energy sources and access to information from Television and Radio channels, the existing energy use practices for children education.

### 4.2. Econometric analysis

The econometrics software package, LIMDEP 10.0 NLOGIT5.0 was used to estimate the parameters of the multinomial logit model. Empirical results below revealed the parameters of the multinomial logit model of rural farm households of energy use for multiple purposes in the North Gondar Zone. Hydropower, transition fuel, biogas production, and solar energy were considered in the model. The models are statistically significant as the p-value of the likelihood ratios is significant at a 1% level.

The variable age was statistically significant at 5% level and positive sign for transition fuel. This result indicated that 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. Thus they preferred the improved energy options. This finding is inconsistent 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.

Again, this variable was statistically significant (P < 0.032) for bio gas production but with negative influence of choosing bio gas. This is due to the fact that, alike fuel wood, this energy option requests more resources as an inputs such as labor in each and every stages of production. To be more specific, a 1% increase in the age of the household head causes 0.04 per cent increase in the use of transition fuels, 0.96 per cent decrease in the use of biogas sources of energy. However, it was found to be statistically insignificant for hydro power and solar energy. Whether the respondent is younger or older, it has nothing to do with the choice in the use of hydro power and solar energy.

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), and 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. Albeit, there is no difference between female headed and male headed households in choosing biogas energy for this study. 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. The variable marital status of the household head has nothing to do with a choice on among different sets of energy sources. There is no difference in making choices between the reference category, solid fuels and other improved sources of energy by married and unmarried households.

The estimates for household size revealed that a positive relationship for biogas production and a negative preferences for hydro power. The implication is that as the size of households’ increases by 1 %, the likelihood of using hydro power decreases. Fire wood as it is relatively cheap that larger households may have extra and free labor for firewood collection and biogas production no matter the productivities. Further, the coefficient for educational level was significant and has a positive relationship with the choice of improved options. The implication was that respondents with higher level of education were more likely to support the upswing energy sources with cleaner and uninterrupted services. This was due to the fact that education can increase the awareness of respondents about the negative effect of using solid fuels and the importance of having good energy sources. This was not contradictory with findings of Mekonnen and Kohlin (2008), Deshmukh et al. (2014), and Reta (2020).

Concerning about engagement in non-farming activity, it was found to be statistically significant and had positive signs for hydro power, transition fuels, and solar energy but not for biogas energy. Hence, any concerned bodies shall create opportunities other than farming activities so that farmers will be able to left out of energy poverty and adopt improved energy technologies. Besides, respondents who have received a credit opportunity were more likely to use improved energy services than who did not received. Thus, access to credit from formal financial institutions has a positive effect for better energy options. It can speed up the transition from the conventional source of energy to transition fuel to sophisticated and environment friendly energy options in energy ladder hypothesis.

The coefficient for the income of the respondents was significant and had a positive relationship with the choice of the improvement for transition sources of energy. As income increases, the choice for this improved energy sources also increases. This was consistent with economic theory and many environmental literatures; positive relationship is there between income and demand for environmental good, increase demand for improved energy services, presuming the good is normal. However, in this study, an inconclusive result was investigated on the relationship between income and adoption of the highest improved energy sources such as hydro power. Applicability of the Energy Ladder Hypothesis (ELH) does not mean that the alternative sources of energy are mutually exclusive to one another. A high level of income caused the household to reduce the number of traditional sources of energy consumption. But, it can’t be zero due to power shortage and if renewable energy sources are limited in supply and the existence of sudden shock to income which leads back to the consumption of primary biomass energy choices. Thus, the author argued about the applicability of ELH relies on many factors. When there is an uninterrupted power supply and ability of secondary sources of energy to meet all domestic needs and wants, feasible prices, the rationality of consumer, and consciousness of households about the benefit and cost of multiple sets of energy source, there would be a positive relationship between income and consumption of environment-friendly energy sources.

### 5. Conclusions

Energy is a critical determinant in answering the question of a country’s long-term development. Access to proper energy services makes it feasible to achieve any development goal. It’s worth noting that proper energy services are critical issues for homes that should be prioritized. However, the preferences and WTP of the households should be taken into account for the successful adoption of sufficient energy options. Nothing has been investigated concerning the current WTP for the transition from existing to upgraded energy sources, to the best of the
6. Policy implications

Based on the results of this study, the following policy recommendations are forwarded to have efficient energy options.

➢ Within farm households in the North Gondar Zone, there is significant choice variation. As a result, any policy that aims to create a more efficient energy sector should take into consideration information regarding household preferences before deciding on the best energy solutions.

➢ Respondents were willing to pay a higher price for better energy service. This implies that the service provider can generate revenue from households in order to strengthen the energy sector. Finally, in the energy sector, the imbalances or lack of coincidences between demand and supply can be reconciled.

➢ Any concerned body should encourage intensive public awareness of the advantages of proper energy services.

➢ Access to credit plays a vital role in maintaining adequate energy services. Thus, any concerned body should facilitate credit opportunities for rural farm households to easily adopt better energy technologies.

➢ Engagement in farming activities was found to be significant in determining households’ transition from primary to secondary sources of energy. Thus, policy makers, that have targets for the improvement in the energy sector should promote intensive public awareness of the benefits of using proper energy services, cost of having inadequate energy options, and provide resources to facilitate such activities. Side by side, plants or the supply of energy services should be encouraged and developed, which will generate employment opportunities.

Declarations

Author contribution statement

Eshetie Woretaw Meried: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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