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Hydropower Dam-Based Rural Electrification in Ethiopia: The Case of Amerti-Nashe Hydropower Plant, Horo Guduru Wollega Zone

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Abstract
Expanding electricity access and energy in rural areas is a central policy issue in Ethiopia. The hydropower plant is one of the solutions to solve the shortage of electric energy in remote rural areas. This research deals with Amerti-Nashe dams induced rural electrification in western Ethiopia. The main objectives of this study were to investigate the rural electrification impact of small dams on local communities in Ethiopia in the case of the Ameri Nashi dams. The study collected primary data from a sample of 316 households who live in the vicinity of the dam. Statistical analysis such as Chi-square test, paired t-test, and binary logistics model were performed to determine differences in energy distribution, use of energy before and after the dam project, energy adoption status, challenges of households to adopt electric energy and energy impacts. The result of the research shows that more than half of the population was not provided energy from the nearby Ameri-Nashe and Fincha dams and instead the majority of the population of the zone depends on traditional fuel as a source of energy. There was a disparity in the distribution of electric energy among the sample households due to different factors like distance from grid line unaffordable cost of adoption, and grid-based electric energy.
Keywords: hydropower plant, rural electrification, socio-economic impact, Horo Gudru
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1. Introduction

1.1 Introduction to the study and study objectives

Rural electrification has multiple benefits that include lighting, access to information, improved study environment for school children as well as improved businesses which in turn create employment opportunities and contribute to development and poverty reduction (Nyaboga et al., 2020). Khandker et al., (2009), noted that rural electrification projects are frequently justified because they aim to improve household welfare by providing a higher quality of life or increased productivity. Rural areas continue to be residential places to the majority of Africa's population, but they rely on traditional fuels for their energy needs. As a result, the importance of providing modern energy sources to rural areas cannot be overstated (Karekezi & Kithyoma, 2002).

Access to energy is a major concern in international socio-economic development.(Quoilin & Orosz, 2013). As noted by Imo et al., (2020), adoption of energy is the primary requirement for any country's economic growth and supports the modern economy (Bezabih, 2021). Electrical energy is becoming an essential commodity for modern production process today (Bezabih, 2021).

As a result, one of the 17 Sustainable Development Goals (SDGs) on the agenda is to ensure that all people have access to affordable, dependable, sustainable, and modern energy (Yang & Yang, 2018). According to UN SDG 7, everyone should have access to affordable, reliable, sustainable, and modern energy by 2030 (Uamusse et al., 2019). Providing universal access to affordable, reliable, sustainable, and modern energy by 2030 will open up a new world of possibilities for billions of people, including new economic opportunities and jobs, women's empowerment, improved education and health, more sustainable, equitable, and inclusive communities, and increased climate change protection and resilience (UNDESA, 2018).

However, large parts of the population, particularly in developing countries' rural areas, are unable to meet this basic human need, which is frequently due to a lack of access to modern energy sources such as electricity, liquid and gaseous fuels (Rordorf, 2011). Tiruye et al., (2021) noted that with the growth of population and industrialization, the global energy demand is increasing at an unprecedented rate. For much of the world's population, household fuel demand makes up more than half of total energy demand (Goldemberg et al., 2000). Tucho & Kumsa, (2020) also stated that having access to improved energy technology is essential for social security, livelihood improvement, and economic growth. To achieve these objectives, the global deployment of renewable energy (RE) has been expanding rapidly. For instance, the RE sector grew by 26% between 2005 and 2010 globally and currently provides about 20% of the world's total power (including hydro power) (Fullerton et al., 2008). However as noted by ACPC, (2011) lack of access to energy services is one of the main constraints to economic development in Africa. Only about 31% of the population of Sub-Saharan Africa has access to electricity, with 14% access rate in rural areas.

With the goal of overcoming the energy problem, various studies evaluated renewable-based systems as a rural electrification option, primarily comparing them to other decentralized options such as small diesel generators, PV-diesel-wind hybrid systems, or even fuel cell-based systems (Mahapatra & Dasappa, 2012). For instance Singal et al., (2007) noting the increasing demand of energy and negative impacts of fossil fuels on the environment, has emphasized the need for harnessing energy from renewable sources. RE systems represent the most environmentally friendly and cost-effective means of providing electricity to those living in rural communities (Faruqui, (1994), Urmee et al., 2009).

Ethiopia has an abundance of RE resources and the potential to generate over 60,000 MW of electricity solely from hydropower, wind, geothermal, and solar (Tiruye et al., (2021). According to the energy progress report, approximately 58 million Ethiopians do not have access to electricity, and the overall electrification rate is 43% of the total population (P,erera, 2018). The power industry is almost entirely reliant on hydropower, which accounts for 94% of installed capacity and more than 99% of power generation (FDRE, 2013). According to the National Electrification Program, Ethiopia aims to achieve universal access to electricity by 2025 (W. BANK, 2018). Despite having a large hydropower potential, Ethiopia has been unable to use its water resources to generate electricity, owing to a lack of financial resources. Ethiopia entered the new millennium as one of the world's worst countries in terms of rural electrification, owing to the world's lowest per capita energy consumption rates (Fried & Lagakos, 2021).

Electricity distribution and usage differ significantly across the country, with rural residents frequently overlooked due to high prices and technical issues. As noted by Perera, (2018) the rural/urban disparity in access to electricity remains stark: despite electricity access in urban areas have grown steadily over the period 1990–2016, access in rural areas has only really picked up since the early 2000s. The rural/urban gap is so wide that 55 million people in rural areas do not have access to electricity, compared to 3 million in urban areas. Ethiopia is building numerous dams to meet the electricity needs of the country's large communities. In line with this, the Amerti-Nashe dam was built as part of a solution to the country's high energy demand.

The construction of dams has implications for the local community in addressing their energy demands. However local communities around the dam area are not considered as priority concerns. As a result, hydropower dam-based rural electrification in the vicinity of Ethiopia's dams has not been the subject of a study by researchers and developers. For instance, Degefu et al.,(2015) research on "Hydropower for sustainable water and energy development in Ethiopia" was mainly about hydropower as an agent of national development in general. van der Zwaan et al (2018) study on "Prospects for hydropower in Ethiopia: An energy-water nexus analysis" focused on the development of hydropower for irrigation and national electrification. Therefore, there is a gap in research that focuses on hydro dam projects and the ability of the community to access grid-based energy from these projects.

Hydroelectric dam construction has recently become a significant development intervention in an attempt to meet the demand for electric energy in both rural and urban areas. The study provides important information for planners, policymakers, administrators, researchers, and other stakeholders who are concerned with the construction of the hydroelectric dam in the rural community, at the national and local levels. The study contributes to the literature on rural electrification by generating information on dam-induced electrification as opposed to other sources of electricity.

The Nashe dam alone has a capacity of 97 MW of electric energy generating potential and was built for both electricity and irrigation systems. The electricity generated by the Amerti-Nashe project uses the power lines of the 134MW Fincha hydroelectric dam project to enter the national power grid for distribution. This study focuses on analyzing the energy contribution and impact of Amerti-Nashe in combination with the old dam Fincha-hydro project on the local community in the study area. In particular, it addresses whether the community in the vicinity of these hydropower potential reservoirs has access to electric energy or not and fills the research gap stated above.

The principal objective of the study was to investigate the impact of small dams on rural electrification in Ethiopia. Particularly, this research was undertaken to achieve the following specific objectives: (1) assess dam induced rural electrification in the Amerti-Nashe hydroelectric dam vicinity area (2) identify the challenges households face to adopt grid-based hydroelectric energy in the study area; (3) Determine the socio-economic effects of hydroelectric grid-based energy on households in the research area following its adoption.

2. Materials and methods

The materials and methods section contains a logical design of the study in order to achieve the stated objective. The section combines the methodological parts of the study such as research approach, data collection, sampling, and methods of data organization and analysis.

2.1 Description of the study area

Amarti_Nashe dams are located about 250 km Northwest of Addis Ababa in the Blue Nile River basin (Abay river). The area comprises high land, Plateau, with an elevation of more than 2000m around the dams above sea level and dramatic escarpments dropping over 600m to low land to the Abay/Nile gorge. The Blue Nile is also known as the Abay River and it drains most of the north central and northwestern parts of Ethiopia which includes Horo Guduru wellega zone. Administratively, the study area is located within Horo Buluq and Abay Coman districts in Horo Guduru Wollega zone. The Nashe river valley on which the reservoir was built, starts on the highland plateau to the North East of Shambu town and flows from west to east for above 10 km and then in the northerly directions for another 7 km. The valley elevation is 2200m above sea level with the surrounding ridges extending to over 2500m above sea level. The Amerti river also starts from northeast of Shambu town parallel to Nashe rever with 5 to 10 km distance and merge with Nashe river before they mix with the Abay River.

Climatically, the Amerti-Nashe dams are located on a high land plateau at an elevation around 2200 mas. The plateau is characterized by a tropical climate, an average air temperature of 22-degree centigrade, and an average annual rainfall of 1200 to 1600 mm. The climate is classified as warm temperate. The dam areas are characterized by dry winter months and the altitude influences the temperature variation between day and night.

Official data shows that Ethiopia has an exploitable hydropower potential of more than 45,000 megawatts. Despite this, the exploitation rate is less than 5 percent of the total. Majority of the dams planned and operated in Ethiopia are either located in the Nile *River* basin or on the Omo *River*. Neshe and Amerti rivers are the tributaries of Fincha river which is the subsidiary of the Nile River. Nashe, the 97-megawatt power generation project commenced in September 2007 and began generating electricity in 2011. The dam, owned by the Ethiopian electric power corporation, was constructed by the China Gezhouba group company.

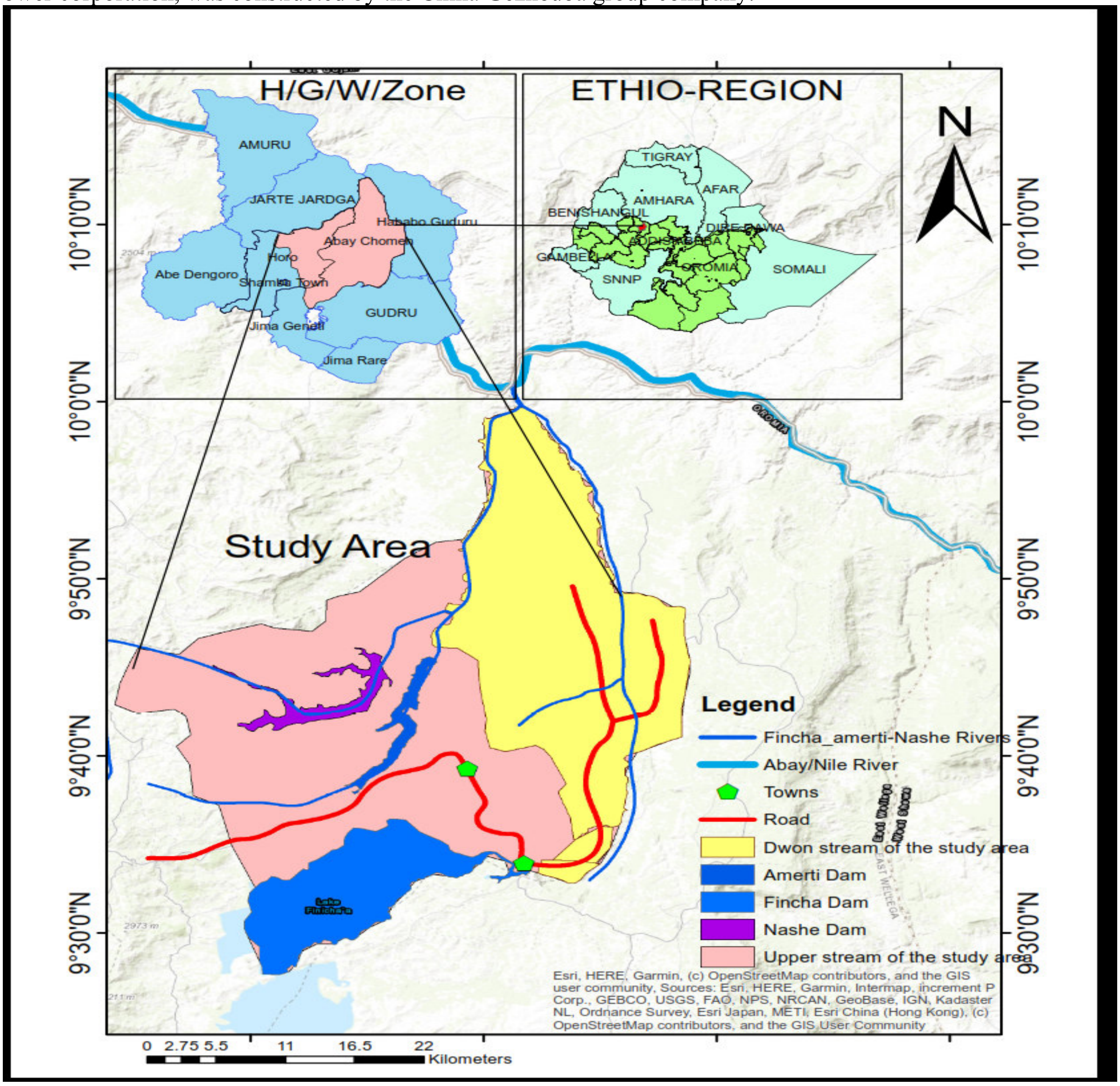

Figure 1: Study area map

The Nashe dam was constructed on the Nashe river at a distance of 5km before it converges with the Amerti river and can hold 448 million cubic meters of water. The electricity generated by the Amerti-Nashe project uses the power lines of the 134MW of Fincha hydroelectric dam project to enter the national power grid for distribution. Amerti reservoir was built in 1987 as a feeder of Fincha hydroelectric power reservoir to enhance the capacity of this old power plant. Water from the near Amarti River was dammed up and diverted via a tunnel to the Fincha reservoir to boost hydropower production (Eguavoen, 2009).

Even though it is not the main concern of this study, there is a high potential of photovoltaic power in the study area. Wassie & Adaramola (2021) noted that several studies indicate that solar PVs systems offer a cost-effective and viable option for off-grid electrification in the developing world. Solar energy is playing an important role in Ethiopia's rural electrification by providing off-grid energy to households and enterprises across the country (Lakew et al., 2017).

2.2 Research approach

As noted by Creswell, (2014) study approaches are research plans and procedures that cover everything from general assumptions to detailed data collecting, analysis, and interpretation methodologies. This research follows a mixed method approach which is a type of study in which researchers gather and analyze both quantitative and qualitative data in the same study (Shorten & Smith, 2017). The general goal and basic premise of a mixed method approach is that combining quantitative and qualitative approaches yields a greater grasp of research difficulties and complicated phenomena than either approach alone (Creswell, 2006). The main driver for using mixed method for this study was the need to address a wide range of questions that necessitate triangulation and integration of different data from different sources.

2.3. Data collection method

2.3.1 Sources and methods of data collection

The data for this research comes from both a survey and focus group discussion conducted in Amarti-Nashi dam areas in the Upper Blue Nile Basin of Ethiopia. The survey was conducted in February 2021. Data were collected on basic information about households: sources of electric energy before and after the dam project, household energy adoption status, challenges households face to adopt electric energy (grid line, cost of adoption,), the impact of energy on women's workload, education, income, agricultural production and SME.

The household survey was based on recall method before the dam project and stating their current condition. This method is two times recall method with the same households being questioned. The main limitation of the approach is that respondents may have difficulties answering double responses by recalling the past events. However, due to the recentness of the dam projects, it was not difficult to remember the condition of the events before the hydroelectric dam projects. The survey data was complemented by collecting qualitative data using a focus group discussion (FGD). As stated by Eeuwijk, (2018), a FGD is a qualitative research approach and data collection technique in which a nominated group of people discusses a given issue or problem in-depth, facilitated by a professional, external moderator. This method was used to ask participants about the socio-cultural and, economic impacts of the Amerti-Nashe hydroelectric dam project. Accordingly, the focus group discussion was held with community representatives, and kebele[1] administrators from each sample kebeles. The total number of participants in each FGD was eight with four males and four women. Accordingly, three FGDs were used from these three kebeles.

2.3.2. Sampling technique

The study area, Horo Guduru Wollega Zone is purposively selected due to its high concentration of dams like Fincha, Amerti, and Nashe. Due to its long age, Fincha dam was not included in the study because of the difficulty to establish the socio-economic impacts induced by the dam before and after the hydropower plant on recall basis. The dams are located on the same watershed in the region. Fincha dam was built in 1973 making it one of the oldest Hydro Electric Power Dam (HEPD) in the country and generates 134 MW of hydroelectric energy. Amerti reservoir was built in 1987 as additional storage to the old dam, Fincha. Nashe dam was built in 2011 and generates 97 MW. Household surveys were conducted in three kebeles Homa Kulkula, Sandabo Dogora (Aby Choman district), and Ashaya Higu (Horo Buluk district[2]). Homa Kulkula and Sandabo Dongoro kebeles were selected due to their location being enclosed by Amerti-Nashe lakes and affected by both. Ashaya Higu kebele is elongated along the west side of Nashe lake and is highly affected by the dam.

2.3.3 Determining sampling size

Yamane (1967) cited in D.Israel, (2003) provides a simplified formula to calculate sample sizes for Proportions. Therefore, the formula was used to calculate the sample sizes at a 95% confidence level and e=0.05 are

$$n = \frac{N}{1+N(e)^2} \tag{1}$$

Where n is the sample size, N is the population size, and e is the level of precision. This formula was applied to the total households of 1102 in the three kebeles in the study area. Based on the above sampling technique, the

[1] Kebele is the lowest administrative unit in Ethiopia similar to a ward, a neighborhood or a localized and delimited group of people
[2] **Districts** of Ethiopia, also called woreda are the third-level of the administrative division of Ethiopia – after *zones* and the *regional states*.

sample size of households from selected sampled kebeles (Homa kulkula, Sandabo Dongoro, and Ashaya Higu) were n= $1102/1+1102(e)^2$=298 Multiplying the sample size by the design effect of 1% and contingency of 5%, the final sample size used for this research was 316. The sample size was apportioned proportionally among the three study kebeles based on the number of the target population. Accordingly, the Household Heads (HH) size of the kebels were 161, 267 and 674 for which the proportional sample sizes were 46, 77and 193 respectively. The sample population was selected using systematic random sampling method based on the location of the villages closer to the dams after having their list.

2.4. Method of data organization and analysis

The data collected from various primary and secondary sources were organized into tables, figures, and maps using SPSS software version 28.0. Statistical analysis (percentage, mean standardization, Chi-square test, t-test, and binary logistic regression model) was performed by the SPSS software program. Demographic backgrounds such as age, sex, education status of household heads, family size, and marital status were among the variables explored. Other variables studied include household appliance, studying time of children, household source of energy use, challenges of energy adoption, and household opinion on the impact of electricity.

2.4.1 Binary logistic model

Binary logistic model is relevant when the dependent variable is dichotomous (Berger, 2017). Based on one or more independent variables that can be either continuous or categorical, logistic regression predicts the likelihood that an observation will fall into one of two categories of a dichotomous dependent variable. Binomial logistic regression was used to analyze the electric energy adoption of sample households in the vicinity area of Amerti-Nashe dam project. Therefore, the dependent variable was adoption status of households {(adopted (1), not adopted (0)}. The independent variables were location of household heads in the three selected sample kebeles (Ashaya-High, Sanadabo-Dongoro, and Homa Kulkula), income and gender of households.

$$\Pr(Yi - 1) = B_0 + B_1X_1 + \ldots + B_kX_k \quad (2)$$

Where; **xs** is the covariate of the model, **βs** are the model parameters, and **Pr** is the probability of household heads adopting electric energy and **k** is the number of covariates (Maroof, 2012). A p-value <0.05 was considered the cutoff point for statistical significance. The strength of the relationship between the dependent and independent variables was determined using Nagelkerke R^2. Chi-square test was used to compare and rule out the goodness of fit of the final models.

2.4.2 Chi-square test

The Chi-square test of independence is a statistical hypothesis test that is used to see if two categorical or nominal variables are likely to be related. As stated by Mchugh, (2013) unlike most statistics, the Chi-square (χ2) can provide information not only on the significance of any observed differences, but also provides detailed information on exactly which categories account for any differences found.

$$\sum_{ij} x^2 = \frac{(O-E)^2}{E} \quad (3)$$

Where: O = Observed (the actual count of cases in each cell of the Table) E = Expected value (calculated below) χ2 = The cell Chi-square value ∑ χ2.

In this study, we use Pearson's chi-squared test for independence measures to determine whether household energy source distributions and energy adoption statues are independent of one another. In other words, the Chi-square test determines whether or not there is a significant relationship between the two variables.

2.4.3. Paired sample statistics

Paired t-test was used to examine variation in children's study time before and after the adoption of electric energy. The null hypothesis is that children's study time after dark was the same or evenly distributed before and after the adoption of electric energy. Paired t-test is a type of t-test for a single sample that examines the difference between two paired results (Kim, 2015). Therefore, the paired samples t-test technique compares the means of two variables (children's study time after the dark per day before and after electric energy adoption) for a single group of sample households.

2.5. Conceptual framework on rural electrification adoption and benefits

Because of various factors, the most pressing energy issue for almost all developing countries is a lack of adoption of affordable and adequate modern energy services (Spalding-Fecher et al., 2005). Similarly, in Ethiopia, the lack of adoption and utilization of modern energy services that are clean, efficient, and environmentally sustainable is a critical constraint to economic growth and long-term development (Guta et al., 2015). Household energy adoption is primarily determined by household characteristics, the degree of community electrification, and energy policy formulation and planning at the local, national, and international levels (Nigussie & Enday, 2017).

Household characteristics such as income, occupation, educational level, gender, and proximity to transformer can determine energy accessibility in rural areas. According to Alem et al (2014) given the significant negative consequences of using biomass energy sources, analyzing the determinants of adoption of the electric energy and the corresponding reduction in biomass fuel use would provide useful insights into the magnitude of the impact of energy transition on the biomass stock of the country.

In order to achieve the objective of rural electrification, energy policy is an important tool. According to M. Energy (2013) one of the main goals of Ethiopia's energy policy is to ensure a reliable supply of energy at an affordable price and to prioritize the development of indigenous energy resources, with a particular emphasis on hydropower resource development. Thus, energy policy can be used as a major factor influencing household adoption of electric energy.

3. Result

This section reports the collected data in an organized manner. It presents the demographic characteristics of the sample population, the status of rural electrification, household access to hydroelectric energy, energy sources before and after the Amerti-Nashe dam construction, household electric energy utilization, the socio economic impacts and households' opinions on the socio-economic impacts of electric energy.

3.1. Demographic characteristics of respondents

The survey was conducted on a sample of 316 households, from three sampled kebeles (Homa Kulkula, Sandabo Dongoro, and Ashaya Higu) in Horo Guduru Wollega Zone (HGWZ). The socio-demographic characteristics of the surveyed sample households are shown in Table 1. The gender composition shows that males (87 per cent) females (13 per cent) in the study area. About 95% percent of the household heads were over 30 years old with the elderly or those above 50 years forming nearly 39%. The majority of households in the study area (82.9 per cent) had a family size of more than six individuals. Household in the study area are relatively educated; nearly 60% have completed primary education and about 12% have completed secondary education.

Table 1; Demographic characteristics of respondents

Variables	Level of variables	Frequency	%
Gender	Male	275	87.0
	Female	41	13.0
Family relationship	Husband	272	86.1
	Wife	41	13.0
	Son	3	.9
Age	20-30	17	5.4
	31-40	46	14.6
	41-50	131	41.5
	>50	122	38.6
Education	None	87	27.5
	primary education	189	59.8
	secondary education	37	11.7
	College/Diploma	1	.3
	1st Degree and above	2	.6
Household family size	1-5	51	16.1
	6-10	219	69.3
	11-15	43	13.6
	>15	3	.9

3.2 Households' energy sources for lighting

Ethiopia is endowed with a variety of RE resources. Hydropower has a 45 GW potential, wind has a 10 GW potential, geothermal has a 5 GW potential, and solar radiation ranges from 4.5 kWh/m2/day to 7.5 kWh/m2/day (Mondal et al., 2018). In rural Ethiopia diesel, kerosene and fuel wood are the most common fossil fuels used for cooking and lighting (FDRE & Abdisa, 2016).

Table 2 shows that despite the proximity of households to the hydropower sources, the majority do not use power from the hydropower energy grid. It is only 35.1 percent of sample households who are connected to the hydroelectric power grid. Households use other sources of energy. In particular, 25.6% uses solar energy, 24.4% uses kerosene and 7.9 % uses candle for lighting in the study area during the survey.

Table 2 Sources of energy for lighting

	Frequency	Percent
Hydropower energy (grid-based)	111	35.1
Solar energy	81	25.6
Kerosene (hydrocarbon liquid)	77	24.4
Candle	25	7.9
Fuel wood	22	7.0
Total	316	100.0

According to Ethio Research Group, (2012) when compared to traditional rural electrification methods, solar electricity has clear advantages in terms of accessibility, cost, and dependability. The World Bank has been studying Global Photovoltaic Power Potential using satellite imagery in each country of the world, providing a consolidated and harmonized view of solar resource and the potential for utility-scale photovoltaic power (PVP) plant development from the perspective of countries and regions. As shown in figure 2, Ethiopia's daily average photovoltaic potential in 2020 ranged from 3.2 to 5.5 kWh/m^2. In comparison, the Amerti-Nashe area has a strong PVP potential, ranging from 4.5 to 5.0 kWh/m^2. As a result, the study area is endowed with photovoltaic power in addition to hydropower power electric energy. PVP potential energy is higher in the lower reaches of the Amerti-Nashe dams than in the upper stream of the research region. Similar to hydropower accessibility, solar energy adoption among households in the research area was not as high as it should have been.

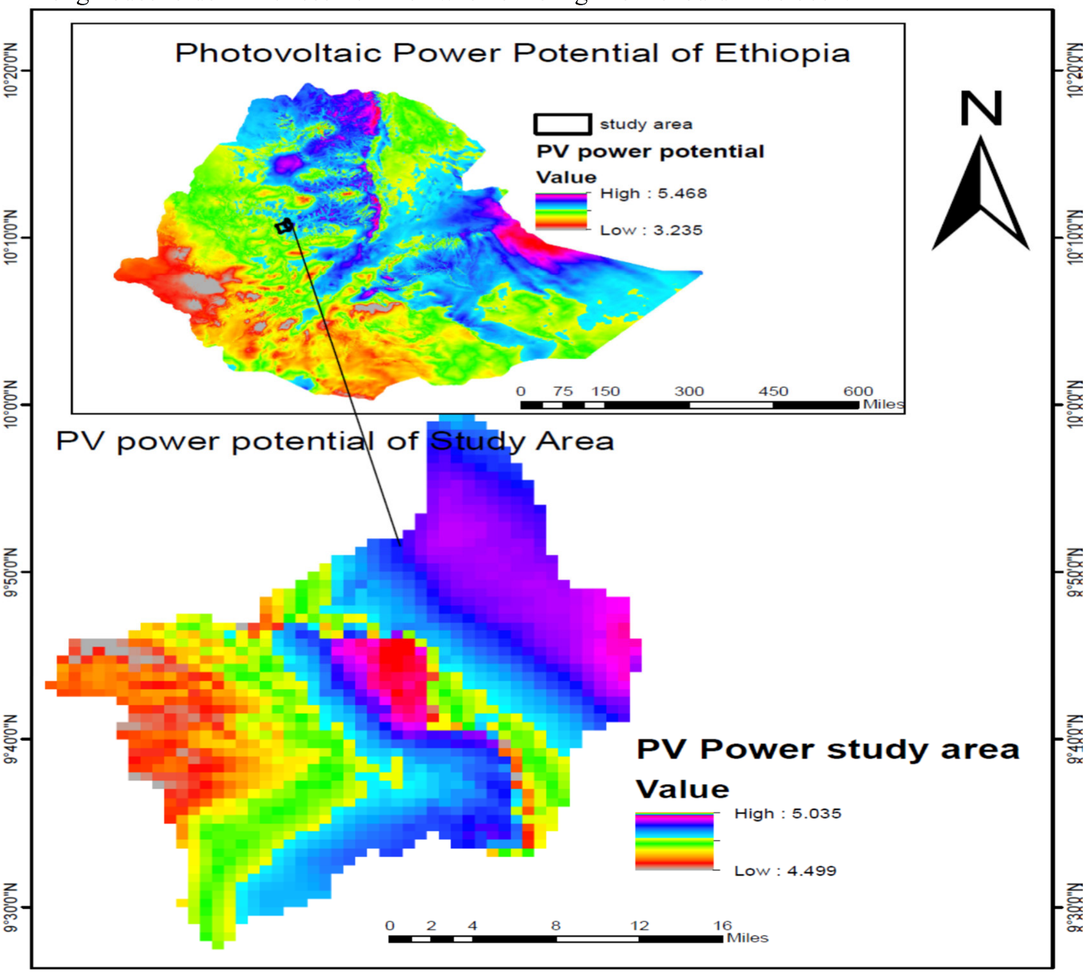

Figure 2 Daily Average Photovoltaic Potential of the Study Area

Sources; processed from Satellite image of ESMAP. 2020. Global Photovoltaic Power Potential by Country. Washington, DC: World Bank

3.3 Rural electrification in the Amerti-Nashe vicinity area

A binary logistic regression was used to identify the distribution of hydroelectric energy among the selected sample kebeles in the vicinity of the Amerti-Nashe dams. Logistic regression was performed to assert the effects of households' residential location relative to the location of the distribution transformer line, income, and gender of household heads on hydroelectric energy distribution in the locality. The model was statistically significant at $X^2(4) = 66.187$, $P < 0.05$, and the model explained 26.0% (Nagelkerke R^2) of the variance in grid-based electrification distribution and correctly classified 74.7% of cases.

Table 3- provides the model which illustrate how each independent variable contributes to the dependent variable including their statistically significance. The Wald and Sig. columns in Table 2 are used to test the null hypothesis that the coefficient (parameter) is zero. Statistically significant coefficients have p-values less than 0.05. The null hypothesis that there is equal distribution of hydroelectric energy connection among all the sample kebeles is rejected since the location of household in the three kebeles has a p-value of 000. The Table also indicated that income of HHs birr per year (*p* = .001), added significantly to the model, but Gender of HHs (*p* = 0.970) did not add significantly to the model.

Table 3 Variables in the Equation of electric adoption in selected three kebeles

Variables in the Equation	B	S.E.	Wald	df	Sig	Exp(B)
Kebeles (place of HHs)	_	_	37.391	2	.000	-
Homa-Kulkula (1)	2.621	.448	34.241	1	.000	.073
Sandabo-Dongoro (2)	.212	.316	.450	1	.503	1.236
Income of HHs (birr per year)	.021	.043	10.428	1	.001	1.000
Gender of HHs(1)	.015	.398	.001	1	.970	1.015
Constant	2.028	.500	16.450	1	.000	7.600

The variable 'place of household residential area' is statistically significant. The one degree of freedom tests for the Homa Kulkula (1) and Sandabo Dongoro (2) shows that Homa Kulkula (1) is statistically significantly different from the dummy Ashaya Higu (3) (which is reference, category), but the Sandabo Dongoro (2) is not statistically significant implying that there is no significant difference in the distribution of hydroelectric energy between Sandabo Dongoro and Ashaya Higu (3) with a p-value of. 0.503.

As shown in Table 2, the Exp(B) for households in Homa Kulkula is 0.073. This suggests that households in Homa Kulkula are 0.073 times more likely than households in Ashaya Higu to have access to hydroelectric energy. The proximity to the national grid line causes a variation in the distribution. Generally, the majority of the households in the vicinity areas of the study were not connected to the hydroelectric energy from Amerti-Nashe hydroelectric power dams. The probability of energy adoption increases based on a one-unit change in the income of households when all other independent variables are kept constant.

3.4. Challenges of households to access hydroelectric energy

As indicated in (Table 2), it is only 35.1 percent of the local community in the vicinity of the Amerti-Nashe hydropower project with access to energy from the national grid. Figure 3 depicts the challenges of connecting to electric energy as identified by households. About 77 percent of households mentioned that there is no electric grid line, 14 Percent were not connected due to the high cost of the connection while 9 percent of households claim that the difficulty in connecting to electric power was due to the local government's failure to respond to their request for connection.

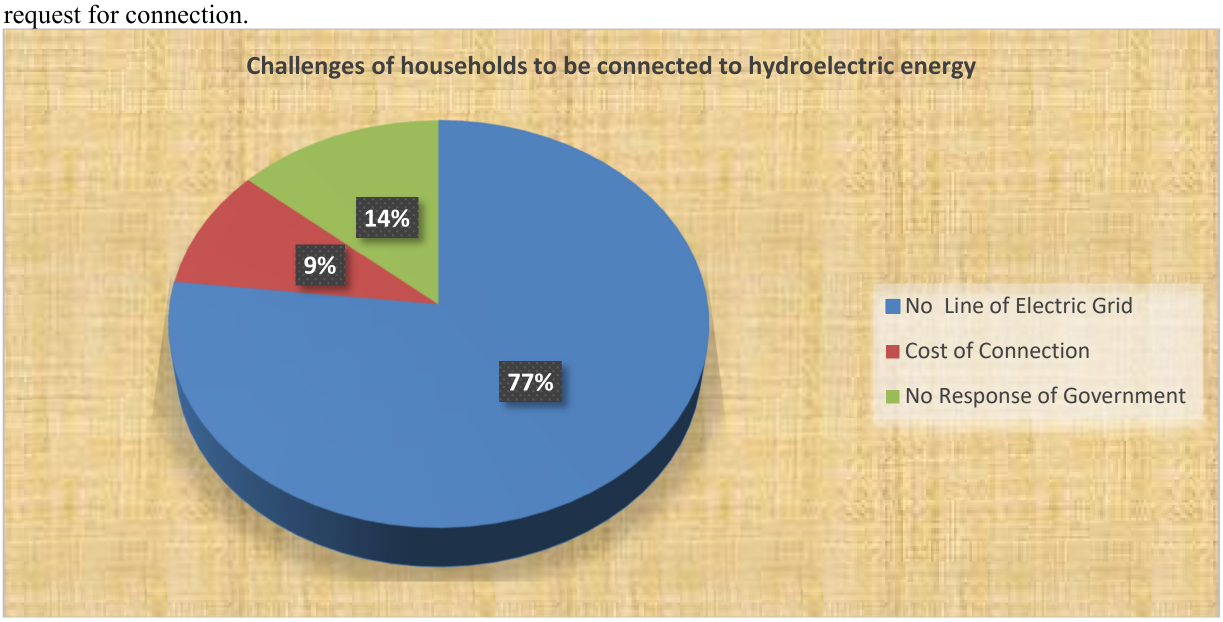

Figure 3; Challenges of connecting to electric energy

Thus the most important challenge of the rural electrification program for local community was the lack of grid line distribution in the study area. Some households had lost hope of obtaining a direct connection to the national grid and instead relied on obtaining power from a neighboring household via an improvised single-line connection. Thus many households get immediate service by using a neighbor's legal metered connection. As indicated by the World Bank (2016), expanding the grid system to more villages and towns is one obvious way to raise electrification coverage.

The FGD revealed that after the construction of Amerti-Nashe dams, the local community has a high demand for access to electric energy generated by these reservoirs. However, due to various factors like the inaccessibility of the grid lines, shortage of finance, and delay of government response, the majority of the local community in the vicinity of the dam does not have access to grid-based energy. The focus group participants mentioned that.

"….at the beginning we had a strong hope to have electricity following the construction of Amerti-Nashe dams. We believed that it would solve the shortage of electric energy in the vicinity. However due to various reasons such as distance from the national grid line, shortage of finance, and low attention of the government to the electrification of the vicinity area of the dam, there is no change in electric energy access before and after the construction of these dams" (FGD of Homa Kulkula kebele 2021)

3.5. Socio-economic impacts of energy adoption in the study area

Electricity provides new opportunities for households, such as improved lighting quality, increased information flow, and improved communication. Households with electricity, rated the impact of rural electrification on lighting quality, information flows, children's study time, and women's workload favorably.

3.5.1 Household electric energy utilization and use of appliances

Table 4 depicts the households' hydroelectric grid-based energy adoption and use of electric appliances in the study area There was a link between household appliance use and adoption of electric energy, as seen in the cross-tabulation (Table 4). A Chi-square test of independence was used to evaluate the association between household hydro energy adoption and households' use of appliances of different purpose. Pearson's chi-squared test allows researchers to determine whether two categorical variable distributions are independent or related to each other (Odum, 2015). The result shows that there was a significant relationship between the two variables, $X^2(3, N=316) = 195, p = .000$. Households that used energy were more likely to use appliances than non-adopting households.

Table 4; Household use of appliance and electric adoption

Household use of appliance (lamp, TV, radio, mobile phone, Cooking stove)		Household energy adoption status		
		Adopted	Non-adopted	Total
Do not use these appliance	Count	0	124	124
	% of total	0.0%	39.2%	39.2%
for lighting (lamp) only	Count	26	63	89
	% Of Total	8.2%	19.9%	28.2%
TV & Radio	Count	25	0	25
	% Of Total	7.9%	0.0%	7.9%
Mobile phone	Count	56	18	74
	% Of Total	17.7%	5.7%	23.4%
Cooking Stove	Count	4	0	4
	% Of Total	1.3%	0.0%	1.3%
Grand-total	Count	111	205	316
	% Of Total	35.1%	64.9%	100.0%

As indicated in Table 4, there was a difference between households who adopt and those who do not adopt electric energy in using it for lighting and communication media (TV & Radio, mobile). As a result, households who adopted electric energy have used appliances for stated purposes. The survey showed that 35.1 percent of the total sample respondents adopted electricity using hydropower energy as their primary energy source. Out of these, 8.2 percent used the energy only for lighting purpose. Energy adopting households also consume energy for TV and radio, mobile phones, and cooking stoves, in addition to lighting. About 25.6 percent of households who adopted grid-based electric energy used communication appliances (radio, TV, and mobile). However, only 19.9 percent of non-adopting families, particularly those with solar energy connections, used appliances for lighting with no use of appliances for other purposes. The majority often charged their phones at charging stations or in neighbors' homes. They also do not have TV and radio in their houses which use electric energy. More than half of the non-adopting households have no electric appliance (lighting bulbs, TV, Radio, Mobil phone charging, and cooking stoves).

Electric energy is likely to provide new opportunities for families, such as improved lighting quality, increased information flow, and improved communication. However, in the vicinity of the Amerti-Nashe hydroelectric, more than half (64.9%) of households were still without electricity due to different reasons such as poor transmission and distribution infrastructure (grid line), high costs of supply to remote areas, or simply inability to afford electricity.

3.5.2. Electric energy for better education

Children are able to study once a household has switched to electricity (Bank, 2016). Improvements in children's education are crucial for their future earnings as adults, as well as for the country as a whole, which benefits from a more educated population. Rural electrification improves the study time of children in households, which is one of the social benefits of the project. Table 5 shows a summary of sample statistics of study time of children hour per day before and after Amerti-Nashe hydroelectric dam project.

Table 5 Paired Samples Statistics; the study time of children hour per day before and after Amerti-Nashe dams.

Children study time	Mean	N	Std. Deviation	Std. Error Mean
Hours of children study in the evening After connection	3.44	111	.55	.052
Hours of children study in the evening before connection	2.39	111	.51	.048

The summary of paired sample statistics in Table 5 shows that the mean study hours of children in the households was 2.39 and 3. 44 hours before and after the adoption of hydroelectric energy respectively. The standard deviation of study time of children before the adoption of electric energy was 0.51 and it increased to 0.55 after electric adoption. The table indicates that though there is more variability, the mean study hour has increased after electric connection implying that adoption of electric energy has an impact on children's study time after the dark

Table 6 Paired Sample test on Children's study time after dark (hours per night)-Before and after electric energy adoption

Children's study time after dark (hours per night)-Before and after electric energy adoption	Paired Differences							
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	T	df	Sig. (2-tailed)
Children's study time Before and after	1.05	0.63	0.06	0.94	1.17	17.59	110	.000

Table 6 provides the results of an inferential t-test in order to determine whether there is a significant difference in children's study time before and after adoption of grid-based hydroelectric energy. The t-test was employed to examine the null hypothesis that there are no differences in children's study time before and after the electric connection. The table shows that the mean differences in children's study time before and after hydroelectric energy adoption are statistically significant ($p = 0.05$). This is because 'Sig. (2-tailed)' or p 0.05. The p-value (Sig. (2-tailed)) is 0.00, and the t statistic (t) is 17.6. As a result, the null hypothesis was rejected at 95% confidence level. The above results indicate that the construction of Amerti-Nashe hydroelectric power dams has an impact on the quality of education for people living around the dam.

3.5.3 Household opinions on socio-economic impacts of electric energy

Households' opinion on the socio-economic impacts of electric energy was sought regarding women workload, agricultural production, SME use and income levels. Alleviating women workloads through access to electricity means that mothers have enough time to cook nutritious food for infants, improve child sanitation and better attend to their children (Aragaw, 2012). Reduced workloads for pregnant women may help to alleviate their suffering and improve their health. Households were asked for their opinion on whether connection to the hydroelectric power energy grid has resulted in decreased women's work load in the households. The responses were positive with nearly 75 percent of the households agreeing that the adoption of electric energy reduced the workload of women (Table 7).

Similarly, the data generated from FGD revealed that the availability of electricity is important for many households in the study area. The FGD group members noted that

"Due to expansion of agricultural land to the forested areas there is shortage of fuel woods for household use. Therefore, electric energy is a crucial option for our day to day socio-economic activities. It has positive effect on our education, employment, income, time uses and women empowerment. For instance, due to grid electrification we have accessed grain mile at shorter distance from our residential area which minimized the travel cost." (FGD of Ayisha Higu kebele 2021)

Energy policymaking and planning at the community, national, and international levels are major topics where the gender-energy nexus has begun to gain attention, among many other current interventions (Nigussie &

Enday, 2017). improving national electricity access also has positive and significant effects on agricultural productivity in sub-Sahara Africa (Osabuohien, 2020). As it indicated in table (7) however, nearly all of the households in the study area do not use electric energy for agricultural production.

Table 7; Household Opinions on socio-economic impacts of electric energy

Rural electrification reduces workload of women house activities	Frequency	Percent
strongly agree	28	25.2
Agree	55	49.5
Average	28	25.3
Do you use electric energy for agricultural production		
Yes	2	1.8
No	109	98.2
Do you think the adoption of electric energy increase your income level?		
Yes	27	24.3
No	84	75.7

3.5.4 Electric energy uses for MSE

Rural MSE ensures that, local economic growth through support for local employment creation and income generations, poverty reduction and wealth creation are attain- able (Richard, 2010). The Electricity service is one of the factors, which may have both a direct and indirect impact on small micro-enterprises development (Maleko, 2005).

Table 8; Household use of electric energy for Small and Micro Enterprises

Electric Energy Based SME	Frequency	Percent
Have No SME	103	92.8
Shops	4	3.6
Barber Shops	2	1.8
Mills	2	1.8

The study showed that the majority of households (92.8 percent) do not operate hydroelectric based micro-enterprises. The reason could be farmers' low experience in business knowledge and the high starting cost of the business itself. The community however benefits from access to hydroelectric based grain milling, and hair cutting enterprises which are all located in close proximity of the residential areas. This saved time and other costs for the households.

4. Discussion

As indicated in the literature many rural communities and households in Ethiopia are not connected to modern electricity services. The Government, in the hope of solving the problem, is building hydroelectric dams in many parts of the country. The Amerti-Nashe hydroelectric project is one of the newly built dams in the Horo Guduru Wollega zone under the Ethiopian electric power corporation to generate hydropower and to provide modern irrigation in the lower stream of the study area. In addition to the old dam Fincha, Amerti-Nashe dams play a significant role in supporting the national economy through electrification, supplying water for sugar factory and promoting fisheries in the area. However, more than half of the study area population lacks access to hydroelectric power. It is therefore evident that more than half of the population were not provided energy from nearby Amerti-Nashe and Fincha dams, and instead they depend on the traditional fuel as a source of energy. The survey revealed that 35.1 percent of the total sample household were connected to grid-based hydroelectric energy, while 64.9% of the study population lacks access to electricity in the study area. Thus despite the presence of three hydroelectric dams in the study region, the majority of the households lacked access to electricity. For instance, in Abay Choman district where the three hydroelectric dams are located, only 44 percent of the population adopted electricity. However, according to Ethiopian electric power corporation (2007), the Fincha hydroelectric power reservoir has met 27% of the country's hydroelectric demand.

The major reason for the study area to suffers from inaccessibility to electricity is due to the fact that the study area's electrification process was based on the national grid, with the rural communities closest to the line having greater access to hydroelectric energy than the others. This implies that residing in the larger dam area presents no advantage over other communities in the country. The probability of energy adoption also increased based on a one unit change in an income of households when all other independent variables are kept constant. This implies that electricity provision is also associated with affordability.

The utilization of electricity requires possession and use of proper appliances. Households that have been connected to the grid need to purchase a range of electric appliances, such as light bulbs, radios, television sets, cooking stoves, and other home based machinery. The World Bank, (2016) noted that these appliances produce results, such as light, which allows more study or home production, more access to information and entertainment, more comfort, better food preservation, more efficient cooking, and finally more motive power for productive uses. The majority of sampled households agreed that being connected to the hydropower grid has great benefits in terms of better lighting conditions, access to information through radio &TV, as well as increasing income and improving the working conditions of the households in the study area. Therefore, with better lighting, communication, and entertainment, family members no doubt changed their time-use patterns, especially during evening hours.

Rural electrification can improve the quality of rural life in a variety of ways. The benefits of rural electrification on women's workload was viewed favorably by households with electricity. It also has an impact on the quality of education in the dam's vicinity. The study found that households who are connected to grid energy are more likely to have better condition than the not-connected households.

The traditional concept of the productive use of energy in rural development is related primarily to the provision of motive power for agricultural, industrial, or commercial activities. (Cabraal et al., 2005). The study revealed that 98.2 percent of the households do not use energy for agricultural purposes. This is primarily due to a lack of financial resources and information from relevant government agencies. In the lower reach of the dam area, however, the hydroelectric power energy was used for commercial farming (sugar cane plantation).

In general, the empirical evidence on the rural electrification showed that the use of electricity for micro enterprise development and other productive uses is limited. Rural households in the study area mainly assume that electric energy is important for lighting purposes only. This attitude is related to the low entrepreneurial skill of households and to the lack of attention paid by responsible institutions, policy makers and other stakeholders about rural electrification program in relation to micro-enterprises and other productive uses.

5. Conclusions

We investigated rural electrification in the vicinity areas of Amerti-Nashe hydroelectric power dams in the Horo Guduru Wolega zone of Ethiopia. The paper mainly focused on dam-induced rural electrification in the study area. Even though Fincha', Amerti, and Nashe hydroelectric power reservoirs are all located in the study area, the majority of the households were not connected to hydropower-induced grid connection. There is also a relatively high potential for photovoltaic power energy in the Amerti-Nashe area, particularly in the lower stream, which is nearly equal to the maximum daily national records in kWh/m^2, but only 25.6 percent of households in the study area were connected to solar energy. Homa Kulkula and Sandabo Dongoro sample kebeles which are located within the Abay Chomen district were connected more to the grid electrification than Ashaya Higu Kebele of Horo Buluq district. The latter is far from the electric grid and hence inaccessible. The other challenges of households adopting grid-based electric energy were the unaffordable cost of connection and the lack of response from the local government to their request to be connected.

Households who are connected to the grid hydropower system have more advantages than non-connected households. Accordingly, households with electricity valued the impact that rural electrification has on lighting quality, information flows, children's study time, and the workload of women.

Generally, Fincha and Amerti-Nashe dams play a significant role in supporting the national economy through electrification, supplying water for sugar factories, and introducing fisheries in the area. But more than half of the population in the study area has no access to hydroelectric energy and uses traditional fuel as a source of energy. There is a need to make concerted efforts to increase connectivity in the area.

This study has identified some topics that require further investigation. While the study addressed some of them, others remain researchable. It has several gaps in other renewable energy-based rural electrification options. As a result, the studies have identified some additional areas for further research which include another RE potential in the study area, dam impact on the local climate, and dam project and its socio-economic impacts.

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