

# 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 the shortage of electric energy in remote rural areas. This research deals with Amerti-Nashe dam-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 that live in the vicinity of the dam. Statistical analyses such as the 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 for 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 the grid line, the 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

### *Introduction to the Study and Study Objectives*

Rural electrification has multiple benefits that include lighting, access to information, an improved study environment for schoolchildren, and improved businesses, which in turn create employment opportunities and contribute to development and poverty reduction [27]. Rural electrification projects are frequently justified because they aim to improve household welfare by providing a higher quality of life or increased productivity [21]. Rural areas continue to be residential places for the majority of Africa's population, but they rely on traditional fuels for their energy needs.

Access to energy is a major concern in international socio-economic development [29]. As noted by [17], adoption of energy is the primary requirement for any country's

economic growth and supports the modern economy [4]. Electrical energy is becoming an essential commodity for modern production process today [4].

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 [39]. According to UN SDG 7, everyone should have access to affordable, reliable, sustainable, and modern energy by 2030 [37].

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 [30]. With the growth of population and industrialization, the global energy demand is increasing at an unprecedented rate [35]. For much of the world's

population, household fuel demand makes up more than half of total energy demand [15]. [36] 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) [14]. However, [1] 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.

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 [35]. 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 [28] The power industry is almost entirely reliant on hydropower, which accounts for 94% of installed capacity and more than 99% of power generation [13].

Electricity distribution and usage differ significantly across the country, with rural residents frequently overlooked due to high prices and technical issues. [28] 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 construction of dams has an implication for the local community in addressing their energy demands. however local communities around the dam area are not considered priority concerns. As a result, hydropower dam-based rural electrification in Ethiopia's dam vicinity has not been the subject of a study by researchers and developers. For instance, [10] “Hydropower for sustainable water and energy development in Ethiopia” which mainly about hydropower as an agent of national development in general. [38] also published a journal on “Prospects for hydropower in Ethiopia: An energy-water nexus analysis” focused on the development of hydropower for irrigation and notional electrification. Therefore, there is a gap in research focusing on hydro dam projects and the priority 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.

Therefore, 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) To identify the challenges of households to adopt grid-based hydroelectric energy in the study area; (3) To determine the socio-economic effects of hydroelectric grid-based energy on households in the research area following its adoption.

## 2. 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, the Plateau, with an elevation of more than 2000 m around the dams above sea level and dramatic escarpments dropping over 600 m 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 north-western parts of Ethiopia, which include the Horo Guduru wellega zone. Administratively, the study area is located within Horo Buluq and Abay Coman districts in the Horo Guduru Wollega zone. The Nashe river valley, on which the reservoir was built, starts on the highland plateau north-east of Shambu town and flows from west to east for above 10 km and then in the northerly directions for further 7 km. The valley elevation is 2200 m above sea level, with the surrounding ridges extending to over 2500 m above sea level. The Amerti River also starts from northeast of Shambu town, parallel to the Nashe River, with a distance of 5 to 10 km, and becomes one with the Nashe River before mixing with the Abay River.

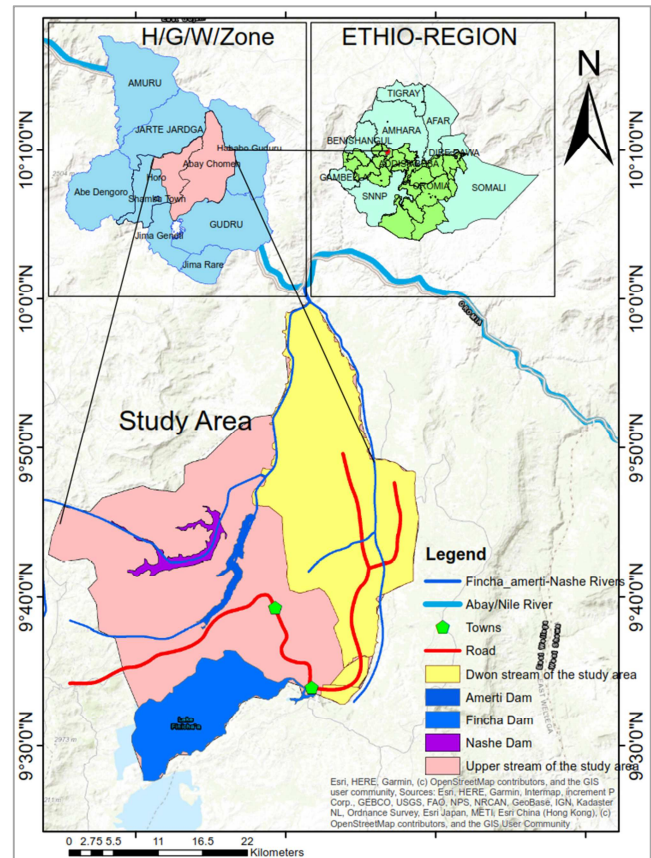


Figure 1. Study area map.

### 3. Materials and Methods

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

#### 3.1. Research Approach

Approaches are research plans and procedures that cover everything from general assumptions to detailed data collection, analysis, and interpretation methodologies [8]. This research was carried out using a mixed-methods approach, which is a type of study in which researchers gather and analyze both quantitative and qualitative data in the same study [31]. A mixed method studies' general goal and basic premise is that combining quantitative and qualitative approaches yields a greater grasp of research difficulties and complicated phenomena than either approach alone [7]. The main driver for using the mixed method for this study was to address a wider range of questions, which were collected through different approaches such as surveys, fieldwork exploratory studies, and focused group discussions (FGD). Therefore, the data from these sources was triangulated to analyze the dam-induced rural electrification impact in the Amerti-Nashe vicinity.

#### 3.2. Data Collection Method

##### 3.2.1. Sources and Methods of Data Collection

The data for this research comes from a survey conducted in Amerti-Nashe 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 of households 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 surveys on the indicated variables were based on recalling conditions before and after the dam construction. This method is a 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 past events. However, due to the recentness of the dam projects, it was not much difficult to remember the condition of the events before the dam and the hydroelectric dam projects. For this objective, data were also collected by using FGD on the contribution of Amerti-Nashe dams as a source of energy in the study area to support the data from the survey. As stated by Eeuwijk, 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 serves to ask participants about the socio-cultural and, economic impacts of the Amerti-Nashe hydroelectric dam

project. Accordingly, the focal group discussion was held with community representatives, and kebele 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.

##### 3.2.2. 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 difficulty to establish the socio-economic impact induced by 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 hydroelectric power dams (HEPD) in the country. It generates 134 MW of hydroelectric energy. Amerti reservoir was built in 1987 as additional storage for the old dam, Fincha. Nashe Dam was built in 2011 and generates 97 MW. The study selected Amerti and Nashe for the household survey. Household surveys were conducted in three kebeles: Homa Kulkula, Sandabo Dogora (Aby Choman district), and Ashaya Higu (Horo Buluk district). 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.

##### 3.2.3. Determining Sampling Size

Yamane [9] 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

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

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

#### 3.3. 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.

### 3.3.1. Binary Logistic Model

Binary logistic model is relevant when the dependent variable is dichotomous [20]. 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 of the Amerti-Nashe dam project. Therefore, the dependent variable is the adoption status of households {(adopted (1), not adopted (0))}. The independent variables are the location of household heads in the three selected sample kebeles (Ashaya-High, Sanadabo-Dongoro, and Homa Kulkula), income, and gender of households.

$$\Pr(Y_i - 1) = B_0 + B_1X_1 + \dots + B_kX_k \quad (2)$$

Where;  $\mathbf{x}$ s is the covariate of the model,  $\mathbf{\beta}$ s are the model parameters, and  $\mathbf{Pr}$  is the probability of household heads adopting electric energy and  $\mathbf{k}$  is the number of covariates [23]. 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.

### 3.3.2. 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. Unlike most statistics, the Chi-square ( $\chi^2$ ) 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 [24].

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

Where: O = Observed (the actual count of cases in each cell of the Table) E = Expected value (calculated below)  $\chi^2$  = The cell Chi-square value  $\sum \chi^2$ .

In this study, we use Pearson's chi-squared test for independence measures to determine whether household energy source distributions and energy adoption status 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.

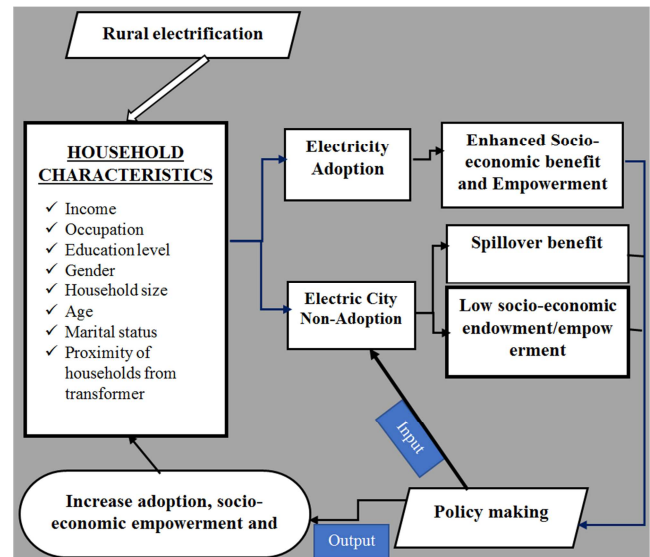
### 3.3.3. Paired Sample Statistics

A paired t-test was used to examine the 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-tests are a type of t-test for a single sample that examines the difference between two paired results [12]. 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.

### 3.4. 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, adequate modern energy services [32]. 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 [16]. 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 [26].



Source; Adopted from Kageni, [19].

**Figure 2.** Conceptual Framework on Rural Electrification Adoption and Benefits.

## 4. Result

The primary goal of a research result section is to use the data gathered to answer the research question(s) posed in the introduction. Other relevant discoveries, trends, or insights revealed by raw data analysis should also be described in the results section [18]. This section mainly concerns reporting the collected data in an organized manner. These data include 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 conditions, the impact of energy on education, and household opinions on the socio-economic impacts of electric energy.

#### 4.1. 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. As a result, 87 percent and 13 percent of the surveyed sample households were males and females, respectively. About 95% of the household heads were over 35 years old, and 82.9 percent of these households had a family size of more than six individuals. The majority of the household heads (59.8%) have finished elementary school.

**Table 1.** Description of the 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
	None	87	27.5
Education	primary education	189	59.8
	secondary education	37	11.7
	College/Diploma	1	.3

**Table 2.** 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 Homa Kulkula (1) and Sandabo Dongoro (2) show that Homa Kulkula (1) is statistically significantly different from the dummy Ashaya Higu (3) (which is a reference category), but 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 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

Variables	Level of variables	Frequency	%
Household family size	1st Degree and above	2	.6
	1-5	51	16.1
	6-10	219	69.3
	11-15	43	13.6
	>15	3	.9

#### 4.2. Rural Electrification in the Amerti-Nashe Dam Vicinity

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 the place of the household residential areas related to the distribution transformer line, income, and gender of household heads. 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 2 provides the model, which illustrates how each independent variable contributes to the dependent variable, including their statistical 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 an equal distribution of hydroelectric energy connections among all the sample kebeles is rejected since the location of households in the three kebeles has a p-value of 0.000. The table also indicated that income of HHs per year ( $p = .001$ ) added significantly to the model, but gender of HHs ( $p = 0.970$ ) did not add significantly to the model.

change in the income of households when all other independent variables are kept constant.

#### 4.3. Households' Energy Sources Before and After Dam Construction for Lighting

As previously stated, the country 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/m<sup>2</sup>/day to 7.5 kWh/m<sup>2</sup>/day [25]. In rural Ethiopia diesel, kerosene and fuel wood are the most common fossil fuels used for cooking and lighting [12].

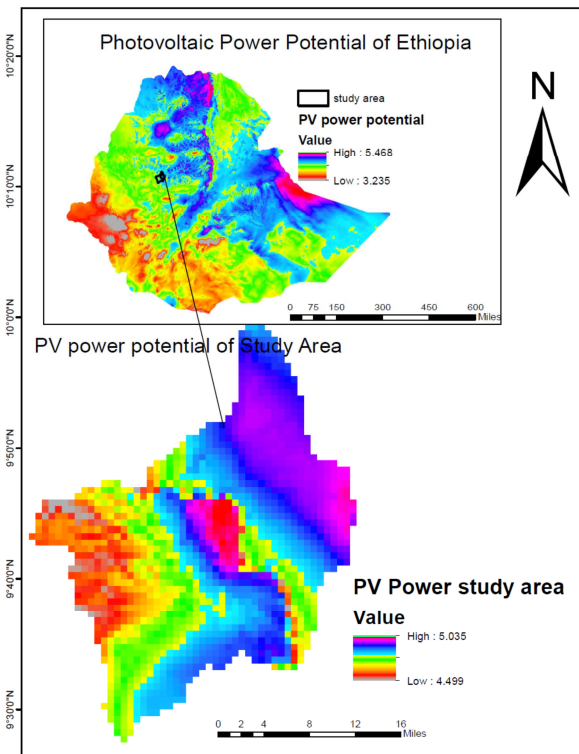
Table 3 shows that despite the proximity of households to hydropower sources, the majority do not use power from the hydropower energy grid. Only 35.1 percent of sample households are connected to the hydroelectric power grid and use other sources of energy. In particular, 25.6% uses solar

energy, 24.4% uses kerosene, and 7.9% uses candles for lighting in the study area during the survey.

**Table 3.** Households connected to different sources of energy.

Households' 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 [11] 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 resources and the potential for utility-scale photovoltaic power (PVP) plant development from the perspective of countries and regions. As shown in Figure 3, Ethiopia's daily average photovoltaic potential in 2020 ranged from 3.2 to 5.5 kWh/m<sup>2</sup>. In comparison, the Amerti-Nashe area has a strong PVP potential, ranging from 4.5 to 5.0 kWh/m<sup>2</sup>. As a result, the study area is endowed with photovoltaic power in addition to hydroelectric power. 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.

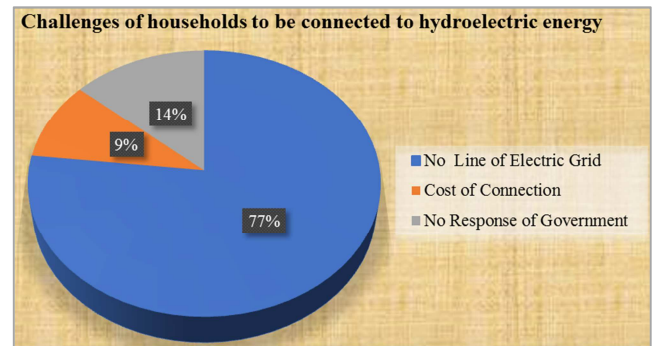


**Figure 3.** Daily Average Photovoltaic Potential of the Study Area.

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

#### 4.4. Challenges of Households to Access Hydroelectric Energy

As indicated in Table 3, only 35.1 percent of the local community in the vicinity of the Amerti-Nashe hydropower project has access to energy from the national grid. Figure 4 depicts the challenges identified by households, in which 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, and 9 percent of households claimed that the difficulty in connecting to electric power was due to the local government's failure to respond to their request for connection. Figure 4 shows the main challenges of sample households to be connected to a hydroelectric energy-based grid system in the vicinity area of the Amerti-Nashe dams.



**Figure 4.** The main challenges of electric energy adoption.

Thus, a serious challenge of the rural electrification program was mainly due to 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 [3], 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 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. One of the FGD group members, Ayisha Higu Kebele, noted that

“..... At the beginning, we had strong ambitions related to the construction of Amerti-Nashe dams. We believed that it would solve the shortage of electric energy. However, due to various reasons, such as distance from the national grid line, a shortage of finance, and the low attention of the government to the electrification of the vicinity area of the dam, there has been no change in accessing electric energy compared to the period before the construction of these dams.”

#### 4.5. 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.

##### 4.5.1. Household Electric Energy Utilization

There was a link between household appliance use and the adoption of electric energy, as seen in the cross-tabulation. A

Chi-square test of independence was used to evaluate the association between household hydroelectric energy adoption and households' use of appliances for different purposes. Pearson's chi-squared test allows researchers to determine whether two categorical variable distributions are independent or related to one another [34]. 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 depicts the households' hydroelectric grid-based energy adoption and use of electric appliances in the study area.

**Table 4.** Household use of appliance.

Household use of appliance (lamp, TV, radio, mobile phone, Cooking stove)		Household energy adoption status		Total
		Adopted	Non-adopted	
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 adopting and non-adopting 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. Based on a survey of households, 35.1 percent of total sample respondents adopted electricity using hydropower energy as their primary energy source. Out of this, 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. 25.6 percent of households who adopted grid-based electric energy uses 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 of often charged their phones at charging stations or in neighbors' homes. Also, they have no 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 a lack of affordability for electricity.

##### 4.5.2. Electric Energy for Better Education

Children are able to study once a household has switched to electricity [3]. 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 on the study time of children per hour per day before and after the 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 of study hours of children in the households was increased from 2.39 to 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 increased to 0.55 after electric

adoption. Therefore, there is more variability in the children's average time of study of the sampled households after electric energy than before. This indicates that the

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					T	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Children’s study time Before and after	1.05	0.63	0.06	0.94	1.17	17.59	110	.000

To determine whether there is a significant difference in children's study time before and after adoption of grid-based hydroelectric energy, and inferential t-test was used. The t-test was employed to examine the hypothesis of no time differences. Table 6 shows that the mean differences in children's study time before and after the 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 (that there was no difference in the means of children's study time before and after hydroelectric energy adoption) was rejected with a 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.

#### 4.5.3. Household Opinions on Socio-Economic Impacts of Electric Energy

Alleviating 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 [2]. Reduced workloads for pregnant women may help to alleviate their suffering and improve their health. When families were asked to respond to the statement that being connected to the hydroelectric power grid has resulted in a decrease in women's work load in households, they gave a positive response. As a result, 74.7 percent of households

agreed that the adoption of electric energy reduced the workload of women.

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

*"Due to the expansion of agricultural land into the forested areas, there is a shortage of fuel wood for household use. Therefore, electric energy is a crucial option for our day-to-day socio-economic activities. It has a positive effect on our education, employment, income, time use, and women's empowerment. For instance, due to grid electrification, we have accessed grain miles at a shorter distance from our residential area, which minimizes the travel cost."*

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 [25]. Table 7 shows that the sample household's opinions on socio-economic impacts of access to electric energy. According, the majority of the households in the study area both with and without hydroelectric connection, agreed that they have access to grain mill at a close distance from their residential area, which was considered quite important for women. Women could now transport grain to an electric-powered mill to be ground into flour instead of crushing it by hand.

**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
Electric Energy Based SME		
Have No SME	103	92.8
Shops	4	3.6
Barber Shops	2	1.8
Mills	2	1.8
Do you think the adoption of electric energy increase your income level?		
Yes	27	24.3
No	84	75.7

Electricity service is one of the factors, which may have both a direct and indirect impact on small micro-enterprises development [22]. 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 to the residential areas. This saves time and other costs for the households.

## 5. Discussion

As indicated in the literature many rural communities and households in Ethiopia are not connected to modern electricity services. To solve the shortage of energy the state is building hydroelectric dams in many areas 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.

The result of the study thus indicated that, despite the presence of three hydroelectric dams in the study region, the majority of the households lacked access to electricity. For instance, just 44 percent of the population in Abay Choman district, where those three hydroelectric dams are located, has adopted electricity. However, according to Ethiopian electric power corporation (2007), the Fincha hydroelectric power reservoir has met 27% of the country's hydroelectric demand. [33] also noted that despite this and other socio-economic benefits for national economy, the Amerti-Nashe and Fincha hydroelectric power project has far reaching social, economic, cultural, environmental, and political side effects in the zone in general and for the people living in these watersheds in particular.

The study area despite its proximity to the Amerti-Nashe and Fincha hydropower project, suffers from inaccessibility and regular interruptions of hydroelectric power supply due to different reasons. Mainly 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. The probability of energy adoption increase based on a one unit change in an income of households when all other independent variables are kept constant. Dams have extraordinary positive social impacts, directly or indirectly [6]. It is the main sources of electricity in Ethiopia and supplies over 95% of Ethiopia's electric power. However, hydropower-induced electric energy is solely distributed through the national grid, and communities near dams have no advantage over other communities in the country because of their proximity to the dam. Therefore, more than half of households in the vicinity

area of Amerti-Nashe dams, have no access to hydropower energy.

Grid electricity requires first and foremost access to a stable hydroelectric dam-based electricity supply. 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. World Bank, noted that these appliances produce results, such as lighter, 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 were agreed that being connected to the hydropower grid has great benefits in terms of better lighting conditions, access to information through radio & TV, and as well as increasing income and 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, income, and impact on micro-enterprise development are 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 connected to grid energy is more likely have better condition than none 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. [5]. 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). Obviously, the enhanced rural energy is likely to result in increased rural productivity, greater economic growth, and a rise in rural employment. The community members in the study area, however, were not fortunate to use these opportunities.

In general, the empirical evidence on rural electrification showed that the use of electricity for microenterprise 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 skills of households and to the lack of attention paid by responsible institutions, policymakers, and other stakeholders about the rural electrification program in relation to micro-enterprises and other productive uses.

## 6. Conclusions

We investigated rural electrification in the vicinity of

Amerti-Nashe hydroelectric power dams in the Horo Guduru Wollega zone of Ethiopia. The paper mainly focused on dam-induced rural electrification and some potential alternative energy 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 connections. 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<sup>2</sup>, 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.

## Conflicts of Interest

The authors declare no conflicts of interest.

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