ROLE AND SUSTAINABILITY MICRO HYDROPOWER: - THE CASE STUDY OF LELTA RIVER MICRO HYDROPOWER IN ALETA WONEDO, SIDAMA ZONE, SOUTHERN ETHIOPIA.

M Sc. THESIS

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Final Thesis Approval Form

Submission Sheet

We, the understand advisors of Mulugeta Feleke have read and evaluated his thesis entitled "ROLE AND SUSTAINABILITY MICRO HYDROPOWER: THE CASE STUDY OF LELTA RIVER MICRO HYDROPOWER IN ALETA WONEDO, SIDAMA ZONE, SOUTHERN ETHIOPIA." and approved the candidate for defense. This is therefore to certify that the thesis has been approved for defense as the in partial fulfillment of the requirements for the degree of Master of Science with specialization Water Resource Engineering and Management.

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Final Thesis Approval Form

(Submission Sheet)

As members of the board of examiners of the final open defense, we certify that we have read and evaluated the thesis by **Mulugeta Feleke** under the title **"Role and Sustainability Micro Hydropower: The Case Study of Lelta River Micro Hydropower in Aleta Wonedo, Sidama Zone, Southern Ethiopia."** and examined the candidate. This is therefore to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of Master of Science with specialization Water Resource Engineering and Management.

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_______________ ______________ ____________________

DECLARATION

I, Mulugeta Feleke, do hereby declare that the thesis entitled *"ROLE AND SUSTAINABILITY MICRO HYDROPOWER: THE CASE STUDY OF LELTA RIVER MICRO HYDROPOWER IN ALETA WONEDO, SIDAMA ZONE, and SOUTHERN ETHIOPIA."* Submitted in partial fulfillment of the requirements for the award of the degree of Master of Science with specialization Water Resource Engineering and Management in Hawassa University, School of Bio System and Environmental Engineering, my original work has not been presented for the award of any other degree or diploma, of any other Universities or Institutions.

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Place: Hawassa University, Ethiopia.

DEDICATION

I dedicate this thesis manuscript to my daughter Misrake Mulugeta, and to her mother Wubealem Mulate Estifo for all academic year and supporting me in my works and their heartily satisfaction with my success in all way.

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ACRONYMS AND ABBREVATIONS

AKRSP	Aga Khan Rural Support Programme
DRE	Decentralised Renewable Energy
E.C	Ethiopian Calendar
EEA	Ethiopia Economist Association
EIA	Energy Information Administration
EPA	Ethiopian Privatisation Agency
EREDPC	Ethiopia Rural Energy Development and Promotion Center
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GNESD	the Global Network on Energy for Sustainable Development
HH	Household
KW	Kilo Watt
MCE	multi-criteria evaluation
MEA	Mine and Energy Agency
MHP	Micro hydro power
Mtoe:	Million Tons of Oil Equivalents.
MW	Mega Watt
O&M	Operation and maintenance
PVC	Polyvinyl Chloride
RED	Rural Energy Demand
ROR	Run off River
SHP	Small-scale hydropower
SNNPRG	Southern Nations Nationalities and People Regional Government
UEAP	Universal Electricity Access Program.
UNDP	United Nation Development Program
WMEO	Water, Mine and Energy Office

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ABSTRACT

The overall aim of the study was assessment of sustainability of Micro hydropower to the local community in Aleta Wonedo Woreda in the Southern Ethiopia. From Woreda two representatives Kebeles namely Agara Sodicha and Gordama were selected purposively based on presence of Micro hydropower plant. Demographic, socio-economic and electric end user appliance type and quantity inventory data were gathered from randomly selected 134 household. Using water balance model the result of maximum and minimum readable level allowed the flow rate measurement of 0.616 m^3/s *and 0.062* m^3/s *respectively. The power in KW output were 21.2 in December, 19.47 in December with probability of 92.3%, and 20.4 in January. Then electric end user appliance type and quantity per household identified. Moreover, a total 32 key informants used to categorize the households into age, six and monthly electric service fee. Focus group discussions were also held to triangulate the information collected during household survey. The survey result indicated that 67% of household unsatisfied on electric tariff against the service, they receive and 100% of power line connected to domestic lighting. Beside this 1% percent of household use all type appliance such as TV, charging and domestic lighting even radio play. A sustainability assessment model for the operation of micro hydropower plants in a rural area of Aleta Wonedo Woreda, Southern Ethiopia was developed. Our model includes 32 assessment indicators taking into account economic, social, environmental, and technical sustainability dimensions and a scoring system (ranging from 1 to 5, with 5 being the best). It was found that the environmental dimension shows the best performance with a score of 3.833 for the studied MHP, followed by social (2.625), economic (2.5), and technical dimensions (1.7). Future electric demand forecasting result show, that the demand of electricity at 2020 E.C will reach (229±18.75) MWh. Finally concluded that communities are very keen to sustainability of MHP and participation community requires improvement.*

Keywords: electricity, demand, HH, sustainability, MHP, efficiency

1. INTRODUCTION

1.1. Background

The vast majority of rural population in developing countries depends on biomass as their primary fuel. In 2016, an estimated 1.1 billion (around 14% of the world's population) still lacked access to electricity (IEA, 2017). Electrification correlates closely with key aspects of sustainable development. Expanding access to modern energy services for the poor is essential for achieving the Sustainable Development Goals (SDGs) (SDG 7, SDG 5, and SDG 3) set by the (United Nations, 2014). Energy services for poverty reduction are less about technology and more about understanding the role that energy plays in people's lives and responding to the constraints in improving livelihoods. Energy needs should be considered within the overall context of community life, and energy policies and projects should be integrated in a holistic way with other improvement efforts relating to health, education, agriculture, and job creation. Policies, programs, and projects should start from an assessment of people's needs rather than a plan to promote a particular technology (Kaygusuz, 2011).

Sustainability evaluations based on MCA are referred to as multi-criteria evaluation (MCE). These approaches make the alternatives and their contributions to the different criteria explicit and, therefore, require the exercise of judgment. However, they differ in the way they combine the data, integrate stakeholder views, develop weights, and score the performance of a particular indicator relative to a specific alternative (Ramanathan, 2002). The main role of these techniques is to deal with the difficulties that human decision-makers have demonstrated in handling large amounts of complex information in a consistent way (Kijak and Moy 2004).

Renewable energy defined as the “energy obtained from the continuous or repetitive currents of energy recurring in the natural environment”, encompasses a wide variety of energy sources including solar, wind, biomass, geothermal, hydropower, ocean energy, biofuels, and hydrogen (Moselle, Padilla and Schmalensee 2010). Technologies developed to harvests these vast resources are diverse, which allows their utilization in different geographical locations. Affordability, sustainability, and adaptability are the main factors justifying the use of renewable energy technologies to produce electricity.

In addition to GIZ, SNNPRG Mine and Energy Agency the involved in the development of MHP and also working to implement its regional program called Southern Regional Rural Electrification programme, since 2011 through coordination of Zone Water, Mine, and Energy department and Woreda Water, Mine and Energy office mainly MHP to the rural kebeles of ROR potential area.

1.2. Statement of the Problem

In a region like Sub-Saharan Africa, nearly 730 million people rely on the traditional use of solid biomass (mainly fuelwood, charcoal, and dung) for cooking, typically with inefficient stoves or simple three-stone fires, in poorly ventilated spaces. Access to modern energy services remains limited; more than 620 million people have no electricity (IEA, 2014). Moreover, 25% of developing countries population, 69% of Sub-Saharan African countries population and 63 % of Ethiopian population have no access to electricity (UNDP, 2009; IEA, 2010; DGEP, 2011; and EPA, 2012). In Ethiopia, the lack of access to modern energy services that are clean, efficient and environmentally sustainable is a critical limitation on economic growth and sustainable development. Recognizing the critical role played by the energy sector in the economic growth and development process, the Government of Ethiopia (GoE) has embarked on large scale hydroelectricity projects, with a view to developing renewable and sustainable energy sources (Guta et al,, 2015).

Many have criticized that renewable energy projects and programs have often failed to create long-term impacts such as better livelihoods and increased well-being or sustainable energy services, thus it could be speculated whether energy has had any major impacts so far in reducing poverty (World Bank & Winrock International 2003, UNDP 2004a, b, GNESD 2006, 2007, Urmee et al. 2008, 2009). Despite huge efforts from the implementing agencies and the advance in technologies, experiences show that these projects are not achieving their goals up to the stakeholder's expectations (Bhandari et al., 2018). Technical, economic, and social sustainability of such projects are lacking in many cases. Despite the increasing, unmet demand in electricity and the increasing installations of small-scale renewable energy projects such as MHPs, the sustainability of the installations is still in question. Similarly, Urmee & Harris, 2009 state that program success could be enhanced in many cases by following best practice guidelines, defining specified program objectives in terms of outcomes to users, ensuring availability of adequate funding and policy support and by guaranteeing that program implementers have adequate training in program management (Urmee & Harris, 2009). Rural electrification is seen as a key mechanism to improve living standard (Practical Action, 2010); increase income through income generating activities' (Practical Action, 2012); improve community services such as education and healthcare (Practical Action, 2013

MHP has been recognized as one of the important projects in alleviating poverty in rural areas of Ethiopia. However, to date, mechanisms to implement rural electrification projects are far from perfect as problems with dissemination and sustainability in rural areas have not abated(Williams and Simpson, 2009; Peters et al., 2009). RE projects have earned over their failure largely due to inefficiency and ineffectiveness in management (GNESD, 2006) and only a few empirical studies exist which analyze the impacts of such project on local living conditions and its sustainability post-implementation. Therefore, as of the running and maintenance, in the perspective of achieving medium to long term operations, it is important that several aspects of sustainability -such as social, technical, economic and environmental are attained, thus guaranteeing that the local communities can run the systems by their own without the continuous dependence from external aid.

To better understand the impacts, the sustainability, and the factors influencing sustainability of these projects, the case study presented in this paper evaluated the sustainability of a Lelta MHP project in Aleta Wonedo Woreda. A thorough sustainability assessment comprising technical, social, economic, and environmental factors has been carried out in this work. The overall aim of this study estimates that the total benefits attributable to electricity access and the sustainability, and the factors influencing sustainability MHP projects in rural areas of SNNPRG.

1.3. Objective of the Study

1.3.1. General objective

- The general objective of the study is to evaluate sustainability and benefit of Micro-hydropower development in Lelta Sodicha, Aleta Wonedo Woreda.

1.3.2 Specific objectives

- To identify resource availability for electric energy production
- To establish flow duration curve of river
- To estimate supply and demand of river electric energy
- To investigate benefits of Micro-hydro power development to rural community.
- To determine technical efficiency of the Lelta MHP.

- To identify factors affect the sustainability of Lelta MHP.
- To estimate power requirement of the study area for the next 10 years.

1.4. Research questions

To fulfill the above objective of the study, the following specific research questions were employed.

- Is river potential for long time electric power production?
- How the flows vary throughout the year?
- Can supply fit the demand of community/
- What are the benefits from development MHP to the rural community of the study area?
- What are determinants of sustainability of MHP?
- How technically efficient the MHP?
- How the demands vary throughout the year?
- How much is the future energy demand and MHP potential in the next 10 years?

1.5. Scope and Limitation of the Study

Geographically, this study was limited role of community in rural MHP services to Agara Sodicha and Goredma of Aleta Wonedo Woreda, South Regional State of Ethiopia. Conceptually, this research was limited to identifying benefits and factors affecting sustainability of Lelta MHP at the rural household level. This research limited in Lelta MHP beneficiaries of Agara Sodicha and Goredma of Aleta Wonedo Woreda.

1.6. Organization of the Thesis

The remaining parts of this thesis organized into four parts. Chapter two deals with review of literature related literature to study. The approach and method applied in the analysis presented in chapter three. Major findings and discussion presented in chapter four. The final chapter presents conclusion and recommendations based on the study result.

2. LITERATURE REVIEW

2.1. Overview MHP Development

Ethiopia there is supplies with excellent potential hydropower resources of which only less than 8.5 % have been exploited (Ministry of Water, Irrigation and Electricity, 2017). Electricity mainly generated by large hydropower stations and after transmission distributed by means of the ICS. About 90 % of electricity generated from hydropower and the remainder from wind, geothermal and diesel. The estimated economically exploitable hydropower potential ranges between 40,000- 45,000 Megawatts (Ministry of Water, Irrigation and Electricity, 2017).

Table 2-1:- The energy resource potential of Ethiopia (MWE, 2017).

Resource	unit	Exploitable Reserve	Exploited	
			Amount	Percent
Hydropower	MW	45,000	3810	<8.5%
Solar/day	kWh/m^2	4-6		<1%
Wind: Power Speed	GW m/s	1350 >7	324MW	<1%
Geothermal	MW	7,000	7.3MW	<1%
Wood	Million tons	1120	560	50%
Agricultural waste	Million tons	15-20	~6	30%
Natural gas	Billion m^3	113	-	0%
Coal	Million tons	>300	-	0%
Oil Shale	Million tons	253	-	0%

Careful estimations suggest that there are more than 5,000 potential sites for mini and micro hydropower (MHP) in Ethiopia in addition to the sites for large hydro plants (Fekadu, 2000). Traditionally, since the last century, hydropower was used in Ethiopia for grain milling. About one thousand "arab mills", so-called **Yareb Wefcho** were in operation of which only about 50 % remained, mainly due to confiscation following the

1974 revolution and discouragement of private business during the years of socialist rule. According (Feibel,1999), during the last ten years only 33 micro hydropower plants for grain milling purposes have been implemented, 30 by the Ethiopian Evangelical Church of Mekane Yesus (EECMY). Due to lower investment cost, spatial flexibility and ease of installation most mills in operation are driven by diesel geneses and a few hydropower driven mills were even superseded by so-called "diesel mills".

According to world small hydropower, development (2013) report stated that in February 2012 three MHP plants with a cumulative capacity of 125 kW were inaugurated in the villages of Beshiro Gute, Gobecho, and Agara Sodicha in Sidama zone in the Southern Nations, Nationalities and the Peoples’ Regional State (SNNPR). The plants were implemented in partnership with Sidama Mines, Water and Energy Agency, the Sidama Development Association and local communities, and with the support of the Energy Coordination Office of GIZ.

2.1.1. Water resources available

Multiple studies have been conducted on the different aspects of determining water availability. Equations for determining water availability in Oregon are provided in Cooper (2002). A statewide evaluation of low-flow characteristics was published by Lystrom (1970) that included low-flow equations. Harris and others (1979) developed regression equations for predicting peak discharges in rural unregulated streams in western Oregon. Harris and Hubbard (1983) developed peak-discharge regression equations for eastern Oregon. Using additional years of data and stream flow sites, Cooper (2005; 2006) developed peak-discharge regression equations for streams in western and eastern Oregon, respectively.

The frequency distribution of stream flow of a specific time period is represented by flow duration curve (FDC) (normally daily, but can also be hourly) (Vogel and Fennessey, 1994 &1995; Smakhtin, 2001). It is effectively an alternative representation of the cumulative distribution function of daily (or hourly) stream flow. Hydrologists have traditionally analyzed the FDC using purely graphical representations (Ward and Robinson, 1990), or using stochastic models that focus on fitting appropriate statistical distributions and estimating associated parameters (Castellarin et al., 2004a; Iacobellis, 2008).

Furthermore, Stream flow duration curves (FDC) have been advocated for use in hydrologic studies such as hydropower, water supply, and irrigation planning (Chow, 1964; Warnick, 1984). According to Mitchell (1957) and Searcy (1959) describe additional applications to waste-load allocation and other water-quality management problems. Male and Ogawa (1984) show how FDCs can be used to illustrate and evaluate the trade-offs among the variables involved in the selection of a wastewater-treatment-plant capacity. The U .S. Bureau of Reclamation (Strand and Pemberton 1982) use FDCs in river and reservoir sedimentation studies that examine the frequency of suspended sediment loads and determine the long-term average suspended sediment yield for a given site. Furthermore, the relationship between rainfall and runoff was derived so that the mean annual and mean monthly flows can be estimated for any location, based on the mean annual rainfall (Fry et al., 2004).

2.1.2. Technical Components of MHP

MHP system has become the main interest for future hydro-developments in Europe, where large-scale stations have indeed been utilized but in return giving negative effects to the environment (Paish, 2002; Yaakob, 2014). Most low head micro-hydropower plants generatepower less than100kW (Burton, 1992; Edy, 2009), but there are also other categories with classification below 500kW (Paish, 2002). Micro hydropower System component as shown in Figure 2.1: consists of a civil parts which weir (diversion dam, thrash rack and intake), desander (desilting, spillway), headrace (open canal, culvert, pipe, tunnel), forebay (temporary storage, pressure relief, surge tank, spillway) and powerhouse which protects turbine-generator. Micro hydropower System consists of a civil parts which weir (diversion dam, thrash rack and intake), desander (desilting, spillway), headrace (open canal, culvert, pipe, tunnel), forebay (temporary storage, pressure relief, surge tank, spillway) and powerhouse which protects turbine-generator.

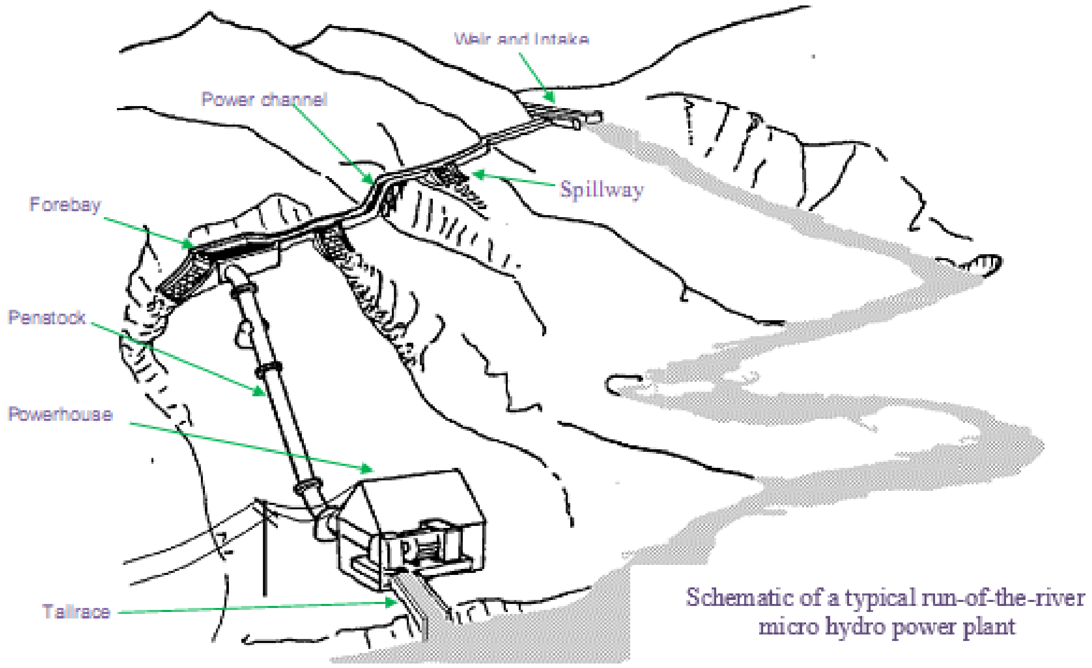


Figure 2-1:- Micro hydropower plant overview (Singh, 2009)

Mechanical part include penstock (pressurized pipe), water turbine (converts static head and velocity head to rotating mechanical energy), generator (converts rotating mechanical energy to electrical energy), tailrace (directs diverted water back into the main river), and other electro-mechanical equipment, metering, monitoring and control).

The general formula for any hydropower system output is (Stout, 1990),

$$P=\eta*g*Q*\rho*H \quad \text{---------------------------}1.$$

Where P is the mechanical power produced at the turbine shaft (watts),

η is the hydraulic efficiency of the turbine, ρ is the density of water volume (kg/m3),

g is the acceleration due to gravity (m/s2),
Q is the flow rate passing through the turbine (m3/s) and
H is the effective pressure head of water across the turbine (m).

The selection range of the turbines generally depends on many criteria, such as various ranges of the head, flow rate, shaft speed and specific speed (Table 2-2) (Williamson et al., 2014). There are also other factors that need to be taken into account when selecting turbines, including the depth at which the turbine should be positioned, its performance and cost effectiveness (Ghosh and Prelas , 2011). Proposed a method to select the most efficient turbine for a low – head hydro- specification by using quantitative and qualitative analyses (Williamson et al., , 2014).

Table 2-2 Range of selection turbine ((williamson et al., 2014

Quantitative criteria	Qualitative criteria
Rated flow/head efficiency	Environmental – weather – location
Part flow/head efficiency	Required civil works
Cost	Portability and Maintainability
Turbine rotational speed	Reliability
Power for given site	Ease of manufacture
Size of system	Design modularity

A cross-flow turbine (CFT) is another significant impulse turbine. It is commonly applied in horizontal and vertical configurations. This type of turbine is usually used at the higher flow rate and lower head than the Pelton and turgo turbines (Tushar, 2011) and (Ossberger, 2011). The average efficiency of CFT turbines is usually 80% for small and micro-power outputs; but can reach up to 86% in the case of medium and large units (Ossberger, 2011).

2.2. Sustainability of MHP

The sustainability of any kind of off-grid rural electrification usually requires active local participation in the development and implementation of the electrification projects (Pigaht and Plas, 2009). Mobilizing the necessary resources is often challenging. Rural electrification can hardly advance without the involvement of private finance and public coordination. At the same time, the commercial financial sector is reluctant to engage in rural off-grid investments. Increasing mobilization of local financial resources with active participation of the community in the rural areas is necessary but is hard to achieve among the poorest. Therefore, identifying innovative mechanisms to attract capital and increase financing is key to advancements in rural electrification and, ultimately, rural development (Mainali and Silveira, 2011). The question always remains how to achieve this in rural regions. Besides the social benefits, decision makers tend to give more importance to the economic impact of access to electricity as an income-generating process. Such economic growth is obviously an important achievement of any rural electrification program (Kaygusuz, 2011).

Developed and applied a multicriteria analysis (MCA) for a national-scale sustainability assessment and ranking of 11 different renewable energy technologies in Scotland (Troldborg et al., 2014). The developed MCA considers nine criteria comprising three technical, three environmental, and three socio-economic criteria. The authors suggested that, when assessing the sustainability of different energy projects, it is important to address uncertainties associated with the input information which the MCA is based, in order to obtain more robust results and ensure better informed decision-making. Liu (2014) proposed an assessment framework for renewable energy systems including the aggregation of several basic sustainability indicators to a general sustainability indicator or index. The framework that used as guidance for the development of sustainability indicators for various renewable energy systems, but it does not provide a detailed assessment framework in an electrification context. According Kumar and Katoch (2014) presented a review of sustainability indicators for run off river hydropower projects in India. They presented the hydropower sustainability indicators under social, environmental, and economic dimensions.

In another study, Kumar and Katoch (2015) carried out a sustainability assessment of small hydropower plants in the western Indian Himalayan Region. They used the common perspectives of sustainability: environmental, social, and economic. Small hydropower plants identified as one of the main pressure points in the sustainable development of Himalayan regions of India and neighboring countries. On the other hand, Painuly (2001) classified problems as 1) market, 2) economics and finance, 3) institutional, 4) technical and 5) social and cultural which are related to the development of renewable energy infrastructure needs to be more strongly based on comprehensive consideration of technical, economic and social feasibility.

2.2.2 Social Sustainability of MHP

Micro-hydropower source is significantly cost effective in socio-economic development of isolated hilly and mountain areas. According Khennas and Barnett (2000) in addition, low head micro- hydropower can reduce the poverty level in these areas, considering the cost per person to pass above the poverty line. Social and economic development requires much more than just power and water, such projects appeal to politicians and financiers seeking a path to national development that is centralized and thus conceptually and administratively ‘simple’(John et.l, 2006). According to Terrapon et.al (2014) on impacts and sustainability of small-scale renewable energy projects in developing countries stated as access to sustainable and affordable energy services is a crucial factor in reducing poverty in developing countries.

However, most governments favor solar and wind schemes over micro-hydropower installation (Wallace and Whittington, 2008; Wachter, 2009). For domestic applications, like light bulbs, radios, televisions, rice cookers, heaters, refrigerators, and food processors, electricity is required. This system is commonly used where cost of direct electrification is prohibitive due to scattered and sparsely populated housings (Anderson et al., 1999).

2.2.3. Financial and economic sustainability of MHP

In fact, SHPs already play an important role in the economic development of some remote rural areas. Small-scale hydropower-based rural electrification in China has been one of the most successful examples, where over 45,000 small hydropower plants totaling 55 GW have been built that are producing 160 TWh (0.58 EJ) annually. Though many of these plants are used in centralized electricity networks, SHPs constitute one-third of China's total hydropower capacity and are providing services to over 300 million people (Liu and Hu, 2010). According European Commissions (1997), manual financial and economic analysis of development projects state the difference between economic and financial.

Economic analysis would include calculating, all the effects induced in the economy, determining the project's viability within the framework of the international economy, calculating the return on invested capital (based on the total effective cost, the foreign exchange cost, and or the international market cost), and examining the project's relevance from the standpoint of the economic policies and any structural reforms being carried out. Financial analysis include identifying and estimating all the flows of money, goods and services resulting from the activities of the entity in the with- and without-project situations, including investment costs, operating costs, and benefits which the entity earns from these activities and estimating the borrowing requirements for the with-project situation.

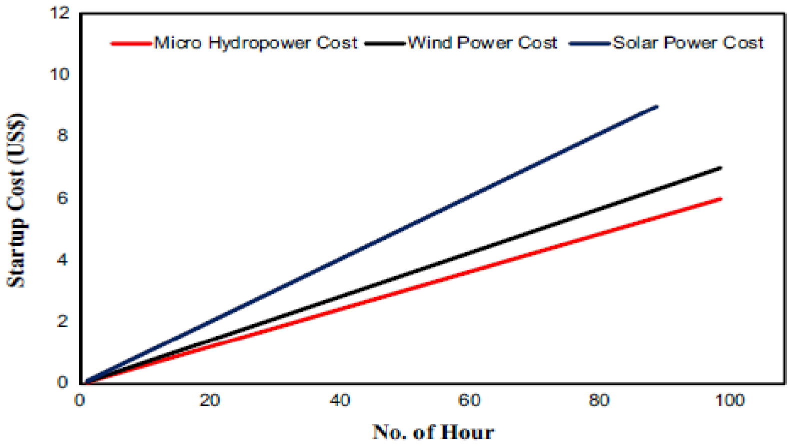


Figure 2.2:- initial cost with number of hour for different renewable energy schemes (source: - Wachter, 2009).

According to studies by World Bank, the startup cost of micro-hydropower consumes almost 6cent/h, while the estimated initial costs of wind and solar power plants are 7cents/h and10cents/h, respectively; defining the initial cost of a micro-hydropower plant is around half of that of solar energy plant, as shown in figure 2.4. In general, the cost of the establishment of a micro-hydro power station can be divided into four parts (Laghari et.al,2013): the civil work which represents about 40% of the total cost, turbine and generator set (30%), control equipment (22%) and management cost (8%), respectively. References by scholars suggested about proposed micro- hydropower projects with the total budget varying from $1500 to $2500 per kilowatt of power capacity (Ranjitkar et.al, 2006 and Kusakana et.al, 2008).

2.3. Micro Hydro Power and Rural Electrification in the rural area

Scholars in the field of the ownership of a micro hydropower project pay close attention to the sustainability of technology Khennas and Barnett (2000), explain that the form that takes is a factor that does not make much difference. They do recommend that community-based micro-hydro projects adopt a concrete business management style, citing the importance of job training, the creation of by-laws, and the recording and filing of meeting minutes as critical to project success. Risal (2002) study supports this view by recommending that private investors take the lead in managing hydro projects. Similarly, in a comparative study by Khennas and Barnett (2000), they found both Zimbabwe and Mozambique, in their efforts to develop effective renewable energy, have had greater financial success through privately-owned schemes than domestic use community-based micro-hydro projects.

According to the EEA (2002), there is a huge energy resource potential in Ethiopia, the total exploitable renewable energy that derived annually from primary solar radiation, wind, forest biomass, hydropower, animal waste, crop residue and human waste is about 1,959x103 Tcal per year. As Wolde-Giorgis (2002) stated, the rural energy problem in Ethiopia will continue to be one of the chief causes of underdevelopment and poverty unless timely interventions are made. Based on the estimated resources as established in various energy assessments and appraisals (World Bank, 1984; CESEN, 1986), a national energy policy was adopted in 1994, giving priority to the harnessing of the immense hydropower potential in the country (Ministry of Mines and Energy, 1994).

2.4. HH Electric Energy Consumption and Demand Forecasting

Micro-hydropower schemes can be used to generate enough electrical power for home, farm, and plantation or for small village (Mohibullah et.al. , 2004).They canal so be used in mechanicalend-uses like agro-processing, textiles fabrication, ice cream production, cooling, and drying (Dilip,2009). The main advantages of low head micro-power system are that it is predictable if enough water supplies is available (Teuteberg, 2010) and possesses positive environmental impacts (Yaakob, 2014). Reviews of the impacts of both grid connections and distributed energy find no particularly noticeable impacts on economic development, which are generally thought to be uncertain and largely anecdotal (Schillebeeck et al., 2012; Terrapon-Pfaff et al., 2014). Yet there are single studies that find systematic and generalizable impacts, showing that electrification drives increases in income and improvements in economic activity. These mixed results suggest that while electrification matters for economic development, by itself it is insufficient to drive development, and other factors likely matter in determining economic outcomes (Cook, 2011).

Similarly, find that only a few HHs use electricity for productive purposes (World Bank, 2008). Among those that do, the focus is on a few small business owners who use electric lighting to extend their business hours (Azimoh et al., 2015; Bhattacharyya & Palit, 2016; Broto et al., 2015). The small number of HHs that use electricity to start new businesses, such as hairdressing salons (Broto et al., 2015; K. Lee et al., 2014) and cold storage facilities (Broto et.al., 2015). Notably, there is limited evidence of HHs using electricity for productive purposes involving motive power (such as carpentry or milling) (Khandker et al., 2009b; K. Lee et al., 2014). Therefore, end-use, the demand will be the estimated number of appliances multiplied by an intensity factor based on surveys. McAleer 1982), Farahbakhsk et al 1998), Tanatvanit et al (2003) use this approach to analyze their economy"s residential energy demand. This approach has an obvious benefit that it could explain the actual dynamics of residential energy demand. The approach is therefore, Swan and Ugursal (2009) built a typology of residential energy models and showed that the bottom-up approach enables to determine the energy consumption without relying on historical data.

3. MATERIALS AND METHODS

3.1. Description of the Study area

3.1.1. **Location**

They study area entirely lies within the Sidama Zone, in the SNNPRS. Astronomically, the area under consideration is located between38^{0}15´ and 38^{0}45` E longitude and 6`15’ and 6^{0}45 N latitude. In relative terms, it is bordered Darra Woreda in the South, Bursa Woreda in the West, Dale Woreda in the NorthChukko Woreda in the East, and Hulla Woreda in the South West.

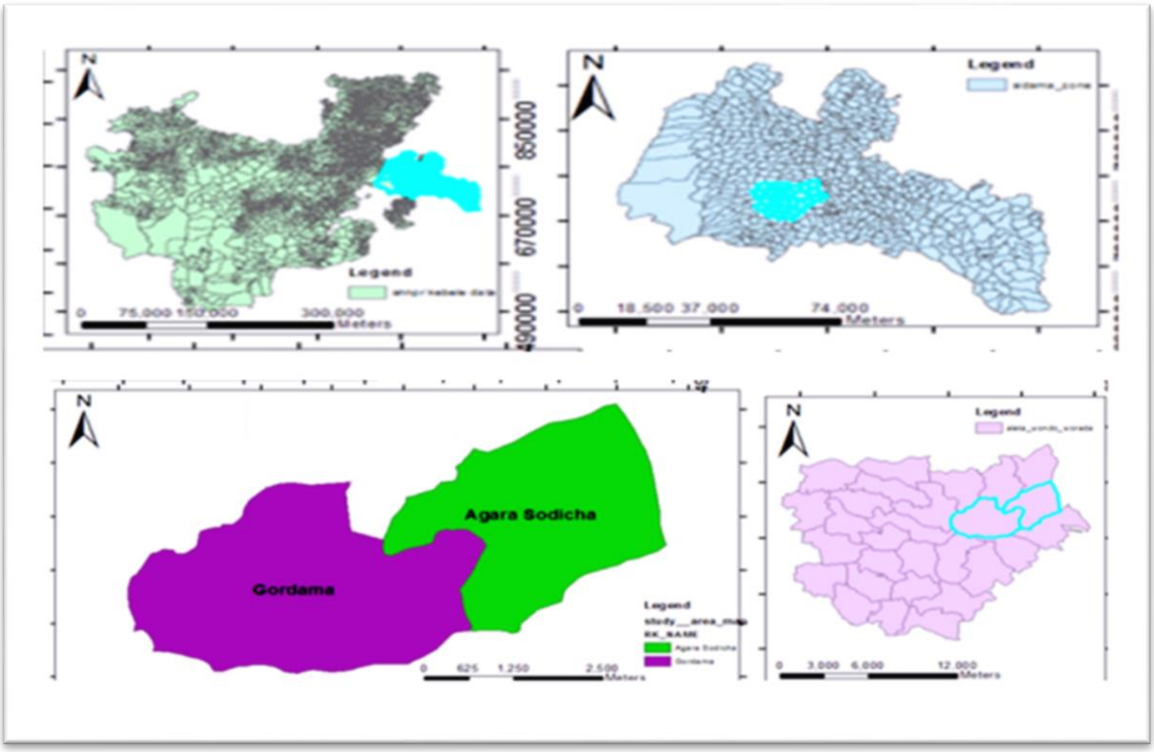


Figure 3-1Map of study area

The study area spans over a total area of about 567.03 square kilometer and inhabited by 347,123 people with crude density of 612.2 persons per sq. km. This is very high as compared against the regional and the national one, i.e. 183.3 and 54.4 persons per square kilometer respectively. However, it is slightly lower as compared to Sidama Zone which is 383.5 persons per sq.km (CSA, 2002). The high population density of the study area was indicated in the Central Statistical Agency Abstracts (CSA, 2006) report. The report indicated that the average population density is actually, 102.6 persons per sq. km while the highest population density is 1,120.8 persons per sq. km in Wonago, followed by 746.4 persons per sq. km in Damot Gale and 704.8 persons per sq. km in Aleta Wondo (area of study) of the southern region. The overall population density of the study area testifies the presence of high population pressure in the area under consideration. The current population of the Woreda is estimated to be 436,672 of which the rural population comprises 418,135 and urban population of 18,537.

3.1.2. Topography

The nature of topography of a particular geographic entity has multi-dimensional implications up on the development of physical infrastructure, human way of life and the type of flora and fauna exists. For that matter the topographic setting of the area under study was dealt with. Aleta wondo woreda is by large falls within the southeastern highlands and in fact yet small portion lies within the rift valley physiographic regions. The map obtained from Sidama Zone Planning and Economic Development Department (SZPEDD, 2001) reveals that the elevation of the study area ranges between 1001 and 2,500 meters above sea level. Consequently, the elevation difference in the study area is about 2,230 meters that demonstrate the existence of variegated agro climatic zones.

3.1.2 Climate

The woreda possesses three climatic divisions of 12% highlands (Dega), 71% medium land (Woina Dega) and 17% Kola. The majority of the area of the woreda is kola/woina dega. The average annual rain fall is 1200-1600mm. and the elevation ranges from 1700-2000 m.a.s.l (, 2008). There are two cropping seasons in the area Belg (short rainy season) from March to April and Meher (Main rainy season) from June to September. Belg rains are mainly used for land preparation and planting long cycle crops such as maize and seedbed preparation for Meher crops. The Meher rains are used for planting of cereal crops like haricot been, teff and vegetable crops and also responsible for perennial crops such as enset coffee and chat.

3.1.4 Economy

The economy situation of the Agara Sodicha and Gordma is slowly improving. Prices for crops and livestock had been stable over the last year and guaranteed a reliable income. In addition larger areas were cultivated increasing the crop yield per farm. One of the main problems that plague the local agricultural business is the increasing fragmentation of land ownership due to the tradition of granting all heirs within a family a piece of the land owned.

3.2. Data Sources and Data Collection Method

This research relied on both qualitative and quantitative data collected from primary and secondary.

3.2.1. Primary source of data

Primary sources of data include field observation, HH survey, key informant and focus group discussion.

Field observation: - This method was employed in order to enrich and maintain the quality of data and assure the accuracy of the research finding.

Household survey: - A structured questionnaire was administered. The researcher developed the questionnaire in English and translated into Amharic. The questionnaire, which takes 25-30 minutes to fill, included information about rural households' fuel type, status and importance of electricity, the respondent's characteristics, type of appliance, fee of electricity annual, total annual income of household, general factors that affect sustainability of MHP.

Key informants: - Based on snow balling method eight informants interviewed from each kebele. Interviews used to explore variables under investigation in detail. Semi-structured interviews held with key informants of beneficiaries of electricity in each kebele.

Focus Group Discussion: - Discussions focused on the study issues carried out among groups classified by age, six and monthly fee for electricity. Separate discussions were held with the young, old, women and different level of fee for service so to avoid specific group's idea dominancy. One focus group discussions held in each of the selected kebeles.

Document Analysis: - Secondary data collected from baseline survey, design document, connected household, and type of appliance in use per household and fee of electric energy per month. During field survey in 2017 cooperative committee indicated that Lelta MHP plant full fund GIZ-EnDev rural electrification project which serves 240 HH and 16 public and religion institutions and one school and generates a monthly are 850 birr per month and income of 3,650 birr per month from connected household. On average, HH uses 100 W per HH and 200 W per institution. During past 4 year lifespan of Lelta MHP, there was three minor repairs carried out by GIZ-EnDev and with the collaboration of Stockholders and community.

General Lelta MHP Information and Characteristics

At the outset of the project, the tariff rate was 10birr/Lamp connected due to the absence of metering system. Tariff collection comes between birr 4500-5000/month. The total operating cost per month is approximately birr 2400 (Personal interview with villagers and committee members in Lelta MHP, 20 October 2017). The Lelta MH plant generates capacity 66 kW (from design document) of electricity and runs 18 hours per day (interview with operator of Lelta, 2018). The total construction cost in birr was 3,146,670.77 of which was Covered by GIZ EnDev rural electrification programme part.

Villagers, through sweat equity and labour contribution, contributed to them during construction.

Table 3-1:- Results from Lelta MHP

No	Criteria	Unit(s)	Lelta MHP(2012)
1	Financial and economic sustainability	Total capital construction cost(birr)	3,146,670.77
		Loan (%)	None
		Grant (%)	100%
		Villagers' monetary contribution	None
		Number of days village labor contribution per person per	60
		List of funders/donors	GIZ
		List of NGOs working on the project	GIZ
		Operation/Maintenance cost per month	2,400
		Tariff collection per month	
2	Technical performance and project efficiency	Power output (kW)	66
		Hours of usage per day drop last one	From 18 to12
		No. of households served	236
		No. of days the project was shut down for repair and maintenance	30 days per year
		Total cost of repair and Maintenance per month	2300birr last two
		Skill of local operator	Trained on the job
		No. of operators working	2
		Monthly salary of operators	1600

Salam Business Technology Group (SBTG) collaborated with the GIZ EnDev to design and manufacture the Cross flow turbine Model T-15 for the project. The purpose document analysis was to see what have been done before and what the gaps would up until now so that the researcher is able to come up with theories, which use to make analytic generalizations of the empirical data collect.

3.3. Sampling Design and Procedures

To generalize, the whole population different sampling designs and procedures are used to get the truly representative sample (Tillé and Matei, 2016). Thus, this section presents the sampling designs and procedures that were employed for this study. For the purpose of study selected two electricity beneficiaries Kebeles(Agara Sodicha and Gordma) from Lelta MHP in Aleta Wonedo Woreda by using purposive sampling technique. At large, there is homogeneity of HH socio-economic characteristics, institutional set up and livelihood structures in two beneficiate rural kebeles of Aleta Wonedo Woreda. When the response for the attributes being measured is assumed a dichotomous, the use of Yamane's (1967) tables and formulas to determine sample size is more appropriate. Since the dependent variable in this study was dichotomous, the researcher used Yamane's formula to determine the sample size for the questionnaire respondents, that is;

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

n=Sample size, N=total population, e= level of precision (0.08)

In the two beneficiaries of rural kebeles, there were a total of 240 HHs. Therefore, the sample size (n): $n = \frac{N}{1+N(e)^2}$=148/(1+148(0.08)$^{2)}$ +94/(1+94(0.08)^{2})=134

Table 3-2:- Sample size per kebele

Kebele	Total house hold of kebele	Total beneficiaries house hold from each Kebele	Sample of house hold
Agara Sodicha	1,143	148	76
Gordma	1804	92	58
total	2,947	240	134

Source: Field survey, 2017

To determine sample size in each kebele, the researcher employed proportional sampling technique and 94 samples were selected proportionally. Each kebele sample size was computed as above in table 3.1.

3.4. Electrical Energy Household survey

A household electrical energy survey was undertaken for the sampled households. The survey involved collecting data on existing electrical appliances in a household. Observations as well as personal interviews were used in the study. A questionnaire was designed to collect the following data among others: Electrical appliances existing in the household; name, type, number of each appliance type in the household and power rating where possible and numbers of hours each of the appliances are used in the household,

3.5. Data Analysis

3.5.1 Flow duration curve development using water balance method

Development of Flow Duration Curves (FDC) using Method of river flow by the water balance model used here is taken from Yokoo et al. (2008) of drainage area. The model used here have involved the exploration of

1. Mean annual water balance within the Budyko (1974) framework (Reggiani et al., 2000), and
2. Mean monthly runoff (Yokoo et al., 2008).

The relation of rainfall, runoff (direct runoff, base runoff), and evaporation is indicated by the viewpoint of annual water balance as shown in the formula below. In this case, pooling of drainage area and inflow and runoff from/to other drainage area are not necessary.

$$\mathrm{P = R + Et} - - - - - - - - - - - - - - 3$$

$$\mathrm{P = Rd + Rb + Et} - - - - - - - - - - 4$$

Where, P : Annual rainfall (mm)

R : Annual runoff (mm)

Rd : Annual direct runoff (mm)

Rb : Annual base runoff (mm)

Et : Annual evaporation (mm) , Runoff (R) is obtained from calculated evaporation (Et) by the presumption formula and observed rainfall (P).

The calculation formulas are Blaney-Criddle formula, Penman formula, and Thornthwaite formula etc. Herein, Blaney-Criddle formula was used which is the simplest method using the longitude and temperature of the project site. The observed value of evaporation from free water surface was also considered.

(b)Blaney-Criddle formula

$$U = K.P\frac{(45.7 * t + 813)}{100} - - - - - - - - - 4$$

Where, u : Monthly evaporation (mm)

K : Monthly coefficient of vegetation, where K value depends on the vegetation condition. Herein, a constant of 0.6 was used.

P : Monthly rate of annual sunshine (%)

t : Monthly average temperature (°C)

(c) Derivation of the monthly mean discharge of Lelta river using formula.

$$Q(i) = \frac{\text{monthly runoff}(4)(1-5)}{1000} * CA * 10^6 * \frac{1}{86{,}400 * n} - - - - - - 5$$

Where, Q (i): Monthly mean discharge at dam site in ‘i (month)’ (m3/s)

CA : Drainage area (km2)

n: Number of days in the month

Descriptive Statistics: - The descriptive statistics of frequency, percentage, means and standard deviation were used by using the SPSS software version 20 in analyzing the data collected through questionnaire. The data collected through semi-structured interviews and focus group discussions were analyzed by the use of intensive textual analysis.

3.5.2 End-Use methods

The end use method captures the impact of ownership and energy usage patterns of various electrical appliances and systems. The penetration (% access level) of each appliance in an income class was computed from the data collected for both urban and rural samples. The percentage penetration levels of a particular appliance (e.g. TV) were obtained by dividing the total number of appliances by the number of households in the sample and multiplying by 100. The standard consumption of all the appliances had been arrived at by the product of average power rating (p) of the appliance and the hours (t) of use of the appliance per year. The standard consumption of a built in oven was calculated as follows equation 7:

$$S=P*t \text{--} 6.$$

The consumption of a particular appliance was obtained by multiplying the standard consumption with the penetration level for the appliance as shown in equation 5.

$$Ea=P*S \text{--} 7.$$

Where, Ea= consumption per appliance in KWh

P=penetration level of the appliance %

S= Standard consumption of appliance in KWh

Once all the end uses were determined, the total residential energy demand was computed based on the Equation 8 by Swisher et al (1987), total consumption per household was then given by summing the consumption of all the appliances as Equation 8;

$$E_i = \sum_i^n E_a \text{---------------------} 8.$$

Where, E_i = Calculated Consumption per appliance type

E_a = Consumption per appliance

n = number of appliances

Lastly, the total energy consumption for each income group was obtained by multiplying the specific consumption with the number of connected households in that income group.

3.5.3 Evaluation sustainability of Lelta Micro hydropower projects

The methodology distributed the different criteria into four sustainability assessment dimensions: economic, social, environmental and technical. Each criterion was divided further into indicators as shown in table 3-3

Table 3-3:- illustrates Adams and Ghaly's framework with attributes and tools.

Criteria	Indicators	tools
Financial and economic sustainability	Total capital construction cost Percentage of loans and grant Tariff collection Operation and maintenance cost List of funders and donors	Appendix 2
Technical Performance and project efficiency	Power output No. of household served Repair and maintenance Skill of operator and manager	
Environmental Effects	Regulations associated with the micro-hydro project	
Social Acceptance	Increase in number and type of service of household. Satisfaction with the project	
User Satisfaction	No complaints about the system Reliable electricity for domestic and/or small business industrial use Improvement in education and health	Appendix 2

This research uses a rating technique of multi criteria analysis adapted from Adams and Ghaly (2007) to evaluate sustainability against the baseline survey and design document of Lelta MHP.

I used the following steps to create an index and evaluate the sustainability of Lelta MHP:

- select success indicators;
- assign weight to each indicator;
- assign point values to projects for each indicator on a scale of 0 to 1;
- sum up indicator point values to arrive at an overall performance score for each micro hydro project; and
- Categorize micro-hydro projects according to their performance scores.

Whereas I selected seventeen indicators based on the relevant data provided by the GIZ EnDev's final report on micro-hydro projects (2012), as well based on drawing from academic literature and experts in the micro-hydro field. The indicators were weighted within each theme, and the themes again were weighted within the dimensions.

$$ELSE=Weighting(X_j)/1-\sum^{m}_{i=1}X_j,\ X_{j,}\ i=1,\ldots m\text{---------}9.$$

This means the actual weighting of an indicator within a theme is the pre-set weighting divided by the sum of indicator weightings within the theme which are not zero. If none is zero, the actual weighting equals to weighting. The same method applies for the actual weighting of themes within a dimension (in that case, xj is a theme). According to Bowen (2007) and Simon and Cleary (2005), coding allows the researcher to identify patterns, variations, and emerging themes within the data that may present links between related events, and present a way to move beyond mere description to more general dimensions of analysis.

3.5.3.1 Financial and Economic analysis

Financial analysis of the project compares benefits and costs to the enterprise. It uses market prices to check the balance of investment and the sustainability of the project. Economic analysis uses economic price that were converted from market price by excluding tax, profit and subsidy. This analysis is estimated on excel spreadsheets. Data that was used for this analysis is initial capital cost of Lelta Micro hydropower units, operating and maintenance cost and total cost. This data was obtained through primary survey from the beneficiaries and cooperative committee of the electricity generation plants. The benefits of the project are the tariffs collected from the households and owners of businesses and service shops that use the electricity generated by Micro hydro power plants. The values of benefits in monetary terms were entered into the excel spreadsheet. The economic life of Lelta MHP plant taken is 6 years. In financial analysis, I estimated Net Present Value (NPV), Benefit Cost Ratio (BCR), and Internal Rate of Return (IRR).

The formula to calculate lifecycle costs per kWh is:

Lifecycle cost per kWh = [(construction cost + operation, repair and maintenance cost till date) - (tariff collected till date)] / [(kWh/yr)*no. of years].-----------10

For Lelta MHP, the "operation and maintenance cost" and "tariff collected" are approximate values. Neither project kept a logbook or performed proper accounting.

3.5.3.2 Standard Conversion Factor for Economic Analysis

According Muhammad and Anwar (2014) Standard conversion factor is used to convert financial values into Economic values. This conversion factor is 0.9 or 90%. For Economic analysis, the costs & benefits of financial analysis cash flows are multiplied by 90% to get economic costs and benefits. For Micro hydropower projects there are no CO_2 emissions from the project. Therefore, there is no environmental cost of carbon emissions. The standard conversion factor has been used by different projects for economic evaluation.

3.5.3.3 Internal Rate of Return (IRR)

Internal Rate of Return of a cash flow is defined as the discount rate that makes the Net Present Value (NPV) equal to zero (Bierman and Smidt, 2012). The higher the internal rate of return, the more desirable it is to undertake the project. It means that at a breakeven point, the total benefits equal the total cost. If IRR is greater than the interest rate, the project can be considered to be carried out (Kierulff, 2008).

IRR=Lower discount rate $(d_1)+(d_2-d_1)(NPV_1/(NPV_1-NPV_2)$ --------------------11 .

Where, d_1=lower discount rate

d_2=higher discount rate

$NVP_1=NPV_1$ at lower discount rate

$NPV_2=NPV_1$ at lower discount rate

3.5.3.4 Net Present Value (NPV)

It is the difference between net discounted benefits and net discounted costs. If NPV>0, the project is feasible. It can also be defined as the algebraic sum of the present value of the proceeds and the present value of the outlays (Bierman and Smidt, 2012). It is the net benefits and net costs of the project. Subtracting the discounted costs from discounted benefits give us Financial Net Present value.

3.5.3.5 Benefit Cost Ratio (BCR)

It is the ratio of discounted benefits to discounted costs. Benefit Cost ratio is the ratio of the present value of benefits to the present value of cost (Bierman and Smidt, 2012).

$$\mathbf{BCR=\sum^{n}_{t=1}B_t/(1+i)t/\sum^{n}_{t=1}C_t/(1+i)t} \text{ -------------12}$$

3.5.4. Future energy demand

The demand for electrical power is based on the number of inhabitants and their activities. The population demand at the end of the maturity is determined by the following formula (Lejeune, 2000).

$$\mathbf{En=(EmPo(1+\alpha)^n)/Hm} \text{ ……………..13}$$

Where; En: Future needs of the population in electrical power, n: Project duration, Em: Needs per household in kW, Po: current population, α: annual growth rate of the population and Hm: average number of persons per household.

4. RESULT AND DISCUSSIONS

4.1. Flow duration curve of Lelta River

The availability of resource for hydropower scheme is very much dependent on the river discharge. Since, the chance of variability through time for gross head of a given site is very unlikely. Therefore, Flow-duration curves were constructed in the water balance model application shown below in figure 4-1, which includes the exceedance probability.

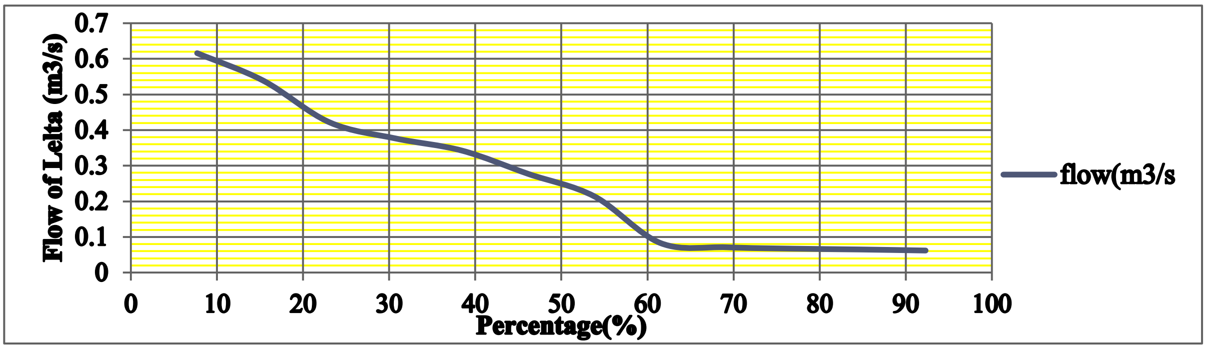


Figure 4-1:- Flow duration curve for the Lelta River.

The results are presented in Figure 4-1. The flow-duration intervals were expressed as a percentage, with zero corresponding to the highest stream discharge in the recorded were attached detail step attached on Appendix 2. The discharge measurements of Lelta River were performed using water balance model the result attached. The maximum and minimum readable level allowed the flow rate measurement of 0.616 m^3/ s and 0.062 m^3 / s respectively. The data analysis result from online Data source RetScreen data base; the three month such as November, December, and January were nullified because the river discharges were lower than 0.07 m^3/s or they were too short for hydroelectric exploitation as shown below in table 4.2. The power in KW output were 21.2 in December, 19.47 in December with probability of 92.3%, and 20.4 in January.

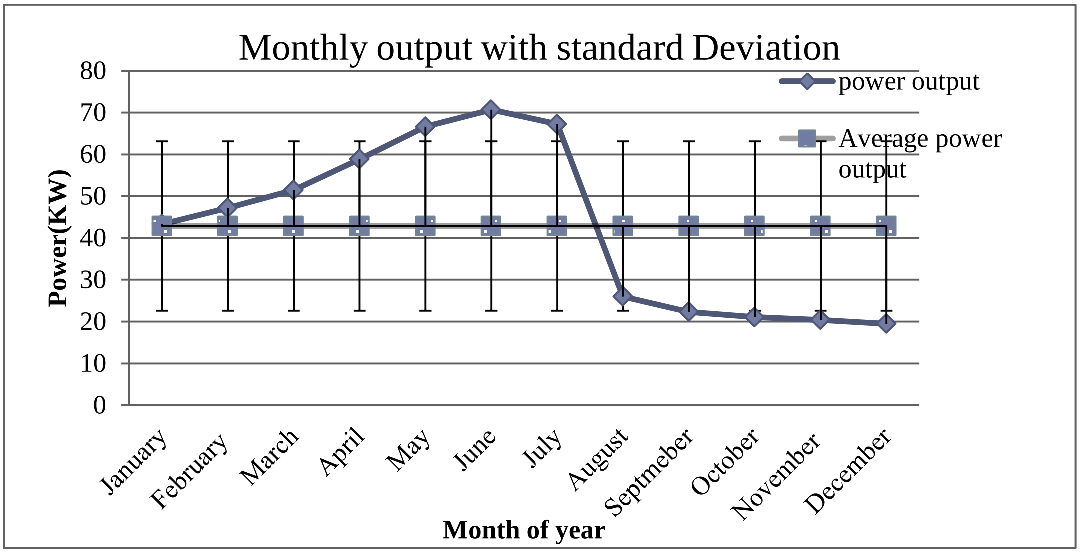


Figure 4-2 Monthly power output and average power per year

4.2. Socioeconomic characteristics of study site

Micro hydro has played the vital role for electrification in the ruler area of SNNPRS. This Lelta MHP project electrify areas are two kebeles of the Aleta Wonedo Woreda. In these study areas, both kebeles has densely settlement in comparison to the other rural kebeles. To make the study more effective/reliable, questionnaires were asked equally according to the population tile of two kebeles with the help of sample ransom sampling.

4.2.1 Gender of the Respondents

There was a significant imbalance in the participant respondents regarding gender. The population ratio of male and female are nearly 50-50 but female respondents were fewer in number than male this research because in many households male were head of the family and the society is patriarchal so male participation was larger number compares to female in this sampling process. Of the total sample, 78.36 %(105) were male respondents where only 21.64 % (29) were female. The gender wise participation percentage of respondents of study area has presented in pie chart 4.1

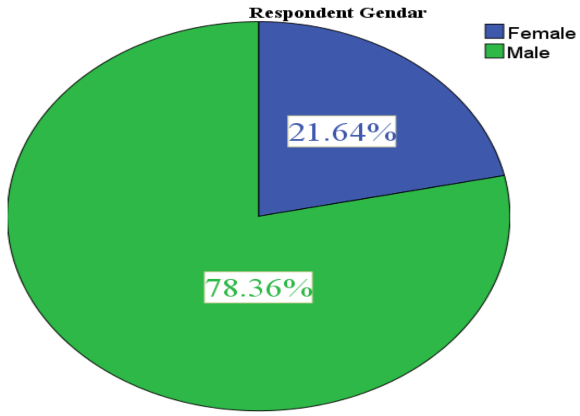


Figure 4-3: Gender of Respondent

From this pie chart, we can say that the study area was still male oriented. In the social work, male had played the leading role whereas female are follower of them. Due to the less activeness of female and shaming to speak, female respondents were less in number than the male respondents.

4.2.2 Education and annual electricity cost of the respondents

The relationship between respondent education and electrical energy consumption annual has been the subject of extensive research. The results education level presented in bar chart 4-2, concerning education 22(16.4%) and 66(49.3%) of respondents have uneducated and completed primary school education respectively, while only 13(9.7%) with secondary school education.

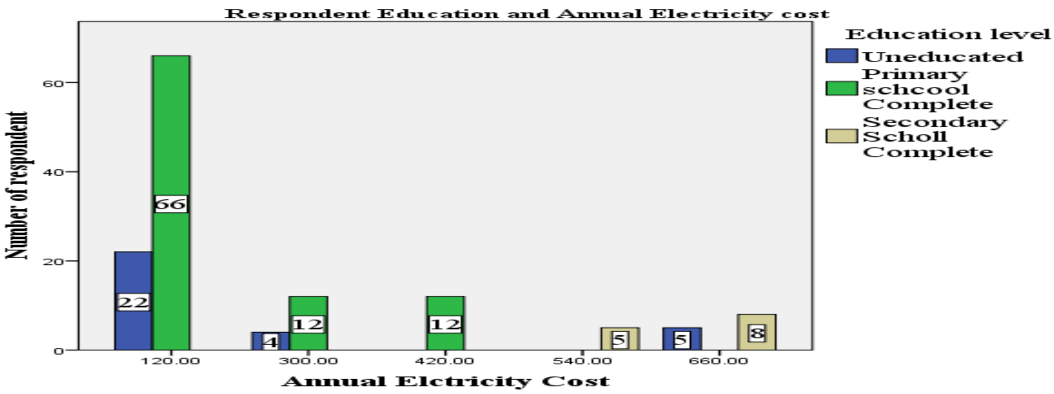


Figure 4-4: Respondent Education and annual electricity cost

The Chi – Square Test for the annual electricity cost was carried out against the level of education, the result was a p-value of 0.000. Therefore p<0.05 thus we accept the alternative hypothesis and reject the null hypothesis. Thus the hypothesis can be restated that there is a significant relationship between level of education and usage of electricity other than lighting.

Table 4-1: Respondent Education against annual fee

Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1.097E2[a]	8	.000
Likelihood Ratio	88.770	8	.000
Linear-by-Linear Association	18.641	1	.000
N of Valid Cases	134		

a. 9 cells (60.0%) have expected count less than 5. The minimum expected count is .49.

4.2.3. Socio-Economic Impact of Lelta MHP in the Study

This section analyses the pattern of household energy consumption on the basis of the data collected from our study area. The households in study area all are found to use electrical bulbs for the purpose of lighting and firewood main baking and cooking fuel of household, even in household using electricity. This study is also consistent with the empirical works of Ahlborg and Sjöstedt (2015) that found firewood (and to some degree charcoal) remains the dominant fuel for cooking, even in household shaving electricity.

The figure 4-4 depicts that, the electricity consumption by HH lighting is 72%(286) power line connected to lighting, 15%(58) power line connected institutional light, 9% (36)of the total connected to charging and the radio playing, only 2.5 %(10) connected to Male Barber and the remain 1.5% (6)of total connected to TV playing.

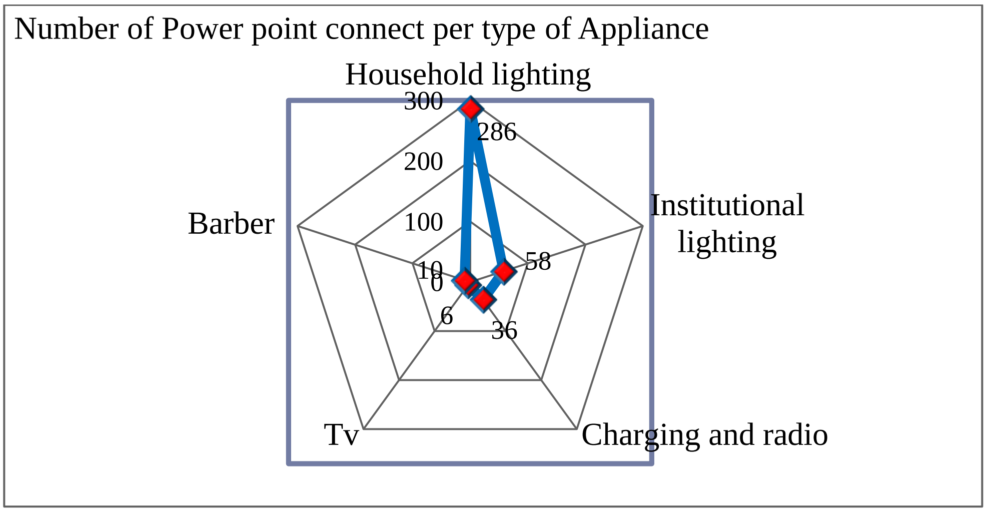


Figure 4-5: Type of Appliances (service) of beneficiary.

This analysis shows that the type of device in use per households of both kebele using the electronic products for the purpose of lighting is highest as compared to the other type of device. Also the hours of using the electricity by the men hair equipment are the highest compared to other device per day. From table 4.3, total power consumption for light was 27.43MWh/year, which account 9.2 % of power generated per year from Lelta MHP.

Figure 4-2 Beneficiaries' house of Lelta MHP (photo)

Device	No of HH using device	Consumption per year
Incandescent bulb	34	4.18MWh/year
CFL	202	9.25MWh/year
Institutions lamp	14	14MWh/year
Men hair equipment	10	8.4MWh/year
TV, Radio and charge	TV=6,R+Ch=36= 42	8MWh/year
Total		43.83MWh/year

Source: Own survey data (2018).

As shown above in table 4.3, about 16.4 MWh/year electric powers were operating a small business and electric device. It means about 4.12 % of total power generated per year from Lelta MHP. Therefore, the total power consumed from plant generated was 43.83MWh/year (11%) only. In another word, there is about 89 % of power waste per year. It means more than the power consumption used for lighting per year. However, in terms of productive use the impacts were limited. Consequently, the evaluation findings support the results of other studies on rural electrification (World Bank, 2008; UNDP, 2011) stating that although electrification may provide opportunities for small business activities, productive use should not necessarily be anticipated from small-scale electrification projects.

Figure 4-6: Lelta MHP villages

4.2.4 Job opportunities due to Lelta MHP

In study site, "we a full-time Lelta MHP operator and Guard was been given employment". The Operator of Lelta MHP has received a short training in Hawassa on the running of the power plant. He has no formal training in maintenance of the MHP. The Operator and Guard received monthly salary of 800Birr and 600Birr per month respectively and works all seven days in weeks. This part of the study shows that having a power plant does not necessarily lead an increase in the number of jobs created directly.

This is consistent with what (Cherni et al., 2009) have found in Cuba where job creation and rise in HH income were minimal from off-grid electrification technologies

4.2.5 Effect of student study hours using Lelta MHP

The basic use of electricity in HHs for lighting, radios, communications and basic home appliances, the application of electricity to activities that might bring economic development through production. By the use of MHP, the study hours of Student have raised.

Table 4-3 Effects on students' study hours using MHP

	Categories	Frequency	Percentile
Increased hours	1 to 2 hour per day	18	47.4
	2 to 3hour per day	15	39.5
	3 to 4 hours per day	5	13.1
	Total	38	100

The finding confirms that 97percent HHs is agreed that the performance of the children has improved in the school then without MHP. In the ruler sector, in the absence of electricity, the students (children) are obliged to use kerosene lamp while studying in evening and nighttime. By this situation schooling, aged generation is mostly affected. They cannot study for a long time due to the deficiency of enough kerosene and deem light. Of the total 38 sample, the finding result confirm that 15 (39.5%) HHs' students raised their study time 2 to 3 hours, 18 (47.4%) HHs children raised 1 to 2 hours and 5 (13.35%) HH children rose up to 3 to 4 hour only. The finding in line to (Azimoh et al., 2015; Khandker et al., 2009a; Prasad & Visagie, 2006) found electrification to have positive impacts on education by increasing study hours, enrollment rates (Khandker et al., 2009b) and reduce kerosene-related fires problem.

Figure 4-7: Agara Sodicha elementary school (photo)

4.2.6 Annual expenditure for Electricity

The management committee of Lelta MHP project makes the rules that payment by HHs up to one lamp is only 120 birr per year. Which is minimum charge of per month for each HH is 10 birr per month costs per one lamp. The national grid costumers pay 0.5birr per KWh where the customers of MH get high cost electricity in comparison to central grid. Also there is no meter system for payment in Lelta MHP. The table 4.4 shows that, the HHs paid maximum birr 720 is seven and minimum birr 120 where about 65 (69.1%) of the total HH during my survey 2017. The data shows that the HHs who manly used MH for lighting purpose pay birr 120 per year but who run the many appliance/business used to pay max 720 birr per year.

In additional, MH is the loss transparence on payment and rise comment due to lack of metering system and user mention during service out that enforced to pay per connected number electric power line per HH. There is comment, due to cost according their comment energy sources in comparison to the national grid. . For households in the electrified villages this reduces of cost from replacing kerosene with electricity for lighting. This finding in line to Tracy and Jacobson (2012) that found rural consumers pays 23% more for kerosene.

Table 4-4:-Regression result of annual electricity expenditure per household electricity

R	R-Squared	Adjusted R-Squared	S	MSE	observation
0.808	0.653	0.6477	108.63	11,801.8	134

Annual cost = - 70.9761 + 0.0131 * Annual income + 28.3631 * Famsize

ANOVA

	d.f.	SS	MS	F	p-value
Regression	2	2,909,048.24	1,454,524.12	123.2462	0
Residual	131	1,546,032.35	11,801.77		
Total	133	4,455,080.60			

Source: - Own survey data (2018).

4.3 Sustainability of Lelta MHP

This different dimensions comprising sustainability of an MHP project must be weighted according to their importance. Based on our data collection, interviews, and observation of the impact of the MHP project pre- and post-implementation, we assigned the weightages to economic 30%, and social and technical dimensions equally at 25%, and environmental at 20%. subsection evaluates the effectiveness of community-based micro-hydro projects based on our six research criteria, which are as follows: adequacy of funding, technical performance/project efficiency, cultural acceptance, social acceptance, user satisfaction and environmental effects. For the qualitative analysis of our data, I used both open and focused coding.

4.2.1 Economical sustainability

The study shows the results of Financial and Economic Analysis in detail in Table 4.7 and 4.8. Initial capital cost of MHP was birr 3,146,670.77. The life of the MHP projects ranges from 20 years to 35 years. However, to analysis both financial and economic sustainability I have been taken the life of the project as 6 years performance. Completion time for the project is one year. Initial costs, operating and maintenance cost, expected benefits and net benefits are calculated on excel spreadsheet. To assess the financial success of a particular project, we analyzed them based on the following indicators:

Table 4-5:- Financial Analysis of Cash Flow (birr) of Lelta MHP Plant

Year(E.C)	Initial cost	O&M Cost	Total cost	Benefit cost	Net Benefit
2004	3,146,670.77	0	3,146,670.77	0	-3,146,670.77
2005		28800	28800	50400	21600
2006		28800	28800	51000	22200
2007		28800	28800	52200	23400
2008		86300	86300	53136	-33164
2009		86300	86300	54,000	-32300
Benefit cost ration			0.080005		
NPV			2,959,711.16		
IRR			-79% for first three years		

Table 4-6:-Economic Analysis of Cash Flow of MHP

year	I.C	O&M C	Total cost	B	NB
2012	2,663,740	0	2,663,740	0	-2,663,740.044
2013		25920	25920	45360	19440
2014		25920	25920	45900	19980
2015		25920	25920	46980	21060
2016		77670	77670	47822.4	-29847.6
2017		77670	77670	48600	-29070
		Sum	2896840	234662.4	
Benefit cost ration			0.081006		
NPV			-2,505,000.75		
IRR			-79% first the three year		

Source: Own survey data (2018).

The study shows the results of Financial and Economic Analysis in detail in Table 4-9 and 4-10. Initial capital cost of MHP is birr 3,146,670.77. The life of the MHP projects ranges from 20 years to 35 years. However, we have taken the life of the project as 6 year project performance. Completion time for the project is one year. Initial costs, operating and maintenance cost, expected benefits and net benefits are calculated on excel spread sheet. The results of Financial and Economic analysis are summarized in Table 4.11.

Table 4-7:-IRR, NPV, and BCR of Lelta MHP Project of last six year

Description	Financial Analysis	Economic Analysis
Benefit cost ration	0.080005	0.076559
NPV	-2,959,711.16	-2,505,000.75
IRR	-79% for first three years	-79% first the three year

Source: Own survey data (2018).

In the table, 4-11 results indicated that the BCR in financial analysis is 0.08 and in the Economic analysis, it is 0.076, which is less than one. Now, power plant system was usually not able to collect enough money for operation and maintenance and the communities were usually dependent on external donors. However, the MHP plant is found with negative NPV, B/C ratio of less than 1. This results indicates that at initial existing condition, the MHP system was financially and economically infeasible were summarized in Table 4.9. This result confirm the empirical work of (Mitlin et.al., 2007; Kamat,2004) that found an NGO-led and donor-funded project, and such development interventions are criticized as being economically unsustainable, donor-dependent, short-term and top-down interventions. Therefore, similarly financial analysis result show existing tariff system cover only operation and minor of MHP and it is can conclude that according to this criterion, the Lelta MHP project is neither viable nor worthy to be undertaken.

The result of survey indicates that average O&M cost of Lelta MHP was 46, 620 birr annual which below 69,226.75 birr. The graph in figure 4-5 show, which, as year of operation increase operation and maintenance cost higher than benefit cost. The result contradict to the result of IRENA and GIZ (IRENA, 2015), show O&M costs for small-scale hydropower ranging between USD 40 50/ kW/ year (1 10 MW) and from USD 45-250/kW/year (below 1 MW). The O&M costs, typically quoted as percentages of investment costs, range from 2.2 percent to 3.0 percent for small HPP percent. This operating and maintenance cost, expected benefits and net benefits cost earned for Lelta MHP performance score 20% of weight.

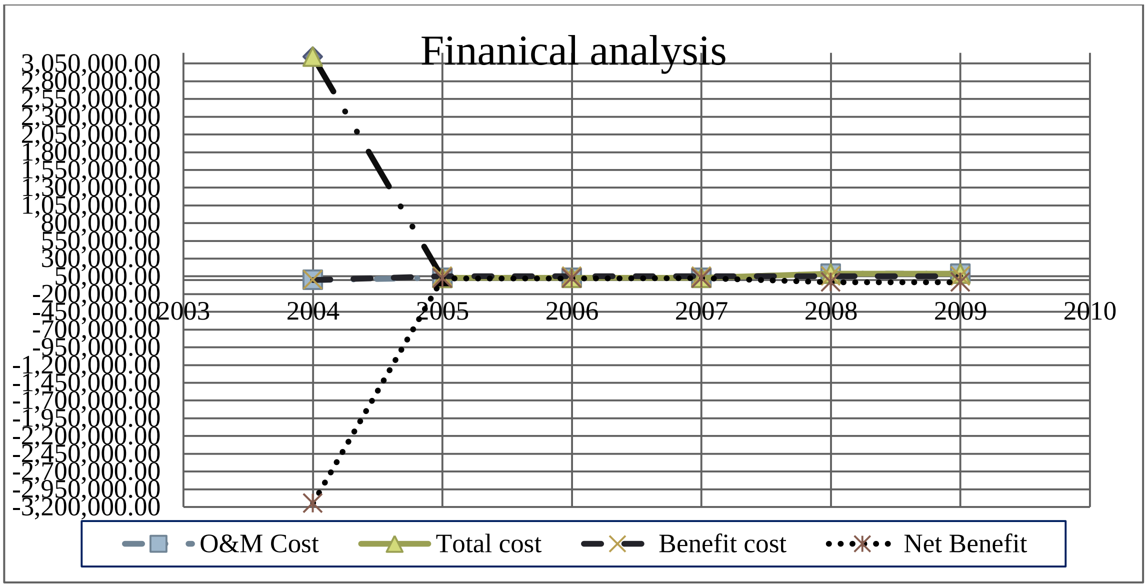


Figure 4-8: Financial analysis of Lelta MHP (**Source: Own survey data (2018).**

Costs contained by good design (Lifecycle costs/kWh):- factor was evaluated through calculating, for projects, the lifecycle costs per kWh. The International Standards Organization (ISO) defines lifecycle costs as "the cost of an asset throughout its lifecycle while fulfilling the performance requirements." Over the first six years in projects, the life cycle cost per KWh Lelta MHP. Due to project, the "operation and maintenance cost" and "tariff collected" are approximate values. Project no kept a logbook or performed proper accounting. The life cycle costs per KWh of Lelta MHP are 1.34birr. This lifetime cycle cost earned for Lelta MHP performance score 80% of weight.

Detail survey and effective installation: - In Lelta MHP, GIZ EnDev involved performed detailed survey of potential and energy demand. During these, period stakeholder selection carried out to establish effective management of power plant. Based on interviews with the user's committee members, we have determined the construction cost quoted by GIZ EnDev. Because the work reached completion by the projected date, the village is satisfied with their performance. There have been no major problems within the last six years. Due to these factors, the project earned a performance score of 100% due to the detailed initial survey and but only earned a performance score of 30% for the effective participation of users and stakeholders.

Collection of tariffs and integration with other developmental projects: - The tariff rate in Lelta MHP has unchanging over the duration last six year in use.

Table 4-8:- descriptive of annual expenditure of HHs

Annual expenditure of HHs	Total	Mean	Std. Error	Std. Dev.	Minimum	Maximum
	N	219.4	14.01	162.22	120	660

Source: Own survey data (2018).

After analyzing the data, it was found that the households who are connected to Lelta MHP maximum electricity pay 660 annual per the MHP connected households. The mean connection charges are also 219.4 with standard deviation of 162.2 for electricity user from Lelta MHP households. Even though, the availability of light is more in case of MHP households. This shows that the consumers of Lelta MHP electricity were used for domestic light.

Based on field observation and interview, the serious tariff management problems for the Lelta MHP have been caused by committee member resign and set for new committee and maintenance issues caused by silt canal during the rainy season. If the tariff steadily increased over time, the project would not have faced these major financial setbacks. In Lelta MHP, there has been no integration of the micro-hydro with other infrastructure projects. Hence, this hydro project earns a performance score of 30%, largely for the uncontrolled tariff expenditure, and a score of zero for their project's integration with other development projects.

Subsidy/grants, local capacity, and availability of developers: - The 2011-2012 GIZ EnDev rural electrification Programme guaranteed 100% of the Lelta MHP. Due to these factors, projects received full amount of grants. However, both kebeles' villagers contribute much of their own labour to supply local construction material and access road to site construction and participation during canal construction on excavation work to ensure the completion of the project. Therefore, this project earned performance scores of 80%t for grants because there is no subsidy from government and zero for subsidy. Hence, the project earned a performance score of 50% for local capacity and input. For projects, the involved NGOs provided significant financial and technical backing during the construction phase. Once the project began operating, the NGOs were generally not involved in project operation or maintenance.

According to GIZ EnDev SNNPR office Coordinator, in community-based rural electrification projects, the policy does not require the NGOs involvement post-completion of a project. Once the management committee is established, the community is responsible for the project. I understand that the community requires help with follow up (Personal interview, GIZ EnDev SNNPR office Coordinator, 7 October 2017). The limited resources of these NGOs restrict them from investing additional time and money into these projects. Lelta MHP projects earn a performance score of 100% for the availability of NGOs during the construction phase and a 50% for NGO availability during the management phase.

Table 4-9: Economic sustainability dimension scores

Dimension	Indicators	Assgm.P	score	Remark
Economic (30%)	Costs contained by good design (Lifecycle costs/kWh)	5	5	
	Detail survey and effective installation	5	3.75	
	Collection of tariffs and integration with other developmental projects	5	0	Unable to score
	Subsidy	5	0	Unable to score
	Grants	5	5	Completely founded
	Operation and Maintenance cost	5	2.5	very high in relation to benefit
	Life cycle cost	5	1.25	Very low
	Local capacity and input	5	1.25	
	Salary levels of employees/ operator MHP(absolute number	5	2.5	Fully not satisfied
	Tariff collection pattern	5	5	Satisfying
	General income increase per household	5	1.25	Partial satisfying
	Aggregated score	55	27.5	2.5

4.2.2. Technical performance and project efficiency

For the technical success and efficiency of a project, this study utilized the following indicators:

- Repair and maintenance
- High load factor (the actual consumption as a proportion of total possible generation)
- Financially sustainable end-use
- Subsidies cover all aspects of the project including end-use investments

Repair and Maintenance: - The Lelta MHP project serves 240 households from both kebeles and generates a monthly income of 4,500-5,000 birr each month. On average, a household will use 100 W, and small business center generally use 0.3 kW. During the six lifespan of the Lelta MHP, there were six minor repair and maintenance issues. Due to lack of market access to buy quality belt and now bad quality belt which require monthly replacing with new. But now there is problem of belt alignment between the turbine and generator.

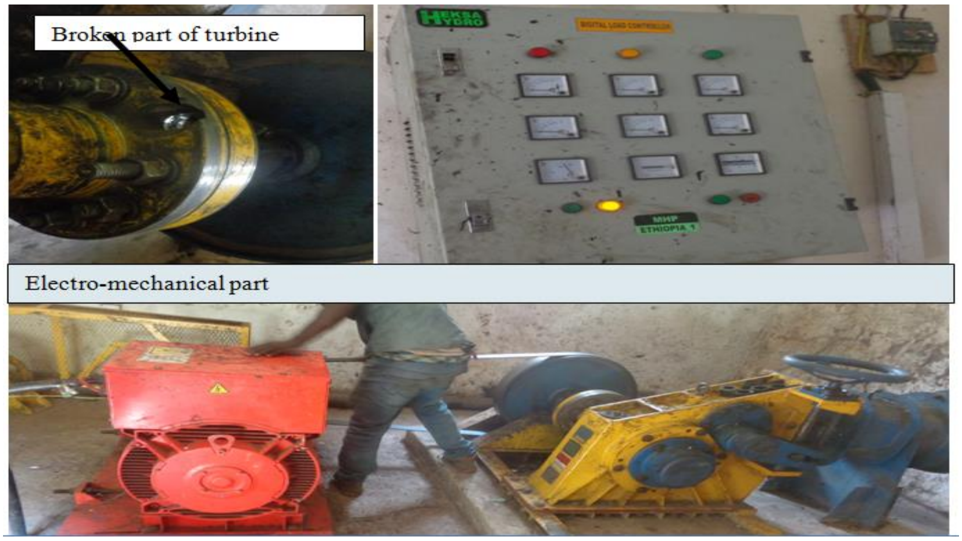


Figure 4-9:- Electro-mechanical part of Lelta MHP

The figure 4-10 showed that the debris accumulation could lead to blockage of the trash rack that could. In turn, decrease water discharge flowing into intake of the MHPP. In one observation during the study, the power plant even stopped working in less than four hours due to total trash rack blockage. The challenge described above shows importance of strengthening the capacity thoroughly. Efficient and timely cleaning of trash rack can have a significant impact on the plant's efficiency and generation. However, it carried out using hands cleaned trash rack with tools developed by the personnel who used it. So, bad quality with the channel regulatory was having problems during rainy season and community not willing to fix it any more.

Figure 4-10:- Sedimentation problem of at settling basin of Lelta MHP

These problems largely concerned having to change the trash rack and canal clearing source and repairing the turbine and generator. The cost of the recent two year repair and maintenance work is 115,000 (personal communication during Committee of Cooperative), but the first two-year repair and maintenances cost covered by donor and the rest covered by collected tariff from beneficiary. The findings further indicate that availability of knowledge, expertise and skills required to sustain the technical systems was central to the technical viability of the projects. This observation is in line with the findings from other studies (Balkema et al., 2010; World Bank, 2008; Chaurey and Kandpal, 2010), which acknowledged problems resulting from lack of technical capacity in rural areas and the logistical difficulties of servicing equipment as one of the major issues. That the availability of local maintenance service is not only an important factor for the sustainability of small-scale projects but also one of the concerns that the users have with regards to renewable technologies in developing countries Pode (2013). However, these reasons that the project earned a performance score of 30% for repair and maintenance work.

High load factor and sustainable end-use:- During the daytime hours, the villagers do not utilize power to its full capacity. The load factor was quite low and electricity used inefficiently according data collected from household load profile of plant. In addition, interview of committee and beneficiary suggest that that the demand during daytime is insignificant when compared to nighttime. This is due to rural poverty and poorly developed economies and markets in study area. The finding of this study is similar to previous works (Ilskog et.al., 2005; Ilskog and Kjellström, 2008) that found low demand for electricity services, slow development of economically productive electricity use and a weak customer base make hard sustainable small-scale energy systems to poor rural areas . However, there are no any government subsidies, which would allow the village to begin productive business, which improve resources efficient use.

Table 4-10:- overall scores for the technical sustainability dimension

Dimension	Indicators	Assgm.P	score	Remark
Technical (25%)	The availability, skills and other capacities of the project developer/ NGOs involved in the project during management	5	2.5	Local Community, GIZ and GOV institutions participation
	Program of asset upgrades	5	0	Unable to score
	Replication of program in nearby villages	5	0	Unable to score
	load factor	5	2	Around 40%
	Maintenance program	5	1.5	No clear schedule communicated
	Capacity factor	5	2	around 40%
	Quality of power	5	3.75	Fluctuations are generally not noticeable
	Aggregated score	35	11.75	1.7

In general, the government subsidy policy does not focus on sustainable end-uses. In addition, there is no selling or purchase agreement and plan to micro hydroelectricity to the national. Given this data, the Lelta MHP project earns a performance score of 30% for both sustainable end-use and Sale of micro hydroelectricity to the national grid.

4.2.3 Social acceptance

Social acceptance is another success indicator for these projects. The type of economic benefit that a project will bring to a village often defines its social acceptance. As a point of comparison, household in the both village have enough power for their daily demand to use domestic light and televisions (Personal interview, 12octber, 2016). About 90% of Beneficiaries' use electricity of light demand. Major goal of project electrifying 1,000 household and supporting product activity not achieved as set during planned. The project had a strong social orientation from the start. But to make electricity affordable for more than the high income households, cost of connection and tariffs were not subsidized. This approach contradict finding (Sovacool, 2013; Palit et.al, 2013) that found financial subsidies are needed to cover the high up-front cost of technology.

4.2.3.1 User satisfaction

User satisfaction is also a success indicator for these projects, where the satisfaction level of beneficiaries often determines the overall sustainability of a project. The result reflects that, Lelta MHP, 33% of the users of electric energy from Lelta MHP were satisfied with the project and 33% thought it was reliable. The regression result of user satisfaction is shown in the table 4-11. The R^2 was found to be 22.57% which is slightly determining. But F-test was also found to be highly significant. User Satisfaction result showed that the family size and household head gender negatively and significantly affected. The t-test value of coefficient is found to be highly significant at 5% level of confidence. Thus user satisfaction is highly determined by annual expenditure of electricity, family size and household head gender.

Table 4-11:- Regression of user satisfaction

Regression Statistics						
R	R-Squared	Adjusted R-Squared	S	MSE	observation	
0.5105	0.2607	0.2257	0.4123	0.17	134	
Satisfaction = 1.3530 - 0.0024 * Age - 0.1368 * Famsize + 0.0096 * Education - 0.2825 * Gender + 0.0009 * Annual expenditure + 0.1194 * Awareness						
ANOVA						
	d.f.	SS	MS	F	p-value	
Regression	6	7.6115	1.2686	7.4622	7.36E-07	
Residual	127	21.59	0.17			
Total	133	29.2015				
	Coefficient	Standard Error	LCL	UCL	t Stat	p-value
Intercept	1.353	0.2279	0.9021	1.804	5.937	2.60E-08
Age	-0.0024	0.003	-0.0084	0.0036	-0.7839	0.4346
Famsize	-0.1368	0.0377	-0.2114	-0.0623	-3.6323	0.0004***
Education	0.0096	0.0851	-0.1587	0.1779	0.1127	0.9104
Gender	-0.2825	0.1067	-0.4936	-0.0713	-2.647	0.0092***
Annual expenditure	0.0009	0.0003	0.0002	0.0016	2.6542	0.009***
Awareness	0.1194	0.1278	-0.1335	0.3722	0.934	0.3521

Source: - Own survey data (2018). NB: *** indicates 1% level of significance.

This result in line to study to (Skutsch, 1998; Grint, 1995) that found gender inequalities in energy project planning, or to more general unequal gender distribution of technology use. Therefore, these results reflect the finding result of Key informant and focus group discussion. The Lelta MHP project has existed for 6 years and even with three minor repair and maintenances, it is not running smoothly. However, available data shows that 67% of the villagers felt the project to be unreliable. At the time of data collection, a major landslide had destroyed all canals, and the power had been out for a more than weeks. This situation may have influenced the responses we received in our interviews.

The data collected consists of quantifiable evidence of summarized in Table 4-10 of respondents were asked whether they agreed with a series of statements representing increasing levels of commitment to implement for a community MHP project.

Table 4-12: Knowledge of meeting and decision making

Total respondent number	Knowledge of meeting		Meeting attendance		Decision making	
	No	Yes	Never	Yes	Never	sometime
134	60.6%	39.4%	57.4%	42.6%	57.4	42.6

In Lelta MHP, (see Table 4-10) 57% of respondents were under the impression that committee meetings were held Quarterly (once in three months). 42.6% of the respondents reported attended the meetings "sometimes" while 57.4% "never" attended. When asked if they took part in the decision-making process, 42.6% said "sometimes" while the rest said "never".

Table 4-13: User of Lelta MHP electricity satisfaction

Users Satisfaction			
	Categories	Frequency	Percent
Satisfaction	Unsatisfactory	63	67.0
	Satisfied	31	33.0
	Total	94	100.0

Source: - Source: Own survey data (2018).

Based on field observations of both villages, one of the primary reasons for nonattendance at meetings is a perceived lack of transparency and poor communication between the Management Committee and villagers. The result inline to previous studies by (Smith et al., 1999) found that sustainability projects in areas without strong networks relied on outside agencies' input. This result is similar to the previous works (Walker et. al., 2007a) that concluded community energy projects can foster trust and cooperative working, whether they do depend heavily on preexisting community dynamics. This implies that to be effective, calls for participation in a community energy project here must be more than the ‘‘knee-jerky generalised appeals’’ for participation warned against by Blake (1999).

Table 4-14: Social sustainability dimension score

Dimension	Indicators	Assgm.P	score	Remark
Social(25)	Training of community members and local community	5	5	
	Sense of ownership	5	1.25	There is problem of participation
	Self-governability	5	2.5	
	Self sufficient	5	1.25	Not cover it cost
	Equity	5	2.5	Women were not participating
	Grid access	5	0	Unable to score
	Satisfaction of the management	5	2.5	Partial
	Satisfaction with costs	5	1.5	partial
	Aggregated score	40	16.5	2.625

4.2.4 Environmental effects

The effect of this power Plant on the watershed could be considered an important factor when evaluating these Micro hydropower generators. It began in 2012, as part of GTZ Access to Modern Energy Services (GTZ AMES) program, which aimed to reduce stress on forest resources which leading to deforestation and degradation. The program focuses on supply electric power to rural villages, elementary schools, health centers and other activities, which need electric power. As survey result shown there is no household or small business use of electric energy for cooking or baking. There is 100% dependence on firewood for cooking, baking and cooking.

Table 4-15: Scores for the environmental sustainability dimension

Dimension	Indicators	Assgm.P	score	Remark
Environmental (20%)	Share of water taken from the river	5	4.25	No impact on aquatic
	Landscape	5	5	No impact on aquatic
	Noise emission from powerhouse	5	5	No impact on aquatic
	Erosion	5	5	No impact on aquatic
	Sedimentation	5	2.5	There is problem sedimentation during rainy season
	Rate of deforestation	5	1.25	Firewood consumption is reduced not remarkably by MHP electricity
	Aggregated score	30	23	3.833

Overall Performance Score

The scores assigned for each evaluation criterion were then summed to arrive at an overall performance score. With case study indicator scores defined and weightages included in the model, the theme and dimensional scores were calculated and the results are presented in Tables 4-11, 4-12, 4-16 and 4-17. As seen in Tables 4-11,4-12,4-16 and 4-17, environmental dimension shows the best performance with a score of 3.833 for the studied Lelta MHP, followed by social (2.625), economic (2.5), and technical dimensions (1.7). The finding inline to result (Shradha, 2009; Bhandari et al., 2018) obtained to 'evaluation the effectiveness of MHP project'. However, project obtained adequate financial support during the construction phase. The Management Committees not work to improve the economic status of the village by establishing financially sustainable end-use.

4.4. Future Energy Demand Forecast

The only available generation data was based on equipment type or appliances, which were, used electricity energy. Due to unavailability of electric consumption metering system and sell data, we were used connected appliance and time of operation per appliance. Assuming 90% plant capacity factor, which is a standard value for a runoff the river type electric power station. To estimate future electricity demand of study area, I used an average consumption per HH of 70.5KWh/month and an estimated growth rate of energy consumption based on GDP growth rate and the income elasticity of study areas' the agricultural sector. The GDP growth rate of agricultural sector was estimated to be 5% based on the average rate from 2002-2007. Income elasticity is considered to be 1.4 (for Ethiopia, according to UNU-WIDER Research Paper No. 2008/107). So, Future electric energy demand from Lelta MHP is calculated using the following equation.

Table 4-16:- HHs and Annual Energy demand growth.

HHs and Annual Energy demand growth							
Year (E.C)	Average monthly Energy consumption per HH(KWh)	HH	Annual Energy Consumption(MWh)	Mean	Std. Dev.	95% Confidence Interval of the Difference	
						Lower Bound	Upper Bound
2010	70.5	236	199				
2015		271	226				
2020		302	255.6	226.86	28.31	216.5	241.7

Since, it was calculated in section 4.13, the annual energy generation of the Lelta MHP is 398.9MWh. This shows that there is enough generation capacity including both technical and non-technical losses to meet the projected demand by 2020 even with increase in population and HHs. The findings in line to other study have applied these parameters (Karma, 2007) that found the productivity of project is insignificant relative to power production, and project intended plan. From beneficiaries and type service of data onto cooperative MHP, provide service of domestic light.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

The subsequent conclusions and recommendations are made on the existing electric consumption of Lelta MHP, productive use of Electric power and Stakeholder and community integration to sustain the plant. Further, if stakeholders and Cooperative committed to created job using surplus power they can create economic benefit to members. The Lelta MHP plant gives service for community from 1PM to 6AM and shutdown every day from 7A.M to 12A.M. During daytime hours, the communities do not utilize power to fully capacity. The load factor of daytime is lower than nighttime. Especially in dry season, there is insufficient power output to provide beneficiaries of electricity through the evening hours, according to chairperson of cooperative. The electric consumption and future demand of MHP during this study are analysis carried out using GDP and HH and population growth rate. Accessibility to electricity in the studied Woreda was assessed in terms of availability of electricity, type of end user electric appliance and type of service. Household domestic lighting account 22.61% of electric generate from Lelta MHP and small business service account for 45.61% of electric power generated from MHP of studied area.

According to the result of forecasting future 10 year electric energy demand analysis, the demand of studied area grow from existing 202MWh annual demand at 2010 to 258.4MWh at 2020 E.C. This result indicated that exist capacity of plant can serve the community of studied area at 2020E.C if the trend of end use electric type service remand as now. Unless it require, upgrading the capacity of plant. Sustainability of MHP was assessed in terms of adequacy of funding, technical performance and project efficiency, technology transfer, social acceptance, user satisfaction and environment effects. It was scored that the project 52% of total criteria. These indicate that level of sustainability of MHP in the study Woreda require improvement. These due to limited capacity of government institution, insignificant stakeholder participation, poor tariff management and lack of community in decision making process.

5.2. Recommendations

The research finding provide for general picture on sustainability of Lelta MHP in Aleta Wonedo Woreda. The following measure should be taken to sustain Lelta MHP.

Firstly, In relation to job opportunities and sustainable end use, the government should organize the project to generate income and makes awareness to the community. Secondly, in relation to the high load factor, both the local people and the government should not emphasis on paying attention to the contribution of income generation

Third, the sustainability of MHP is another issue. The intake and canal constructed is located at the weak, which built on sloppy area. Therefore, there is fear of landside. Therefore, that to sustain the canal community should have to construct erosion diversion structure with collaboration to responsible government institution.

Fourthly, the solution could be systematic and comprehensive capacity building in local community level.

Sixth, Rural energy technology broadens the living standards of people in the remote and scattered settlements of SNNPRS that are not likely to be connected to a national grid in the foreseeable future. Sustainability of these technologies depends upon an integrated development approach that emphasizes financial responsibility, economic growth and community cooperation through sound leadership. SNNPRS has more potential for the development of community based MHP projects in our country because of the high electricity demand that are encouraging customers interest in MHP and the segmented power grids that are motivating the development of energy storage in response to the limited capacity of each electricity grid access in rural area.

REFERENCE

Adam, F. W., Brew-Hammond, A. and Essandoh, E.O. 2013. Relationships Between Energy Use and Income Levels, for HHs in Ghana. Mechanical Engineering Department/The Energy Center Kwame Nkrumah University of Science and Technology (KNUST), Kumasi

Adams, M. A., & Ghaly, A. E. 2007. The foundations of a multi-criterion evaluation methodology for assessing sustainability. International Journal of Sustainable Development & World Ecology, 14, 437-449.

AEPC/NERRE/CESC 2013. Guideline for Cooperative Model for Mini-Micro Hydro project, Phulchoki Energy Pvt. Ltd, Lalitpur, (December, 2013).

Ahlborg, H and Sjöstedt, M. 2015. Small-scale hydropower in Africa: Socio-technical designs for renewable energy in Tanzanian villages. Energy Research & Social Science 5 (2015) 20–33

Alternative Energy Promotion Center 2005. Micro-hydro data of Nepal AEPC. Kathmandu, Nepal.

Anderson T., Doig A., Khennas S., Rees D. 1999. Rural Energy Services: A handbook for stainable energy development, Intermediate Technology Development Group (ITDG), London.

Ashden Awards 2006.The Ashden Award promotes inspirational renewable energy projects for providing social and economic benefit to local communities and is handed over by Prince Charles.

Azimoh, C. L., Klintenberg, P., Wallin, F., & Karlsson, B. (2015). Illuminated but not electrified: An assessment of the impact of solar home system on rural households in South Africa. Applied Energy, 155, 354–364.

Balkema, A.J., Dijk, S.V., Heijnen, S., Verbong, G.P.J., Romijn, H.A., and Huntjens, E., 2010. An impact assessment methodology for small scale renewable energy projects in developing countries funded under Dutch policies defined to contribute to the millennium development goals. In: Proceedings of the Berlin conference on the human dimensions of global environmental change. Berlin, Germany; p.1–11.

Baseline Survey(2010) Small hydropower, AMES-E, 2010.

Bhandari, R., Saptalenal,L.G. and KuschW., 2018. Sustainability assessment of a micro hydropower plant in Nepal. *Energy, Sustainability and Society* 8:3; 10-15.

Bhandari1,R., Saptalena, L. G. and Kusch W., 2018. Sustainability assessment of a micro hydropower plant in Nepal. Sustainability and Society 8:3; 1-15.

Bhattacharyya, S.C., 2012. Energy access programmes and sustainable development: a critical review and analysis. Energy Sustain Dev16: 260 – 71

Bierman, J. H., & Smidt, S. (2012). The capital budgeting decision: economic analysis of investment projects: Routledge.

Blake, J. 1999. Overcoming the 'value-action gap' in environmental policy: tensions between national policy and local experience. Local Environment 4 (3), 257.

Bowen, G. A. 2007. An analysis of citizen participation in anti-poverty programmes. *Community Development Journal*, 43(1), 65-78.

Boyle Godfrey 2004. Renewable Energy, Power for a Sustainable Future. New York: Oxford.

Budiarto, R., and Puteroa, S. H. 2009. Design criteria of Renewable fuel for SME's in Yogyakarta special Region, Proc. Nat. *Seminar on Applied Science for Technology Innovation*, pp. I-70 I-78, Yogyakarta, 2009

Burton, J. D, Muluget A.G. 1992. Running centrifugal pumps as micro-hydro turbines performance prediction using the area ratio method. Renew Energy Technol Environ 1992:2839–47.

Chaurey, A. and Kandpal, T. C., 2010.Assessment and evaluation of PV based decentralized rural electrification: an overview. Renew Sustain Energy Rev; 14: 2266–78.

Chow, V. T. 1964. Handbook of applied hydrology, Mc-Graw Hill Book Co., New York (N.Y.).

Collin, A. 2000. Analysis of different financing mechanisms for small and MHP appropriate under Ethiopian conditions, unpublished master thesis.

Cooper, R.M. 2002. Determining surface-water availability in Oregon: State of Oregon Water Resources Department Open-File Report SW 02-002, 157 p.

Cooper, R.M. 2005. Estimation of peak discharges for rural, unregulated streams in western Oregon: U.S. Geological Survey Scientific Investigations Report 2005-5116, 134 p.

Cooper, R.M. 2006. Estimation of peak discharges for rural, unregulated streams in eastern Oregon: Oregon Water Resources Department Open-File Report SW 02-002, Salem, Oregon, 57 p.

CSA, 2006. Statistical Abstracts 2005, Addis Ababa.

Castellarin, A., Vogel, R. M., and Brath, A., 2004a. A stochastic index flow model of flow duration curves, Water Resour. Res., 40, W03104,doi:10.1029/2003WR002524

CSA, 2002. Statistical Abstracts 2001, Addis Ababa.

DGEP. 2011. Access to Different Energy Sources for Developing Countries in European Parliaments, Expo/b/deve/2011/19.

Dilip Singh. 2009. Micro hydropower resource assessment hand book. Prepared for APCTT Asian and Pacific Centre for Transfer of Technology of the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), September 2009.

Dzioubinski Oleg and Chipman Ralph. 1999. Trends in Consumption and Production: Household Energy Consumption. Discussion Paper of the United Nations Department of Economic and Social Affairs Pp 21.

e7. 2003. Feasibility Study Report. e7 Bhutan Micro Hydropower CDM Project, Kansai, AEP, EDF, HQ.

Edy E. Jiménez 2009. Final study report, achievable renewable energy targets for Puerto Rico's renewable energy portfolio standard. Puerto Rico: Puerto Rico's energy affairsadministration; 2009. ⟨http://www.uprm.edu/aret/⟩ (chapter8, availableat).

EPA, 2012. National Report of Ethiopia: United Nations Conference on Sustainable Development (Rio+20) , Addis Ababa, Ethiopia .

ESHA (European Small Hydropower Association), 2004. Guide on How to develop a Small Hydropower plant, 2004.

European Commission (EC), 2003. Technical Assistance Support for the Monitoring of the EC Support to the Aga Khan Rural Development Network in the Northern Areas and Chitral. Final Evaluation Mission. Rome.

European Small Hydropower Association (ESHA) 2010. "Energy recovery in existing infrastructures with small hydropower plants", Sixth Framework Programme, Publication by Mhylab, Switzerland, June, 2010.

Faye, S. 2002. Households' Consumption Pattern and Demand for Energy in Urban Ethiopia. M.Sc thesis, Addis Ababa University, Ethiopia.

Feibel, H. 1999. Policy change in Ethiopia offers opportunities for small hydropower; in "The International Journal on Hydropower and Dams", Volume 6, Issue 5, 1999, p.104.

Fry, M. J., Houghton-Carr, HA, Folwell, S.S. and Butao, U. Z. 2004. Development and implementation of GIS water resources software. In: Meigh, J and Fry, M, Southern Africa Friend Phase II 2000-2003, Ch. 4, 39-60. UNESCO, Paris, France.

Ghosh Tushar K, Prelas Mark A. 2011. Energy resources and systems. Renewable resources, 2. Netherlands: Springer; (chapter 3).

GNESD, 2006. Poverty Reduction Can Renewable Energy make a real contribution? Report. 50 pp.

Gordon, N. D., McMahon, T. A., and Fin\ayson, B. L. 1992. Stream hydrologyan introduction for ecologists. John Wiley & Sons, New York, N.Y., 373-377.

Grint, K and Gill, R 1995 .The gender technology relation: contemporary theory and research. London: Talyor & Francis.

Guta, F, Abebe Damte, and Tadele Ferede 2015. The Residential Demand for Electricity in Ethiopia. Discussion Paper Series; *Environment for Development EfD DP 15-07.*

Harris, D.D., and Hubbard, L.E., 1983. Magnitude and frequency of floods in eastern Oregon: U.S. Geological Survey Water-Resources Investigations Report 82-4078, 39 p.

Harris, D.D., Hubbard, L.L., and Hubbard, L.E. 1979. Magnitude and frequency of floods in western Oregon: U.S. Geological Survey Open-File Report 79-553, 29 p.

Iacobellis, V., 2008. Probabilistic model for the estimation of T year flow duration curves, Water Resour. Res., 44, W02413, doi:10.1029/2006WR005400.

IEA. 2010. Energy Poverty: How to Make Modern Energy Access Universal? Special Edition for Experts of World Energy Outlooks 2010 on the MDGs, Paris, France.

Ilskog, E. Kjellström, B. 2008. And then they lived sustainably ever after? Assess-ment of rural electrification cases by means of indicators. Energy Policy; 36(7):2674–84.

Ilskog, E. Kjellström,B. Gullberg, M. Katyega, M and Chambala, W. 2005. Electrification cooperatives bring new light to rural Tanzania. Energy Policy; 33(10):1299–307.

IMF. 2015. The Federal Democratic Republic Of Ethiopia Selected Issues, September 4, 2015.

International Energy Agency (IEA) 2017. Energy Access Outlook 2017: from poverty to prosperity. IEA, Paris, France.

IPSA, 2003 .Initial Poverty & Social Assessment. Asian Development Bank TA No.3875 Project for Bhutan’s Rural Electrification Phase III Project., SMEC International Pty. Ltd. In association with Eco Consultant Ltd.

Jäger, T., Schmidt, S., and Karl, U. 2009. A system dynamics model for the German electricity market - model development and application. In The 27th International Conference of the System Dynamics Society. Albuquerque, New Mexico, USA, 2009.

John Twidell and Tony Weir 2006. Renewable Energy Resources 2nd edition, Taylor & Francis 2 Park Square, Milton Park, Abingdon, Oxon OX14 4RN.

Kamat, S. 2004. The privatization of public interest: theorizing NGO discourse in a neoliberal era. Rev Int. Polit. Econ; 11(1):155–76.

Karekezi, S. and Kithyoma, W. 2002. ‘Renewable Energy Strategies for Rural Africa: Is PV Led Renewable Energy Strategy the Right Approach for Providing Modern Energy to the Rural Poor of Sub-Saharan Africa?’ Energy Policy, Vol. 30 Nos. 11-12. Oxford, United Kingdom: Elsevier Science Publishers. pp. 1071-1086.

Karma Penjor 2007. The sustainable management of microhydropower systems for rural electrification. The case of Bhutan.

Kaygusuz, K., 2011. Energy services and energy poverty for sustainable rural development. Renew Sust Energ Rev 15(2):936–947.

Kaygusuz, K., 2011. Energy services and energy poverty for sustainable rural development. Renew Sust Energ Rev 15(2):936–947

Khandker, S. R., Barnes, D. F., and Samad, H. A. 2009a. Welfare impacts of rural electrification: A case study from Bangladesh (Policy Research Working Paper No. 4859). Washington, DC: World Bank Development Research Group, Sustainable Rural and Urban Development.

Khandker, S. R., Barnes, D. F., Samad, H. A., & Minh, N. H. 2009b. Welfare impacts of rural electrification: Evidence from Vietnam (Policy Research Working Paper No. 5057; Impact Evaluation Series No. 38). Washington, DC: World Bank Development Research Group.

Khennas Smail, and Barnett Andrew 2000. Micro-hydropower:an option for socio- economic development. In: Proceedings of world renewable energy congress; 2000.p.1511–7.

Kierulff, H. 2008. MIRR: A better measure. Business Horizons, 51(4), 321-329.

Kijak, R. and Moy, D., 2004. A Decision Support Framework for Sustainable Waste Management. Journal of Industrial Ecology;8(3):33–50.

Kumar D, Katoch S.S. 2014. Sustainability indicators for run off river (RoR) hydropower projects in hydro rich regions of India. Renew Sust Energ Rev 35:101–108.

Kumar, D., Katoch. S.S., 2015. Sustainability suspense of small hydropower projects: a study from western Himalayan region of India. Renew Energy 76:220–233.

Laghari, J. A., Mokhlis, H, Bakar A.H.A, and Mohammad H, 20013. A comprehensive overview of new designs in the hydraulic, electrical equipments and controllers of mini hydropower plants making it cost effective technology. Renew Sustain EnergyRev2013;20:279–93.

LBNL (Lawrence Berkeley National Laboratory) 2008. Global Potential of Energy Efficiency Standards and Labeling Programs, see: http:// ies.lbl.gov/iespubs/LBNL-760E.pdf.

Leach, G., Gowen, M.1987. HH energy hand book. World Bank Technical Report No. 67. Washington, D.C.

Lejeune, A. 2000. Introduction about hydroelectric power plants (small scale). University of Yaoundé 1. 2000; pp.51.

Liu, G. 2014. Development of a general sustainability indicator for renewable energy systems: a review. Renew Sust Energ Rev 31:611–621.

Lystrom, D.J., (1970) Evaluation of the flow-data program in Oregon: U.S. Geological Survey Open-File Report, 29 p.

Mainali, B. Silveira, S., 2011. Financing off-grid rural electrification: country case Nepal. Energy 36(4):2194–2201

Male, J. W., and Ogawa, H. 1984. "Tradeoffs in water quality management." I. Water Resour. PIng. and Mgmt., 110(4),434-444.

MEA, 2016. Performance report of GTP 1 of Mine and Energy agency, Hawassa.

Mitchell, W. D. 1957. "Flow duration curves of Illinois streams." Illinois Dept. of Public Works and Buildings, Division of Waterways.

Mitlin, D. Hickey, S. and Bebbington. A. 2007. Reclaiming development? NGOs and the challenge of alternatives. World Dev; 35(10):1699–720.

Mohibullah Mohd Amran, Mohd Radzi, Mohd Iqbal, Abdul Hakim. 2004. Basic design aspects of micro-hydropower plant and its potential development in Malaysia.In:Proceedings of the national power and energy conference, PECON, IEEE0-7803-8724-4;29–30 November2004.

Muhammad Umar and Anwar Hussain. 2014. Micro Hydro Power: A source of Sustainable Energy in Rural Communities: Economic and Environmental Perspectives, 30th, AGM and Conference, PSDE.

OECD/IEA, 1994. Energy in developing countries: a sectoral analysis.

Ossberger GmbH Co. 2011. The Ossberger turbine. Bayern, Germany. The Ossberger turbine for asynchronous and synchronous water plants/⟩.

Painuly J.P. 2001. Barriers to renewable energy penetration; a framework for analysis, Jour. Of Renewable Energy 24 (2001), pp.73-89.

Paish O. 2002. Small hydropower: technology and current status. Renew Sustain Energy Rev, 6; 537–56.

Palit, D. Sovacool, B.K. Cooper, C. Zoppo, D. Eidsness, J. and Crafton, M. 2013. The trials andtribulations of the Village Energy Security Programme (VESP) in India. EnergyPolicy;57:407–17.

Peters, J., Harsdorff ,M. and Ziegler F.,2009. Rural electrification: accelerating impacts with complementary services. Energy Sustain Dev; 13:38–42.

Pigaht, M. and Plas, R.J., 2009. Innovative private micro-hydro power development in Rwanda. Energy Policy 37(11):4753–4760.

Pode, R., 2013. Financing LED solar home systems in developing countries. Renew Sustain Energy Rev; 25:596–629.

Practical Action, 2010. Poor people's energy outlook. Rugby, UK: Practical Action Publishing.

Practical Action, 2012. Poor people's energy outlook:energy for earning a living. Rugby, UK: Practical Action Publishing.

Practical Action, 2013. Poor people's energy outlook: energy for community services. Rugby,UK: Practical Action Publishing.

Prasad, G., & Visagie, E. 2006. Impact of energy reforms on the poor in Southern Africa (Report for the Global Network on Energy and Sustainable Development under Electricity Access Theme III: Explicit Focus on the Poor). Cape Town: Energy Research Centre.

Ramanathan, R., 2002. Successful Transfer of Environmentally Sound Technologies for Greenhouse Gas Mitigation: A Framework for Matching the Needs of Developing Countries. Ecological Economics; 42:117 – 29.

REMP, 2005. Integrated Master Plan Study for the Dzongkhag-wise Electrification in Bhutan (REMP). Japan International Cooperation Agency (JICA) and Nippon Koei Co. Final Report. Bhutan.

REN21 (Renewable Energy Policy Network for the 21st Century) and ISEP (Institute for Sustainable Energy Policies) 2013. Renewable GLOBAL FUTURES REPORT.

Searcy, J.K., 1956. “Flow duration curves." Water Supply Paper 1542-A, U.S.,Geological Survey, Reston, Virginia.

Shewarega Fekadu. 2000. Micro Hydropower – Current Constraints and Future Prospects; in: Ethiopian Journal of Electrical Engineering, Volume 1, Number 1, June 2000

Shradha Upadhaya. 2009. Evaluation the effectiveness of Micro hydropower Project in Nepal.

Simon, L., & Cleary, B. 2005. Student and Community Perceptions of the "Value Added" for Service-Learners. Journal of Experimental Education, 28(2), 164-188.

Singh D. 2009. Micro Hydro Power Resource Assessment Handbook, no. September. Asian and Pacific Center for Transfer of Technology, 2009, pp. 1–69.

Singh, M., and Chandra, A. (2010) Modeling and Control of Isolated Micro-Hydro Power Plant with Battery Storage System. National Power Electronic Conference, Roorkee, India.

Skutsch, M., 1998. The gender issue in energy project planning Welfare, empowerment or efficiency? EnergyPolicy;26:945–55.

Smakhtin, V. U, 2001. Low flow hydrology: a review, J. Hydrol., 240, 147–186.

SMEC (2002). Rural Electrification and Network Project Phase 3. Asian Development Bank TA No. 3825-BHU, Snowy Mountain Engineering Consultant Ptv. Ltd. (Australia), Department of Energy, Bhutan.

Smith, J., Blake, J., Grove-white, R., Kashefi, E., Madden, S., Percy, S., (1999). Social learning and sustainable communities: an interim assessment of research into sustainable communities projects in the UK. Local Environment 4 (2), 195.

Sovacool, B.K., 2013. A qualitative factor analysis of renewable energy and SustainableEnergy for All (SE4ALL) in the Asia-Pacific. Energy Policy 2013;59:393–403.

Stout, B. A., 1990. Hand book of energy for world agriculture. Amsterdam: Pergamon; 1990;384–430 (chapterVIII – hydropower).

Strand, R. I., and Pemberton, E. L., (1982). "Reservoir sedimentation." Tech. Guideline for Bureau of Reclamation, U .S. Bureau of Reclamation, Denver, Colo.

Sugam Maharjan and Rajendra Shrestha, (2011) : Technical Problem Analysis of Micro Hydro Plants: A Case Study at Pokhari Chauri of Kavre District Journal of the Institute of Engineering, Vol. 10, No. 1, pp. 149–156.

Swan, L., and Ugursal V., 2009. Modeling of end-use energy consumption in the residential sector: A review, Renewable and Sustainable Energy Reviews 13, 1819–1835.

SWISHER J.N., G.M. JANNUZZI, and R.Y. REDLINGER, (1987).Tools and Methods for Integrated Resource Planning: Improving Energy Efficiency and Protecting the Environment,Grafisk Service, Riso National Laboratory, Denmark, P. 29.

Terrapon, P. J , CarmenDienst, JulianKönig and Willington Ortiz 2014. Impacts and sustainability of small-scale renewable energy projects in developing countries.

Tracy, J. and Jacobson, A. 2012. The true cost of kerosene in rural Africa. Light Africa.

Troldborg, M., Heslop, S., Hough, R.L., (2014) Assessing the sustainability of renewable energy technologies using multi-criteria analysis: suitability of approach for national-scale assessments and associated uncertainties. Renew Sust Energ Rev 39:1173–1184.

U.S Department of Energy “Energy Saver. Available [Online]: http://www.energysavers.gov.

UNDP (2009). The Energy Access Situation in Developing countries. A Review of Focusing on Least Developed Countries and Sub Saharan Africa. New York, USA.

UNDP (United Nations Development Programme) and World Energy Assessment Overview (WEC), 2004. Update. UNDP, UN-DESA and WEC. New York, USA, 88 pp.

UNDP (United Nations Development Programme), (2004b. Energy for Sustainable Development in Asia and the Pacific Region: Challenges and Lessons from UNDP Projects. New York, 108 pp. UNDP (United Nations Development Programme), (2000) World energy assessment: energy and the challenge of sustainability. New York: UNDP.

United Nation (UN), 2014, United Nations Open Working Group proposal for Sustainable Development Goals. New York: United Nations.

United Nations Development Programme (UNDP), 2011.Towardsan “energy plus” approach for the poor. A review of good practices and lessons learned from Asia and the Pacific. Bangkok.

Urmee, T & Harries, D. (2009) A survey of solar PV program implementers in Asia and the Pacific regions. Energy for Sustainable Development, electronic journal, p. 24-32.

Vogel, R. M. and Fennessey, N. M.: Flow-duration curves I: New interpretation and confidence intervals, J.Water Resour. Pl.-ASCE, 120(4), 485–504, 1994.

Vogel, R. M. and Fennessey, N. M.: Flow-duration curves II: A Review of applications in water resources planning, Water Resour. Bull., 31(6), 1029–1039, 1995.

W. Wolde-Ghiorgis (2002) Energy policy.

Wachter SJ. (2009) Pint-size dams harness streams, New York Times; 16 March 2009.

Walker, G., Devine-Wright, P., Hunter, S., High, H., Evans, B., (2007a). Trust and community: exploring the meanings, contexts and dynamics of community renewable energy. Working Paper 1: Community Energy Initiatives Project.

Wallace A.R., and Whittington, H.W., 2008. Performance prediction of standardized impulse turbines for micro-hydro. U.K.: Elsevier B.V.

Ward, R. C. and Robinson, M., 1990. Principles of Hydrology, 3rd Edn., McGraw-Hill, Maidenhead, Berkshire, England, 1990.

Warnick, C. C. (1984). Hydropower engineering. Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 59- 73.

William, S. J., Stark, B.H, andBooker, J.D. (2014) Low head Pico hydro turbine selection using a multi-criteria analysis. RenewEnergy; 61:43–50.

Williams A. (2003) Pumps as Turbines: a user's guide, 2nd Edition, Practical Action Publishing.

Williams, A. A. and Simpson,R., 2009.Picohydro – reducing technical risks for rural electrification. Renew Energy; 34:1986–91.

World Bank & Winrock International., 2003. Monitoring and Evaluation in Rural Electrification Projects:A Demand-Oriented Approach. Joint UNDP/World Bank Energy Sector Management Assistance Programme (ESMAP). 170 pp

World Bank, 2003. Household Energy use in Developing countries A multicounty study. ‖EMAP Technical paper, no:42 Washington, DC:World Bank.

World Bank, 2008. The welfare impact of rural electrification: are assessment of the costs and benefits? An IEG impact evaluation, Washington D. C.

World Energy Council, 1999. The Challenge of Rural Energy Poverty in Developing Countries. London, United Kingdom: World Energy Council.

Worley, (1998) Rural Electrification Project Phase1. Asian Development Bank TA No. 2043-BHU, Worley Consultants (New Zealand), Department of Power, Bhutan.

Yaakob OB, Ahmed YasserM, Elbatran AH, Shabara HM (2014) Are view on micro hydro gravitational vortex power and turbine systems. JTeknol (SciEng) 2014;69(7):1–7.

Yokoo, Y., Sivapalan, M., and Oki, T.: Investigating the roles of climate seasonality and landscape characteristics on mean annual and monthly water balances, J. Hydrol., 357, 255–269, 2008.

Appendix1: Questionnaire

Hawassa University Department of Water Resource Engineering and Management.

Ethical Considerations

During the research undergo, researcher legality all the feeling relationships, cultural and norms of the community the real environment of the studied area used considered and respected .During the questionnaire distribution to the respondents all sample targets of the population treated in an ethical manner. At the beginning of the data collection, the researcher made to explain the overall objectives of the study to make respondents confident enough to their responses .The researcher have told that the data collected will use only for academic purpose and will keep confidentiality all personal secrets.

Dear respondent, this questionnaire is prepared to collect information about the role of Lelta River Micro-hydropower in SNNPR. A case study in Hagre Sodicha area of Aleta Wonedo. Your responses are valuable to make the study attractive and alive. Please be free and provide your genuine responses and all your responses are only sued for the purpose.

Instruction: - please fill your answers in the spaces provided or circle your choice where appropriate.

General Information

A. Address:-household head

1. Kebele__________ six_______ age_____ Male____ Female________
2. Marital status A) Couple B) Single+
3. Family size_____________
4. occupation/job/source of income____________
5. How long You live in the kebele?_________

B. Specific Questions

1. What is/are your staple daily energy source?
    a. Solar panel
    b. Electricity
    c. Biogas
    d. Fuel /kerosene

2. Which one of the following/are your most source of light energy?
a. Wood
b. Kerosene
c. Micro-hydropower d) solar energy from panel
3. How do you get electricity?
a. by purchase b) free supply
4. If other specify____

If you answer for question "a" for what purpose are you using?

a. lighting
b. cooking
c. to play radio and TV
d. for both lighting and radio and TV playing
5. If other specify____

if your choice to question (4) "d" when did you start to use?_______________E.C

6. How much money do you spent for the purchase of electricity?________________
7. How long per day you use electricity?____________________________
8. Do you think capacity of power generation inhibits your capacity to consume?
a. yes
b. no
c. cannot say
9. How many lamps and other equipment do you use?_____________________________

Compare the amount of kerosene cost to electricity cost

a. Cost of kerosene_____________per month
b. Cost of electricity_________________per month
10. Do you face any problem to use this?____________________________________

What is your source of income?

11. How much is your average net income per month in birr?

How do you express the contribution of MHP for your income?
____

12. Your average monthly expenditure to purchase kerosene in birr before development of MHP for last 3 years?
a. 2001_____
b. 2002_____
c. 2003___
13. How often are you supposed to pay?
a. weekly
b. monthly
14. To whom do you pay the electric bills?
a. Head of village
b. Community committee
c. Woreda Water Mine and Energy office
d. others
15. What other importance do you get after development of MHP?
____
____

16. Do you satisfied by the service you get from MHP?

a) Yes b) No

17. At which stage you participate well during development?
   a. a. at planning
   b. during construction
   c. during operation
   d. during maintenance
   e. all
18. If your answer to question 20 “e” how you participate ?

   Do you know your responsibility during development?

a. Yes b.No
19. How you contribute to development of MHP?
a. by money b. labour C. no
20. Do you think electricity is affordable?

   current tariff

a. High b. Low c. Cannot say

if increase, will you be able to afford

a. Yes b. No c. Stop using

21. Do you intend to buy more appliances that are electric? If so, what are those?
a. Lighting equipments
b. Cooking Appliances
c. Entertainment Appliances
d. Power Tools
22. Who should manage the system?
a. NGO
b. Woreda Water Mine and Energy office
c. Community
d. private
23. Do you participate at operation and maintenance activity?
a. yes
b. no
24. If your answer to question 18 "a" how you participate?_______________
25. What do you predict about future's demand for and supply of electricity? ____

If you have any additional comments, please specify.________________________

Focus group discussion questionnaires

The focus group will be a free flowing conversion between the participants.

1. What do you think about the Lelta Micro hydropower?
2. Do you know it is a community based MHP? If yes can you explain what it means?
3. Do you think participation important to beneficiary and power plant?
4. How you define or understand participation?
5. Do you think services provided by the MHP are reliable and fair to all local community?
6. Who are male/female more participate or less with the MHP management task?
7. Why is?
8. Do you think MHP should be expanded its services to the entire village?

Appendix 1: Monthly rate of annual sunshine (Northern Hemisphere) (%)

North Latitude	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
65	3.52	5.13	7.96	9.97	12.72	14.15	13.59	11.18	8.55	6.53	4.08	2.62
64	3.81	5.27	8.00	9.92	12.50	13.63	13.26	11.08	8.56	6.63	4.32	3.02
63	4.07	5.39	8.04	9.86	12.29	13.24	12.97	10.97	8.56	6.73	4.52	3.36
62	4.31	5.49	8.07	9.80	12.11	12.92	12.73	10.87	8.55	6.80	4.70	3.65
61	4.51	5.58	8.09	9.74	11.94	12.66	12.51	10.77	8.55	6.88	4.86	3.91
60	4.70	5.67	8.11	9.69	11.78	12.41	12.31	10.68	8.54	6.95	5.02	4.14
59	4.86	5.76	8.13	9.64	11.64	12.19	12.13	10.60	8.53	7.00	5.17	4.35
58	5.02	5.84	8.14	9.59	11.50	12.00	11.96	10.52	8.53	7.06	5.30	4.54
57	5.17	5.91	8.15	9.53	11.38	11.83	11.81	10.44	8.52	7.13	5.42	4.71
56	5.31	5.98	8.17	9.48	11.26	11.68	11.67	10.36	8.52	7.18	5.52	4.87
55	5.44	6.04	8.18	9.44	11.15	11.53	11.54	10.29	8.51	7.23	5.63	5.02
54	5.56	6.10	8.19	9.40	11.04	11.39	11.42	10.22	8.50	7.28	5.74	5.16
53	5.68	6.16	8.20	9.36	10.94	11.26	11.30	10.16	8.49	7.32	5.83	5.30
52	5.79	6.22	8.21	9.32	10.85	11.14	11.19	10.10	8.48	7.36	5.92	5.42
51	5.89	6.27	8.23	9.28	10.76	11.02	11.09	10.05	8.47	7.40	6.00	5.54
50	5.99	6.32	8.24	9.24	10.68	10.92	10.99	9.99	8.46	7.44	6.08	5.65
48	6.17	6.41	8.26	9.17	10.52	10.72	10.81	9.89	8.45	7.51	6.24	5.85
46	6.33	6.50	8.28	9.11	10.38	10.53	10.65	9.79	8.43	7.58	6.37	6.05
44	6.48	6.57	8.29	9.05	10.25	10.39	10.49	9.71	8.41	7.64	6.50	6.22
42	6.61	6.65	8.30	8.99	10.13	10.24	10.35	9.62	8.40	7.70	6.62	6.39
40	6.75	6.72	8.32	8.93	10.01	10.09	10.22	9.55	8.39	7.75	6.73	6.54
38	6.87	6.79	8.33	8.89	9.90	9.96	10.11	9.47	8.37	7.80	6.83	6.68
36	6.98	6.85	8.35	8.85	9.80	9.82	9.99	9.41	8.36	7.85	6.93	6.81
34	7.10	6.91	8.35	8.80	9.71	9.71	9.88	9.34	8.35	7.90	7.02	6.93
32	7.20	6.97	8.36	8.75	9.62	9.60	9.77	9.28	8.34	7.95	7.11	7.05
30	7.31	7.02	8.37	8.71	9.54	9.49	9.67	9.21	8.33	7.99	7.20	7.16
28	7.40	7.07	8.37	8.67	9.46	9.39	9.58	9.17	8.32	8.02	7.28	7.27
26	7.49	7.12	8.38	8.64	9.37	9.29	9.49	9.11	8.32	8.06	7.36	7.37
24	7.58	7.16	8.39	8.60	9.30	9.19	9.40	9.06	8.31	8.10	7.44	7.47
22	7.67	7.21	8.40	8.56	9.22	9.11	9.32	9.01	8.30	8.13	7.51	7.56
20	7.75	7.26	8.41	8.53	9.15	9.02	9.24	8.95	8.29	8.17	7.58	7.65
18	7.83	7.31	8.41	8.50	9.08	8.93	9.16	8.90	8.29	8.20	7.65	7.74
16	7.91	7.35	8.42	8.47	9.01	8.85	9.08	8.85	8.28	8.23	7.72	7.83
14	7.98	7.39	8.43	8.43	8.94	8.77	9.00	8.80	8.27	8.27	7.79	7.93
12	8.06	7.43	8.44	8.40	8.87	8.69	8.92	8.76	8.26	8.31	7.85	8.01
10	8.14	7.47	8.45	8.37	8.81	8.61	8.85	8.71	8.25	8.34	7.91	8.09
8	8.21	7.51	8.45	8.34	8.74	8.53	8.78	8.66	8.25	8.37	7.98	8.18
6	8.28	7.55	8.46	8.31	8.68	8.45	8.71	8.62	8.24	8.40	8.04	8.26
4	8.36	7.59	8.47	8.28	8.62	8.37	8.64	8.58	8.23	8.43	8.10	8.34
2	8.43	7.63	8.49	8.25	8.55	8.29	8.57	8.53	8.22	8.46	8.16	8.42
0	8.50	7.67	8.49	8.22	8.49	8.22	8.50	8.49	8.21	8.49	8.22	8.50

Appendix 2:- Resource data room on line NASA database

Month	Temp (°C)	Monthly rate of annual sunshine (Northern Hemisphere) (%)	Precipitation (mm)	Daily solar Radiation Horizontal Kmh/m²/d	Atmospheric Pressure(Kpa)	wind speed (m/s)	Earth Temp (°C)	Heating degree-Days (18°C)	Cooling Degree -day 10(°C)
January	19.4	8.28	36.11	6.25	81.4	3.7	22.6	0	291
February	20.5	7.55	37.35	6.6	81.4	3.4	24.1	0	293
March	20.9	8.46	92.92	6.44	81.3	3.2	24.6	0	337
April	19.9	8.31	165.73	5.95	81.3	3.1	22.9	0	296
May	18.5	8.68	184.73	5.81	81.4	3.1	20.8	0	264
June	17.5	8.45	107.11	5.34	81.5	3.1	19.4	16	224
July	16.5	8.71	132.88	4.86	81.5	2.9	18.1	47	201
August	16.7	8.62	137.09	5.18	81.5	2.8	18.2	41	207
September	17.7	8.24	117.04	5.68	81.5	2.8	19.6	10	230
October	17.9	8.4	146.02	5.69	81.4	3	19.8	3	245
November	18.2	8.04	70.39	6.11	81.4	4	20.4	0	245
December	18.6	8.26	34.23	6.17	81.4	3.6	21.2	0	265
Annual	18.5	57.9	1261.6	5.83	81.4	3.2	21	117	3098
			NASA	NASA	NASA	NASA		NASA	NASA
				Measured 10m above the ground					

(a) Calculation method

$$U = K.P\frac{(45.7 * t + 813)}{100} - - - - - - - - - - - - 1$$

where,

u : Monthly evaporation (mm)

K : Monthly coefficient of vegetation, where K value depends on the vegetation condition. Herein, a constant of 0.6 was used.

P : Monthly rate of annual sunshine (%)

t : Monthly average temperature (°C)

Appendix 3: Calculation example of possible evaporation and real evaporation

Month	(1)Temp (°C)	(2) Monthly rate of annual sunshine (Northern Hemisphere) (%)	(3) Possible evaporation from Blaney-Criddle formula (mm)	(4)Precipitation (mm)	(5)Real Evaporation smaller value of (3) and (4)
January	19.4	8.28	84.43	36.11	36.11
February	20.5	7.55	79.27	37.35	37.35
March	20.9	8.46	89.75	92.92	89.75
April	19.9	8.31	85.88	165.73	85.88
May	18.5	8.68	86.37	184.73	86.37
June	17.5	8.45	81.766	107.11	81.766
July	16.5	8.71	81.89	132.88	81.89
August	16.7	8.62	81.52	137.09	81.52
September	17.7	8.24	80.18	117.04	80.186
October	17.9	8.4	82.20	146.02	82.2
November	18.2	8.04	79.34	70.39	70.39
December	18.6	8.26	82.41927	34.23	34.23

Note: - (1) obtained data RETSCREEN: from Table 9-10 ③: calculated value

Computation of monthly runoff data

a) Computation by the procedure shown in Table 12

b) Derivation of the monthly mean discharge of Lelta river using formula.

$$Q(i) = \frac{\text{monthly runoff}(4)(1-5)}{1000} * CA * 10^6 * \frac{1}{86{,}400 * n} ------2$$

Where,

Q (i): Monthly mean discharge at dam site in 'i (month)' (m3/s)

CA : Drainage area (km2)

n: Number of days in the month

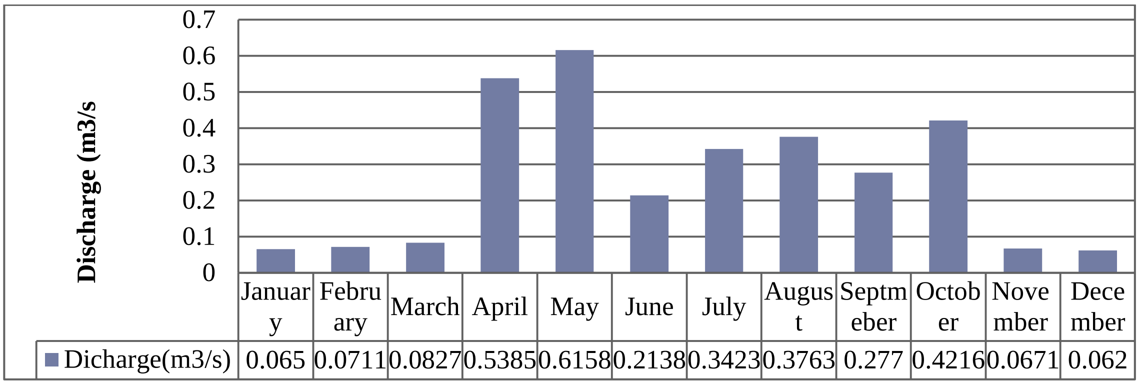
The discharge for the drainage area of 20 km^2 is shown in Table 12.

In addition, the ratio of the base runoff to the total runoff (25%) and the monthly distribution of base runoff (constant) can be analyzed with regards to the characteristic of runoff at the area.

Monthly mean discharge data calculated value of the Lelta river Power plant site.

Appendix -4 : Calculation of Lelta river flow

Month	(1)Runoff (4)-(5) Of chart 1-4	(2)Direct runoff (1)*0.75	(3)Base runoff	(4) Monthly runoff (2)+(3) (mm)	(5) Monthly Mean discharge (m^3/s)
January	0	0	8.7	8.7	0.064964
February	0	0	8.6	8.6	0.071098
March	3.17	2.3775	8.7	11.077	0.082714
April	79.85	59.8875	9.9	69.7875	0.538484
May	98.36	73.77	8.7	82.47	0.615815
June	25.344	19.008	8.7	27.708	0.213796
July	50.99	38.2425	7.6	45.8425	0.342313
August	55.57	41.6775	8.7	50.4	0.376344
September	36.854	27.6405	8.3	35.9	0.277006
October	63.82	47.865	8.6	56.465	0.421632
November	0	0	8.7	8.7	0.06713
December	0	0	8.3	8.3	0.061977
Total	413.95	310.4685	103.5	413.95	
(Note) Base runoff: distribute uniformity 413.958×0.25 = 103.5 mm to each month					



The equation used to compute the exceedance probability, which also is referred to as the flow-duration,

$$P = \frac{m}{n+1}$$

Where P= the exceedance probability, m= the ranking, from highest to lowest, of all daily mean flows for the specified period of record, n= the total number of daily mean flows. Percentile

$$P = \frac{m}{n+1} * 100$$

Appendix-5: calculated discharge and percentile of flow of Lelta River

month	Discharge (m3/s)	Discharge(m3/s) in descending order	Ranking (m)	the exceedance probability (p=m/(n+1))	Percentile
January	0.0649642	0.615815412	1	0.076923077	7.69
February	0.0710979	0.538483796	2	0.153846154	15.38
March	0.0827136	0.421632318	3	0.230769231	23.07
April	0.5384838	0.376344086	4	0.307692308	30.8
May	0.6158154	0.342312575	5	0.384615385	38.46
June	0.2137963	0.277006173	6	0.461538462	46.15
July	0.3423126	0.213796296	7	0.538461538	53.84
August	0.3763441	0.08271356	8	0.615384615	61.538
September	0.2770062	0.071097884	9	0.692307692	69.23
October	0.4216323	0.06712963	10	0.769230769	76.92

November	0.0671296	0.064964158	11	0.846153846	84.6
December	0.0619773	0.0619773	12	0.923076923	92.30

Appendix 6:- Electric power output from Lelta River in KW and KWh respectively

Probability of exceedance (P) (%)												
(P) (%)	7.7	15.4	23.1	30.77	38.46	46.15	53.85	61.54	69.23	76.9	84.6	92.3
$Q(m^3/s)$	0.616	0.54	0.421	0.376	0.342	0.277	0.214	0.0827	0.0711	0.067	0.065	0.062
$H_{\text{cross flow turbine}}$= 75								Gross Head(m)= 46				
Rated flow(Q_{50}) (m^3/s)= 0.2455												
H(m)	32	34.46	37	40	42.7	42.7	42.7	42.7	42.7	42.7	42.7	42.7
η	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Flow through $Q_{\text{turbine}(m^3/s)}$, Power (P) using equation 1												
$Q(m^3/s$	0.184	0.186	0.189	0.2	0.212	0.225	0.214	0.0827	0.0711	0.067	0.065	0.062
P(KW)	43.32	47.16	51.45	58.86	66.6	70.7	67.23	26	22.33	21	20.42	19.48

Appendix -7: List of Appliance in use

Appliance	Unit	Average Power Rating (W)	No Hours use Day	Hours Of use Week	Standard Unit Yearly Consolidated (S)(KWh)	Penetration(P)	Computed consumption in (KWh)n(E)=P*S
TV	year	75	8		219	10%	22
VCD Player	>>	25	8		73	10%	7.3
Lighting	>>	25	5		46	50%	23
Lighting	>>	60	12		283	10%	28.3
Lighting	>>	40	5		73	11%	8.03
Radio/ Tape Recorder	>>	25	8		73	5%	3.65
Hair Shaver	>>	20	8		58	2%	1.16
Mobile charging	>>	5	8		14.6	2%	0.292
Total					839.6	100	

1. Calculated consumption

Appliance	Unit	Quantity (n)	Computed consumption(E)	Consumption of each appliance(Ea)=n*E

TV	Year	6	22	132
VCD Player	>>	6	7.3	43.8
Lighting(25W)	>>	214	23	4922
Lighting(60W)	>>	29	28.3	820.7
Lighting(40)	>>	43	8.03	345.29
Radio/ Tape Recorder	>>	36	3.65	131.4
Hair Shaver	>>	10	1.16	11.6
Mobile charging	>>	36	0.292	10.512
Total				6417.302

No	Device	No of HH using device	Number of points	Device rating (W)	Connected load (W)	Operation hour per day	Operation days per year	Consumption per year
1	Incandescent bulb	34	52	40	2080	6	335	4.18MWh/year
2	CFL	202	230	20	4600	6	335	9.25MWh/year
3	Institutions lamp	14	58	60	3480	12	335	14MWh/year
	Sum of total							27.43MWh/year
		No of HH using device	Number of points	Device rating(W)	Connected load(W)	Operation hour per day	Operation days per year	Consumption per year
1	Men hair equipment	10	10	250	2,500	10	335	8.4MWh/year
2	TV, Radio and charge	TV=6,R+Ch=36=42	42	TV set=150w R+Ch=40w	2340	10	335	8MWh/year
	Sum Total							16.4MWh/year

1. Life cycle cost per kwh

Lifecycle cost per kWh = [(construction cost + operation, repair and maintenance cost till date) - (tariff collected till date)] / [(kWh/yr)*no. of years]

Based on data obtained from construction cost of Lelta MHP and collected tariff and operation, repair and maintenance cost Data Life cycle cost Lelta MHP of six year calculated as follow:

Construction cost (Birr) = 3,146,670.77

Operation, repair and maintenance cost (Birr) = 259,000

Tariff collected (Birr) = 260,736

Electric power per year= 66*18*330=392,040KWh

Number of year service= 6year

Life Cycle cost per = ([construction cost + operation, repair and maintenances cost till date]- tariff collected from beneficiaries till date)/[(KWh/year)*noyear]

Life cycle cost per KWh= 3,042308.77/2,352,240=1.34birr

Appendix *8*: Future demand

Appendix 8: Future electricity demand

Year	HH no	Energy demand(MWh)/per year
2009	236	202
2010	242	207
2011	248	212
2012	254	217
2013	261	223
2014	267	228
2015	274	234
2016	280.	240
2017	287	246
2018	295	252
2019	302.	258

BIOGRAPHICAL SKETCH

The author was born July 1986 at Waro kebele, of Tembaro Woreda of Kambatta Tembaro Zone, southern Ethiopia. At age of eight, he was enrollrd in Gucha primary school and attended secondary school at Mudulla High School. He joined Gondor University in 2005 and graduated with B.Sc degree in Applied Physics.

He began professional career under the SNNPRG water and irrigation bureau as expert for biogas and biomass in Tembaro Woreda water, mine and energy office of Kembatta Tembaro Zone and served as research expert of Alternative energy sources and technologies of SNNPRG Mine and Energy Agency until know.