Addis Ababa University
Addis Ababa Institute of Technology

School of Civil and Environmental Engineering

Small Scale Hydro Power Development on existing selected Dams in Tigray

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A thesis submitted submitted to
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This is to certify that the thesis prepared by Brhane Hntsa, entitled: Small Scale Hydro power Development on Selected existing Irrigation Dam in Tigray and submitted in partial fulfilment of the requirement for the degree of Master of Sciences (Civil Engineering stream of Hydraulic) complies with the regulation of university and meets the accepted standards with respect to originality and quality.

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DEDICATION

Dedicated to my beloved sister who were greatest educational thirsty in her life time and all my entire family for their support and inspiration me throughout the whole work.

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List of Acronyms

η	Efficiency
TWh	Terawatt hour
STVC	Selam technical &vocational center
SHP	Small scale hydro power
ROR	Run –of –River
RET	Renewable energy technology
Q	Discharge
Pf	Power Factor
Pdc	power duration
Pa	Average power
P	Power
P	Precipitation
Ns	Specific speed
n	Number of station
MWh	Megawatt hour
MW	Megawatt
MQ	Average flow (mean discharge)
MHP	Micro hydro power
MDGs	Millennium development goals
m^3/s	Meter cubic per second
L/sec/hac	liter per second per hectare
KW	Kilowatt
Kg/hr.	Kilogram per hour

HPP	Hydro power plant
H	Head
GWh	Gigawatt hour
GW	Gigawatt
GIS	Geographical information software
GHG	Greenhouse gas
FIT	Feed in tariff
FDC	Flow duration curve
E	Energy
DR	Democratic republic
Canment.	Canadian metrology
Drunner	Diameter of runner
Hnet	Net head
Lrunner	Length of runner
NA and NB	Free surface head at point A and B

ABSTRACT

Ethiopia has a huge amount of both small and large scale hydro power potential. In the reverse of this fact its people are not yet benefited as required, particularly those in the remote scattered rural villages. This research will try to identify the potential to generate hydropower from such dams in Tigray region of Ethiopia. The dams in Tigray could be classified in to two: those with active storage and the corresponding water release for irrigation and those with no active storage (the storage being silted up). For the first set of dams hydropower could be generated during wet and dry season where by the release for irrigation could be used for power production. The second set of dams, since there is no active storage but a height, the hydropower production will focus only on the wet season flow. Since these set of dams will have different flow behavior their hydropower production potential is analyzed separately. For the dams with active live storage reservoir simulation that uses area capacity curve is used to estimate their potential. For the dams with inactive live storage a flow duration analysis that occur in the wet season is used for the hydropower production analysis. The potential analysis is done by RET screen software, by making use of hydrologic and area capacity curves obtained for a selected number of dams in the Tigray regional state.

Collecting and analyzing the hydrologic data for input to RET Screen software, Analyzing the result of energy, capacity factor, financial and economic feasibilities, Specifying the appropriate type of turbine based on the inflow data and available head of the reservoir and Specifying of electromechanical and electrical equipment based on international standard were the analysis performed for the potential identification on monthly basis.

Accordingly the energy output from those study have shown that these dams can produce power capable of serving 64 to 400 households residing nearby the dams. Besides the result have shown that such energy production could be considered for electrifying communities residing nearby other dams in Tigray with affordable cost. The rural electrification policy of the country could be augmented by such approach. The successful completion of this project would form the basis of a best practice guide for future mini-hydro implementations and hence have a significant influence on many communities.

KEY Words: Tigray, Micro hydro, Dams, RET Screen software and small scale hydro power.

1 INTRODUCTION:

1.1 Back ground

Hydropower is the only renewable energy technology which is presently commercially viable on a large scale. It has four major advantages: it is renewable, it produces negligible amounts of greenhouse gases, it is the least costly way of storing large amounts of electricity, and it can easily adjust the amount of electricity produced to the amount demanded by consumers.

More than1.6 billion people in rural areas in the world are without electricity (greenstone, 2014). The reason is that it is too costly to provide electricity services to rural communities through conventional means, due to remote location and low density of population. If we take a look in history we find that hydropower has been used for thousands of years now. History experts guess that the Chinese have been using hydropower for 5000 years now. The oldest hydropower machine is 3500 years old and was used to irrigate the fields. Over two thousand years ago the Greek used hydropower to operate wheat mills for grinding wheat into flour. During the 1700s, mechanical hydropower was used extensively for milling and pumping.

Ethiopia's hydro power potential is estimated up to 45,000MW and is the 2nd highest in Africa (only DR. Congo has higher potential). Approximately 30,000MW is estimated to be economically feasible which is equivalent to an electric city generation of 162TWh.Thirteen of the twenty countries in Eastern Africa use small hydropower to supplement their existing electrification efforts. Due to technical improvements, hydropower plants were able to generate more and more energy and after a while even store the energy with the help of generators which converted the energy in to electrical power. In today's world due to increase in population and economic activities, the need for energy is increasing at a faster rate. It is the life blood of all economic activities i.e. household, agricultural and industrial. Without access to sufficient energy the goal of economic and social development cannot be achieved. This feature of rural population does not allow economies of scale in the provision of electricity services.

The use of diesel and gasoline has been used for decades for provision of electricity to rural areas. But it was not so successful due to economic, technical and environmental problems (Woodruff, 2007a). In Ethiopia about 80 % of the electric energy is gained from hydro power but it cannot access to the rural community because economic standard of the nation and the location of the society not comfortable for distribution electric line; - however, this problem can be solved through implementing of small scale hydro power. In Tigray regional state the development of small scale hydro power was especially important in the reduction of deforestation and accessing of power for the rural area. Many dams in Tigray are constructed primarily for water supply / irrigation. These dams may have enough capacity and runoff to accommodate other uses, particularly hydroelectricity. To provide sufficient energy and also to reduce carbon emissions and obtain a sustainable future, major changes have to be made.

Micro hydropower stations are usually defined as ones with power output of less than 100kW. As dams morph from a developmental solution to a costly endeavor, economic incentive to develop additional hydroelectric dams decreases (Hildyard, 2008).The small scale hydro power (SHP) has different advantages as compared to larger plants such that it is simple in design, construction and operation, it has very minimal adverse impacts on environment, and it has minimal costs for transmission from generation point to load centers (Smail & Andrew, 2000). Small hydropower has emerged as an energy source which is accepted as renewable, easily developed, inexpensive and harmless to the environment.

Ethiopia has energy policy document drafted in 1994, the policy encourage the use of indigenous resource and renewable energy. Hydropower can be generated at a lot of places, has the potential to generate a lot of energy, and the energy can be converted and stored therefore, one of the better substitutes for fossil fuels. The amount of energy that is generated mostly depends on the discharge, which is dependent on the height difference, width of the channel and the depth of the channel. Rural electrification has long been top on the development agenda of many developing countries. Nevertheless, a vast majority of the population in these countries is still in the darkness. The proportion of rural population in the Sub-Saharan Africa that has an access to electricity is, for instance, as low as 4%. Hydro power development contributes to a sustainable environment and better standard living to the society.

To solve the energy problem of the rural community, the study renewable energy source especially the small scale hydro power which is available from the micro dams constructed in the regional state. In this way the micro dams constructed in the region have been chosen as source of energy for the scattered rural community based on the potential and possibility of small scale hydro power plant development of the project. This investigation provide for emphasizing of on developing small scale hydro power in order to feed the rural community with appropriate energy service mechanism for future. The results of the study will form the foundation for carrying out a more detailed analysis to support a balanced decision on further consideration of a site potential to serve energy for the society.

1.2 Statement of the problem:

Most of the people of Tigray (around 80.5% of the population) lives in rural areas where energy access is almost negligible, <1%. Extending the national grid to these areas is not up to the economic capacity of the country because of the high cost of transmission and the very low load factor in these areas. But electrification of the rural communities is very essential especially to ensure the socio economic development of the community and hence of the country. To satisfy their energy needs, these people are using kerosene which is becoming difficult to afford because of the high and day-to-day increasing price of kerosene; and fire wood, cow dung and other traditional biomass resources which are causing deforestation and soil degradation. The global warming is one of the biggest issues in the world at this moment.

The overwhelming majority of the rural people are characterized by low literacy level, poor health status and lack of descent employment due to lack of electric city. These facts are largely and the result of relatively low consumption of commercial energy. Use of wood fuels is contributing to an alarming deforestation and environmental degradation.

1.3 Research questions

The study is designed to answer the following research question "what is the potential of utilizing small-scale hydropower to increase rural electrification in the selected irrigation-dam in Tigray and its significance to reduce greenhouse gas emissions".

1.4 Purpose of study*:*

Small hydro power introduction in the rural community will enhance the quality of life for rural dwellers in numerous ways: improved lighting, more entertainment, communication options, replacement of paraffin lamps, supports rural enterprises, clinics etc.

1.5 Objective of the study

1.5.1 General objective:

- To analyze the viability of small scale hydro power in the existing case of selected irrigation dams and to study the possibility for small scale hydropower development in Tigray regional state (Ethiopia) additional for economical perspective.

1.5.2 THE SPECIFIC OBJECTIVES ARE:

- Analyzing small scale-hydro power potential of the selected irrigation dams.
- Assessing sustainability of the small scale-hydro power in selected irrigation dam compared to the national grid.
- Determining cost and energy created from the selected irrigation dams.
- Energy demand study and socio economic benefit.

1.6 Organization of the study:

The study organize in to six chapters.

The first chapter presents introduction, statement of problem and objective of study.

The second chapter discuss about the small scale hydro power status throughout the world, small scale hydro power potential of some countries and installed power from their potential. Criteria for selection of type of turbine, hydro power type based on various classifications, meaning of energy development to the rural community is also presented. Power demand of some electronic machinery device also described.

Chapter three presents the methodology of the study. It provides description of study area the micro dam that are currently in operation and those reservoir e are silted up. The chapter describes reservoir in operation status, and, for the silted dams' year of construction. Metrologic, hydrologic and topographical dare discussed in this chapter.

Chapter four also deals about the metro logic and hydrologic data analysis: - including checking of the consistency of the hydrologic and metrological data.

Chapter five assess the potential developing of small scale hydro power from both silted up reservoir and reservoir in operation using the RET Screen software and estimation of energy for the reservoir in operation and also using the power estimated also compare the value cost of energy. Power, energy, cost and meaning that energy to the rural community discussed in detail. While concussion and recommendation are incorporated in chapter six.

1.7 Scope of the thesis

Using information available on the capacity of existing irrigation dams in Tigray regional state this thesis address capacity of the dams for alternative power production. This thesis involves investigating the capacity of these micro dam to produce energy for the society mainly power, energy and cos.

1.8 Definition of Terms

Hydro power: energy generated from movement of mass of water. Such that hydroelectric power plant transforming the flowing water from stream or river to electricity. This typical renewable energy source is classified based on capacity Pico, micro, mini, small and large hydro power.

Pico hydro power: its capacity is 0 to 5kw.

Micro hydro power: its capacity is 5 to 100kw

Mini hydro power: its capacity is 101to 1MW

Small hydro power: its capacity is between 1MW to 10MW

RET Screen software**:** renewable energy technology developed by natural resource of Canadian

2 LITERATURE REVIEW

2.1 Hydro power generation processes:

Potential energy of flowing water is converted to kinetic energy as it travels through the penstock.

Kinetic energy of the flowing water is converted to mechanical energy as it turns the turbines.

Mechanical energy of the rotating turbine is then converted to electrical energy as the turbine shaft rotates the generator.

Figure 2.1 Alignment of Hydro Power

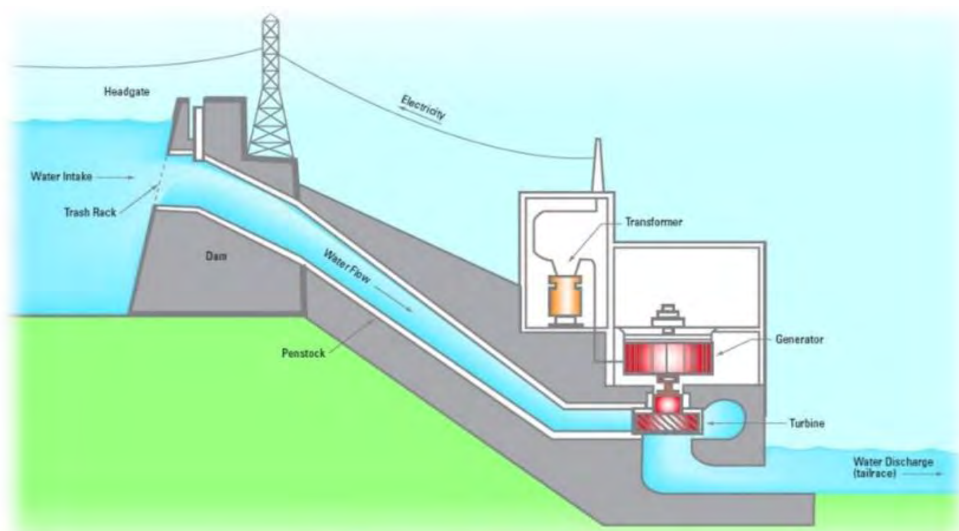
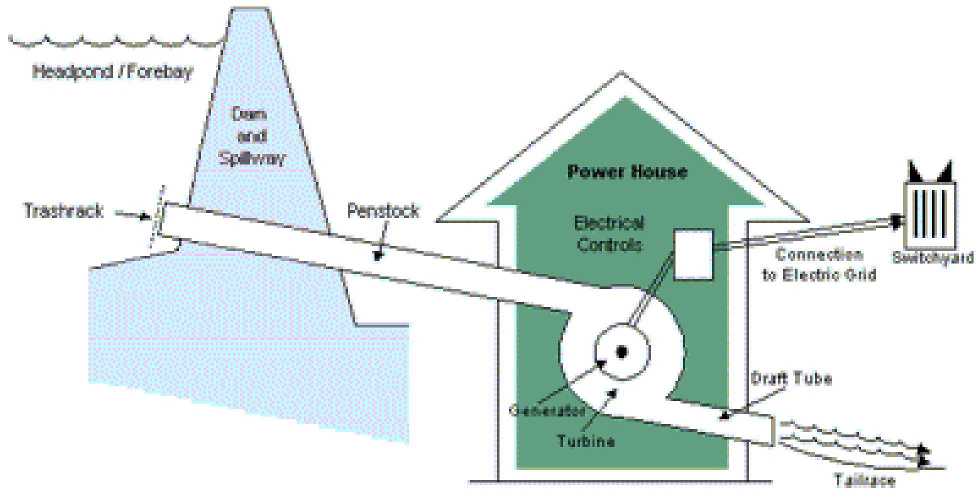


Figure 2.2 Parts of Small Scale Hydro Power



2.2 Hydro power status of Ethiopia and other countries

Most of the developing countries are suffering from what many call the energy crisis, characterized by depletion of locally available energy resources and dependence on imported fuel. In addition, the energy crisis is exacerbating the food crisis by increasing the rate of deforestation and thereby causing degradation of farmlands. Furthermore, dependence on imported fuel is weakening the capacity of the concerned countries to buy food whenever the need arises. Therefore, these people are forced to use traditional energy sources for their demand. However, still there are people living in urban areas but relying on traditional fuels. This may be because that these people are not able to afford for the modern fuel and/or are unaware of the advantage that the modern fuels have over the traditional ones. With this in mind, Ethiopia is a country that relies extremely on traditional fuel, third from Africa, led by Chad and Eritrea. Moreover, more than 99.9% of the rural energy consumption of the country is mate by traditional fuels.

Small hydropower has proven itself as a major contributor to electrification in developing countries with China as an example where small hydro has been developed in large parts of the country.

Europe and North America has already exploited most of their hydropower potential. On the other hand Africa, Asia and South America have still substantial unused potential of hydropower (Altinbilek, 2005). China has developed most of her small hydro potential and most rural areas of that country.

The top 5 largest markets for hydropower in terms of capacity are China, Brazil, the United States, Russia, and Canada, with China far exceeding the others at 249GW. Added to these, India, Norway, Japan, France and Turkey complete the top 10 countries in terms of capacity.

In addition, in several countries, hydropower accounts for over 50% of all electricity generation including: Iceland, Brazil, Canada, Nepal and Mozambique. During 2012, an estimated 27-30GW of new hydropower and 2-3GW of pumped storage hydropower was commissioned during the year. In many cases, this development was accompanied by renewable energy support policies and current and planned regional carbon markets. Ethiopia has a hydro power potential of around 300 MW power from which only 6.5MW developed. But most of the rural community suffer by energy supply. Tigray regional state also have various options to develop power typically the small scale hydro power from the dam both in operation and silted up but still there is no developed energy source mainly the small scale hydro power to supply the rural community.

2.3 Pervious study conducted using the ret screen software

Regional Centre for Renewable Energy and Energy Efficiency (ECREEE) Workshop on the ECOWAS Scale-Up Programmed for small scale hydro power conducted by Canadian government (April, 12012). This analysis conducted in various African country carried by the software particularly in West Africa (Benin, Mali and Togo), central Africa (Cameroon, central republic of Africa, Guinea and Gabon) and East Africa (Burundi, DR. Congo and Rwanda) .This study investigation

- ✓ Identification of mini/micro hydro sites
- ✓ Identification and removal of barriers to the adoption of micro/mini hydropower technologies
- ✓ Deployment of micro/mini hydropower plants on a turnkey basis
- ✓ Systems management/ financing schemes/ ownership structure and plant operation

Findings of Consultant Reports

- ❖ Improved rural access to electricity is a means of improving quality of life and socio-economic development.

- ❖ Participating countries are at various stages of introducing legal and regulatory reforms to liberalize the energy sector.
- ❖ Formulating rural electrification policies and strategies that clearly identify actions to be taken to attract much needed investments.
- ❖ Strong candidates for micro hydro deployment, but the technical, financial and/or managerial resources are often lacking.

Proposed Micro-Hydro Configurations

Table 2.1 Developed Power in African Country RET Screen Software by Canadian Government

cluster configuration	Benin	mali	Togo	total three countries
50-75KW(costUS$300,000)	1	3	1	5
100-150KW(COSTUS$400,000)	3	3	2	8
200-400KW(cost US$600,000)	2	2	2	6
total #system	6	8	5	19
total KW	750	850	650	2,250kw
TOTAL COST	US$2.7million	US$3.3million	US$2.3million	US$8.3million

2.4 Hydro power in the world

Table 2.2 Hydro Power in the World

Country	Annual Hydroelectric Energy Production(TWh)	Installed Capacity (GW)	Load Factor
China(2007)	486.7	145.26	0.37
Canada	350.3	88.974	0.59
Brazil	349.9	69.080	0.56
USA	291.2	79.511	0.42
Russia	157.1	45.000	0.42
Norway	119.8	27.528	0.49
India	112.4	33.600	0.43
Japan	95.0	27.229	0.37
Sweden	61.8	-	-
France	61.5	25.335	0.25

From the table we can see, comparing with other countries, Ethiopia annual hydro electric energy production and installed capacity are the highest in 2007.

2.4.1 Highlights of the Ethiopian Energy Policy

According to EREDPC (2002), Ethiopia's Energy consumption is predominantly based on biomass energy sources. Ethiopia is committed to shaping its economic future. The government has adopted a strategy for sustainable economic development, which places agriculture as its driving force. This strategy is referred as Agricultural Development Led Industrialization (ADLI) Strategy. It envisages the structural transformation of the Ethiopian economy through export-led growth, which feeds into an interdependent agricultural and industrial development.

Though Ethiopia is endowed with vast energy resources (Hydro, solar, wind, geothermal, biomass, natural gas, etc.) it has not been able to develop, transform and utilize these resources for optimal economic development.

Rationale for the policy

Energy is critical for economic development. Its importance stems from the fact that energy is basic input in all productive activities, including the household sector.

- To develop and utilize the country's energy resources on the basis of Ethiopia's overall development strategy;
- To assist other economic sectors to meet their development objectives by putting in place a clearly defined energy policy;
- To save scare foreign exchange resources and to ensure that energy is efficiently utilized;
- To ensure reliable and secure energy supplies to cushion the economy from external and internal disruptions of supply as well as price fluctuations;
- To ensure that development of energy resources is benign to the environment;
- To formulate comprehensive energy prices and to ensure economic profitability;
- To ascertain what energy technologies and equipment are appropriate for and compatible with the country's economic development needs; and
- To raise the efficiency of the energy sector and develop the necessary institutional and man power capabilities to undertake energy development programs.

Priority of The Policy

The Government of Ethiopia's energy sector policy priorities are:

- To place high priority on hydropower resource development, as hydrological resources are Ethiopia's most abundant and sustainable energy forms;
- To take appropriate policy measures to achieve a gradual transition from traditional energy fuels to modern fuels;
- To pay due and close attention to ecological and environmental issues during the development of energy projects;
- To set issues and publicize standards and codes which will ensure that energy is used efficiently;
- To develop human resources and establish competent energy institutions; and
- To provide the private sector with necessary support and incentive to participate in the development of the country's energy resources.

2.5 Defnition of small scale hydro power in Europeian cuntries

There is no consensus in EU member states on the defintion of small hydro power. Some countries like portugal,spain,Ireland,greece and Belgium accept 10MW as the upper limit installed capacity. In Italy the limit is fixed at 3MW (plants with larger installed power should sell their electricity at lower price);in France the limit was established at 8 MW and UK favour 5MW.Hereunder will be considered as small any scheme with an instaled capacity of 10MW or less.

Table 2.3 Energy Resource Potential of Ethiopia (June22, 2013).

	The Energy Resource Potential Ethiopia June22,2013				
1	Resource	Unit	Exploitable Reserve	Exploited	
				Amount	Present
2	Hydropower	MW	45000	2100	<5%
3	Solar/day	KWH/M^2	6		<1%
4	Wind: power speed	GW (m/s)	1350	171MW	
5	Geothermal	MW	7000		
6	Wood	Million tones	1120	7.3MW	50%
7	Agricultural waste	Million tones	15-20	560	30%
8	Natural gas's	Million tones	113	6	0%
9	COAL	Billion m^3	300	-	0%
10	Oil shale	Million tones	253		0%

2.5.1 **Types of small hydro power:**

Small hydro power plants are categorized on the basis of the type of grid it is connected to and the regulation of flow, if any, by the plant. Small hydro can be connected to central grid, to an isolated grid or can be connected to dedicated power load such as a cement factory, lodges, mill and mines etc. Flow available in the river varies over time, from ones season to another and from year to the other. In run off river scheme, there is no water storage and the natural flow available in the river is diverted to generate power. Hence, the power generation from a run- of-river scheme also varies with time and the firm capacity can be quite.

2.5.2 Run –of –river hydro power technologies

In run –of-river (ROR) hydropower systems (and reservoir system), electric city production is driven by the natural flow and elevation drop of river. Run –of-river schemes have little or no storage, although even run –of –river schemes without will sometimes have a dam Run –of –river hydro power plants with storage are said to have "poundage". Those allow very short term water storage (hourly or daily). Plant s with poundage can regulate water flow to some extent and shift generation a few hours or more over the day to when it is most needed. A plant without poundage has no storage and therefore cannot schedule its production.

Power demand of some electronic machinery devices

Table 2.4 Power Consumption of Some Device

equipment	Wattage
Mill (rice, coffee, cassava, etc.)	2-4 kw
Grain thresher (rice, wheat, etc.)	3-4kw
Huller(rice, coffee)	3-5kw
Oil expeller	5-8kw
Kapok mill (50kg/hr.)	2.3kw
Planer	0.5-0.75
Angle grinder	0.5kw
Drilling machine	0.5kw
Circular saw(200ml diameter)	0.75kw
Band saw wheel(300 ml diameter)	0.75kw
Center lathe(mediumduty,160mm)	0.3-0.4kw
Soldering iron	0.07kw

Battery charging	0.1-2kw
Electrical oven (bread, cakes, etc.)	1-2.5kw
Blender/juicer	0.3-0.4kw
Mixer	0.3-0.4kw
Freezer/refrigerator	0.3-0.4kw
Ironing	0.3-0.8kw
Incandescent bulb	0.025-0.1kw
Energy efficient lamp(brightness of 100w bulb)	0.012kw

2.6 Hydrology and energy determination

2.6.1 Hydrology inflow data estimation

Catchment area

The value of expected energy determination is one of the most important to determine the HPP viability. Energy generation mainly depends on availability of flow and hydraulic head provided by the topography. The amount and characteristics of flow at a potential HPP site are evaluated using hydrological analysis from the catchment area of river section. The flow its characteristics, and head are important parameters to determine the hydro power potential energy output. Typically, the water authority can provide measured discharge data for primary rivers and streams.

Discharge data are not available for the secondary and tertiary rivers, since the discharge at the future intake location or out let of the study area is not directly measured. To estimate the flow at the future HPP intake ,gauging station data must be transposed to HPP discharge characteristics usually data from the closest gauging station along the same river are used or, if these are not available, from an area near the HPP. Discharge area should be available for a period no less than 15 years, preferably consecutive, to derive statics sustained conclusion, the longer the period, the more accurate estimates will be.

The three most common methods to determine intake discharges are the following:

- Simultaneous flow measurements
- Relationship between specific runoff and altitude
- Catchment area method

2.6.2 Simultaneous flow measurements:

A temporary gauging point (so-called control profile) is implemented at a place of interest (intake location or its vicinity), usually upstream of an existing gauging station. The two points are measured simultaneously since the same weather conditions prevail. Thus, engineers can correlate measurements of the control profile (temporary station) with those of the gauging station. Next historical hydrological data are transposed from the existing gauging station to the proposed intake. To cover all flow conditions, measurements must be undertaken during dry and wet periods—at least five dry-period, five average-period, and five wet-period measurements to correlate gauging stations. The more simultaneous measurements there are, the more accurate the correlation will be. This is the most accurate method to transpose historical flows from a gauging station to an intake location. Measurements and transposition calculations must be carefully documented.

2.6.3 Specific runoff - altitude relationship:

An alternative approach is to empirically derive a relationship between specific runoff [l/s/km2] and average catchment area altitude. Data from multiple gauging stations and control profiles in the area can be used to generate the regional function (curve).The underlying idea is that the higher the catchment area, the more expected runoff per km^2. After average flow (MQ) is determined using this method, the value is compared to the MQ at the next gauging station and the correlation is determined, then historical hydrological data can be transposed to the intake.

The accuracy of hydrological data obtained by this method depends on (a) the accuracy of data used to prepare the function; and (b) the method used to determine the average height of the catchment area.

2.6.4 Catchment area:

This method assumes that in a specific gauging station catchment area the same quantity of runoff is generated on each km^2, independent of elevation. Thus intake discharge is calculated as a function of the catchment area. The method is a simple approximation, which works best when the gauging station is close to the respective intake. This method does not consider the influences of vegetation, soil type, and geology on the flow in the investigated area.

$$Qungauge = \text{Qgauged catchment} * \left(\frac{\text{Area of ungauged catchment}}{\text{area of gauged catchment}}\right)$$

Where

Qungauge= the estimated discharge at the ungauged in m^3/sec

Qgauged= the discharge at the next gauging station in m^3/sec

A ungauged= the catchment area at the intake of the respective HPP in km^2

A gauging = the catchment area of the next gauging station in km^2

2.7 Estimation of the daily missing rain fall data

Failure of any rain gauge or absence of observation from a station cause a short break in the record of rain fall or the stream flow at the station. The value of these missing value filed by using data from the surrounding gauging located within the basin on the assumption that the group of station has a metrological similarity (patra, 2002).

There are various methods that used to compute the missing records. Some of mostly used statistical methods are arithmetic mean, the normal ratio method, the regression method inverse and the inverse distance methods this study consider the athematic mean method using the xlstate based and normal ratio method.

2.7.1 Athematic mean method

This typical method is used mainly when the normal annual rain fall or the missing station is within 10% of the normal annual rainfall of the surrounding stations. The surrounding index station are necessarily required to be evenly speed around the missing station and ideally as close as possible. The method yield is good estimate the flat area if the gaging are uniformly distributed and the individual gauges catch does not vary widely from the mean. (Patra, 2002: Garg 1989).

The arithmetic mean is given by

$$P = \frac{\text{P1+P2+P3....P3}}{\text{n}} = \frac{1}{n}(x+a)^n = \sum_{i=1}^{n} Pi \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.1$$

Where

P = the station with missing record, mm/d

Pi= index station, mm/d

n = number of index station

2.7.2 Normal ratio method

The method is used when the normal annual precipitation of the index station differs by more than 10% of missing station. The rain fall of the surrounding index station are weighted by the ratio of the normal annual rainfall by using the following relation, (patra, 2002:Garg1989).

$$Px = \frac{\text{Nx}}{\text{n}}(\frac{P1}{N1} + \frac{P2}{N2} \pm \cdots \ldots \ldots \ldots \ldots + \frac{Pn}{Nn} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots 2.2$$

Where

P1, P2, P, Pn= rainfall data of index station, mm/d

N1, N2, Nn= Normal annual rainfall of index station, mm

Px, Nx = the cross ponding value of the missing station Xn =number of station surrounding the station X

2.8 Power and energy

Energy is the amount of work done over time, or a capacity to do work. Generally it express in megawatt-hours (MWh).

$E = (P * t)$

Where

E is the generated energy (MWh)

P is the power produced (MW)

t is the period of time (h)

1 MWh is equal to 3,600,000,000joules. Power is the energy that is converted per second, i.e., the amount of work being done within that second, measured in watts (where 1 watt =1joule/s .and 1kilowatt =1000watts).

Hydro-turbines converts water pressure into mechanical shaft power, which is used to drive a connected electric city generator. Available power is proportional to the product of head and flow rate. The general formula for any HPP power output is described as:

$$P = (\eta * \rho * g * Q * H)/10\text{^}6$$

Where

P is the power produced at the transformer (MW)

η is overall efficiency of power plant

ρ is the density of water ($1000kg/m^3$)

g is the acceleration due to gravity ($9.81m/s^2$)

Q is the volume flow rate passing through the turbine (m^3/sec)

H is the net head (m) for roughly estimation, 87 percent is used as typical over all plant efficiency then the above equation is given as

$$p(kw) = 8.5 * Q * H$$

2.9 Hydroelectric

2.9.1 Principle of hydro power and energy conversion

Hydro power generation is based on the conversion of the hydro potential energy of a flow in to electric energy which corresponds to different available net head. The energy of flow is associated to the gravitational energy through natural or artificially created topographic water falls in river or through hydraulic conversion systems, composed by pressurized pipe or penstocks or by mixed hydraulic conveyance system composed by canal and penstocks. According to the principle of conversion of energy, from A to B will obey the following relationship.

$$ZA + \frac{PA}{\rho g} + \frac{\alpha AUA^2}{2g} = ZB + \frac{PB}{\rho g} + \frac{\alpha BU\text{^}2A}{2g} + \Delta HAB \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..2.3$$

HA HB

Where HA and HB is elevations above the datum plan PA and PB are (Pa) are pressure at the center of gravity the flow across the section A and B, UA and UB (m/s) average flow velocity across point A and B, ρ (kg/m^3) is the density of water, g is the gravitational acceleration and αA and αB are numerical coefficient accounting to non-uniform flow velocity. The difference of elevation between HA and HB equals the head loss ΔHAB between the two flow cross section, where the head is total flow energy by the weight of flowing water and also for free surface flow equation is simplified to the following form.

$$\Delta HAB = NA - NB + \left(\frac{\propto AUA^2 - \propto BU^2A}{2g}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.4$$

Where NA and NB (m) are respectively elevation of the free surface across section A and B and the difference $\alpha AU^2{}_A - \alpha BU^2{}_A$ be very small or equal and the disputed head equals the difference in elevation of NA and NB.

The flow power P and the cross ponding energy E over an interval time (t) of hydro power be respectively.

$$P = \rho g h Q$$

$E = \rho gHQt$

The final use full head delivered to the electrical network smaller than the available gross head

$Hf = \eta Hg$

Where η is the global efficiency, resulting of the multiplication of partial efficiencies from the successive transport and conversion phases (η < 1).

2.9.2 Technically available power:

With conveyance efficiency of 70% and overall efficiency of the plant as 80%, a combined multiplying factor of 0.56 should be used with the average potential power, P50;

$Pa = 0.56 P_{50}$ --2.5

2.9.3 Discharge /design discharge

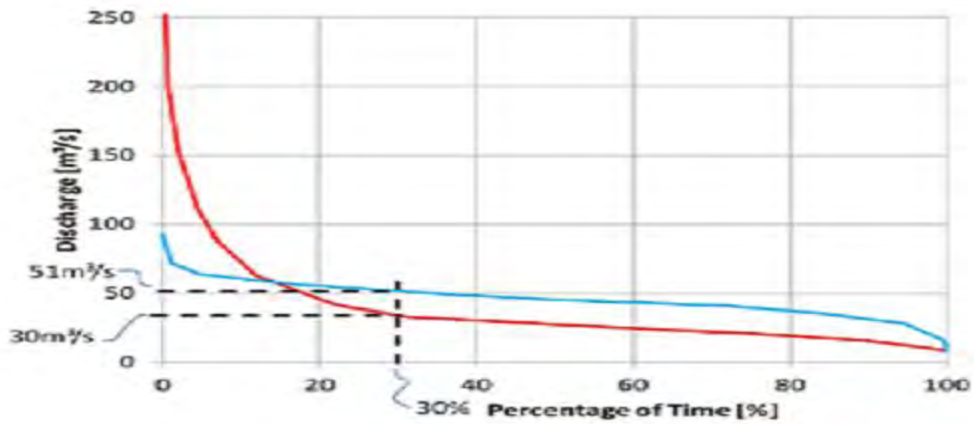
The discharge available for energy production depends on hydrology, the ecological flow to remain in the riverbed, irrigation requirements, leakage evaporation and other water consumption.

2.9.4 Flow duration curve (FDC)

Flow duration curve is a statistical representation of amount of hydro logically available water, and the distribution or characteristics of annual flows? A rather flat FDC implies a constant flow with low fluctuation and small difference between low and high flows. A steep FDC indicates large flow difference between dry and flood seasons, and high variability. Typically, the choice of design of design discharge a run of-river scheme or a storage power plant – is based on hydrological characteristics, in addition to energy demand, topographical condition, environmental and social consideration, and other factors.

Fig: recommended design discharge for run –of-river for HPP for flat FDC (blue line) and steep FDC red line providing equivalent flow.

Figure 2.3 Flow Duration Curve for Design of Power



Design discharge of this study also considered at 30% of the exceedance flow and the energy also as

2.9.5 Efficiency and losses

Overall HPP efficiency includes the efficiency of the turbine, generator, and transform. If the metering point is far from the HPP, electric city transmission efficiency must also be considered.

Overall efficiency is determined as follows:

$\eta_{\text{overall}} = \eta_{\text{turbine}} * \eta_{\text{grantor}} * \eta_{\text{transform}}$……………………………………………………………………………………….2.6

Most hydraulic efficiencies in the range of 80 to over 90 percent

2.9.6 Small scale hydro power in the east and other part of Africa:

Most of the countries in Eastern Africa have national energy policies (e.g. Malawi, Rwanda) or rural electrification policies (e.g. Madagascar, Tanzania) in place to support the use of renewable energy. In Uganda, the renewable energy policy has a target that includes mini- and micro-hydropower and value-added tax exemption for hydropower investors. Micro hydropower and isolated mini-grids are explicitly mentioned in the national energy policy of Rwanda. Kenya possesses a revised feed-in tariff (FIT) policy for small hydropower. Several countries such as Madagascar, Mauritius, Rwanda and Reunion already use FITs. Rwanda also uses other forms of incentives such as tax exemption and direct subsidies. Both Ethiopia and Zambia are preparing to introduce renewable energy FITs.

Table 2.5 Small-Scale Potential and Installed Capacity of Some African Countries.

Country	Potential(MW)	Installed capacity
Burundi	54	15.84
Ethiopia	1500	6.15
Kenya	3000	33.00
Madagascar	…	22.51
Malawi	15	5.80
Multiuse	9.5	8.7
Mozambique	1000	2.1
Reunion	…	11
Rwanda	38.2	23.2
South Sudan	At least 5	…
Uganda	210	22.24
Tanzania	310	25
Zambia	…	31
Zimbabwe	120	1.92
Total	6261.7	208.64

Small hydro power developed and potential in selected African countries

Table 2.6 Some African countries and their small hydro potential.

Country	Small scale hydro potential(MW)	Harnessed(MW)
Uganda	46	8.00
Mauritius	_	6.70
Kenya	600	14.00
Burundi	42	18.00

Zambia	4	1.05
Tanzania	70	9.00
Lesotho	_	5.10
Malawi	20	4.5
Botswana		1.00

Small scale hydro power utilization in Africa

Table 2.7 Utilization of small hydro in selected Africa countries (Source: BHA) Definition of small scale hydro (based on size)

Country	*Harnessed(MW)*	*Country*	*Harnessed(MW)*
Botswana	1.00	Rwanda	1.00
Lesotho	8.74	Somalia	4.60
Burundi	2.93	South Africa	.40
Ghana	1.2	Tanzania	4.00
Kenya	13.64	Uganda	8.00
Malawi	4.50	Zambia	4.50
Mauritius	6.7	Ethiopia	6.5
Mozambique	0.1		

Table 2.8 Small Hydro Classification Based On Size (Source: Http://Www.Microhyropower.Net/Size).

country	Micro	Mini	small
	(KW)	(KW)	(MW)
United states	<100	100-1000	1-30
China	_	<500	0.5-25
USSR	<100	_	0.1-30
France	5-5000	_	_
India	<100	101-1000	1-15

Brazil	<100	101-1000	1-30
Norway	<100	101-1000	1-10
Nepal	<100	101-1000	1-10
Various	<100	<1000	<10

Definition of micro, mini and small hydropower used by RET Screen international.

Table 2.9 Classification of Small Hydro Based On the RET Screen Software.

Type	Typical power	RET Screen ®flow	RET Screen® Runner diameter
Micro	<100 kw	<0.4m^3/s	<0.3m
Mini	100 to 1000 kw	0.4 to 12.8m^3/s	0.3 to 0.8m
Small	1 to 50MW	>12.8m^3/s	>0.8m

Table 2.10 The classification of hydro power in Ethiopia depend on power production.

terminology	Capacity limit	Unit
Large	>30	MW
Medium	10-30	MW
Small	1-10	MW
Mini	501-1000	KW
Micro	11-500	KW
Pico	<10	KW

2.10 Turbines:

Turbines are a mechanical equipment that is to convert energy in the form of kinetic energy into rotating shaft power .The selection of the best turbine for any particular hydro site depends on the site characteristics , the dominant one for this is mainly the head and flow available with the site.

2.10.1 Selection of turbine types depend on various criteria

The selection also depends on desired running speed of the generator or other device loading the turbine. Other consideration such as whether the turbine is expected to produce power under part –flow conditions also play an important role in the selection. All turbine is expected to produce power under speed design characteristics, as they will tend to run more efficiently at a particular speed, head and flow combination.

Table 2.11 Turbine classification based on flow path or pressure change:

Type of turbine based on flow path	Type of turbine based on pressure change
Axial flow hydraulic turbine	Impulse turbine(example Pelton turbine)
Radial flow hydraulic turbine	Reaction turbine(ex. Francis and propeller)
Mixed flow hydraulic turbine	Mixed flow turbine

Turbines can be classified as high head, medium head and low head machines. Turbines are grouped under various catagoriese like under the following heading: impulse turbines and reation turbines.

Table 2.12 The Turbine Classification:

Turbine type	High head	Medium head	Low head
Impluse turbines	Pelton turgo multi- jet pelton	Cross- flow/banki Multi-jet pelton turgo	Cross- flow/ banki
Reaction turbine		francise	Propller kaplan

2.10.2 Cross flow turbine:

In the crossflow turbine, the water in the form of a sheet idirected in to the blades tangentially at about mid way on one side. The flow of water" crosses" through the empty center of the turbine and exist just below the center on the opposite side. Thus the water strikes blades on both sides of the runner. The Cross-flow turbines have low efficiency compared to other turbines and the important loss of head due to the clearance between the runner and the downstream level should be taken into consideration when dealing with low and medium heads. Moreover, high head cross-flow runners may have some troubles with reliability due to high mechanical stress.

Cross-flow turbines are very efficient and cheap turbines that allow a very good cost/benefit ratio for energy production located at the end of conduits carrying water from a water source to a tank. In this paper, a new design procedure for a cross-flow turbine working with a variable flow rate is proposed. The regulation of the head immediately upstream the turbine is faced by adopting a shaped semicircular segment moving around the impeller. The maximum efficiency of the turbine is attained by setting the velocity of the particles entering the impeller at about 2 times the velocity of the rotating system at the impeller inlet. It is an interesting alternative when one has enough water, defined power needs and low investment possibilities, such as for rural electrification programs.

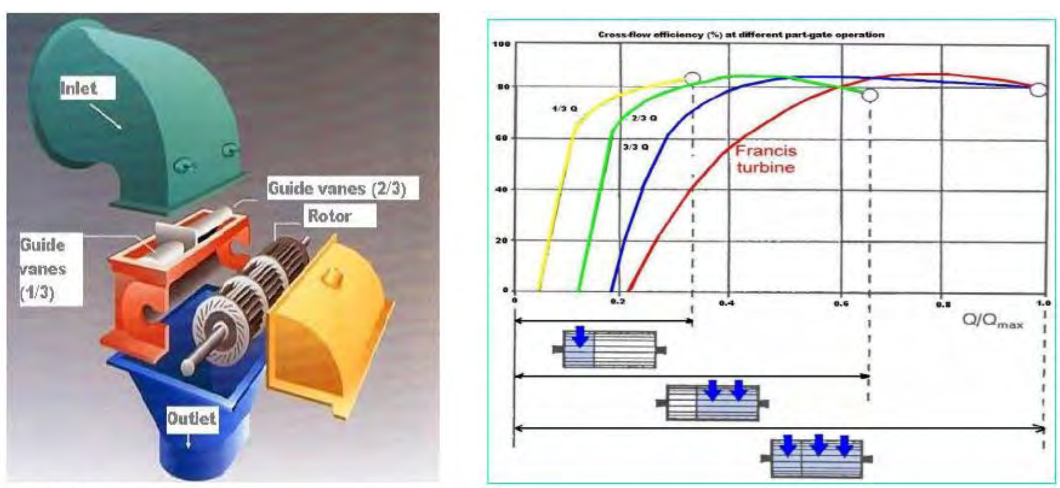
2.10.3 Advantages of divided cells of a cross- flow turbine

- During lowflow 1/3 of runner width operates
- During medium flow 2/3 of runner width operates
- During high flow 3/3 or whole of runner width operates
- The turbine can be operated efficiatly starting from 20% part- gate

Figure 2.4 Typical Cross Flow Turbine

Figure 2.5 Cross Flow Turbine Manufactured by STVC (source: STVC).

Figure 2.6 Cross Flow Turbine Vs Efficiency



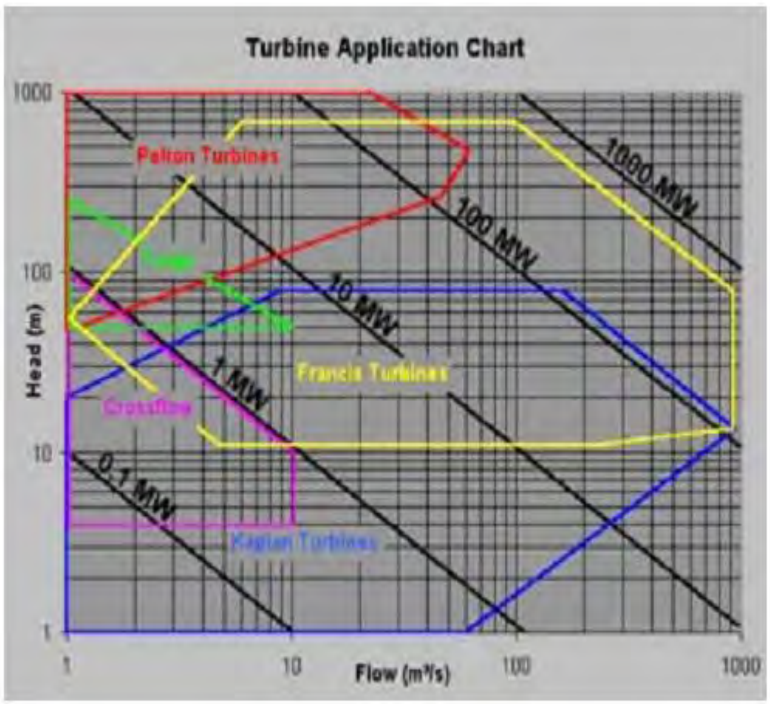
CENG 6803

Table 2.13 Classification of hydro power based on available head

Turbine type	Typical range of heads(H=head in m)
Hydraulic wheel	0.2<H<4
Archimedis' screw turbine	1<H<10
Kaplan and propeller	2<H<40
Francis	10<H<350

Pelton	50<H<1300
Cross flow/michell-banki	3<H<250
Turgo	50<H<250

Figure 2.7 Turbine Classification Based On Head.



7.3.2. Impulse turbines.

Impulse turbines derive their power from a jet stream striking a series of blades or buckets. A distinct feature of an impulse turbine runner is that it operates in air. The momentum of a high-speed water jet turns impulse turbines.

***Pelton Turbine*:**

The Pelton wheel is probably the best known of the tangential flow impulse turbines. Invented by a Californian mining engineer, it has changed little in the last hundred years. It is efficient over a very wide range of flows but at lower heads the speed is a bit too low for convenient belt drives.

The Pelton wheel is used where a small flow of water is available with a large head. It resembles the waterwheels used at water mills in the past. The Pelton wheel has small "buckets" all around its rim. Water from the dam is discharged from one or more nozzles very high speed hitting the buckets, pushing the wheel around.

Figure 2.8 Pelton Wheel

Pelton wheel

Figure 2.9 Typical Pelton Turbine.

Softwares applicable used for determination of small scale hydro power

The small scale hydro power poroject development is challenging process which deserve much time for computation and money in various experties in various disciplines. The feasiblity study and hydrological computation takes more time and finnance but the softwre development solve bth of those problems and it gives quick estimation of the fanancial viablty and energy out put of the project.

Table 2.14 Software applicable to develop small hydro power

Different computer software develop to solve this typical problems analysise for the the new

Assessment Tool		Features				
Software	Applicable countries	hydrology	Power/Energy	Costing	Economic evaluation	preliminary
ASCE Small hydro	USA	X				
HES	USA	X				
Hydra	Europe	X	x			
IMP	**International**	X	x		x	
PEACH	France	X		x		x

PROPHETE	France	X	x		x	
Remote small hydro	Canada	X	x		x	
RET Screen	**International**	X	x	x	x	

Implmented small scale hydro power.computers developed to solve thise typical software such as RETScreen ,IMP,HES,Hydra and PEACH etc. The detail description summerized in the table below.All the software are not internationaly applicable but the IMP and RET Screen software are internationally applicable.

2.11 The RET Screen software

RET Screen Clean Energy Analysis Software RET Screen International Clean Energy Decision Support Centre is managed under the leadership and ongoing financial support of Canmet energy which is a research center of Natural Resources Canada (Natural Resources Canada, 2010). The RET Screen Clean Energy Decision Support Centre seeks the capacity of planners, decision makers and industry to implement renewable energy and energy efficient projects (Leng et al., 2004). This objective is achieved by:

- developing decision-making tools that reduce the cost of pre-feasibility studies (RET Screen Clean Energy Analysis Software);
- disseminating knowledge to help people make better decisions;
- Training people to better analyze the technical and financial viability of possible projects.
- RET Screen can be used worldwide to evaluate the energy production and savings, costs,
- emission reductions, financial viability and risk for various types of Renewable-energy and
- Energy-efficient Technologies (RETs). (Natural Resources Canada, 2010). The usage of RET Screen worldwide has resulted in considerable achievements in different

REET Screen software: is one of the series of renewable energy analysis tools developed by natural resource Canada.it may be down-loaded free –of-charge from the internet (subject to acceptance by the user of a license agreement) at htt: // retscreen.gc.ca or www.retscreen.net. Nit is designed "to help energy project proponents identified and evaluate, relatively quickly and at low cost, the most viable near –term opportunities for cost – effective RETs project implementation." This software is commonly designed to address the remote community full fil the energy demand of the society.

Table 2.15 Predictions for some of the achievements (Leng et al., 2004)

Performance	Future impact (1998 to 2012)	
	Canada	World
User saving	$1.8billion	$7.9 billion
Installed capacity	$4.9GW	24GW
Installed value	$10billion	$41 billion
GHG Reduction	3.6 million tones CO_2 **/yr.**	20million tones CO_2 **/yr.**

2.12 The input data for the ret screen software and its definition*:*

Description: this value refers description or title for reference.

2.12.1 **Resource assessment:**

Type of project from the two option in the drop- down list: "Run of river" and "reservoir "for reservoir projects, the user must enter directly, in the displayed table below, the flow-duration curve data that takes into account the effect of storage.

2.12.2 **Hydrology method:**

The hydrology method from the two options in the drop-down list: "specific run –off" and user defined." When "user- defined "is selected the flow- duration curve data is entered directly by the user in the appropriate given table in the software. The "specific run-off" method is used in conjunction with the RET Screen hydrology data base.

2.13 Head:

The user enters the gross head, which is the drop in elevation at the site. If the gross head at the site is unknown. To determine the head manually, a site survey is required unless very large-scale and accurate mapping is available. This is especially important for low-head small hydro because of the small differences in elevation involved, where the elevation drop can be 10 m or less. The scale of mapping required for determining such a drop would have to be at least 1:5,000. For projects that incorporate a canal, the gross head is the drop in elevation as measured from the end of the canal to the tailrace. Hence the gross head does not include any drop in elevation arising from a canal.

The drop in elevation over the length of the canal can be approximated assuming that the canal drops approximately 1 m every 1,000 m (i.e. has a 0.001 slope). When using the "hydro formula costing method" in the cost analysis worksheet the approximate loss of head over the length of the canal is calculated and provided to assist the user in selecting the appropriate gross head for the site.

2.14 Maximum tail water effect

The user enters the maximum reduction in available gross head that will occur during times of high flows in the river. At most sites, during high flows, the tail water level rises more than the level upstream of the intake and causes a reduction in the gross head. Consequently, during these periods, less power and energy are available. The tail water effect can be significant, especially for low-head sites.

Percent of firm flow available:

The user enters the percentage of the time that the firm flow should be available. Typical values range from 90 to 100%.

2.14.1 **Firm flow:**

The model calculates the firm flow that will be available for electricity production based on the flow-duration curve data (entered in table below), the percentage of time the firm flow should be available and the residual flow. The firm flow is often defined as the flow available at least 95% of the time.

2.15 Hydro turbine

2.15.1 **Design flow:**

The user enters the design flow, which is defined as the maximum flow that can be used by the turbines. The selection of the design flow depends, primarily, on the available flow (hydrology) at the site. For central-grid connected run-of-river projects the optimum design flow is usually close to the flow that is equaled or exceeded about 30% of the time. For isolated-grid and off-grid applications, the flow required to meet the peak load may be the deciding factor for selecting the design flow, provided that this flow is available.

2.15.2 **Manufacturer**

The user enters the name of the equipment manufacturer for reference purposes only. The user can consult the RET Screen Product Database for more information. The name of the equipment model for reference purposes only. The user can consult the RET Screen Product Database for more information.

2.15.3 **Efficiency adjustment**

The adjustment, expressed as a percentage, applies to the entire efficiency curve. For example, a value of -2% will reduce the turbine efficiency by 2% over its entire operating range. The turbine efficiency adjustment can be varied as part of a sensitivity analysis to determine the effect of possible differences in turbine efficiency and to make adjustments to the calculated turbine efficiency curve, if required. Values in the range of -5 to +5% may be used.

2.16 Turbine peak efficiency

The model calculates the turbine peak efficiency (%) based on the standard turbine efficiency curve data.

2.16.1 Turbine efficiency at design flow

The model calculates the turbine efficiency at design flow (%) for the type of turbine selected. This value can range from 80% to over 90%.

2.16.2 Flow-duration and turbine efficiency data

The user indicates whether or not the flow-duration and turbine efficiency data are displayed in the worksheet.

2.16.3 Flow-duration curve data

A flow-duration curve (FDC) is a graph of the historical flow at a site ordered from maximum to minimum flow. The flow-duration curve is used to assess the anticipated availability of flow over time, and consequently the power and energy, at a site. It should be noted that each hydro site is unique. In the absence of site specific hydrologic information, the specific run-off method used in the RET Screen model for assessing the hydrology at a site will provide useful preliminary information. The user can consult the RET Screen Product Database for more information. Note that the flow-duration curve data is entered based on the percentage of time the flow is equaled or exceeded.

Losses

2.16.4 Maximum hydraulic losses

In a hydro plant, energy is lost as water flows through the water passages. A value of 5% is appropriate for most hydro plants. For plants. For plants with very short water passages, a value of 2% is appropriate for most hydro plants. For low- head hydro plants with long water passages, the factor can be increased to 7%.

2.16.5 Miscellaneous losses

This value of accounts for miscellaneous loss for transformer losses, parasitic electric city losses etc. A transformer is generally required to match the voltage of the generator with that of the transformer is generally required to match the voltage of the generator with that of that of the transmission line or distribution system to which it is connected. Transformer losses are typically minor. A value of 1% is appropriate as an estimate of transform losses.

Some of the energy generated by a hydro plant is used by the system itself for auxiliary equipment (e.g. Shut –off valves, by-pass gates, protection and control system, etc.) lighting, etc. For small hydro plants, parasitic electric city losses are typically minimal.

Parasitic electricity losses can range from 1to 3%. A value of 2% is appropriate for most hydro plants.

2.16.6 Availability

Downtime losses are a result of scheduled maintenance, hydro turbine failures, station outage and utility outage. A value of 96% represents approximately 15 days of down time (assuming 100% capacity factor) and is an approximate value for most hydro plants. For hydro system located in regions where increased maintenance requirements are anticipated (e.g. 94%) should be used.

2.16.7 Power capacity

The model calculates the hydro system power capacity, or maximum power output of the site. Note that the power capacity calculated here is the output of the site as exported to the grid (central-grid or isolated-grid) not the installed capacity. The model also calculates the firm capacity at the site based on the firm flow, the gross head, and design flow and efficiency /losses .this value is compared to the power capacity and the lower of the two values is displayed as a firm capacity .for isolated –grid applications, compared the firm capacity with the peak load provides an indication of the additional power that is required from other sources (e.g. reciprocating engines).

2.16.8 Available flow adjustment factor

The available flow adjustment factor which provides the user with a means to adjust the capacity factor, the electricity exported to the grid and is provided primarily for purpose of conducting sensitivity analyses. Using this adjustment factor, the user can easily check the effect of changes in these values on the projects finical viability.

The available flow adjustment factor is applied to each value in the flow-duration curve table given. During the calculation of the capacity factor, the electric city exported to the grid (e.g. a value of 1.1 increase each value in the flow duration curve by 10 %). Note that the available flow adjustment factor does not change the value in the flow duration curve.

2.16.9 **Capacity factor**:

The net capacity factor of a power plant is the ratio of its actual output over a period of time, to its potential output if it were possible for it to operate at full nameplate capacity indefinitely. To calculate the capacity factor, take the total amount of energy the plant produced during a period of time and divide by the amount of energy the plant would have produced at full capacity. Capacity factors vary greatly depending on the type of fuel that is used and the design of the plant. The capacity factor should not be confused with the availability factor, capacity credit (firm capacity) or with efficiency.

$$capacity\ factor = \frac{power\ out\ put}{power\ intsalled\ capacity}$$

Capacity factor of dams having different size:

Table 2.16 Hydro power defining in terms of cost, capacity factor and O&M.

technology	Installed cost(US$/KW)	Operation and maintenance cost (% yearly of installed cost)	Capacity factor (%)	Leveled cost of electric city (LCOE)(2010 US$/KW)
Large hydro	1050-7650	2-2.5	25 to 90	0.02-0.19
Small hydro	1300-8000	1-4	20 to 95	0.02-0.27
Refurbishment/upgrade	500-1000	1-6		0.01-0.05

The model calculates the capacity factor, which represents the ratio of the average power produced by the hydro plant over a year to its rated power capacity. Typical values for hydro plant capacity factor range from 40 to 95%. For a selected river with a given hydro system design, the higher the design flow, the lower the capacity factor. Provided that there are no restrictions on the maximum output of a hydro plant, the optimum size of the plant will depend primarily on the availability of water (illustrated by the flow-duration curve). At some point, the cost of building a larger plant cannot be justified by the resulting increase in energy production. Typically, for a run-of-river hydro plant, this point is usually close to the mean flow at the site.

2.17 Electricity export revenue:

The model calculates the annual electricity export revenue. This value is calculated by multiplying the electricity exported to grid by the electricity export rate.

2.18 Hydro power advantages

2.18.1 **Small hydro power economic advantages and cost**

Hydroelectric plants generally are quite competitive and economical when compared to the conventional fossil fuels based power plant. However, the small hydro, especially the mini and micro hydro, installed in remote hilly regions are somewhat costlier and are competitive to conventional power only when allowances for external cost associated with fossil fuels and nuclear power extra are considered. The geographical and geological features along with the effective head, available flow, equipment (turbine, generators etc.) and civil engineering works determine the capital required for any small hydro power project. If the project can make use of existing weirs, dams, storage reservoirs (ponds), etc. these can significantly reduce both environmental and impact and cost.

MHP sites with low heads and high flows require greater input of capital as larger civil engineering works and turbine machines are used to handle the large volume of water. If, however the MHP project can serve a dual purpose- power generation as well as flood control or power generation and water supply purpose, then the payback period significantly reduces. While deciding to invest in MHP plant, it is also necessary to keep in mind the cost of using water (water charges and concession fees) and the administrative procedure to obtain the clearance /licenses.

Operation and maintenance (O and M) cost, including repairs and insurance form another set of recurring expense for MHP. For MHP plants this can be in the range of 1.5-5% of total capital cost. For estimating whether a given MHP is financially feasible, several financial tools and techniques can be used the RET Screen software is the best to compute the payback period and its benefit gained from the MHP through the life of the project.

3 Material and METHODOLOGY

3.1 BACKGROUND OF THE STUDY AREA

Tigray region has many micro and medium providing excellent opportunities for small hydropower development. While large scale hydropower development is becoming a challenge due to environmental and socio-economic concerns and more recently its vulnerability to changing climates, small hydropower development continues to be an attractive resource, especially in remote parts of the region that's above 80.5% of the total population and have total are 56451528633.199997km^2. It is a proven technology that can be connected to the national grid, isolated grid or as a stand-alone option, or combined with irrigation systems.

Small hydropower can adequately contribute to the electricity needs of our country. In Tigray regional state various type of irrigation dam are implemented but some of them affected by sedimentation and different failure, additionally most of them give only irrigational service but they are still not functional in case of small- scale hydro power even those affected by sedimentation they can give service for electric city. Dominantly in the southern part of the regional state huge amount of energy can be produced by the available irrigation dams even some of them affect by sediment they become functional in case of small scale energy production because of its head and the flow of the river come across the dam.

General description of location of the Tigray water shed

Figure 3.1 Tekeze water shed and location of some existing irrigation dams

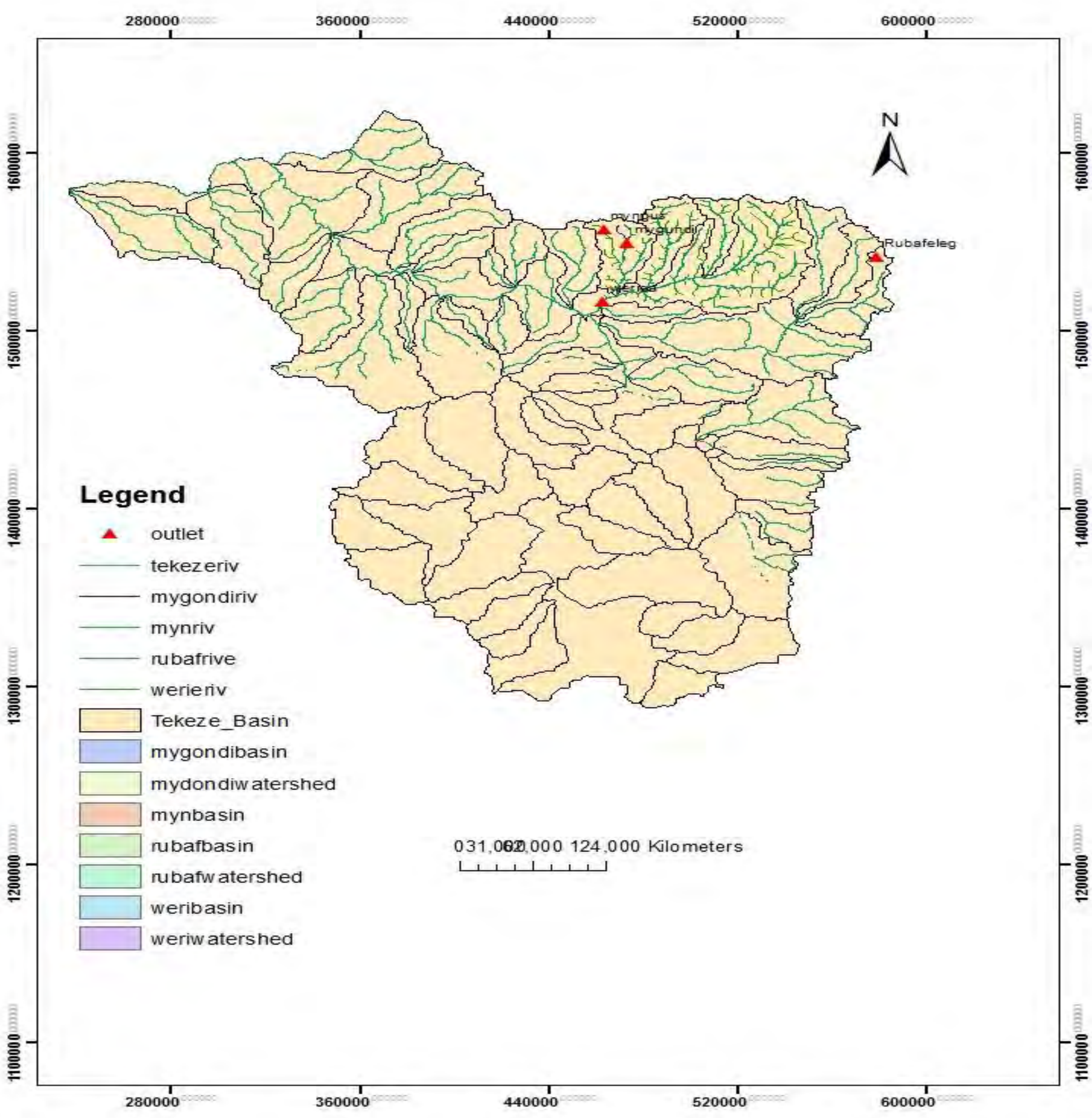


Figure 3.2 Weriee Watershed

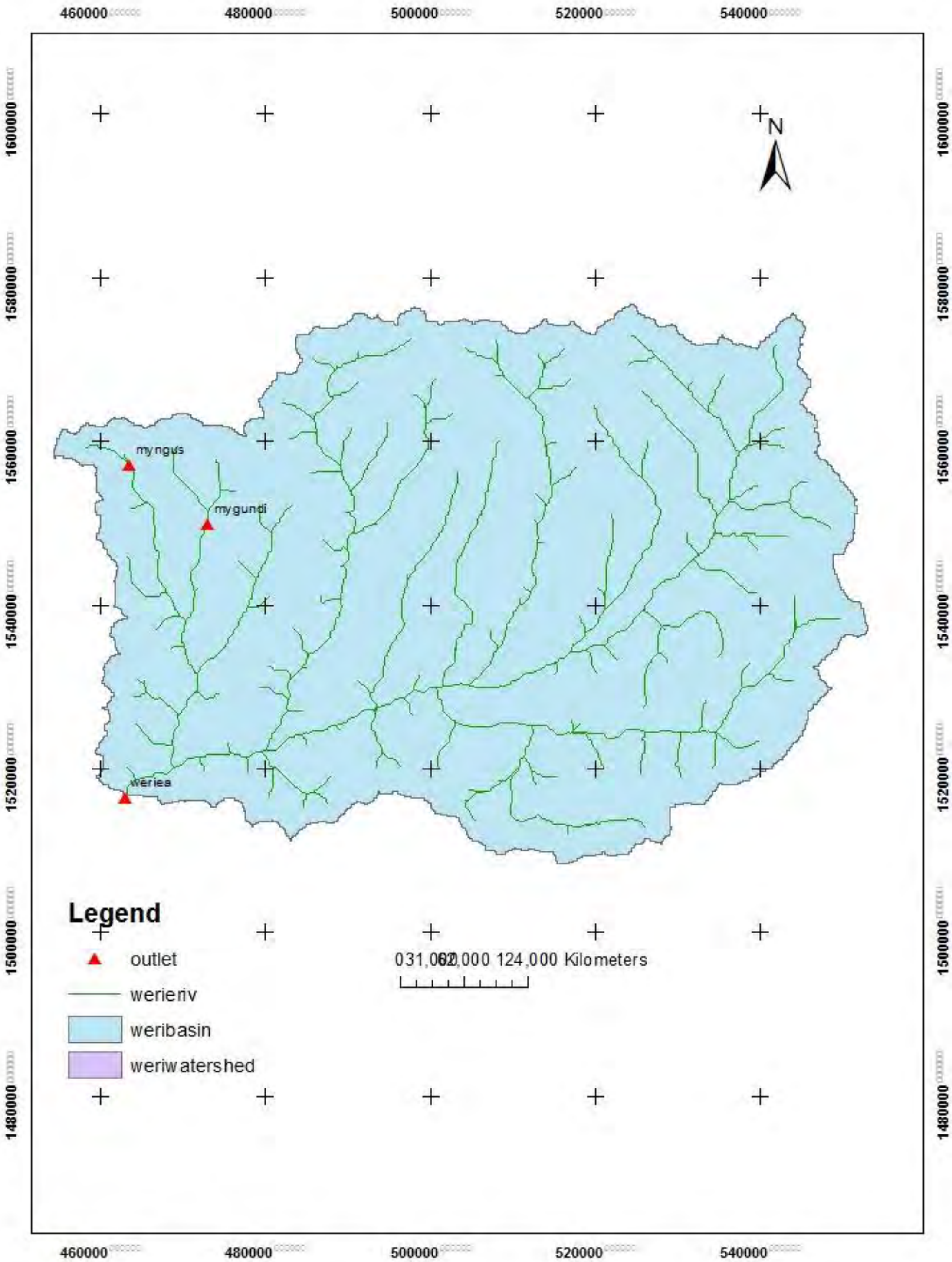

460000
480000
500000
520000
540000
1600000
1580000
1560000
1540000
1520000
1500000
1480000
N
myngus
mygundi
weriea
Legend
outlet
werieriv
weribasin
weriwatershed
031,062,000 124,000 Kilometers

Figure 3.3 Mygundi watershed

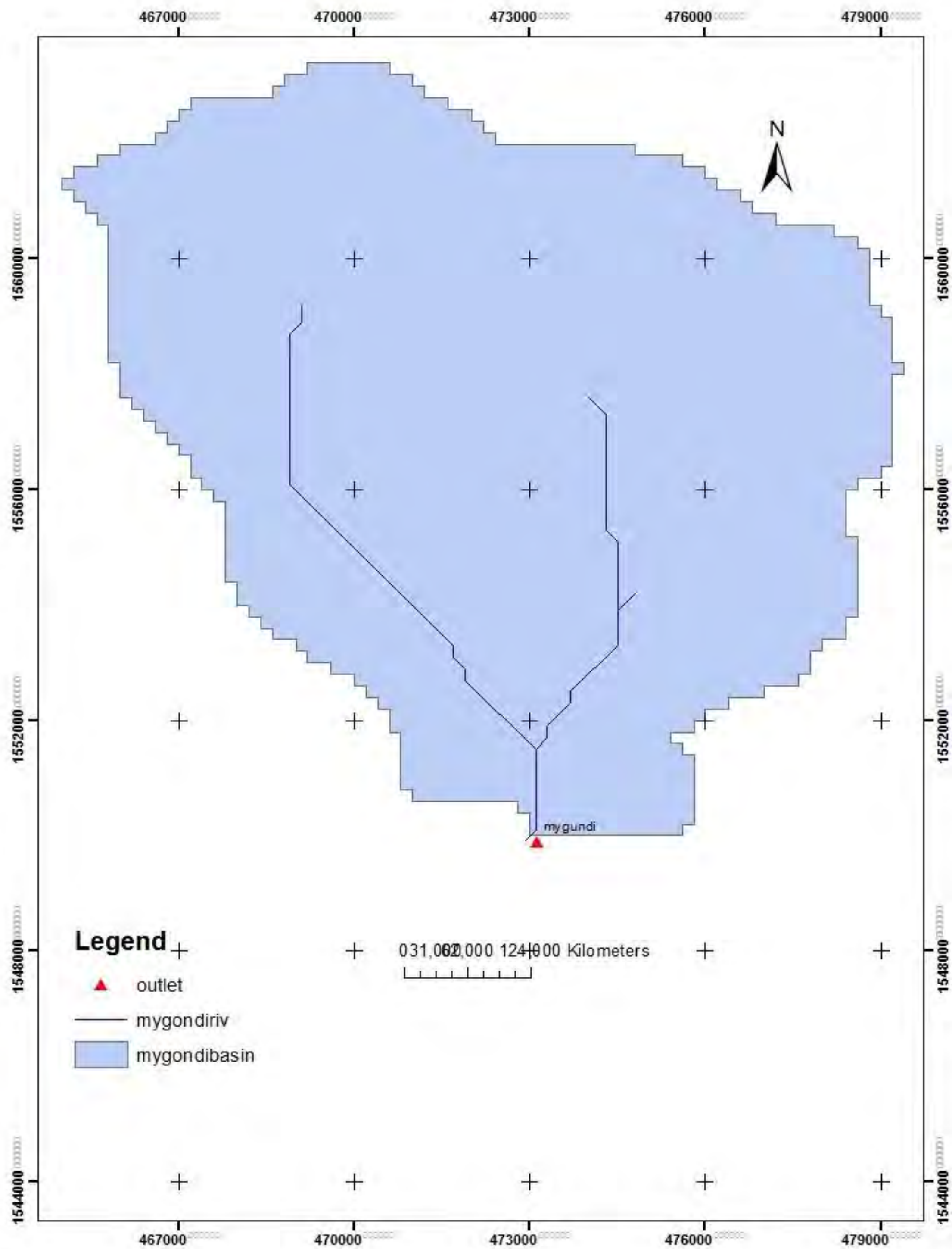


Figure 3.4 Myngus watershed

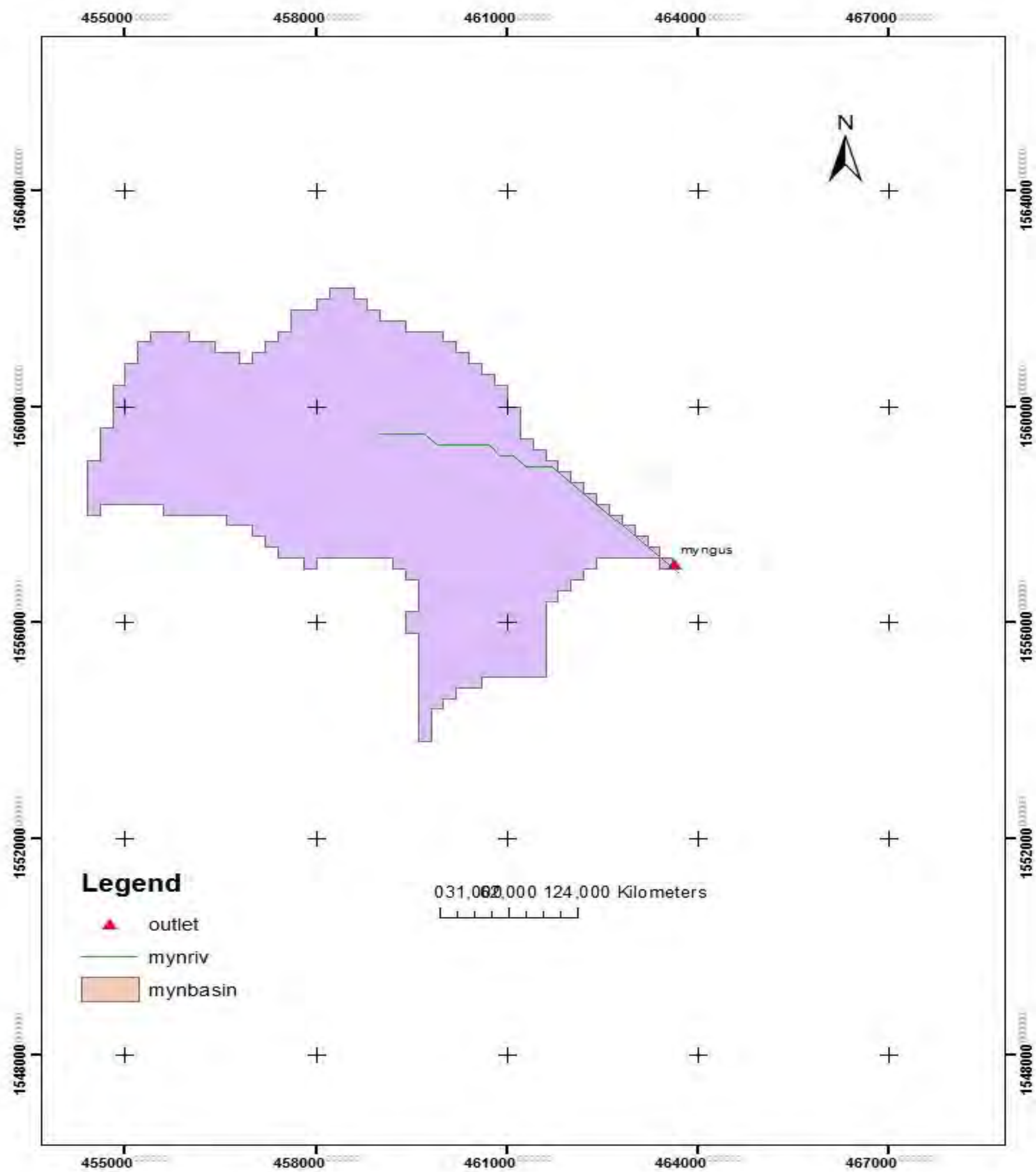


Figure 3.5 Rubafeleg watershed

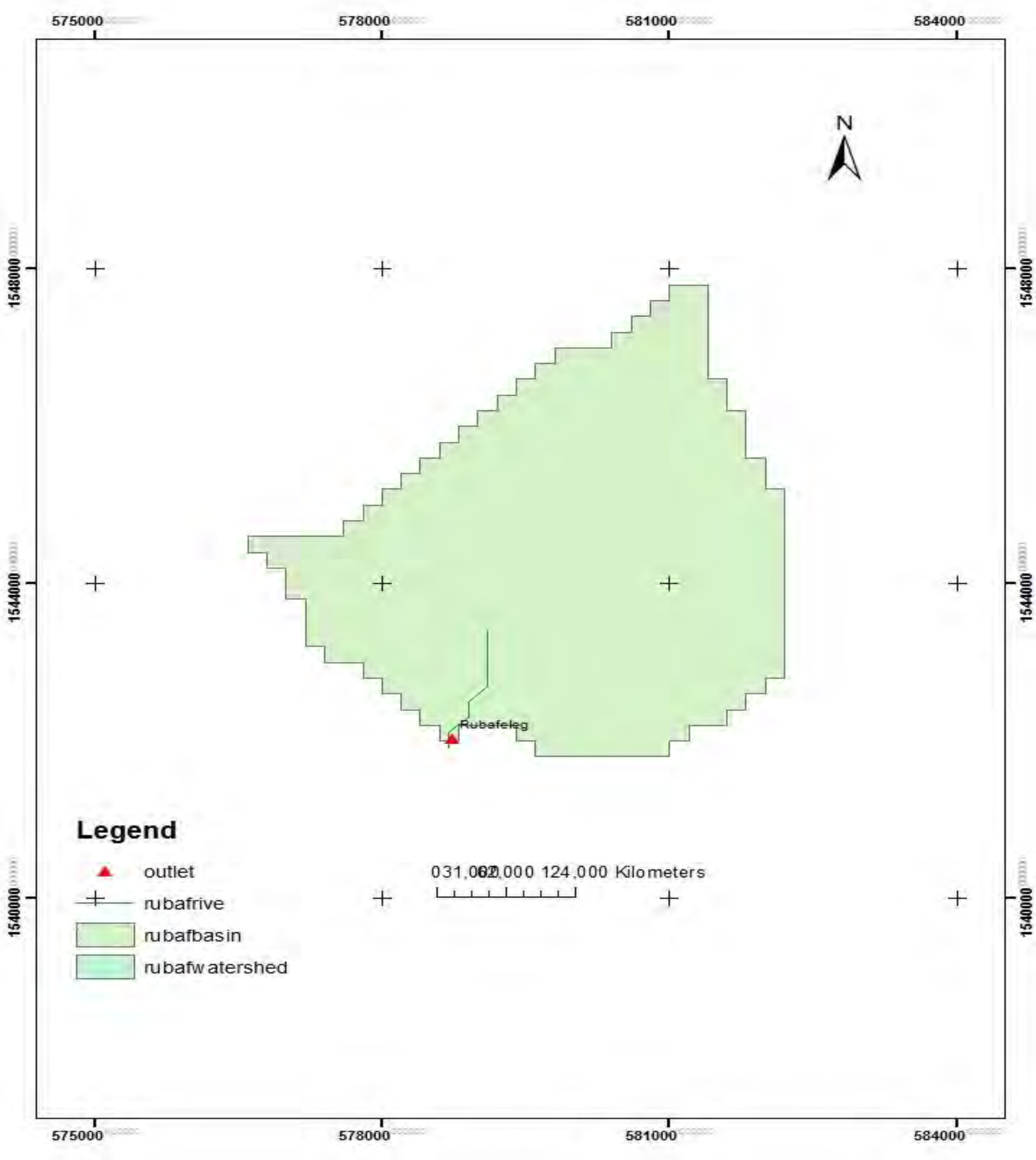


Figure 3.6 Laelay wukro watershed

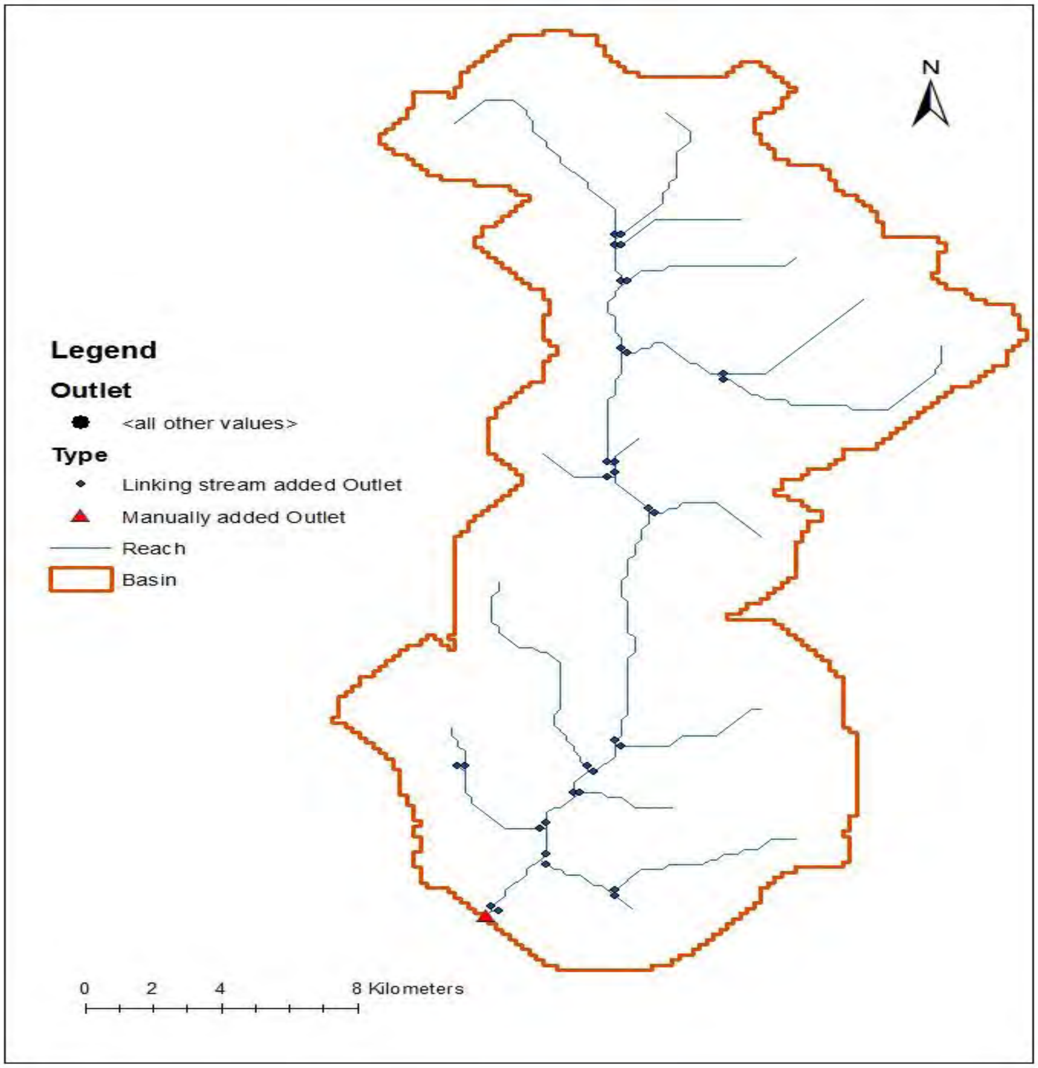


Table 3.1 Location of the Irrigation Dam Implemented In Tigray Regional State:

SITE_NAME	WOREDA_COD	Elevation(m)	catchment .A(m^2)	RESERVIOR	POTENTIAL	YEAR CONST.	CONSTRUCTI	service life
Seysa	Adwa	1930	83		400			25
Bahre weira		2299	_	_	–	–	–	
Zamra	Hintalo wejerat	2168	67	–	–	–	–	

Nazra	Hintalo wejerat	2132	56.2	–	–	–	–	
Hizati Afras	Hintalo wejerat	2062	70.5	–	–	–	–	
Shilanat 1	Hintalo wejerat	2067	3.42	1609000	108	1990	1990	20
Shilanat 3	Hintalo wejerat	2045	–	150223	7	1990	1990	15
Shilanat 4	Hintalo wejerat	2092	–	2860000	181	1990	1990	35
Adi_Gela	AG	2067	8.78	1250000	0	–	–	
Mai_Delle	AG	2117	10.1	1570000	90	1989	1990	
Mai_Haidi	AG	2189	1.96	150000	9	1990	1990	
Mejae	AG	2238	3.15	166000	14	1990	1990	
Gra_shito	AG	2115	2.88	170000	12	1990	1990	
Gum_sellas a	AG	2134	18.55	1902000	110	1987	1987	16.5
Filiglig	Hintalo wejerat	2112	3.2	–	–	–	–	–
Adi_Kenafiz	Hintalo wejerat	2158	8.8	670480	60	1990	1990	–
Mai_Agam	Hintalo wejerat	2159	2.11	169733	10	1990	1990	–
Dur_anbess a	Endrta	2124	10.07	900000	61	1993	1993	–
Gereb_sege n	Endrta	2106	4.79	340000	24	1991	1992	–
Mai_Gassa 1	Endrta	2138	9.05	1300000	80	1989	1989	–
Mai_Gassa 2	Endrta	2141	–	–	–	1990	_	–
Gereb_Mihi z	Endrta	2338	17.27	1300000	80	1990	1990	–
Betqua	Endrta	2275	6.13	606337	70	–	–	–
Meala	Endrta	2371	14.37	1400000	100	1989	1990	–
Haiba	Hintalo wejerat	2273	24.7	3100000	250	1989	1990	–
Meskebet	AD	1782	9.26	2700000	100	1987	1987	20
Mai_Negus	Luelay michew	2090	13.05	2381900	150	1987	1989	30
Mai_Gundi	luelay michew	–	–	–	–	–	–	20
Gindae	Wenberta	1979	_	730000	53	1990	1990	
Luelay wukro	wukro	2045	9.16	930000	50	1990	1990	20
Korir	Hintalo wejerat	2052	–	1600000	100	1987	1988	–

Ruba feleg	Atsbe Wenberta	2756	_	2713200	25	_	_	_
Teghane	A	2741	8.8	1080000	60	1989	1989	_
Adi_shihu	Atsbe Wenberta	2312	9.4	1000000	40	1989	1989	_
Felaga	Atsbe Wenberta	2872	_	900000	80	1986	1988	_
Arato	Endrta	2432	20.77	2590700	120	1987	1989	_
Mai_serakit	ENDERTA	2441	4.48	488000	31	1990	1990	_
Hashenge	Endrta	2418	25.7	2230000	120	1989	1989	_
Endazeoy	ENDERTA	2428	1.65	182543	13	1990	1991	_
Era quhila	ENDERTA	2349	11.5	1185000	70	_	1889	_
Adi_akor	ENDERTA	2375	2.75	510777	30	1990	1990	30
Sewhineda	ENDERTA	1998	4.7	360000	23	1990	19900	_
Gereb_Beat i	ENDERTA	2162	5.4	1500000	90	1991	1992	_
Adi_Hilo	ENDERTA	2314	0.71	104478	9	1990	1990	9
Gereb_Aws o	ENDERTA	2296	0.97	107720	9	1990	1990	15
Emabgedo	Endrta	2311	12.4	1776000	80	1989	1990	_
Adi_Amhar ay	Endrta	2338	6	960000	60	1989	1989	_
	E	2237	30.01	1100000	80	0	1989	_

Figure 3.7 Location of Mygundi Reservoir Dam Site

3.1.1 Description of the selected study area:

In the following section the general overview of the selected different irrigation dam (seyas, aftsebibe, migorzo, serenta, Mygundi, luelay wukro, mynguse and ruba felege) those are located in different part of the Tigray regional state.

3.1.2 Back ground of the Seysa dam site

Location

- Zone: central zone of Tigray region
- Woreda: Adwa
- Tibia: Laeli-logomti
- village: Eshure
- Dam site: Seysa River

Geographical Location

- Latitude (UTM.): 49900E
- Longitude (UTM): 1561400N
- Altitude: 1941.6 M.a.s.l
- Total Catchment area: 66.43Km²

The topographical representation of the Seysa dam site

Figure 3.8 Location of Seysa Dam Site

The contour of the study area is developed from integrating of the software like google earth, surfer and TCX converter.

Figure 3.9 Contour And Flow Direction of Seysa Dam Site.

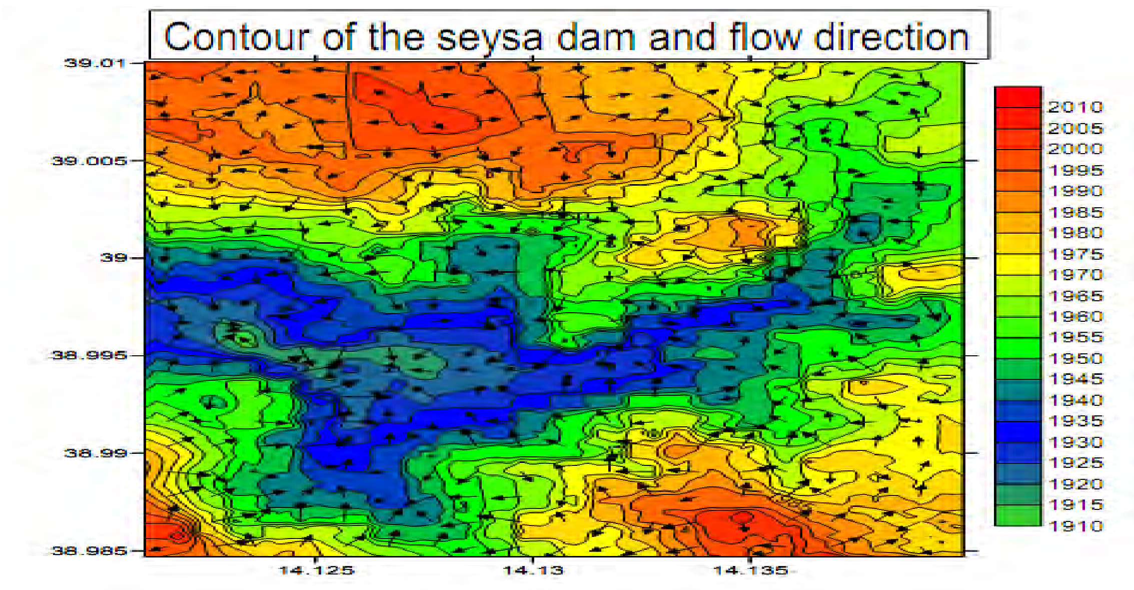


Figure 3.10 View of the Seysa Catchment Area

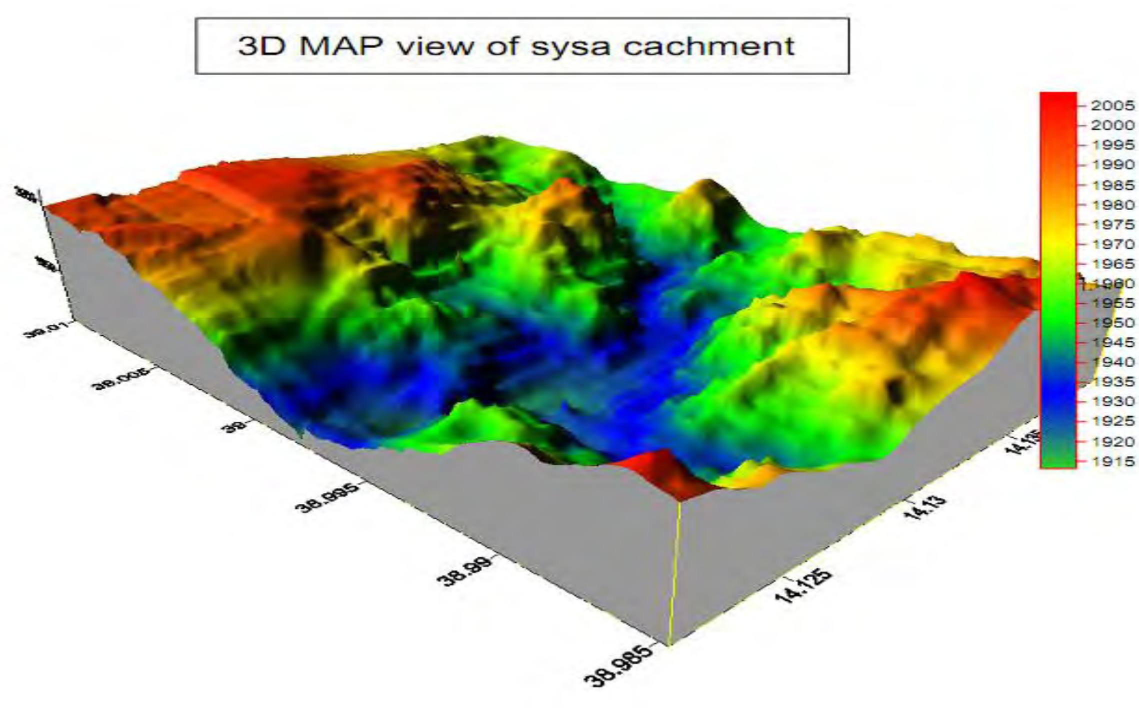


Figure 3.11 Description of the location of Adwa from the RET Screen software

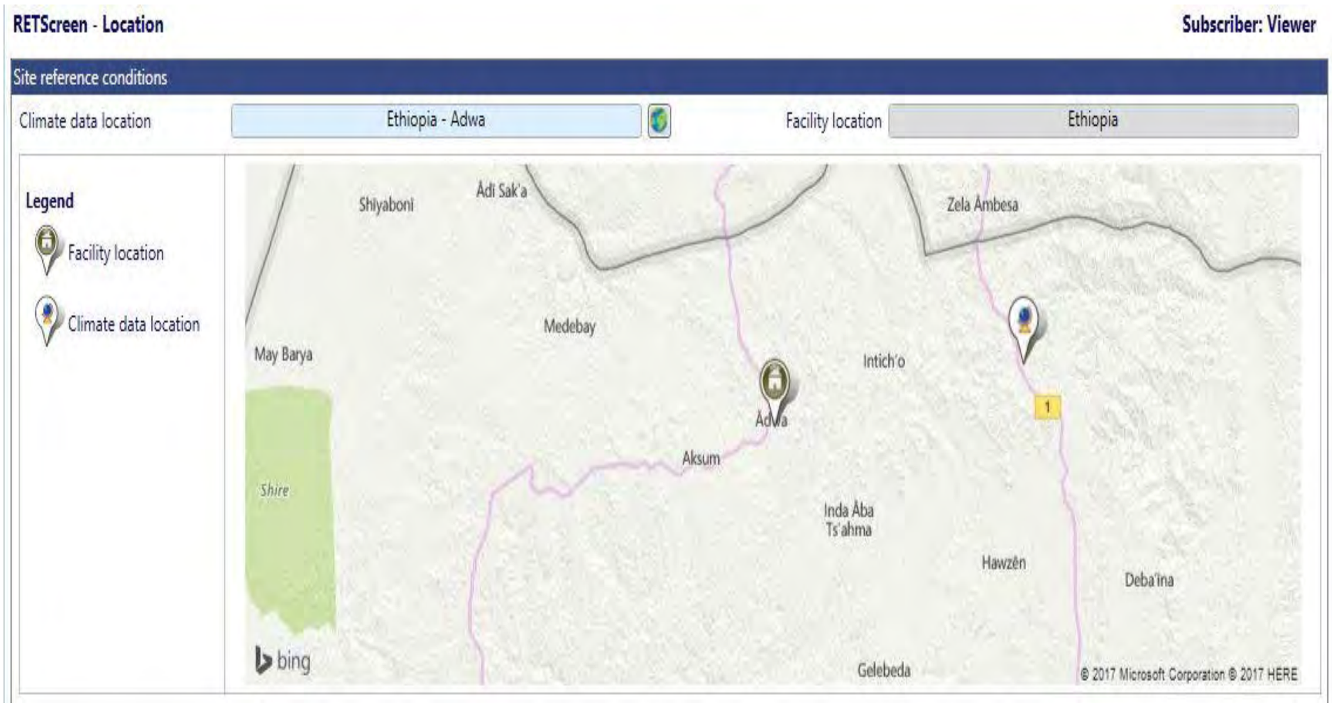


Figure 3.12 Metrologic total data of Adwa station

	Unit	Climate data location	Facility location	Source
Latitude		14.3	14.2	
Longitude		39.5	38.9	
Climate zone		1B - Very hot - Dry		NASA
Elevation	m	1731	1938	NASA – NASA
Heating design temperature	°C	16.0		NASA
Cooling design temperature	°C	33.7		NASA
Earth temperature amplitude	°C	15.6		NASA

Month	Air temperature	Relative humidity	Precipitation	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days 18 °C	Cooling degree-days 10 °C
	°C	%	mm	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January	21.3	56.5%	9.67	5.71	90.4	4.6	24.8	0	352
February	22.3	53.4%	5.04	6.08	90.3	4.7	26.5	0	345
March	24.3	52.0%	26.98	6.33	90.2	4.7	28.6	0	442
April	26.1	49.3%	31.92	6.66	90.1	4.3	30.1	0	482
May	27.9	43.1%	35.57	6.49	90.1	3.7	32.3	0	556
June	27.6	48.6%	27.77	6.10	90.0	5.1	30.6	0	527
July	26.3	54.4%	98.46	5.49	89.9	5.7	28.4	0	506
August	26.0	56.1%	119.95	5.30	90.0	5.3	27.9	0	497
September	26.8	47.0%	59.55	5.95	90.1	4.3	29.8	0	504
October	26.4	38.1%	35.84	6.01	90.3	3.2	30.2	0	508
November	24.0	44.0%	7.74	5.78	90.3	3.5	27.2	0	419
December	22.0	52.6%	10.40	5.46	90.4	4.1	25.2	0	372
Annual	**25.1**	**49.6%**	**468.88**	**5.94**	**90.2**	**4.4**	**28.5**	**0**	**5,509**
Source	NASA	NASA	NASA	NASA	NASA	NASA	NASA	NASA	NASA
Measured at					m	10	0		

Figure 3.13 The Metrologic Data of Adwa Station Gained From the RET Screen *Software*

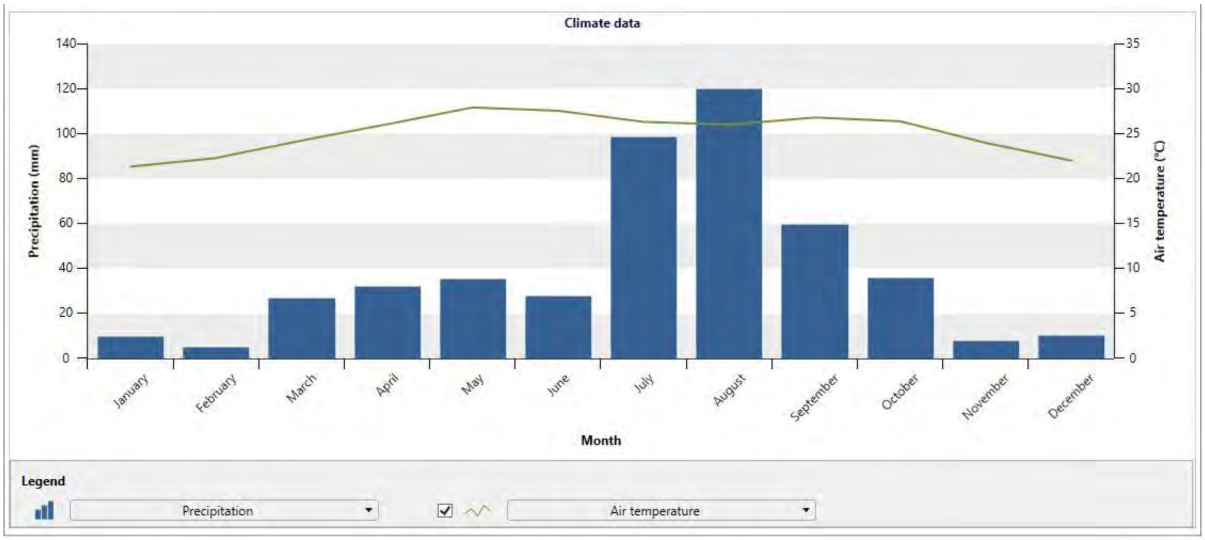
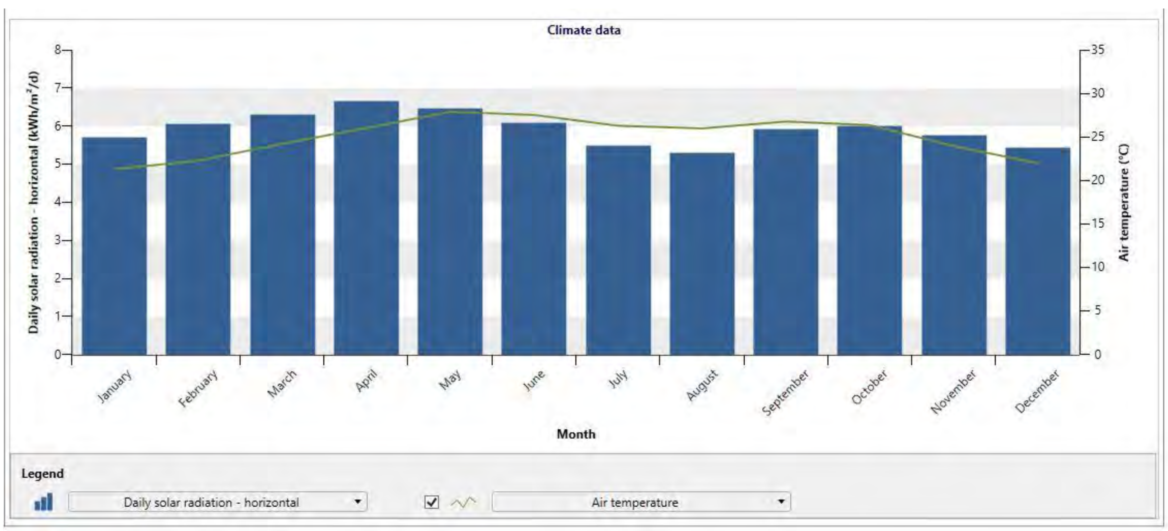


Figure 3.14 Daily Solar Radiation Vs Air Temperature Gained From the RET Screen Software

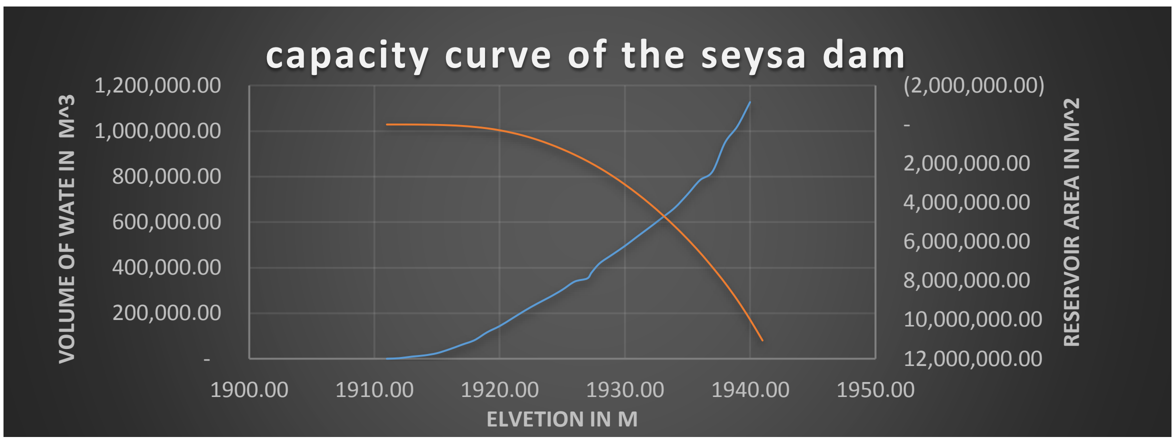


3.1.3 Reservoir capacity

- Gross capacity: 8.1Mm³
- Dead storage: 1.992Mm³
- Net capacity (usable storage): 5.64Mm³
- Live of reservoir: 25 years

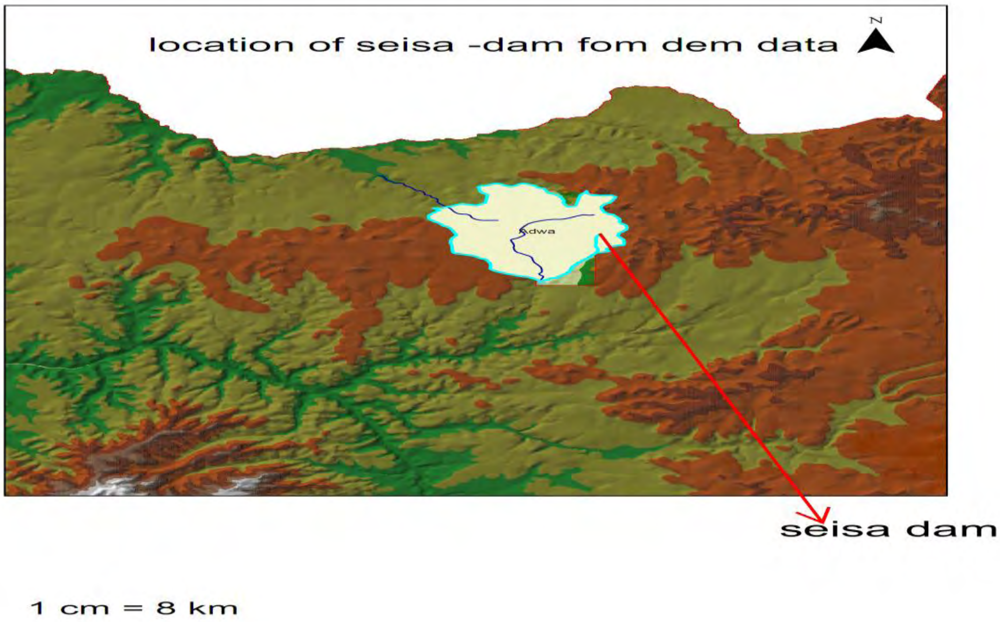
- Maximum reservoir Level: 1939.82m.a.s.l
- Normal Reservoir level: 1938.0m.a.s.l
- Dead Storage Level: 1927.35m.a.s.l
- Inundation area (at Max water level): 112.77ha
- Command area: 400hac
- Command to inundated area ratio (%): 3.55

Figure 3.15 Capacity Curve of Seysa Dam



Watershed area of seysa dam

Figure 3.16 Watershed Area of Seysa Dam Site



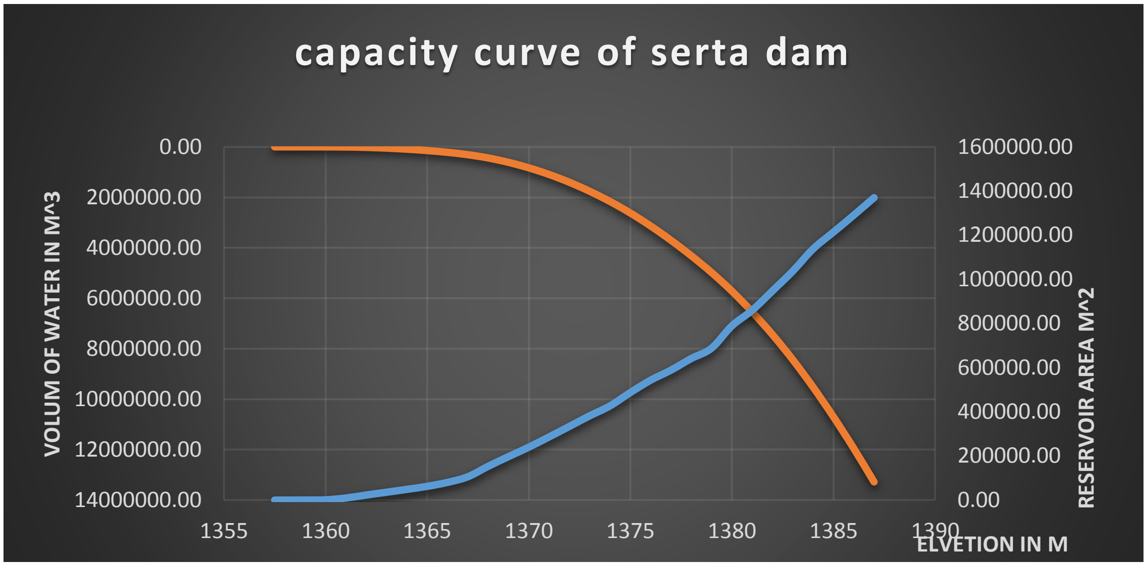
3.1.4 **Serenta dam general description**

3.1.5 **Location and accessibility of the project area**

The project area, Serenta dam site, is located within Tselemti Woreda, northwestern zone, in Tigray National Regional State, northern Ethiopia. Geographically, it is bounded by 0405000-0414000 E and 1492500-1504000 N covering about 103.5 sq.km.

Reservoir volume of serenta

Figure 3.17 Capacity Curve of Serenta Dam



3.1.5.1 CLIMATE AND VEGETATION

Prevailing climate of the watershed is mainly hot semi-arid, with mean max. 34oc and coldest 16.4oc temperature, average rainfall more than 800 mm. Kiremt is the longest rainy season, which starts early of May and ends in October. Rainfall pattern is mono-modal with a distinct peak in the period of June-September.

3.1.6 DRAINAGE SYSTEM

The drainage system of the study area consists of numerous intermittent and some perennial streams. The streams are poorly to well developed mainly controlled by the influence of the underlying lithological units and/or topographic nature of that particular area. The main perennial river in the study area is Serenta, which is the major tributary of Tekeze River and flows from south to north. The drainage pattern of the study area is sub dendritic and its density is higher up stream than downstream.

3.1.7 Aftsebibe irrigation dam description area

3.1.7.1 Location

- Region - Tigray
- Zone – Central
- Woreda – Ahfereom
- Tabia – Mezbir
- Kushet - Mai Shewit and Debreabrha

Location and Catchment Characteristics of the Project Area

The Aftsebib irrigation dam project area source is situated at Geographical location UTM of 504009mE & 1582267mN. The project area covers 39.35km^2 and surrounding towns and small villages in north western zone of Tigray region woreda Ahiforom kushet Mezbir. The main source of Water proposed for the study area is the different stream tributaries of the River. The basin lies in the altitude above 1996m.a.s.l. with respect to land cover and use, the vegetation of the study area has disappeared and only little of the original vegetation is evident. The current vegetation.

3.1.8 **Topography**

Topography is a field of geosciences and planetary science comprising the study of surface shape and features of the Earth and other observable astronomical objects including planets, moons, and asteroids. It is also the description of such surface shapes and features (especially their depiction in maps). The topography of the Aftsebib dam is forest dense and hot environment condition around the reservoir and both left and right side of the dam has mountains. However it has huge plane area of the command area. The geographical topographic location of the dam site is in the following table below.

Figure 3.18 Topographical of the Aftsebib River

3.1.9 General description of the watershed

The Aftsebib earth dam site is found in the Aftsebib sub basins having good potential of surface water that can irrigate more than 600ha during dry season. For the detailed bio-physical description of the area including its location, topography, climate, soil, vegetation, land use types, land capability classification problems of the area.

3.1.10 Climate characteristics of the project area

The climate of the project area is governed by its physiographic position, temperature regime, amount and distribution of rainfall, humidity and wind regime. The main factors that influences the climate of the area are; the seasonal variations of the Inter Tropical convergence Zone (ICTZ), the northern trade winds and the south western monsoon.

3.2 Methodology and material use:

To conduct this study entails the following activities such as

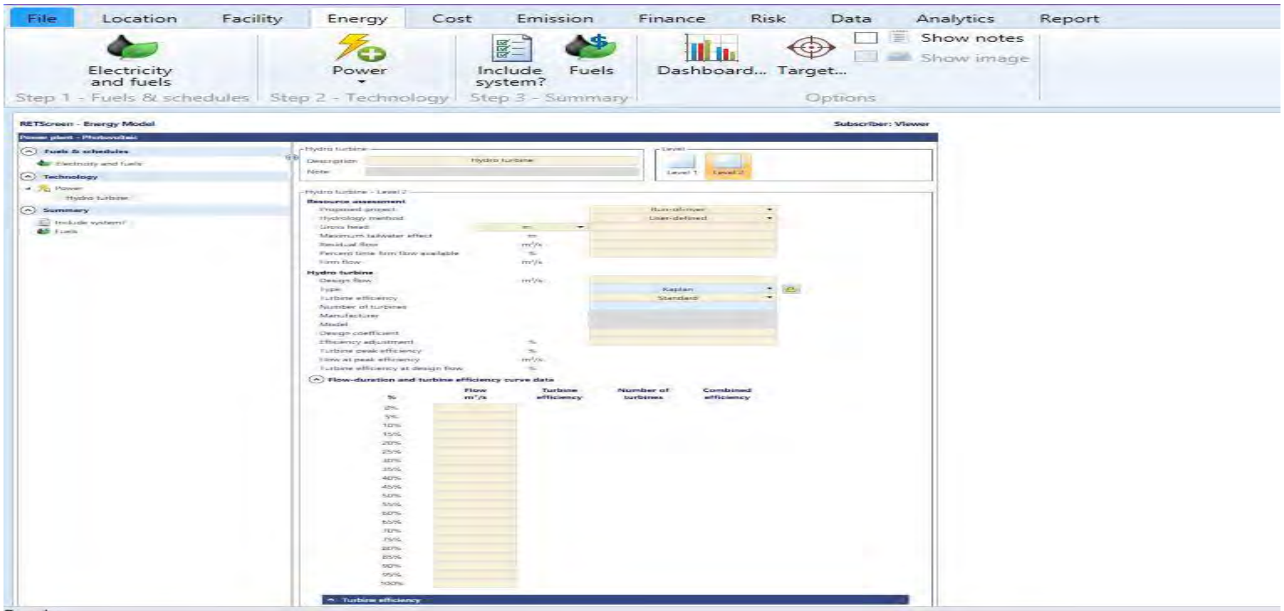
1) Reconnaissance of the study area
2) Data collection such as metrological(precipitation ,rainfall, temperature and solar radiation),hydrological data (stream flow data) and design document data of the study area such feasibility study document of dam, hydrologic design document ,agronomic report document ,geologic condition of site and reservoir condition.
3) GIS data collection in order to describe the topography of the site
4) Checking of the consistency of the hydrologic and Metrologic data
5) Computing the flow for the typical study area and data transferring for the ungauged catchments.
6) Compute the power, energy and cost in two forms using the RET Screen software for the river type of small hydro power and excel based for the reservoir type small scale hydro power.

3.2.1 **An introduction to the RET Screen software:**

The RET Screen software pre- feasibility analysis software (2004), natural RET Screen international is the renewable energy technology software developed by the Canada to small hydro project development. The software down- loaded free-of-charge from the http: // www.ret.net from the internet. It is designed "to help energy project proponents identifying and evaluate, relatively quickly and lower research cost, the most viable near-term opportunities for cost-effective renewable energy technology's project implementation." The RET Screen particularly important in remote area.

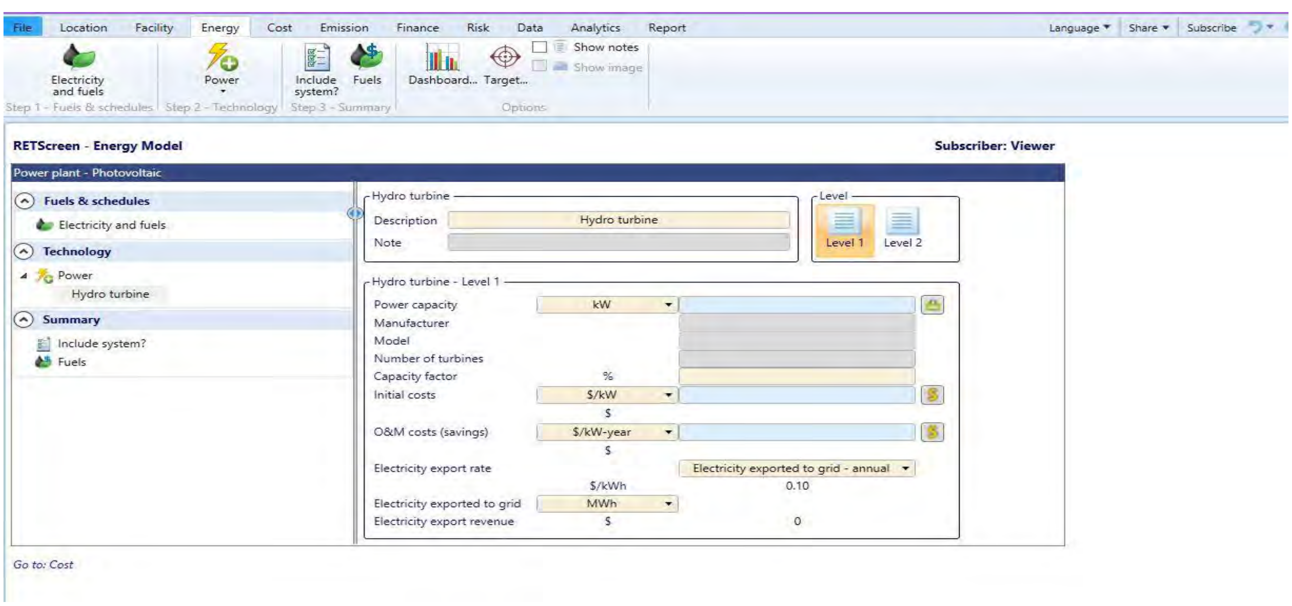
Figure 3.19 RET Screen software

Figure 3.20 Hydrologic Input for The Ret Software Communities That's Universal Application.



The RET Screen software energy analysis have two options level one and level two. For the detail design of small scale hydro power project analysis we use level two (level 2).To analysis the energy management software typically for small scale hydro power, click Energy and from that drop menu selecting the hydro turbine and add all the input data such head, tailrace, number of turbine, inflow hydrologic data, etc.

Figure 3.21 Energy Analysis of the Ret Screen Software



3.3 Methodology to compute the RET Screen software

The RET Screen software command allows to largely model the small scale hydro power with hydrological, hydro turbine, power capacity, yearly energy, cost and GHG.

Generally the RET Screen software requires the following main steps to compute.

1) Selecting the energy menu and select hydro turbine
2) Selecting the typical level depend of the project design
3) Specifying the type of hydrologic method (river run off or reservoir)
4) Specifying the type of proposed project
5) Specifying the design flow
6) Design of hydro turbine
7) Specifying the type of turbine
8) Specifying the number of turbine
9) % Exceedance of inflow from determined hydrological data.
10) Computing the losses
11) Computing the efficiency of turbine, flow duration curve, power duration curve, power capacity, capacity factor, yearly energy, cost of the energy and GHG emission.

3.4 To develop the energy and cost analysis of *Procedures to compute the storage hydro power*

1) The reservoir capacity curve developing from the (elevation vs area and elevation vs volume)
2) Collecting the stream flow data for the specific site
3) Checking the consistency of the stream flow data using Dixon test and log Pearson type – III
4) Set the orderly the month from level of storage become max level to that of min level of storage
5) Put the number of days in the month
6) And also from reservoir release determine the out flow or from the duty of irrigation from the agronomic report
7) Compute the out flow per decade

8) Computing the out flow per decade
9) Order the volume of the reservoir depend on the time the flow become max
10) Set the elevation by the maximum water level
11) Order the area depend coverage area that become reaches max
12) Gross head determination from the elevation and the canal bed level
13) Power determination
14) Energy and cost estimation

4 Hydro metrological data analysis:

The data analysis and the result gained from this served major input to develop the small scale hydro power in the selected existing dams in Tigray region. The study considered the daily stream flow data, precipitation, irrigation release, duty, inflow and out flow data analysis.

4.1 Rain fall data analysis for study area.

The rain fall data was collected from the Ethiopian metrological agency but due to the missing data presence then checking of the consistency of the data under taken as follows. The metrological station checked their consistency are (shire, Axum, Adwa and Endabaguna).Computing of the missing daily rain fall record data. To compute the missing Metrologic data there are various techniques from them (normal ratio method, arithmetic mean method, XLstate software). The xlstate spread sheet software is essential in computation of the missing data and also checked the consistency of the data.

4.2 Rain fall data consistency:

Rain fall data of gauging station were not consistent due to various failure during the period of records. Thus have been checked their consistency of these data using the double mass curve analysis were applied and a significance correction was made on some records. The double mass curve analysis made at the selected metrological station to compute the consistency of the data given below. The cumulative mean annual rain fall of station cheeked excluding the station that been checked its consistency, example if we want to check the consistency of shire metrological station we take the cumulative of the other station except that station were evaluated. The deviation of the curve from the straight line was considered as an error and the proper adjustment were made.

The annual correction factor was distributed to all daily records by the ration of the previous to the adjustment value.

Figure 4.1 Double Mass Curve Analysis of Shire Metrological Station.

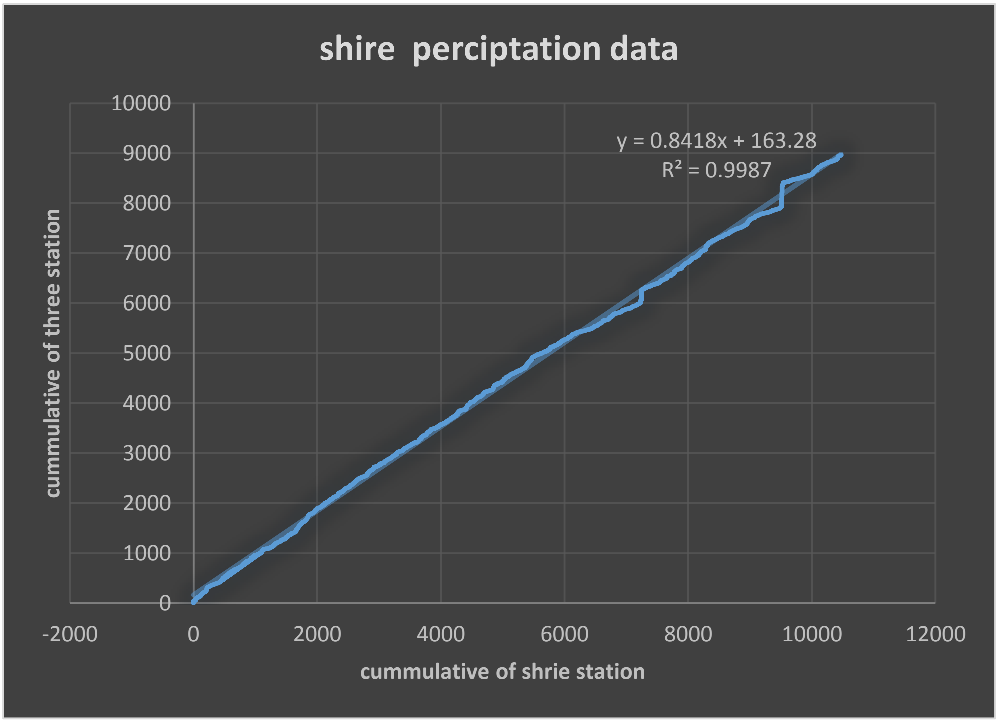


Figure 4.2 Endabaguna metrological station double mass curve analysis

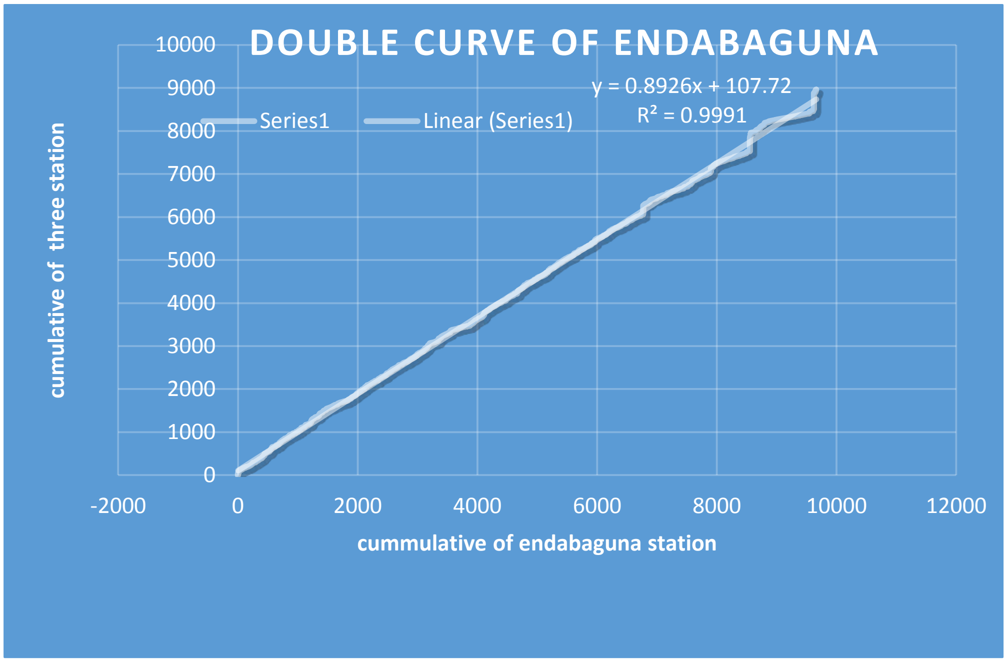


Figure 4.3 Adwa metrological station double mass curve

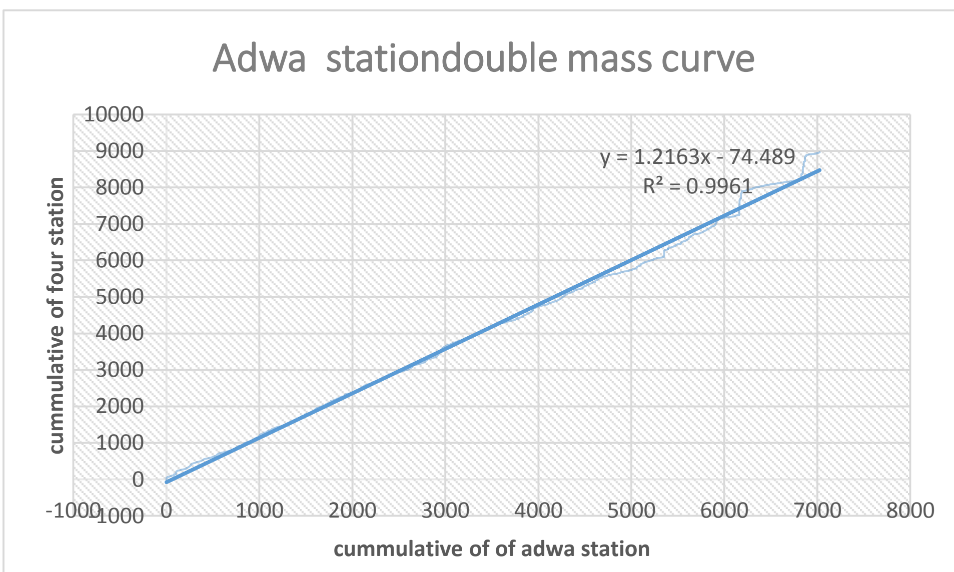


Figure 4.4 Axum metrological station double mass curve.

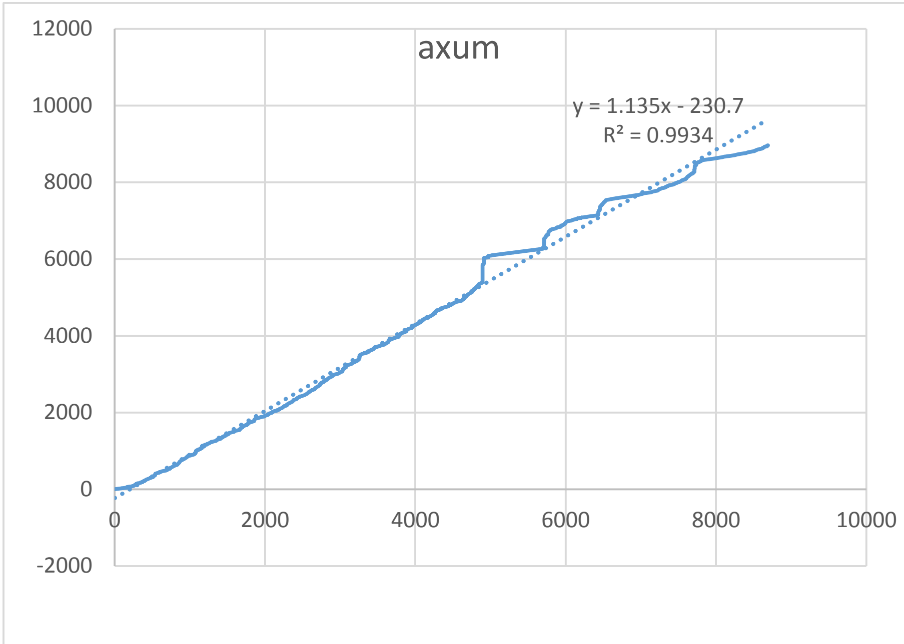
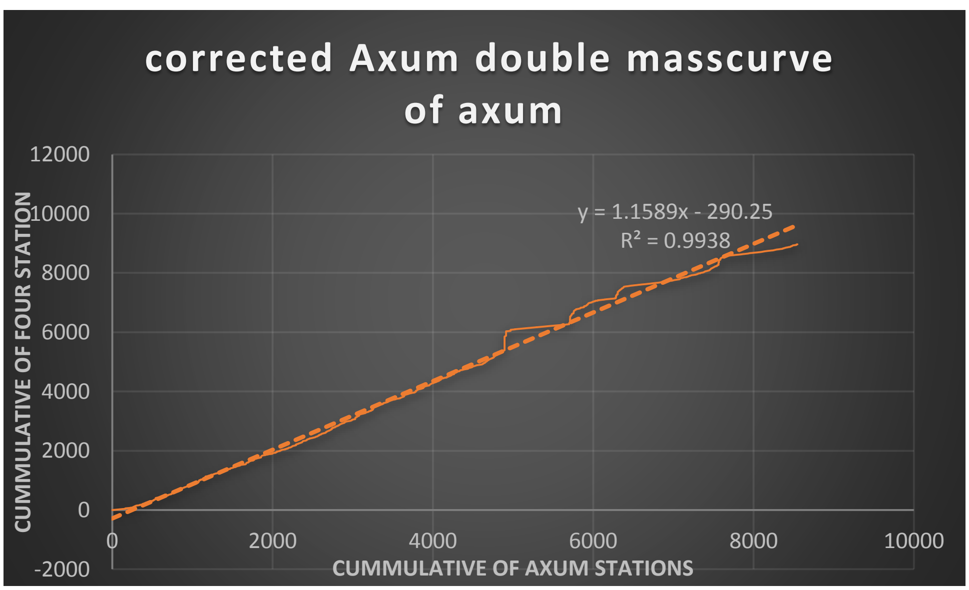


Figure 4.5 Axum metrological station corrected double mass curve



4.3 Stream flow data analysis

The main stream flow data under take in the study area take from the ministry of water resource and energy. The river stream those having daily flow data use for the study area are Tekeze near

Abumidire, Werie near Miknetal, Tekeze abuya near mytsebri, wukro and giba near meklle. Those gauging station was established in different year having the different watershed area and flow characters.

Table 4.1 Hydrologic station in Tigray regional state

The gauging station of the data used for the study		
station name	year of established(E.C)	area(km^2)
Buya nr.mytsebri	1998	219
Tekeze nr. Embamider	1994	45694
Werie nr. Miknetal	1990	1770
Giba	-	2449
Genfel	1992	481

The stream flow use for the study gained from these gauging river listed for both the reservoir type and the river run of that gained from the fully and partially silt dams.

4.4 Filling of the Missing stream flow data:

The continuity of the data may be broken with missing data due to many reasons like instrumental failure, the failure of the observer to make the necessary visit to the gage and Miss typing of the data on the sheet. We have a number of methods proposed for estimating rainfall missing data.

4.4.1 Checking of the stream flow data consistency and reliability.

After completing the missing of stream flow data, data consistency has to be checked. In other words it should be checked whether all individual data is in the same range or not before any statistical calculation are under taken. Data Consistency and Reliability. Before calculations on these given data are being carried out, data consistency has to be checked. In other words it should be checked that all individual data is roughly in the same range before statistical calculations are undertaken. To check whether the raw data is consistence or not, the following general formula was used:

4.4.2 Log Pearson Type- III distribution:

For this distribution, the first step is to take the logarithmic of the hydrologic data Y=Log X usually the logarithmic to the base 10 is used.

The mean (Y_{mean}), the standard deviation Sy, and co-efficient of skewness Cs, are calculated for logarithm of the data. The frequency factor depends on the return period (T) and the coefficient of skewness Cs, when cs, the frequency factor is equal to the standard normal variable, when Cs=0, the frequency factor is equal to the standard normal variable, when Cs ≠ 0 is the frequency factor kt is approximated kt (1977).

$Zr = Zavg + Kz*\delta$

Where Z=LogX, X= the stream flow data series

Zave = Average of the log X value

Zr= design stream flow with T years reoccurrence

δ = standard deviation of the log value

Kz= frequency factor depend on re- occurrence, T and skweness, cs

Table 4.2 The Log Pearson Type III Distribution Probability of serenta dam.

year	Q	Y=LOGQ	Y-Ym	(Y-Ym)^2	(Y-Ym)^3	Higher	Lower
1998.0000	1.3442	0.1285	-0.0553	0.0031	-0.0002	1.5972	-1.2297
1999.0000	1.4883	0.1727	-0.0111	0.0001	0.0000	1.5972	-1.2297
2000.0000	1.5087	0.1786	-0.0051	0.0000	0.0000	1.5972	-1.2297
2001.0000	1.2752	0.1056	-0.0782	0.0061	-0.0005	1.5972	-1.2297
2002.0000	1.5031	0.1770	-0.0068	0.0000	0.0000	1.5972	-1.2297
2003.0000	1.3225	0.1214	-0.0623	0.0039	-0.0002	1.5972	-1.2297
2004.0000	0.6363	-0.1963	-0.3801	0.1445	-0.0549	1.5972	-1.2297
2005.0000	0.6151	-0.2111	-0.3948	0.1559	-0.0615	1.5972	-1.2297
2006.0000	1.2134	0.0840	-0.0997	0.0099	-0.0010	1.5972	-1.2297
2007.0000	1.5177	0.1812	-0.0026	0.0000	0.0000	1.5972	-1.2297
2008.0000	1.3689	0.1364	-0.0474	0.0022	-0.0001	1.5972	-1.2297
2009.0000	2.8495	0.4548	0.2710	0.0735	0.0199	1.5972	-1.2297
2010.0000	2.7354	0.4370	0.2533	0.0642	0.0162	1.5972	-1.2297
2011.0000	2.1490	0.3322	0.1485	0.0220	0.0033	1.5972	-1.2297
2012.0000	2.2685	0.3557	0.1720	0.0296	0.0051	1.5972	-1.2297
2013.0000	2.1339	0.3292	0.1454	0.0212	0.0031	1.5972	-1.2297
2014.0000	2.1713	0.3367	0.1530	0.0234	0.0036	1.5972	-1.2297

Using Log Pearson type III Using the log Pearson then we can determine the skewness, from the following equations.

$Cs = N\sum*(Z-Zm)^3/(N-1)*(N-2)*(\delta z^3)$

$YH = Ym+Kn*\delta$ YH= 1.5972 and 39.55487279 therefore the data is in the range

$YL = Ym-kn*\delta$ YL = -1.2297 and 0.058921626

$\delta = ((Y-Ym)^2/N)^{0.5}$, $\delta = 0.58209$

$Kn = -3.62201 + 6.28446N^{1/4} - 2.49835N^{1/2} + 0.491436N^{3/4} - 0.037911N$

Kn = 2.428241957

The result that we get from this typical checking of data consistency is safe because our data is within the rage.

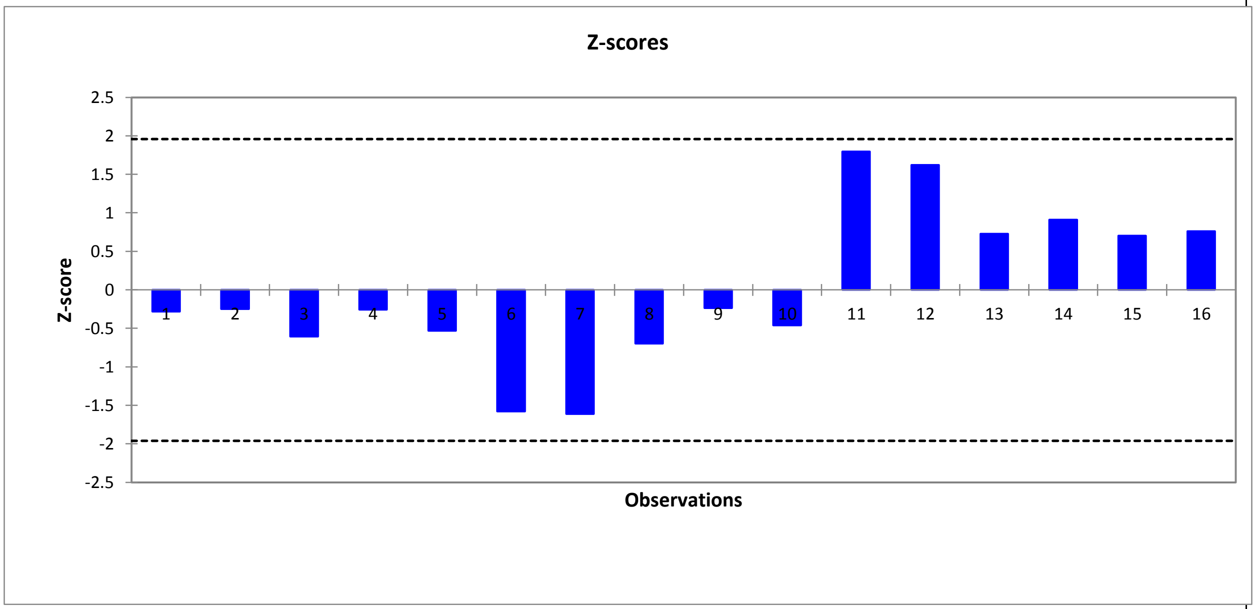
4.4.3 The stream flow checking of the outlier test

The outlier test checks the consistency of the stream flow data trough out the whole data we take during the several periods recorded.

4.5 Outlier test of the stream flow data been given below:

Alternative hypothesis:
Two-sided
Significance level (%): 5
Iterations: Maximum: 1
Number of simulations:
1000000

The graph of outlier t



test of the serenta stream flow data Dixon test for outliers / Two-tailed test:

R10 (Observed value)	0.051
R10 (Critical value)	0.375
p-value (Two-tailed)	0.521
alpha	0.05

99% confidence interval on the p-value:

Test interpretation:

H0: There is no outlier in the data

As the computed p-value is greater than the significance level alpha=0.05, one cannot reject the null hypothesis H0.

The risk to reject the null hypothesis H0 while it is true is 52.11%.

Summary statistics:				
Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum
1.344208348	16	0	16	0.615

5 RESULT AND DISCUSSION:

The selected existing dam in Tigray carried out using the RET Screen software for the fully and partially silted up and for reservoir fully in operation using the available volume, area, elevation, the inflow to the reservoir and out flow from the reservoir by taking during the time of the maximum flow have been occurred by using both the excel and RET Screen. RET Screen software has been used to determine the river hydro power all its capacity factor, power capacity, combined efficiency of turbine and other electro mechanical equipment, flow duration curve, power duration curve, electric city exported to the grid and cost of the electric city. The full result of this program is given in the Annex. Therefore in this chapter carried typical example of the result presented and also the summary of all the output of the result have been conducted.

5.1 Energy estimated using the RET Screen software

The RET Screen software use the analyzed hydrologic stream flow of the stream and also available head with additional of adding the location of the area to get the climatic report of the area. Stream flow of data be use in percentage of exceedance as an input after the data have been checked its hydrologic consistency. Selection of the typical hydro power whether its run –of –river or reservoir type be held on. The power gained from the silted and partially silted up dam was computed like the river- run- off typical hydro power project because the total head of the reservoir and the flow coming through the river along dam have been used.

5.2 Hydrologic data transferred from the gauged catchment to ungauged catchment

To transfer hydrologic data for the ungauged catchment computed using area ratio method this method assumes specific station independent of elevation in the catchment area. Ungauged station computed inflow discharge.

$$Qungauge = \text{Qgauged catchment} * \left(\frac{\text{Area of ungauged catchment}}{\text{area of gauged catchment}}\right)$$

Where

Qungauge= the estimated discharge at the ungauged in m^3/sec

Qgauged= the discharge at the next gauging station in m^3/sec

A ungauged= the catchment area at the intake of the respective HPP in km^2

A gauging = the catchment area of the next gauging station in km^2

Table 5.1 Hydrologic flow Estimated for Ungauged Catchment

transferred data for the un gauged catchment from the daily flow				
Percentage (%)	flow of Myngus	flow of Mygundi	flow of Laelay wukro	flow of Meskebet
0	3.40	3.61	0.08	3.68
5	1.00	1.09	0.07	1.61
10	0.69	0.73	0.07	1.29
15	0.50	0.53	0.61	1.07
20	0.32	0.34	0.06	0.96
25	0.18	0.19	0.05	0.83
30	0.14	0.15	0.04	0.69
35	0.10	0.11	0.04	0.62
40	0.08	0.08	0.04	0.57
45	0.06	0.06	0.04	0.53
50	0.05	0.05	0.03	0.49
55	0.04	0.05	0.03	0.44
60	0.03	0.03	0.03	0.39
65	0.03	0.03	0.03	0.35
70	0.02	0.02	0.03	0.31
75	0.02	0.02	0.03	0.26
80	0.02	0.02	0.03	0.22
85	0.01	0.01	0.03	0.14
90	0.01	0.01	0.02	0.05
95	0.00	0.00	0.00	0.01
100	0.00	0.00	0.00	0

5.3 The power and energy production from the river run-of small hydropower.

5.3.1 Result of the RET Screen software and its input data

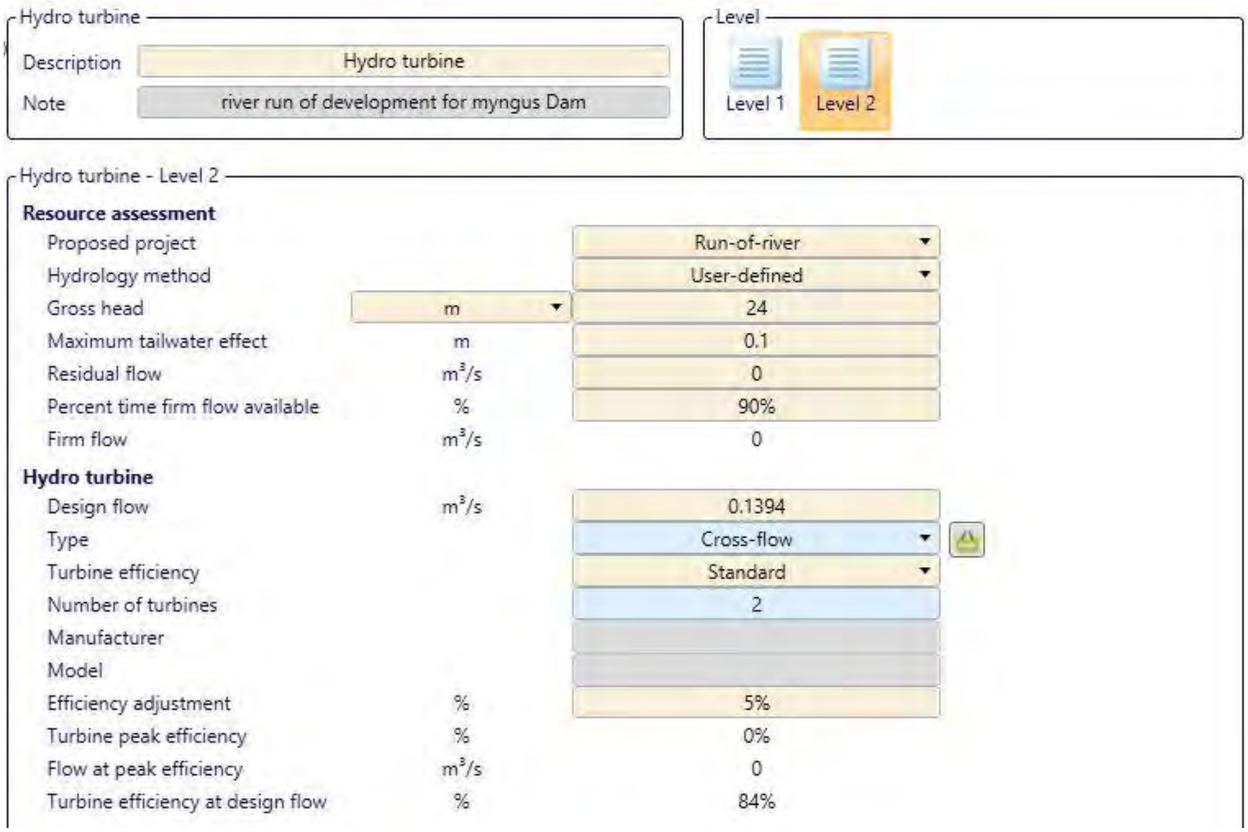
The result of the RET Screen are discussed

- Turbine peak efficiency at the design flow
- Turbine efficiency vs flow graph

- ❖ Flow duration curve graph and Power duration curve
- ❖ Power capacity
- ❖ Capacity factor
- ❖ Energy power
- ❖ Cost exported revenue

The existing dam which are presented in Tigray regional state typically the dams affected fully and partially affected by sediment is taken as river run-of small scale hydro power. In this study the Mygundi, Myngus, luelay wukro and four dam site considered as river run of to generate power. The result of RET Screen of developed power, energy, capacity, cost and design flow is analyzed and discussed considering typically mainly the design flow and capacity factor. Power capacity in kW, capacity factor in percent, efficiency in percent, turbine flow in meter cubic per second, head in meter ,energy in megawatt hour. The input of hydro method selected and the turbine efficiency made standard to compute finally the output of the RET Screen software is given below.

The small scale hydro power development for the available hydrologic model



From the typical river run of the Myngus river run –of hydro power we selected the cross flow typical based on the flow available and the head of dam and also we have taken at 30% of flow exceedance the turbine efficiency is produced 84%.

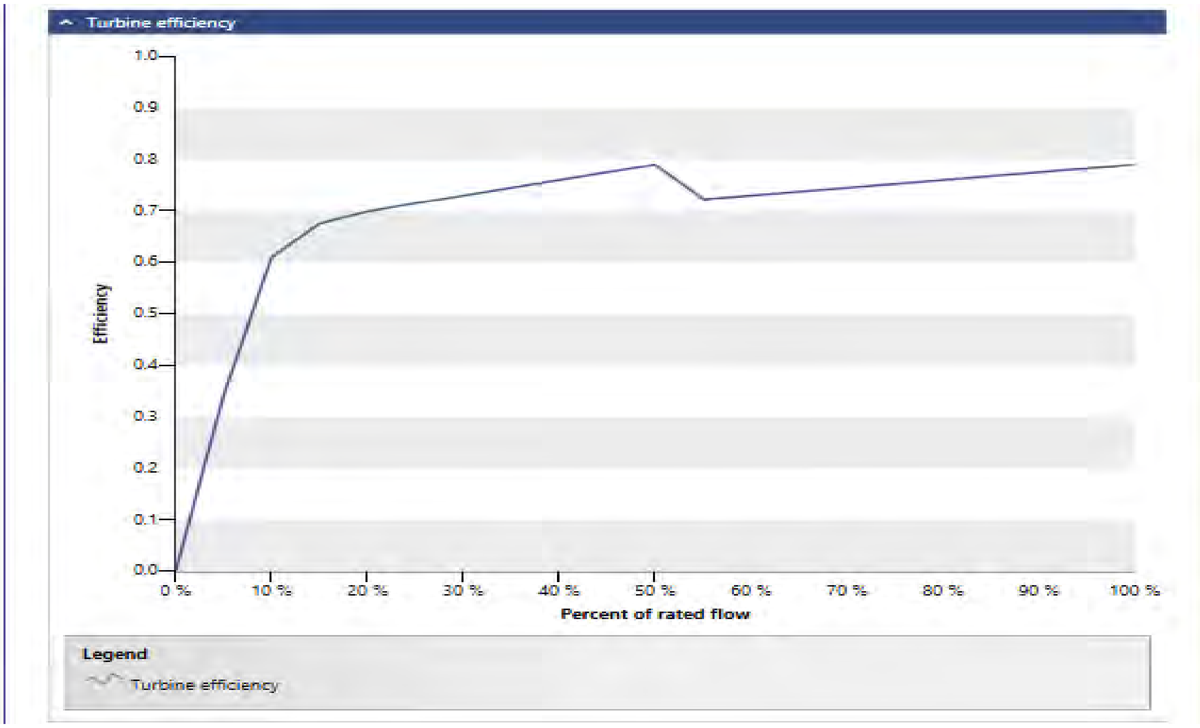
Table 5.2 The stream hydrologic data turbine efficiency, number of turbine and combined efficiency.

Flow-duration and turbine efficiency curve data

%	Flow m^3/s	Turbine efficiency	Number of turbines	Combined efficiency
0%	3.40	0.00	0	0.00
5%	1.03	0.00	1	0.34
10%	0.69	0.34	1	0.61
15%	0.50	0.52	1	0.68
20%	0.32	0.61	1	0.70
25%	0.18	0.65	1	0.71
30%	0.14	0.68	1	0.73
35%	0.10	0.69	1	0.74
40%	0.08	0.70	1	0.76
45%	0.06	0.71	1	0.77
50%	0.05	0.71	1	0.79
55%	0.04	0.72	2	0.72
60%	0.03	0.73	2	0.73
65%	0.03	0.74	2	0.74
70%	0.02	0.74	2	0.74
75%	0.02	0.75	2	0.75
80%	0.02	0.76	2	0.76
85%	0.01	0.77	2	0.77
90%	0.01	0.77	2	0.77
95%	0.00	0.78	2	0.78
100%	0.00	0.79	2	0.79

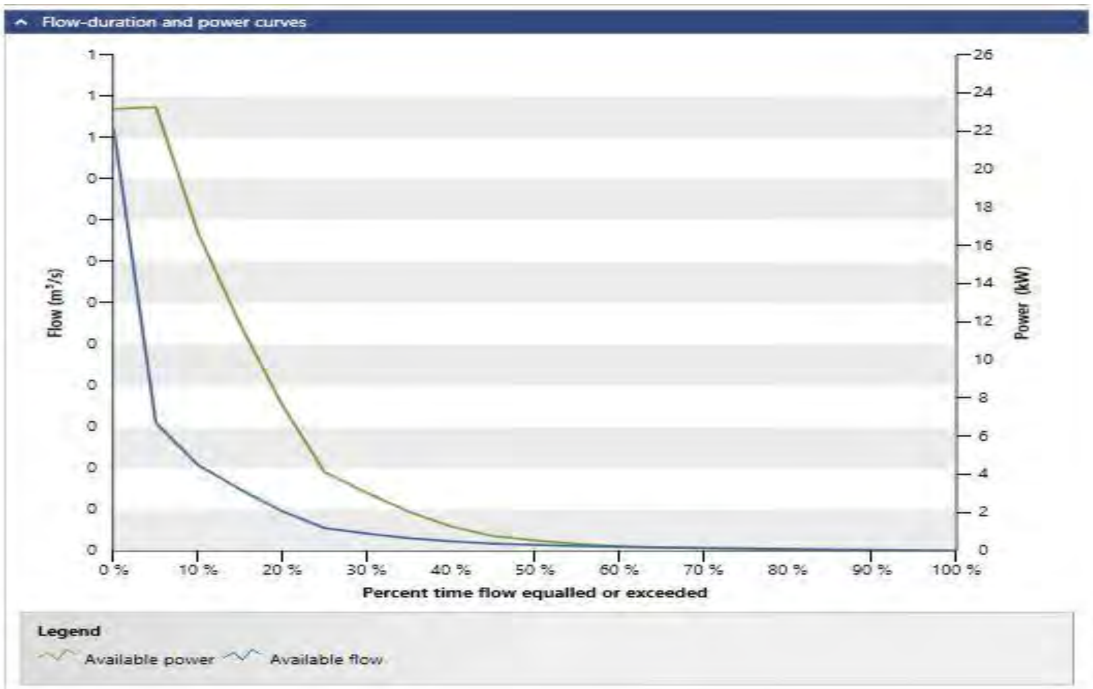
The inflow hydrologic data and number of turbine was computed and the turbine efficiency and combined efficiency computed by the software. The number of turbine input is given based on the inflow of hydrologic data and head of dam.

Figure 5.1 Turbine Efficiency Curve Flow Vs % of Efficiency



The turbine efficiency computed for the cross flow turbine based on the exceedance of flow and number of turbine.

Figure 5.2 Flow Duration Curve (FDC) and the Power Duration Curve (PDC)



The flow exceedance and power duration given based on the flow adjustment factor and the inflow. Flow duration and power duration curve shows the amount of flow available with in this additional determined amount of energy through this therefore, the higher flow available the higher produce energy. From the figure above about 80% of flow exceedance produce energy. The power capacity is determined and the value is 25.1kw and the capacity factor is 28.9 the value show for small scale hydro power is must be given above 25% therefore the capacity factor is acceptable.

The losses related to electro mechanical equipment, power capacity

Losses			
Maximum hydraulic losses	%	2%	
Miscellaneous losses	%	1.5%	
Generator efficiency	%	94%	
Availability	%	95%	
Summary			Firm
Power capacity	kW	25.1	0
Available flow adjustment factor		0.55	
Capacity factor	%	28.9%	
Initial costs	$/kW		
	$		
O&M costs (savings)	$/kW-year		
	$		
Electricity export rate		Electricity exported to grid - annual	
	$/kWh	0.10	
Electricity exported to grid	MWh	63.5	
Electricity export revenue	$	6,353	

The losses of the maximum hydraulic losses is taken maximum 2%and also miscellaneous losses taken 1.5% and also the generator efficiency and available efficiency is taken within the range of standard. Operational& maintenance costs (saving) and initial cost is not computed because the value is not known. The available flow adjustment factor is taken 1.1 this enables to display the power duration curve and flow duration curve and also the value this factor taken depend the graph displayed.

The electric city exported to the grid system is given 63.5 MWh and the cost electric city exported revenue is also estimated 6353 $(US dollar) the electric city exported rate be given 0.10$/kWh this is the electric city exported to grid annual. The capacity of the two turbine is 25.1 kw and we provide one cross flow turbine unit of stand by turbine (2+1) two of them operate at the same time and the later for reserve.

Target

Summary

	Electricity exported to grid MWh	**Electricity export revenue** $	**GHG emission reduction** tCO_2
Proposed case	63.5	6,353	0.52

Total power capacity, electric city export and reduction of GHG emission

Executive summary

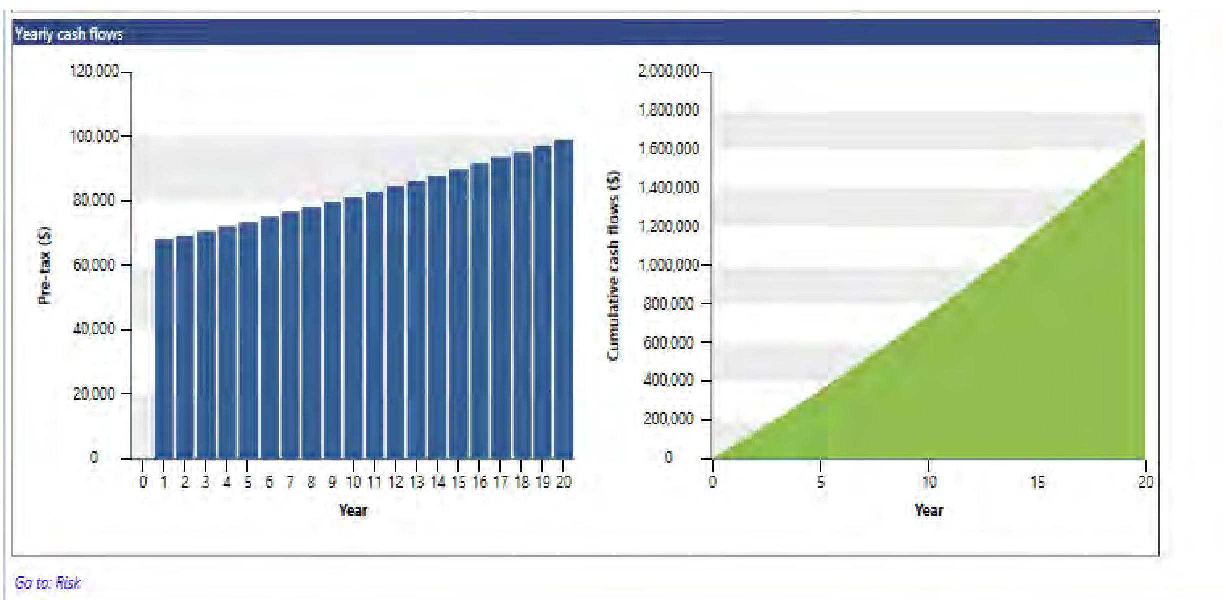
This report was prepared using the RETScreen Clean Energy Management Software. The key findings and recommendations of this analysis are presented below:

Target

	Electricity exported to grid MWh	Electricity export revenue $	GHG emission reduction tCO_2
Proposed case	63.5	6,353	0.52

The amount of cash flow of the small scale hydro power with the life of the project

Figure 5.3 Financial viability of the small scale hydro power



RETScreen - Financial Analysis — Subscriber: Viewer

Financial parameters		
General		
Inflation rate	%	2%
Discount rate	%	9%
Project life	yr	20
Finance		
Incentives and grants	$	
Debt ratio	%	70%
Debt	$	0
Equity	$	0
Debt interest rate	%	7%
Debt term	yr	15
Debt payments	$/yr	0
Income tax analysis		☐
Annual revenue		
Electricity export revenue		
Electricity exported to grid	MWh	64
Electricity export rate	$/kWh	0.10
Electricity export revenue	$	6,353
Electricity export escalation rate	%	2%
GHG reduction revenue		
Gross GHG reduction	tCO_2/yr	1
Gross GHG reduction - 20 yrs	tCO_2	10
GHG reduction revenue	$	0
Other revenue (cost)		☐
Clean Energy (CE) production revenue		☐

Costs | Savings | Revenue		
Initial costs		
-	$	0
Total initial costs	$	**0**
Annual costs and debt payments		
Debt payments - 15 yrs	$	0
Total annual costs	$	**0**
Annual savings and revenue		
Electricity export revenue	$	6,353
Total annual savings and revenue	$	**6,353**
Financial viability		
Pre-tax IRR - equity	%	Positive
Pre-tax IRR - assets	%	Positive
Simple payback	yr	0
Equity payback	yr	Immediate
Net Present Value (NPV)	$	68,028
Annual life cycle savings	$/yr	7,452
Benefit-Cost (B-C) ratio		
Debt service coverage		
GHG reduction cost	$/$tCO_2$	-14,305
Energy production cost	$/kWh	10,000

Yearly cash flows		
Year	Pre-tax	Cumulative
#	$	$
0	0	0
1	6,480	6,480
2	6,610	13,090
3	6,742	19,832
4	6,877	26,708
5	7,014	33,723
6	7,155	40,877
7	7,298	48,175
8	7,444	55,618
9	7,592	63,211
10	7,744	70,955
11	7,899	78,854
12	8,057	86,911
13	8,218	95,130
14	8,383	103,512
15	8,550	112,063
16	8,721	120,784
17	8,896	129,680
18	9,074	138,753
19	9,255	148,009
20	9,440	157,449

The financial report above in the table shows considered the project life for the next 20years and shown the amount of cash gained from developed typical small scale hydro power.

5.4 Comparison of the power output taking into consideration of the capacity factor and the design flow of the stream.

*Ta*ble 5.3 Setout of the Power Capacity Depend On the Qdesign and Capacity Factor of Turbine of Mygundi Dam

comparison of capacity factor and power capacity values gained from the RET Screen software values of Mygundi dam								
%	Q design	type of turbine	No of turbine	CAPACITY FACTOR (%)	power capacity(KW)	Electric export to grid(MWh)	electric export revenue($)	load factor
15%	0.6359	cross flow	3	27.40%	49.4	119	11852	0.4151261
20%	0.5652	cross flow	3	30.4	43.9	117	11680	0.3752137
25%	0.47167	cross flow	3	37%	31.2	100	10009	0.312

30%	0.27936	cross flow	3	37.2881	21.7	70.9	7088	0.3060649
35%	0.14118	cross flow	3	39.30%	11	37.8	3780	0.2910053
capacity factor for small scale hydro power is range from 25% to 100% and for typical large power it ranges from 20% to 95%								

Table 5.4 Setout of the Power Capacity Based On the Qdesign and Capacity Factor of Turbine for the Meskebet Dam

the result gained from RET Screen software for Meskebet dam site								
%	Qdesign	type of turbine	No of turbine	Capacity factor (%)	power capacity(KW)	Electric export to grid(MWh)	electric export revenue($)	load factor
10	1.54395	cross flow	2+1	14.23%	200	448	44758	0.446428571
15	1.23274	cross flow	2+1	16.20%	160	226	22595	0.707964602
20	1.0855	cross flow	2+1	18.80%	141	231	23109	0.61038961
25	1.0204	cross flow	2+1	21.30%	105	297	29656	0.353535354
30	0.6944	cross flow	2+1	24.50%	89.3	192	19172	0.465104167
35	0.473	cross flow	2+1	27.60%	60	147	14715	0.408163265
40	0.46	cross flow	2+1	27.70%	59.6	145	14467	0.411034483
capacity factor for small scale hydro power is range from 25% to 100% and for typical large power it ranges from 20% to 95%								

From the given table above if value of design flow increase there is decreasing of capacity factor but the amount of energy production, power and cost of energy increase .selection of best level of power production is mainly depend on the capacity factor of turbine and available flow in the stream therefore, even the amount of energy production is higher we focused on value of capacity factor. For any small scale hydro power developed standard value of capacity factor range from 25% to 100% therefore values of greater than 25% is acceptable. But for case of large hydro power value of capacity factor due to the available head and flow of the stream increases. In most case of hydro power.

5.5 Comparison of the typical low head turbine (crossflow and Kaplan).

comparison of the cross flow turbine vs Kaplan turbine		
factors considered to comparison	cross turbine flow type	Kaplan turbine
available head	24	24
power capacity	128	145
capacity factor	35.4	32.3
electric city exported to the grid in (MWh)	398	410
electric city export revenue($)	39778	41046
turbine efficiency at design flow	84%	95%
number of turbine	2	2
design flow	0.72	0.72
Efficiently adjustment	5%	5%

Table 5.5 The general report of the RET Screen software

	Dams				
parameters	Mygundi	Meskebet	luelay wukro	Myngus	ruba felg
type of project	runoff -river	runoff -river	runoff -river	runoff -river	runoff - river
available head	10.5	17.5	14.5	24	17.5
number of turbine	2+1	2+1	2+1	2+1	2+1
type of turbine	cross -flow	cross -flow	cross -flow	cross -flow	cross - flow
design flow(Q)	0.5652	0.47	0.07	1.453	0.12
power capacity(KW)	24..5	90.7	7.3	25.1	26.2
Capacity factor (%)	30.9	27.6	44	28.90	34.3
electric city export to grid(MWh)	117	147	28.4	634	78.9
electric city export revenue($)	11680	14715	2842	63376	7888

5.6 Sizing of electro mechanical equipment

1. SPESFIC SPEED OF TURBINE

$$NS = n * \frac{(p)^{0.5}}{H^5/4}$$

For we take n=750

P=258kw

H= 24m

Therefore Ns =750*(258$^{) 0.5}$/ (24)$^{5/4}$=227 for cross flow turbine

2. CROSS- FLOW RUNNER DIAMETER

$$\text{Drunner} = \frac{41*\sqrt{Hnet}}{\text{cross flow RPM}}$$

Drunner = 0.267810879m

For the runner diameter is less than equal to 0.4m based on the (RET Screen, 2004 develop for guidance to developed small scale hydro power) software therefor the value is safe

Cross flow runner revolution per minute (n) is given as, n=750

Hnet = the net head flow of reservoir

3. Cross flow runner length

The jet thickness is always between one-tenth and one fifth of the runner diameter, having estimated, t_{jet} the approximate runner length L_{runner} can be found from the orifice discharge equation

$Q = \text{Anozzle} *(\sqrt{2gHnet}$

Q= tjet*Lrunner*$\sqrt{2gHnet}$

$Lrunner = \frac{0.23*Q}{tjet*\sqrt{2gHnet}}$

Where

$$tjet = \frac{1}{5} * Drunner$$

Thickness of the penstock is tjet= 0.053562176m

And also the length of the runner of can be estimated but the discharge is taken from the 30% of exceedance Q= 1.453m^3/sec

Therefore Lrunner =0.23*1.453/ (0.053562176 *(2*9.81*24)$^{0.5}$=1.274m

Lrunner=1.274m

Sizing of electrical equipment

The output of generator in KVA is calculated from this equation

$$P(KVA) = \frac{9.81\text{H} * \text{Q} * \text{n}}{\text{Pf}}$$

Where Pf= power factor usually 80%

n = combined efficiency of turbine, transmitter and generator.

H= Net head

The P (KVA) of generator given as

P (KVA) = 337.818141

Generally for the typically river hydro power determined the values of specific speed of turbine, type of turbine, selected value of the capacity based on the standard for small hydro power, selected value of design discharge ,the penstock diameter and length the generator P(KVA) and the classification of based on the Ethiopian government and RET Screen software.

Table 5.6 Output of the small scale river hydro power result

parameters	Dams				
	Mygundi	Meskebet	luelay wukro	Myngus	ruba felg
type of project	runoff -river	runoff -river	runoff -river	runoff -river	runoff -river
available head	10.500	17.500	14.500	24.000	17.500
number of turbine	2+1	2+1	2+1	2+1	2+1
type of turbine	cross -flow	cross -flow	cross -flow	cross -flow	cross -flow
design flow	0.565	0.470	0.070	1.453	0.120
power capacity(KW)	43.900	61.000	7.300	258.000	26.200
Capacity factor (%)	30.900	27.600	44.000	28.044	34.300
electric city export to grid(MWh)	117.000	147.000	28.400	634.000	78.900
electric city export revenue($)	11680.000	14715.000	2842.000	63376.000	7888.000
specific speed of turbine(Ns)	262.910	163.655	71.616	226.781	107.254
Drunner	0.177	0.229	0.208	0.268	0.229
thickness of jet	0.035	0.046	0.042	0.054	0.046
length of runner	1.132	0.565	0.102	1.274	0.144
p(kva)	64.768	84.722	10.082	337.818	20.343
hydro power class based on RET Screen software	micro	micro	micro	mini	micro
hydro power class based on Ethiopian government	micro	micro	Pico	micro	micro

The estimated value of for all partially and fully affected dam by sediment considered as a river run off hydro power because the total head is available therefore, the flow coming through it also considered. Classification of the hydro power based on the renewable energy is considered all developed value above micro hydro but on the Ethiopian classification the least start from Pico hydro power. But even this Pico hydro it can serve for around two mills have a load capacity range standard (2-4KW) therefore this give reasonable developing possibility to the community because it reduce emission of pollutant nutrients and reduction of energy of the society to traveling to other place rather than use nearby.

5.7 MONTHLY ENERGY OUT PUT OF THE RESERVOIR (STORAGE HYDRO POWER)

The monthly energy output of reservoir was determined. The yearly average energy for the monthly release of flow found to be 76.878MWh from the Serenta dam, 68.295MWh from the Aftsebib, 22.244MWh for the Migorzo and 80.925MWh for the seysa dam. The plot for the monthly variability of power, energy output and the monthly cost of energy is shown in Fig and table below. During the summer season production of energy reduced. The maximum energy and power was generated at the time of higher released water to the irrigation.

Table 5.7 Monthly power output of the reservoir dams

month	power of seysa(kw)	power of migorzo(kw)	power Aftsebib(GWh)	power serenta(kw)
9	143.2981115	62.94197983	85.52958549	212.9880197
10	67.20324395	35.45394383	80.17727608	119.9718746
11	92.72532245	0	152.0359125	0
12	142.6544906	36.05691273	200.3545846	122.0122621
1	202.01	66.24	219.82	224.16
2	240.98	89.77	158.58	303.77
3	160.14	61.59	43.54	208.42
4	89.76	15.56	46.90	52.65
5	80.36	0	29.203	0
6	2.67	6.30	0	21.32
7	0	0	0	0
8	104.89	0	105.66	0
average	110.55	31.16	93.48	105.44
maximum	240.98	89.77	219.82	303.77

Table 5.8 Monthly energy out put

month	energy of seysa(GWh)	energy of migorzo(GWh)	aftsebibe(GWh)	Energy Serenta(GWh)
9	0.106	0.046	0.063	0.158
10	0.045	0.023	0.053	0.080
11	0.068	0	0.113	0
12	0.102	0.026	0.144	0.087848829
1	0.150	0.049	0.163	0.166
2	0.173	0.064	0.114	0.218
3	0.119	0.045	0.032	0.155
4	0.066	0.012	0.03	0.039
5	0.057	0	0.021	0
6	0.001	0.005	0	0.015
7	0	0	0	0
8	0.0780	0	0.078	0
average	0.080	0.0224	0.068	0.076
max	0.173	0.064	0.163	0.218

Table 5.9 Average result of the reservoir hydro power developed

the reservoir dam energy and related factors								
name of dam	power(kw)	energy(GW)	Capacit y factor (%)	theoretical power(kw)	Plant factor (%)	turbin e type	numbe r of turbine	total cost(birr/kw)
serenta	105.4426	0.922534	99.87	59.04783065	0.998762364	cross flow	1+1	636548.6167
Seysa	110.559	0.971096	100	61.91301702	1.002683705	cross flow	1+1	670056.0769
aftsebib	93.4863	0.819543	100	46.74231393	1.000736332	cross flow	1+1	565484.3747
migorzo	31.16025	0.276226	99.87	17.44973903	1.011951072	cross flow	1+1	188112.0288

The capacity factor determined for the reservoir for preferred typical cross –flow turbine capable of produced at its maximum level because for case of small hydro range from 25% to 100% therefore the turbine operates at its full capacity. The capacity factor and the plant factor also determined based on monthly energy output calculated for each reservoir .estimated value of power, energy and cost shows there is great possibility to develop hydro power to serve energy that have significance importance to both the society and environment. The number of turbine determined on available flow and head of reservoir therefore two cross flow turbine for each and consider one as standby and the remaining operating.

Cost determined also based on the Ethiopia energy cost standard 0.7birr/kw without considering operation and maintenance cost because detail design of the hydro power was not considered in the study. Generally the cost determined from the reservoir is yearly total energy for each therefore have significance value in term of financial value. Classification of the determined hydro power based the Ethiopian classification categorized under micro hydro power classes. But based on the renewable energy technology classification also categorized under mini and micro hydro power classification.

Figure 5.4 The Monthly Power Output of Serenta Dam

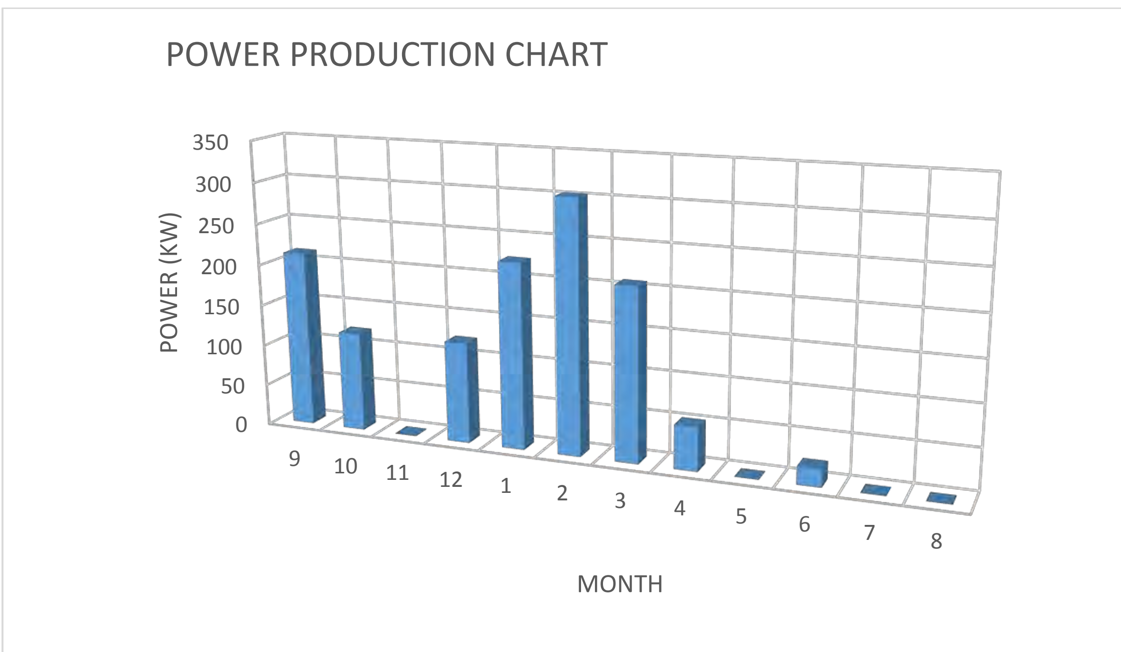


Figure 5.5 Monthly Energy of Serenta Dam.

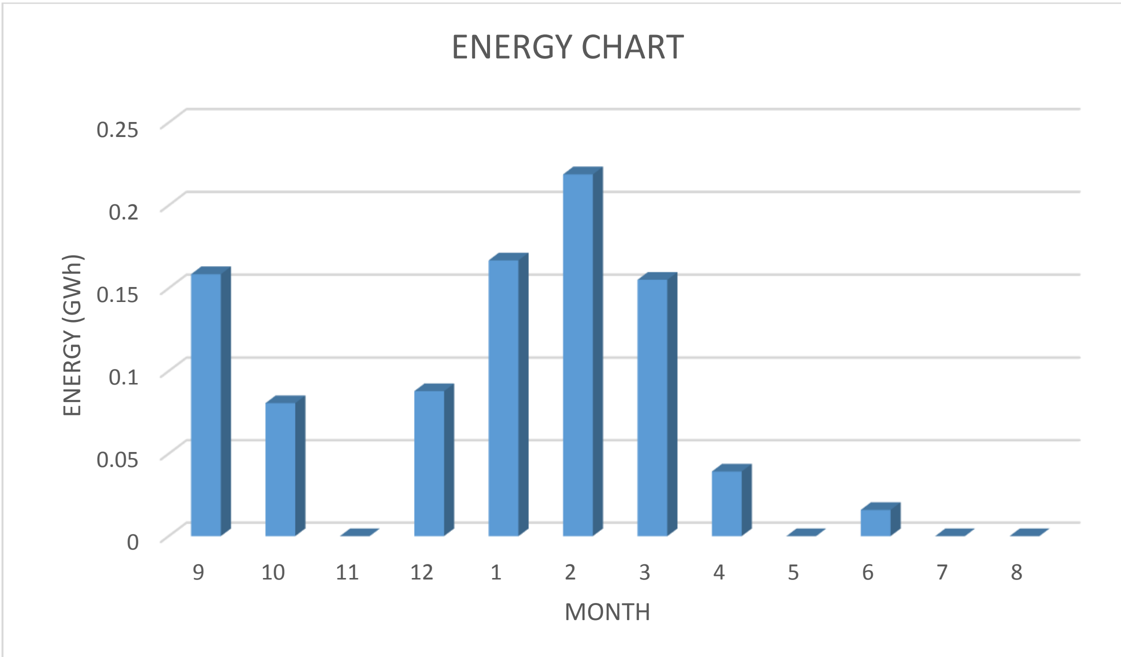
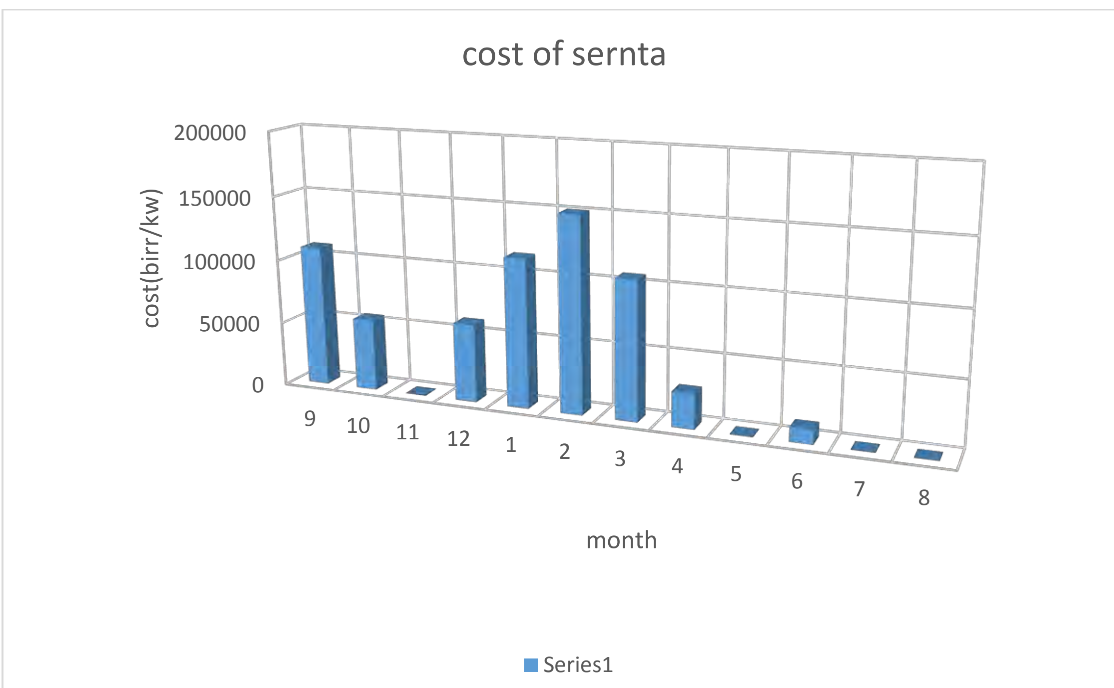


Figure 5.6 Cost of Serenta Dam.



Seysa monthly output of power, energy and cost

Figure 5.7 Seysa monthly power production

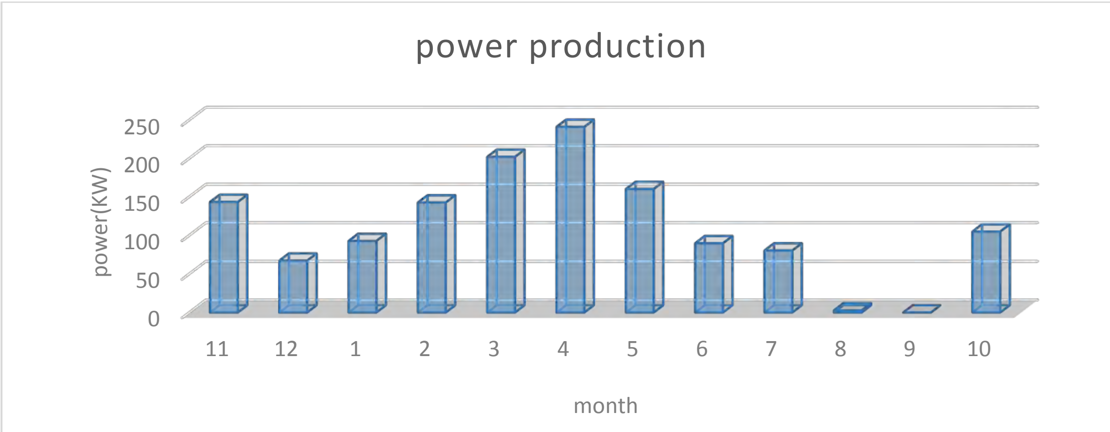


Figure 5.8 Monthly energy output of Seysa Dam.

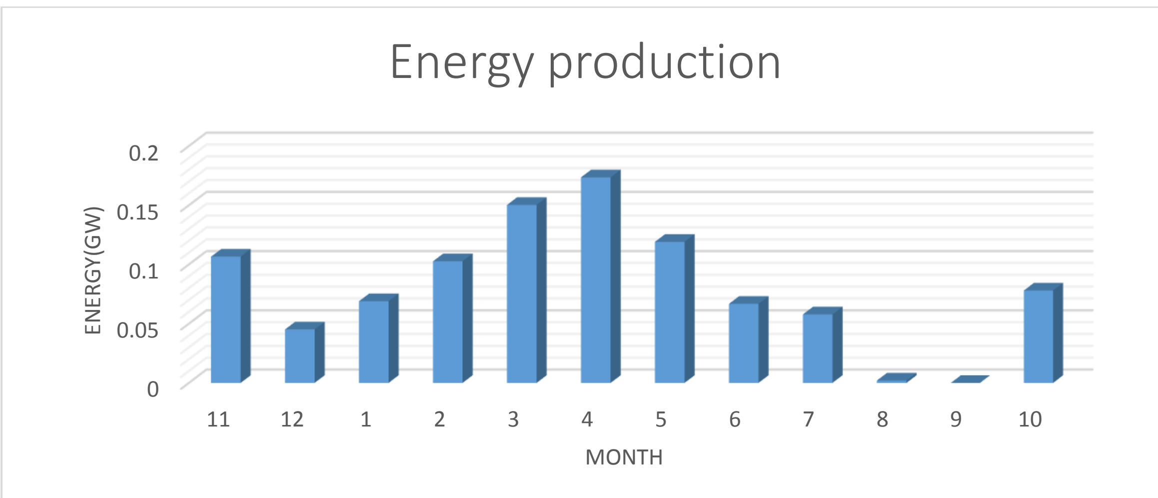
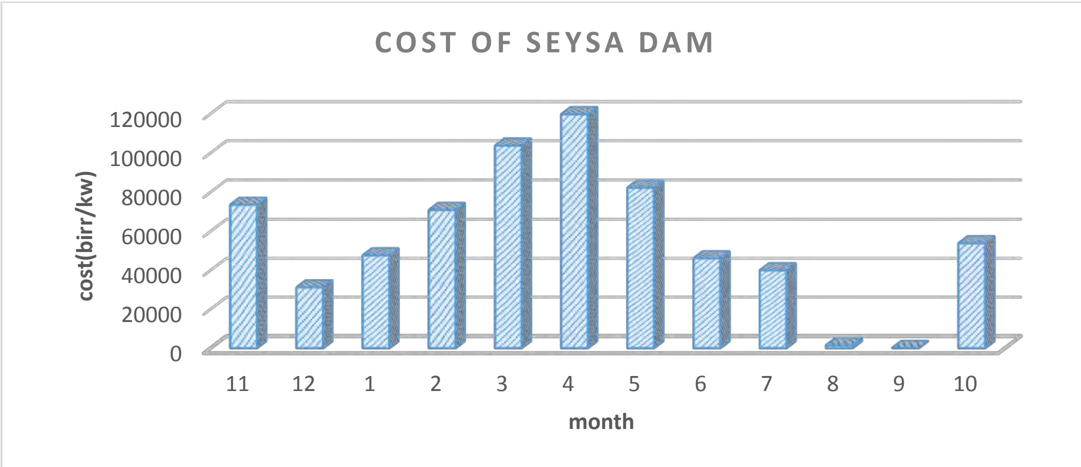


Figure 5.9 Monthly cost output of seysa dam



The maximum and the minimum power, energy and cost out puts can be explained in terms of capacity to serve the rural community electrifying. Power capacity produced from the reservoir minimum during the summer season because of no release of water during the time. The average power produced and its capacity of electrifying the rural community explained as follows.

Seysa dam average power production capability is 110kw, maximum power 240kw and minimum 0 during the month of July. From this to give electrifying the rural community by using bulbs of 60W using the average power capable of illuminate the 100kw for lighting using three light bulbs for each house hold it can serve around 556 households and the remain 10 kW for mill (wheat, rice, etc.). But this not include the July month and also variation in the months raised to240kw during that time we can increase the service of beneficiaries. Serenta dam average power production was determined 105kw, maximum power 303kw and minimum 0 .from this power determined from the reservoir using average value of energy determined for illuminate the 90kw for lighting using three light bulb for each households it can be serve 500 households and also the remaining 15kw use for mill that can serve for two machinery that having capacity of (2-4kw) each of them.

5.8 Cost, energy and GHG of storage hydro power using the ret screen software

Using the RET Screen software the cost and energy estimated is higher than of previously estimated values calculated by excel because the RET Screen software is more efficient.

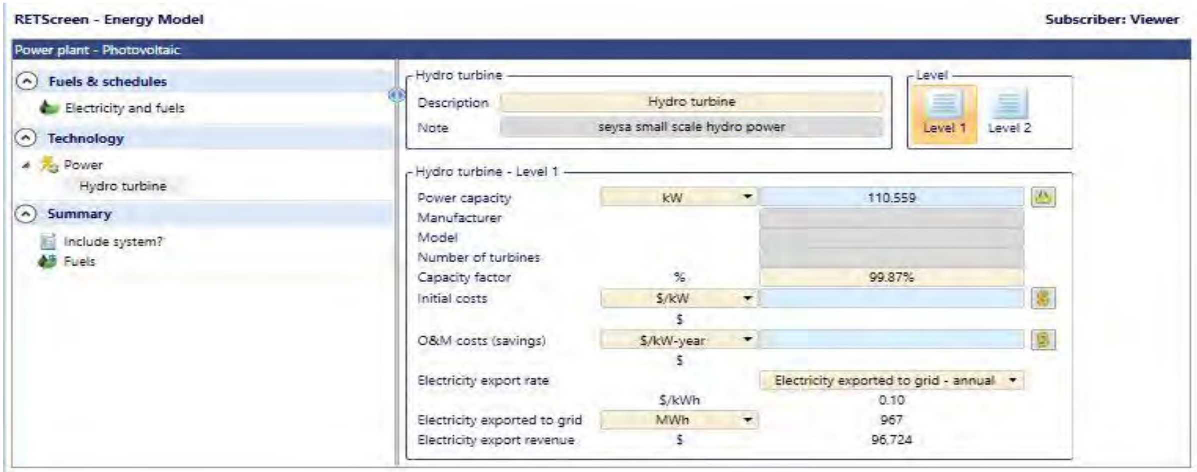
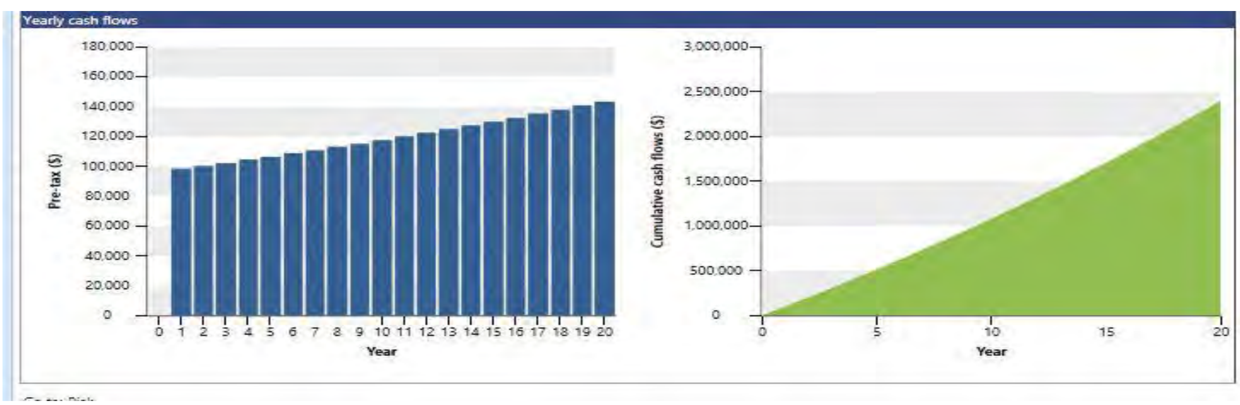


Figure 5.10 Cumulative Cash Flow of Graph of Seysa Dam throughout the Life of Project



The cumulative cash flow graph shows during the life of project above two million cash flow

Figure 5.11 General Financial Report Gained From the RET Screen Software

RETScreen - Financial Analysis Subscriber: Viewer

Financial parameters		
General		
Inflation rate	%	2%
Discount rate	%	9%
Project life	yr	20
Finance		
Incentives and grants	$	
Debt ratio	%	70%
Debt	$	0
Equity	$	0
Debt interest rate	%	7%
Debt term	yr	15
Debt payments	$/yr	0
Income tax analysis		☐

Annual revenue		
Electricity export revenue		
Electricity exported to grid	MWh	967
Electricity export rate	$/kWh	0.10
Electricity export revenue	$	96,724
Electricity export escalation rate	%	2%
GHG reduction revenue		
Gross GHG reduction	tCO_2/yr	8
Gross GHG reduction - 20 yrs	tCO_2	159
GHG reduction revenue	$	0
Other revenue (cost)		☐
Clean Energy (CE) production revenue		☐

Costs | Savings | Revenue		
Initial costs		
-	$	0
Total initial costs	$	**0**
Annual costs and debt payments		
Debt payments - 15 yrs	$	0
Total annual costs	$	**0**
Annual savings and revenue		
Electricity export revenue	$	96,724
Total annual savings and revenue	$	**96,724**

Financial viability		
Pre-tax IRR - equity	%	Positive
Pre-tax IRR - assets	%	Positive
Simple payback	yr	0
Equity payback	yr	Immediate
Net Present Value (NPV)	$	1,035,716
Annual life cycle savings	$/yr	113,459
Benefit-Cost (B-C) ratio		
Debt service coverage		
GHG reduction cost	$/$tCO_2$	-14,305
Energy production cost	$/kWh	10.000

Year	Pre-tax	Cumulative
#	$	$
0	0	0
1	98,658	98,658
2	100,631	199,290
3	102,644	301,934
4	104,697	406,631
5	106,791	513,422
6	108,927	622,348
7	111,105	733,453
8	113,327	846,781
9	115,594	962,375
10	117,906	1,080,280
11	120,264	1,200,544
12	122,669	1,323,213
13	125,123	1,448,336
14	127,625	1,575,961
15	130,177	1,706,138
16	132,781	1,838,919
17	135,437	1,974,356
18	138,145	2,112,501
19	140,908	2,253,410
20	143,726	2,397,136

The whole reported data for selected study area conducted cost, energy, financial report and benefit of the project given in the annex part, is the one which gives possibility of developing of energy generation. Hence, maximum cost estimation option using RET Screen software for Seysa dam which given above.so it considered these alternatives for all the selected study area the reservoir dams in operation. In the case of the river run of hydro power project value like turbine type, efficiency of turbine, flow duration curve, capacity factor, peak turbine efficiency was determined whereas, I the storage type of hydro power mean the irrigation dam is the whole in operation after conducted result of the average hydropower and capacity factor then analyzed the financial analysis and total benefit of the project during the life span of the project considered it serve to the next 20 year.

5.9 *Observation and remakes from small scale hydro power development*

The small scale hydro power development from the micro dams constructed in Tigray regional state possibility to develop and serve the society are wide in terms of energy. The importance can be resulted both to individual level and national level in order of improving the life style of the society. The remote society benefit directly in energy supply from the installation. There are also different environmental and socio-economic benefit which do not direct energy service.

Therefore, the following advantages can be conducted

- ❖ Reduction of the wastage of energy that they engaged for searching traditional energy source.
- ❖ There can be reduce the environmental effect of such deforestation and pollution of the society.
- ❖ The life style of society improving with renewable source
- ❖ Educational service can be upgraded through modern facilities
- ❖ Possibility to work opportunity for the society because of implementing of the manufacturing plants, which are not possible without electric city.
- ❖ For case of the silted dam generally results in higher power generation during rainy season and also during dry time with available flow with the stream like river run off but in the case of reservoir storage hydropower increase during the irrigational period because there is higher water release with the out let.
- ❖ From the analysis turbine selection ,energy determination, cost of energy, meaning of the energy to the society, capacity factor determination and green gas house emission reduction been addressed using the RET Screen software and previously study in Ghana by Charles Ken Adu Boahen(2013) on prefeasibility studies for mini hydro power generation on Kintampo falls like river run of hydro power get result of energy ,cost ,GHG, electro mechanical equipment and payback period project but that's a river flow developed hydro power but in my study I also use capacity factor and design discharge comparison and reservoirs in operation also have been studied therefore I get an alternative energy for the community isolated from the national grid. Specifying of runner diameter conducted based on (RET Screen, 2004) and the result is within the range for the typical selected cross flow turbine.

6 Conclusion and recommendation

6.1 Conclusion

The rural village in Tigray region are very scattered, due to this reason that's difficult to access them energy from national grid. Small scale hydro power very convenient in this regard. It is critical and very wise to develop to use both the reservoir in operation and silted up micro- dams for developing of micro electric serving to the rural community with a minimum effect to the irrigation activity by applying of renewable energy technology mechanisms. From the dam in Tigray much water is lost annually throughout the outlet and spillway without producing valuable energy to the rural community that's have great economical and environmental friendly advantage.

The developed hydro power from the selected dam is within Pico, micro and mini hydro power for both the silted (partially affected) and reservoir in operation. Cross flow type of turbine was selected since it capable to meet both the head and power required and also maintains appreciable efficiency at low flow rate. Energy estimated from silted up dam in terms of electrifying the rural community viable gives minimum 7.3KW and max 90.7kw from the daily flow data .The energy produced Capacity of developed hydro power capable of electrifying 64 minimum to 400household using the energy consumption Ethiopia 0.675KW for each household for a typical single dam developed such a river run of hydro power. The renewable energy software use to conduct this study still it be used for change in its hydrologic, resource is efficient. To help the rural village to meet the energy needs economically, environmentally and socially, sustainable ways while saving money and increasing energy security and self-reliance especially in the areas difficult to assess by the national grid, this micro dam in Tigray region case study is taken as one of the solution to accelerate growth and development and poverty reduction in Ethiopia.

6.2 RECOMMENDATION

The actual stream flow in various river stream flow to the reservoir is not explicitly known. The reason for this is there is no adequate metrological and hydrological station in those various dam site installed within the catchment therefore there must be develop gauging station with in the river site to know the exact value of the flow through the river section.

During the time of the recording the hydrological data mainly the stream flow data accuracy of the data is essential therefore hydrologist must give emphasize toward this I get data filed with one value throughout the year.

To be advantageous from the small scale hydro power potential in Ethiopia, joint effort of government organization and individual investors should be considered. But private investors are mainly interested in benefit of their investment. Therefore, government bodies should give emphasize about the alternative energy source of small scale hydro power development in order to electrifying the rural community and alternative measures which satisfies the financial stability of the private investors in order to promote this work.

There is a high variability of monthly energy output, it is better to use additional source of renewable energy as biogas gas energy as back up to increase the dependable power of the scheme so that the supply to the society could be better in terms of both amount and consistency.

Generally, looking at the enormous benefits of electrifying of the remote society by small scale hydro power installation, it is recommended that the government of Ethiopia must give emphasize to such and other energy alternative source.

Other planning studies for different scenarios like 12-hour mode of energy supply versus 24-hour mode of energy supply and inclusion of night time storage for irrigation use should be conducted and compared be for the implementation of the scheme.

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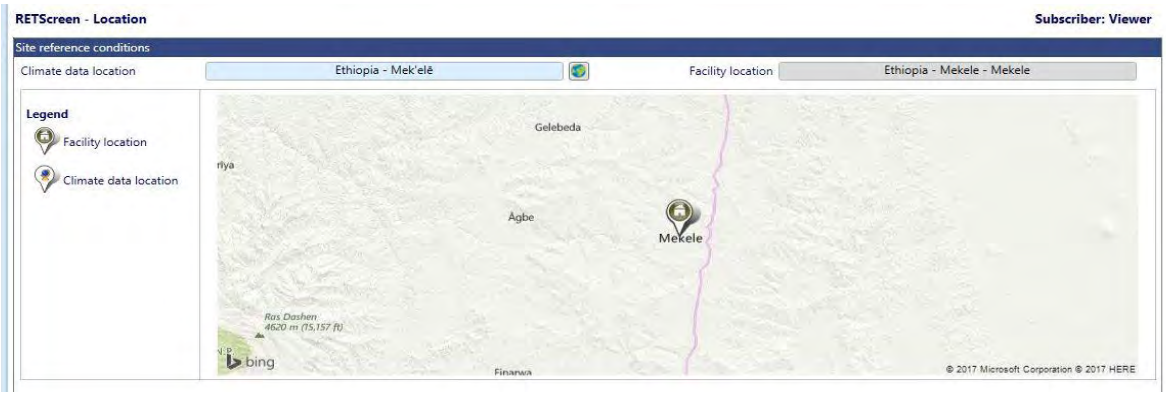
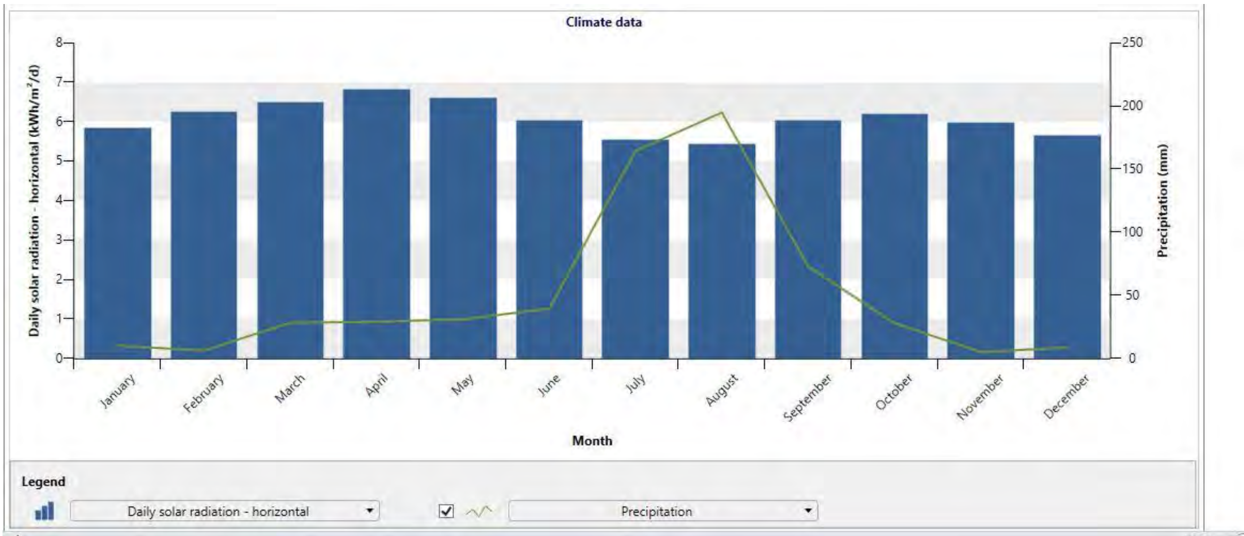
APPENDIX

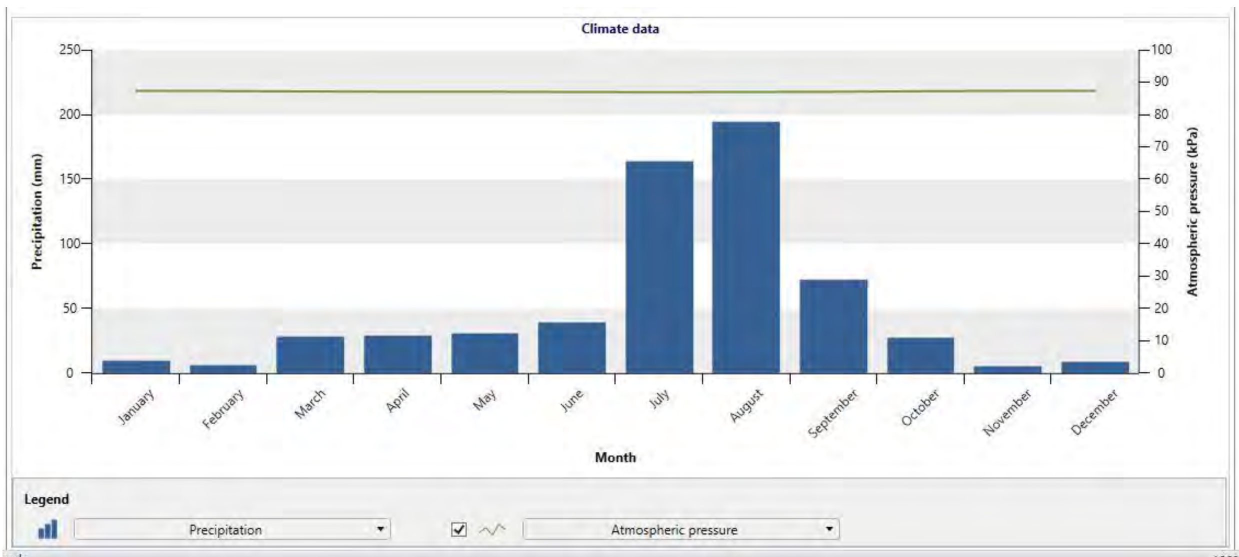
Appendix: A 1 METROLOGIC data of Meklle station gained from RET Screen software

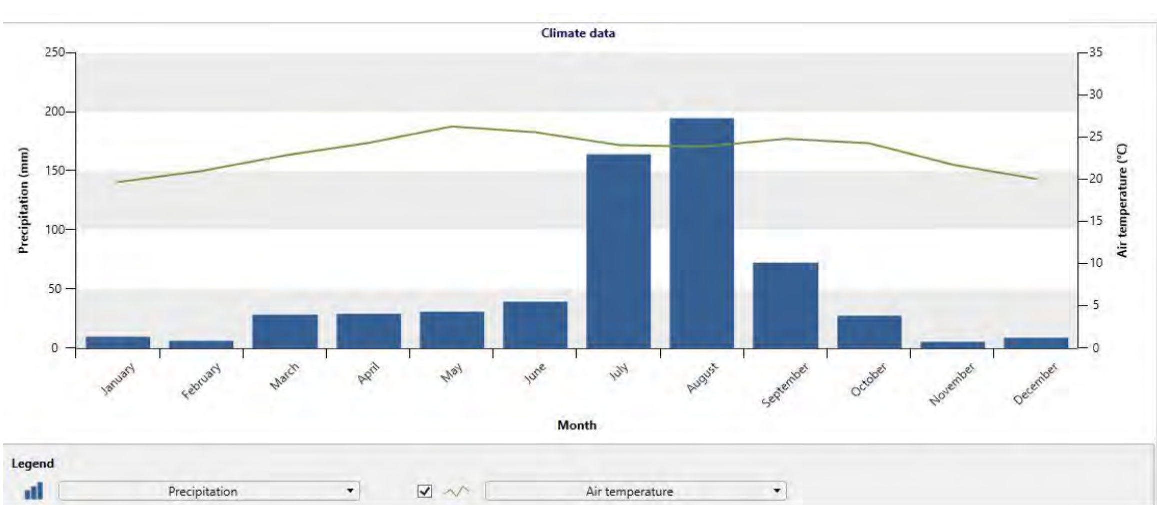


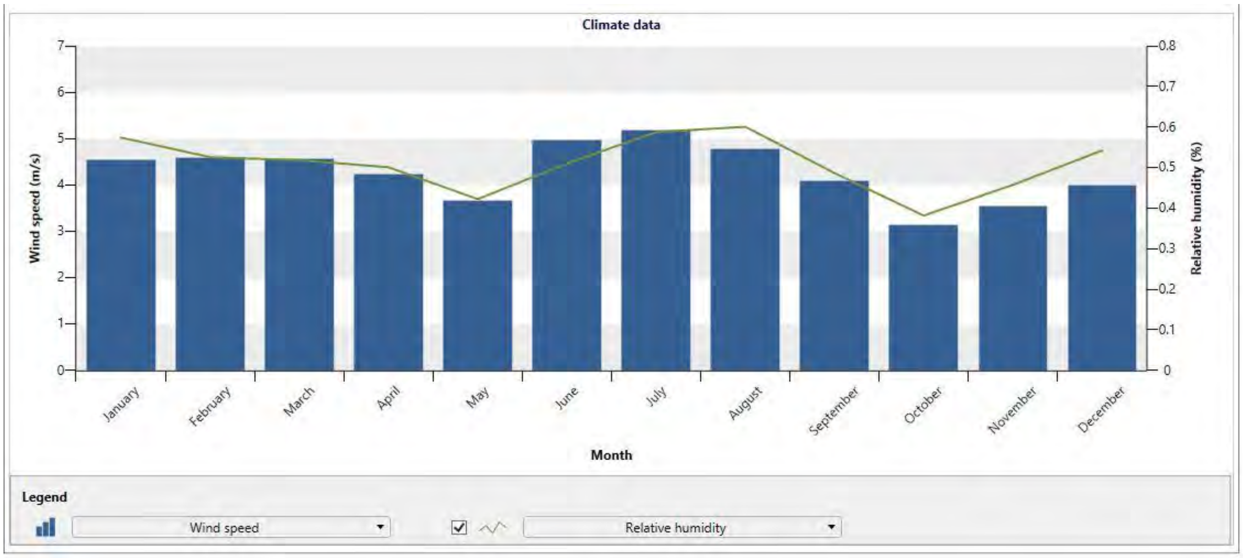
	Unit	Climate data location	Facility location	Source
Latitude		13.5	13.5	
Longitude		39.5	39.5	
Climate zone		2B - Hot - Dry		NASA
Elevation	m	1911	2056	NASA – NASA
Heating design temperature	°C	14.3		NASA
Cooling design temperature	°C	31.5		NASA
Earth temperature amplitude	°C	15.7		NASA

Month	Air temperature	Relative humidity	Precipitation	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days 18 °C	Cooling degree-days 10 °C
	°C	%	mm	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January	19.7	57.5%	10.26	5.85	87.4	4.6	23.4	0	300
February	21.0	52.6%	6.28	6.27	87.4	4.6	25.5	0	308
March	22.8	51.9%	28.30	6.50	87.2	4.6	27.3	0	398
April	24.3	50.1%	29.23	6.82	87.2	4.2	28.4	0	430
May	26.3	42.3%	31.09	6.62	87.2	3.7	30.6	0	504
June	25.6	51.1%	39.44	6.05	87.1	5.0	28.6	0	467
July	24.1	58.8%	164.34	5.57	87.0	5.2	25.9	0	436
August	23.9	60.1%	194.90	5.46	87.1	4.8	25.5	0	430
September	24.8	48.7%	72.95	6.05	87.1	4.1	27.5	0	444
October	24.3	38.2%	27.97	6.22	87.3	3.1	28.0	0	443
November	21.7	45.8%	5.23	6.00	87.4	3.6	25.2	0	352
December	20.1	54.3%	8.75	5.66	87.4	4.0	23.5	0	312
Annual	**23.2**	**51.0%**	**618.73**	**6.09**	**87.2**	**4.3**	**26.6**	**0**	**4,825**
Source	NASA	NASA	NASA	NASA	NASA	NASA	NASA	NASA	NASA
Measured at					m	10	0		


Climate data
Daily solar radiation - horizontal (kWh/m²/d)
Precipitation (mm)
January
February
March
April
May
June
July
August
September
October
November
December
Month
Legend
Daily solar radiation - horizontal
Precipitation


Climate data
Precipitation (mm)
Atmospheric pressure (kPa)
January
February
March
April
May
June
July
August
September
October
November
December
Month
Legend
Precipitation
Atmospheric pressure


Climate data
Precipitation (mm)
Air temperature (°C)
January
February
March
April
May
June
July
August
September
October
November
December
Month
Legend
Precipitation
Air temperature



Annex A1.1: the Metrologic representation **Adwa** metrology from the RET Screen

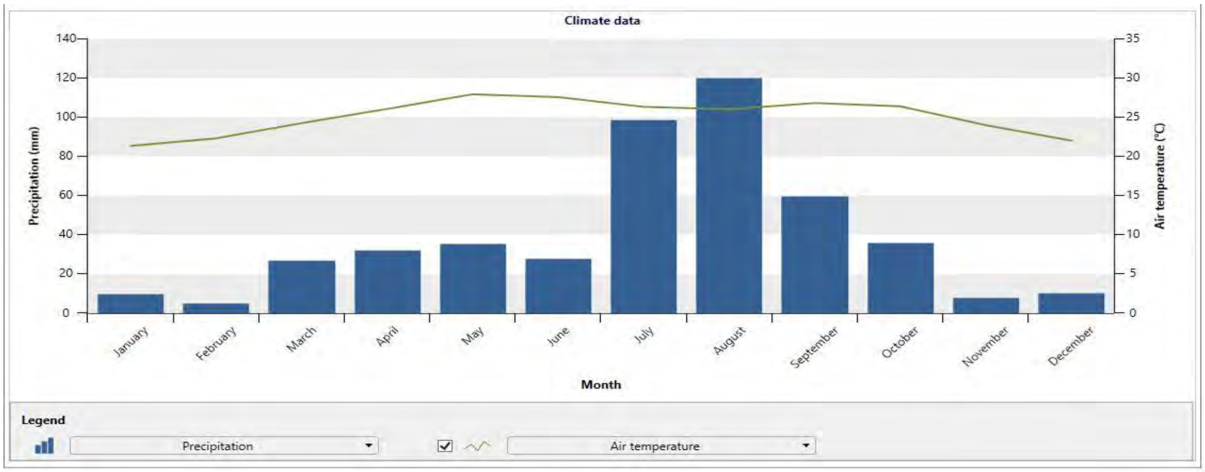
RETScreen - Location **Subscriber: Viewer**

Site reference conditions

Climate data location: Ethiopia - Adwa | Facility location: Ethiopia

	Unit	Climate data location	Facility location	Source
Latitude		14.3	14.2	
Longitude		39.5	38.9	
Climate zone		1B - Very hot - Dry		NASA
Elevation	m	1731	1938	NASA – NASA
Heating design temperature	°C	16.0		NASA
Cooling design temperature	°C	33.7		NASA
Earth temperature amplitude	°C	15.6		NASA

Month	Air temperature	Relative humidity	Precipitation	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days 18 °C	Cooling degree-days 10 °C
	°C	%	mm	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January	21.3	56.5%	9.67	5.71	90.4	4.6	24.8	0	352
February	22.3	53.4%	5.04	6.08	90.3	4.7	26.5	0	345
March	24.3	52.0%	26.98	6.33	90.2	4.7	28.6	0	442
April	26.1	49.3%	31.92	6.66	90.1	4.3	30.1	0	482
May	27.9	43.1%	35.57	6.49	90.1	3.7	32.3	0	556
June	27.6	48.6%	27.77	6.10	90.0	5.1	30.6	0	527
July	26.3	54.4%	98.46	5.49	89.9	5.7	28.4	0	506
August	26.0	56.1%	119.95	5.30	90.0	5.3	27.9	0	497
September	26.8	47.0%	59.55	5.95	90.1	4.3	29.8	0	504
October	26.4	38.1%	35.84	6.01	90.3	3.2	30.2	0	508
November	24.0	44.0%	7.74	5.78	90.3	3.5	27.2	0	419
December	22.0	52.6%	10.40	5.46	90.4	4.1	25.2	0	372
Annual	**25.1**	**49.6%**	**468.88**	**5.94**	**90.2**	**4.4**	**28.5**	**0**	**5,509**
Source	NASA	NASA	NASA	NASA	NASA	NASA	NASA	NASA	NASA
Measured at					m	10	0		



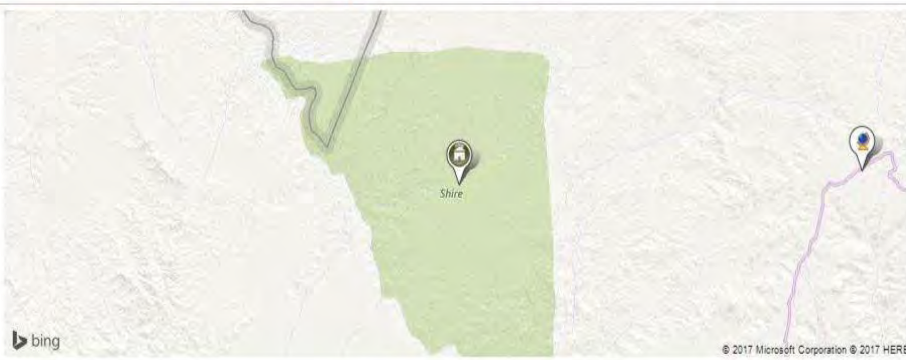
Annex A1.2: the **shire** Metrologic data gained from the RET screen software

RETScreen - Location **Subscriber: Viewer**

Site reference conditions

Climate data location: Ethiopia - Endasilasie | Facility location: Ethiopia

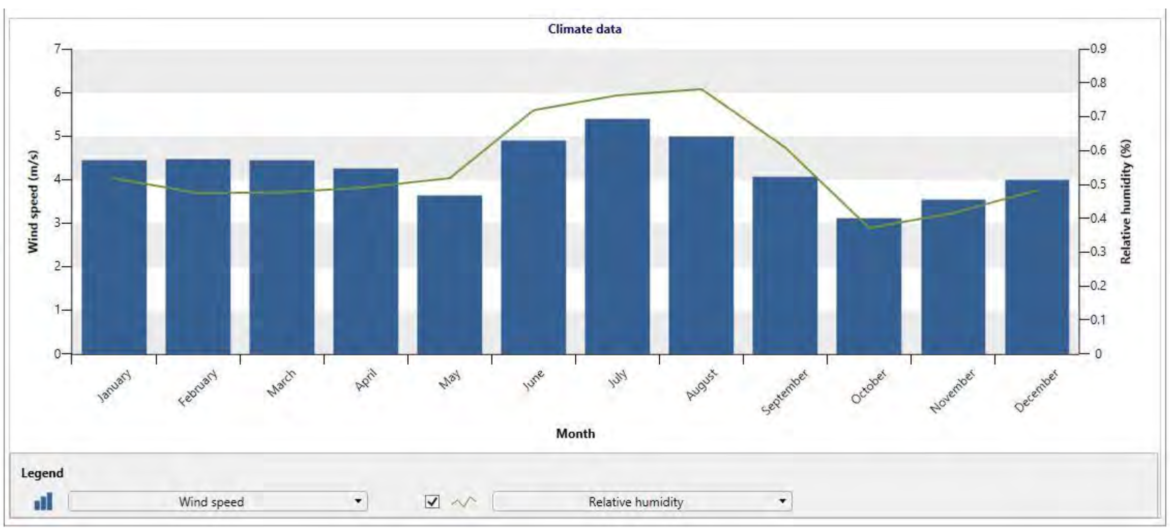
Legend
Facility location
Climate data location



	Unit	Climate data location	Facility location	Source
Latitude		14.1	14.1	
Longitude		38.3	37.7	
Climate zone		2B - Hot - Dry		NASA
Elevation	m	1629	832	NASA – NASA
Heating design temperature	°C	14.5		NASA
Cooling design temperature	°C	30.9		NASA
Earth temperature amplitude	°C	14.9		NASA

Month	Air temperature	Relative humidity	Precipitation	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days 18 °C	Cooling degree-days 10 °C
	°C	%	mm	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January	20.3	51.9%	5.54	5.76	86.5	4.5	23.9	0	321
February	21.6	47.5%	3.09	6.20	86.5	4.5	26.0	0	326
March	23.3	47.8%	14.88	6.59	86.4	4.5	27.7	0	413
April	24.4	49.2%	24.21	6.92	86.3	4.3	28.2	0	433
May	24.9	52.0%	31.83	6.74	86.4	3.6	28.3	0	460
June	22.2	72.0%	58.41	6.49	86.4	4.9	23.8	0	365
July	21.0	76.4%	205.77	5.80	86.4	5.4	22.0	0	341
August	20.7	78.2%	210.93	5.58	86.4	5.0	21.5	0	331
September	22.4	60.9%	70.95	6.25	86.4	4.1	23.9	0	373
October	24.3	37.2%	28.52	6.23	86.5	3.1	27.3	0	444
November	22.5	41.7%	10.19	5.88	86.5	3.6	25.3	0	374
December	20.8	48.4%	6.97	5.51	86.6	4.0	23.8	0	335
Annual	**22.4**	**55.3%**	**671.30**	**6.16**	**86.4**	**4.3**	**25.1**	**0**	**4,516**


Climate data
Precipitation (mm)
Wind speed (m/s)
300
250
200
150
100
50
0
7
6
5
4
3
2
1
0
January
February
March
April
May
June
July
August
September
October
November
December
Month
Legend
Precipitation
Wind speed


Climate data
Wind speed (m/s)
Relative humidity (%)
7
6
5
4
3
2
1
0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
January
February
March
April
May
June
July
August
September
October
November
December
Month
Legend
Wind speed
Relative humidity

Appendix B: MYNGUS input of hydro power for RET Screen software

Hydro turbine

Description	Hydro turbine
Note	mynguse small scale hydro power development

Level: Level 1 | Level 2

Hydro turbine - Level 2

Resource assessment		
Proposed project		Run-of-river
Hydrology method		User-defined
Gross head	m	24
Maximum tailwater effect	m	0.1
Residual flow	m^3/s	0.03
Percent time firm flow available	%	95%
Firm flow	m^3/s	0
Hydro turbine		
Design flow	m^3/s	1.453
Type		Cross-flow
Turbine efficiency		Standard
Number of turbines		2
Manufacturer		
Model		
Efficiency adjustment	%	5%
Turbine peak efficiency	%	0%
Flow at peak efficiency	m^3/s	0
Turbine efficiency at design flow	%	84%

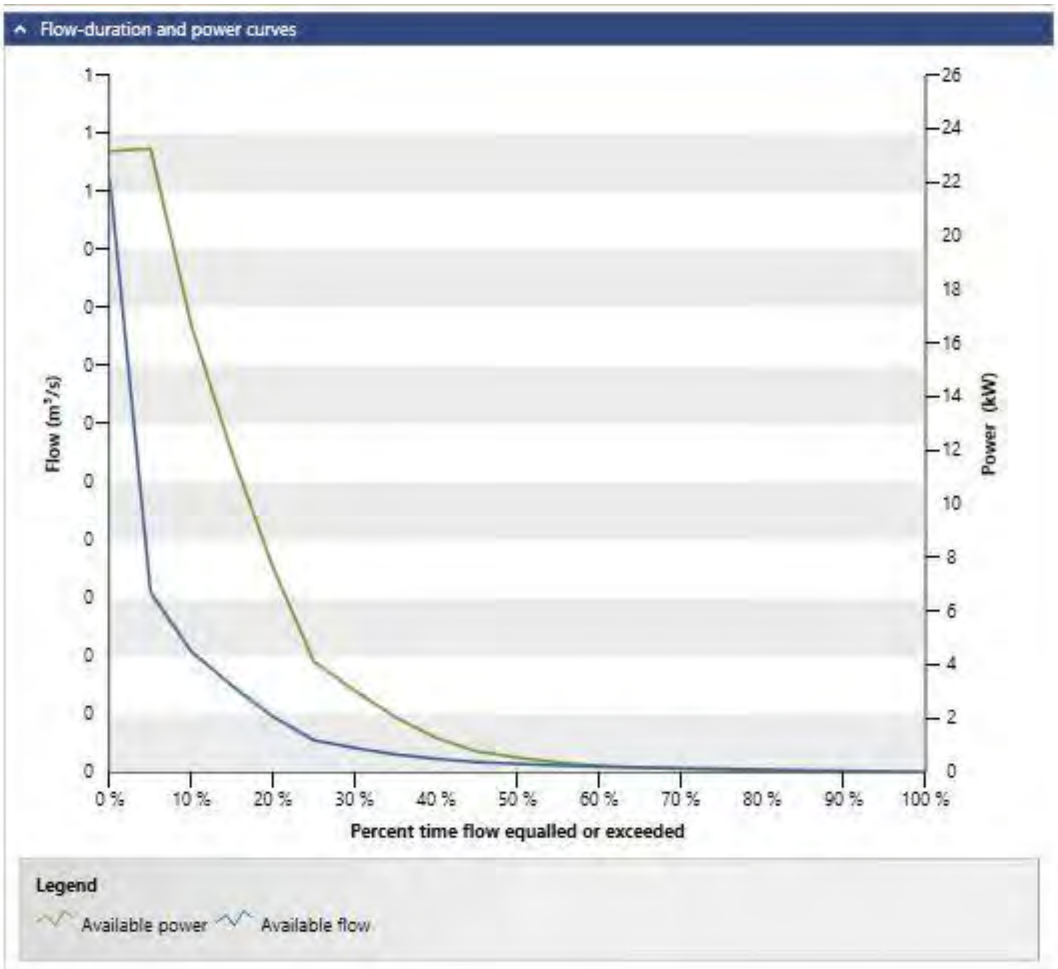
Appendix B 1.1: stream flow data for Myngus River and efficiency, number of turbine and combined efficiency.

Flow-duration and turbine efficiency curve data

%	Flow m^3/s	Turbine efficiency	Number of turbines	Combined efficiency
0%	1.83	0.00	0	0.00
5%	1.76	0.00	1	0.34
10%	1.70	0.34	1	0.61
15%	1.64	0.52	1	0.68
20%	1.45	0.61	1	0.70
25%	1.21	0.65	1	0.71
30%	0.72	0.68	1	0.73
35%	0.36	0.69	1	0.74
40%	0.29	0.70	1	0.76
45%	0.23	0.71	1	0.77
50%	0.19	0.71	1	0.79
55%	0.14	0.72	2	0.72
60%	0.10	0.73	2	0.73
65%	0.09	0.74	2	0.74
70%	0.07	0.74	2	0.74
75%	0.06	0.75	2	0.75
80%	0.06	0.76	2	0.76
85%	0.05	0.77	2	0.77
90%	0.04	0.77	2	0.77
95%	0.04	0.78	2	0.78
100%	0.03	0.79	2	0.79

Appendix B1.2: cross flow turbine and it efficiency

Appendix B 1.3: Power and flow duration curve for Myngus



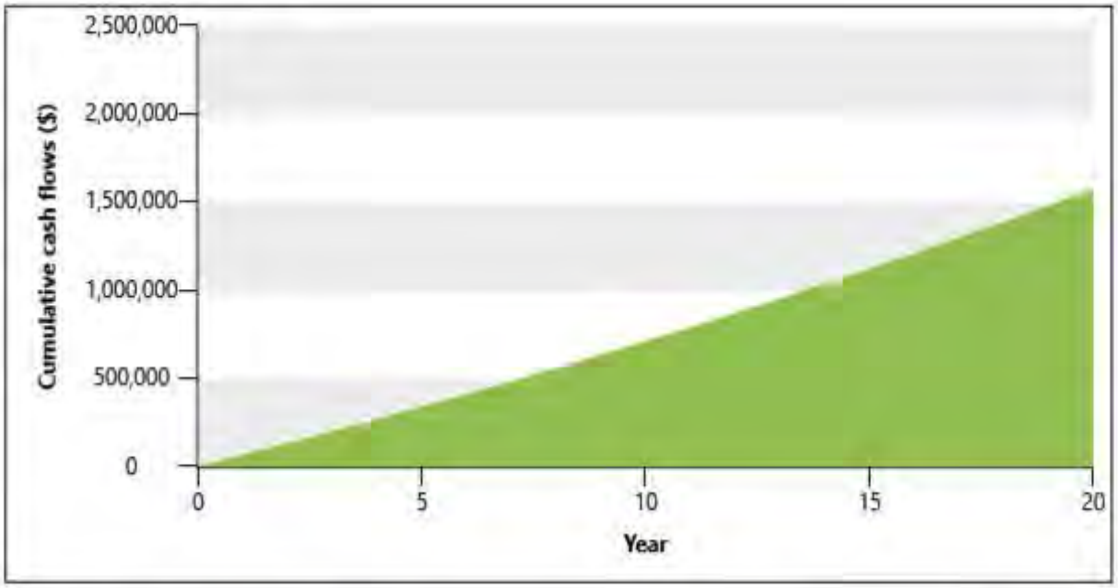
Appendix B1.4: output of the power, energy and cost

Losses			
Maximum hydraulic losses	%	2%	
Miscellaneous losses	%	1.5%	
Generator efficiency	%	94%	
Availability	%	95%	
Summary			Firm
Power capacity	kW	25.1	0
Available flow adjustment factor		0.55	
Capacity factor	%	28.9%	
Initial costs	$/kW		
	$		
O&M costs (savings)	$/kW-year		
	$		
Electricity export rate		Electricity exported to grid - annual	
	$/kWh	0.10	
Electricity exported to grid	MWh	63.5	
Electricity export revenue	$	6,353	

Appendix B1.5: financial value of the Myngus site

The main results are as follows:

Cash flow - Cumulative



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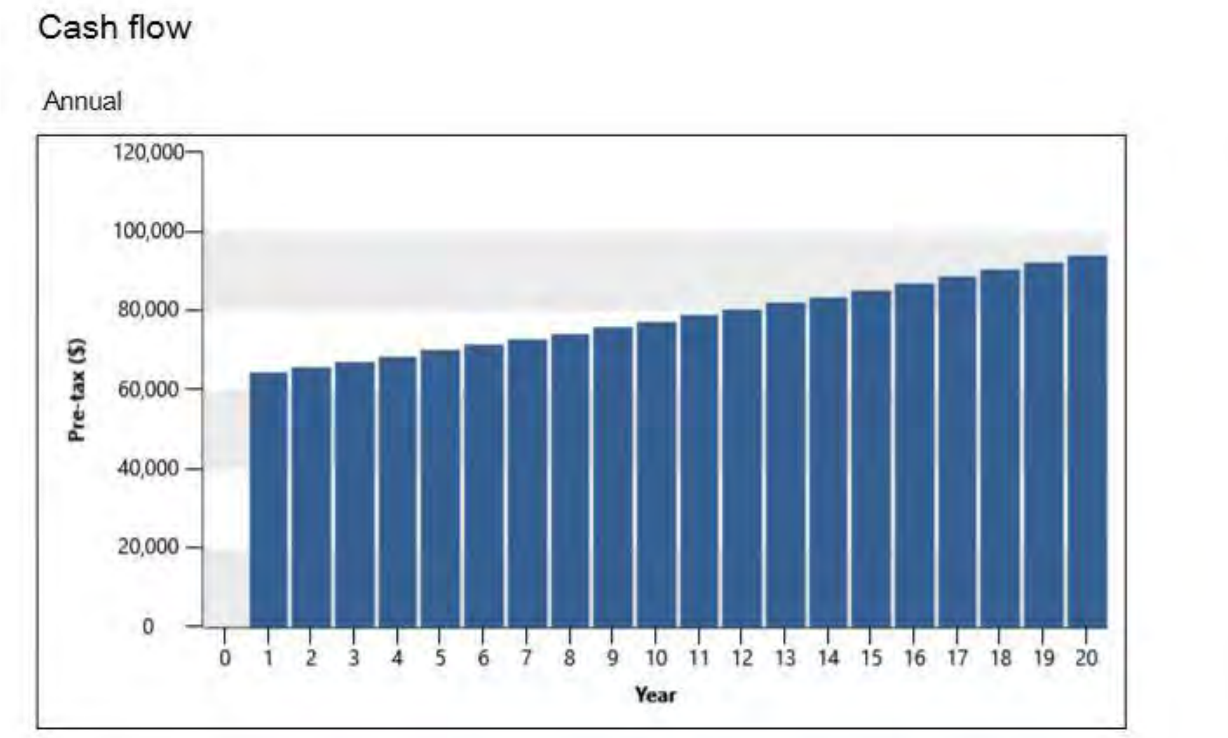
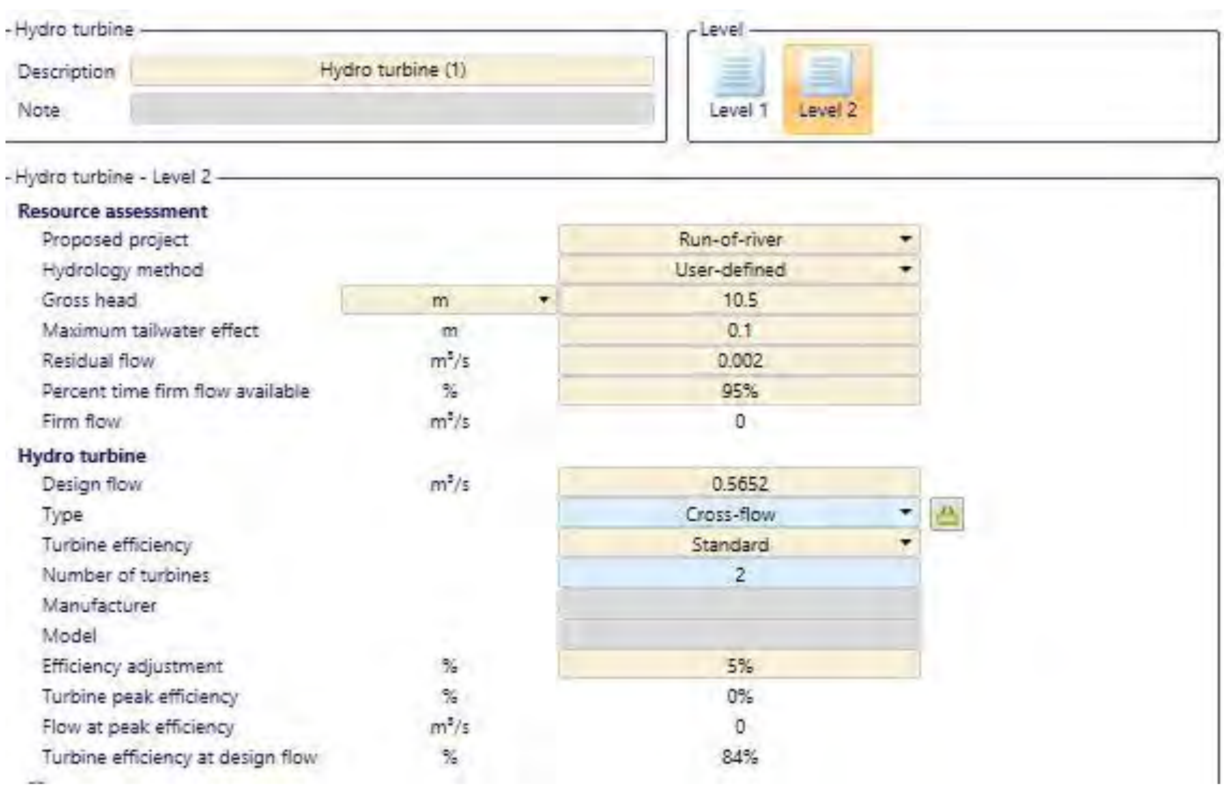


Appendix B2: parameter input of Mygundi hydro development

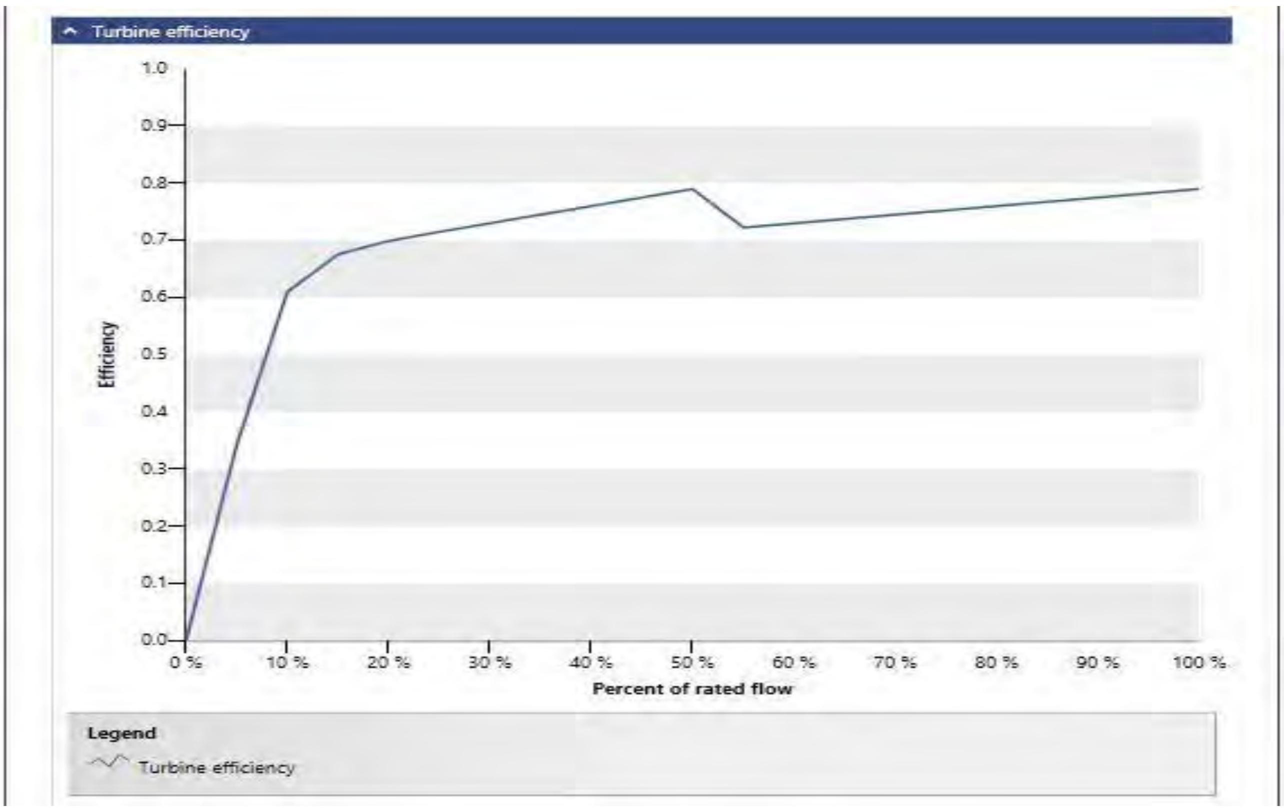


Appendix 2.1: inflow stream flow data and efficiency of turbine

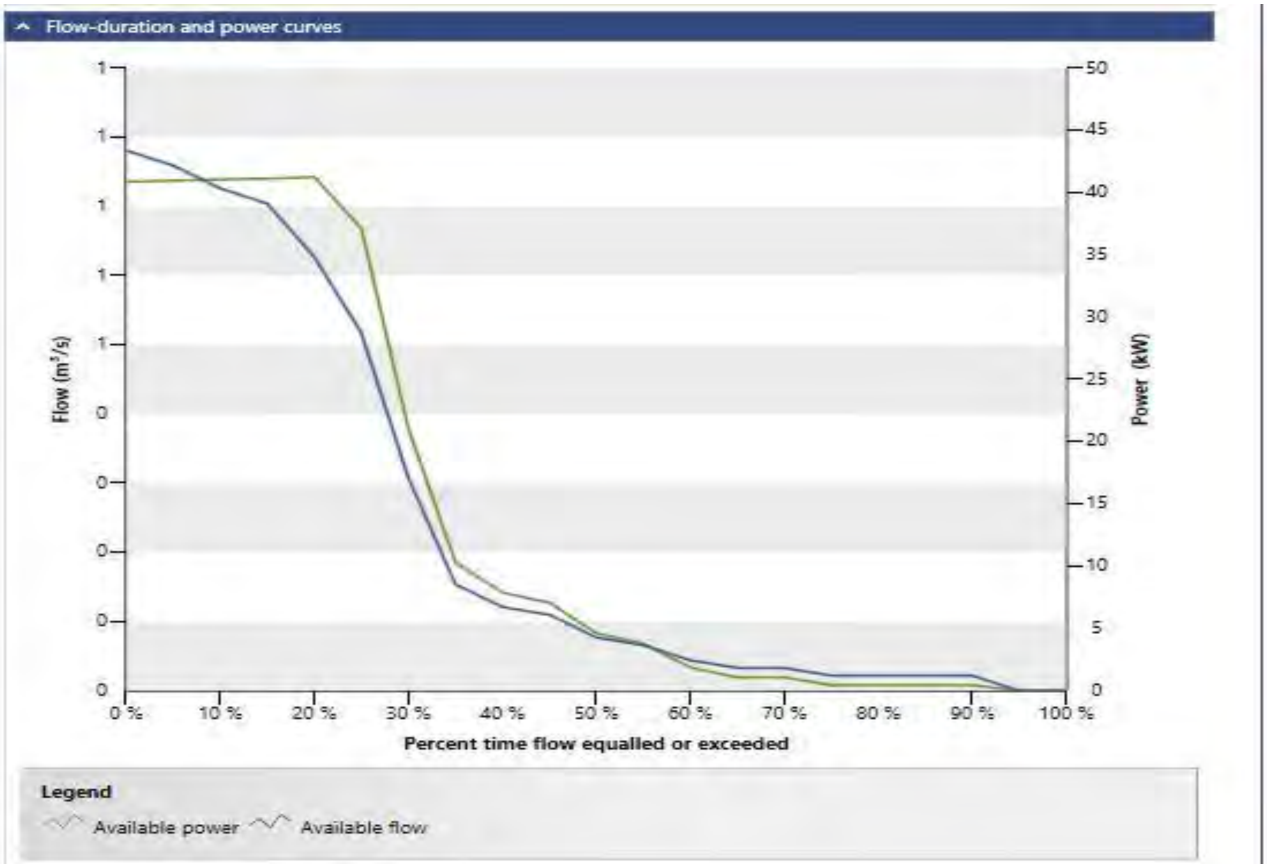
Flow-duration and turbine efficiency curve data

%	Flow m^3/s	Turbine efficiency	Number of turbines	Combined efficiency
0%	0.71	0.00	0	0.00
5%	0.69	0.00	1	0.34
10%	0.66	0.34	1	0.61
15%	0.64	0.52	1	0.68
20%	0.57	0.61	1	0.70
25%	0.47	0.65	1	0.71
30%	0.28	0.68	1	0.73
35%	0.14	0.69	1	0.74
40%	0.11	0.70	1	0.76
45%	0.10	0.71	1	0.77
50%	0.07	0.71	1	0.79
55%	0.06	0.72	2	0.72
60%	0.04	0.73	2	0.73
65%	0.03	0.74	2	0.74
70%	0.03	0.74	2	0.74
75%	0.02	0.75	2	0.75
80%	0.02	0.76	2	0.76
85%	0.02	0.77	2	0.77
90%	0.02	0.77	2	0.77
95%	0.00	0.78	2	0.78
100%	0.00	0.79	2	0.79

Appendix B2.2: efficiency cross flow turbine with the available flow



Appendix2.3: flow and power duration curve



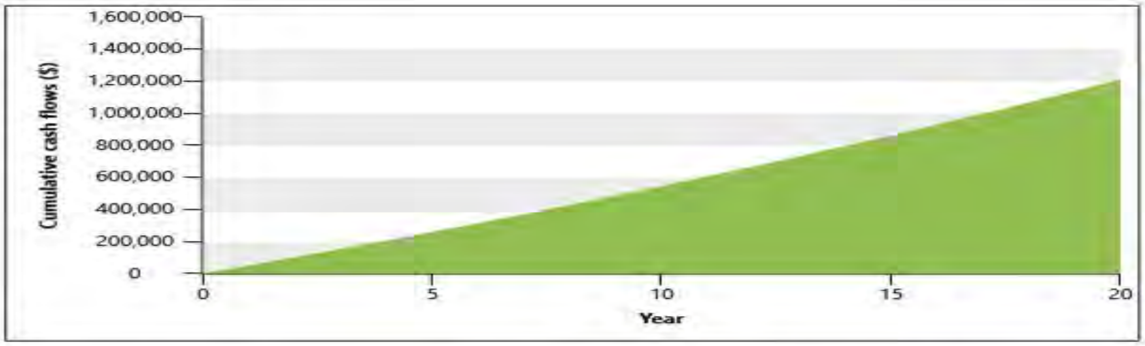
Appendix 2.4: result of capacity factor, power, energy and cost

Losses			
Maximum hydraulic losses	%	2%	
Miscellaneous losses	%	1.5%	
Generator efficiency	%	93%	
Availability	%	94%	
Summary			Firm
Power capacity	kW	43.9	0
Available flow adjustment factor		1.1	
Capacity factor	%	30.4%	
Initial costs	$/kW		
	$		
O&M costs (savings)	$/kW-year		
	$		
Electricity export rate		Electricity exported to grid - annual	
	$/kWh	0.10	
Electricity exported to grid	MWh	117	
Electricity export revenue	$	11,680	

Appendix B2.5: cumulative cash flow result

The main results are as follows:

Cash flow - Cumulative



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Appendix B2.6: total power and turbine capacity production

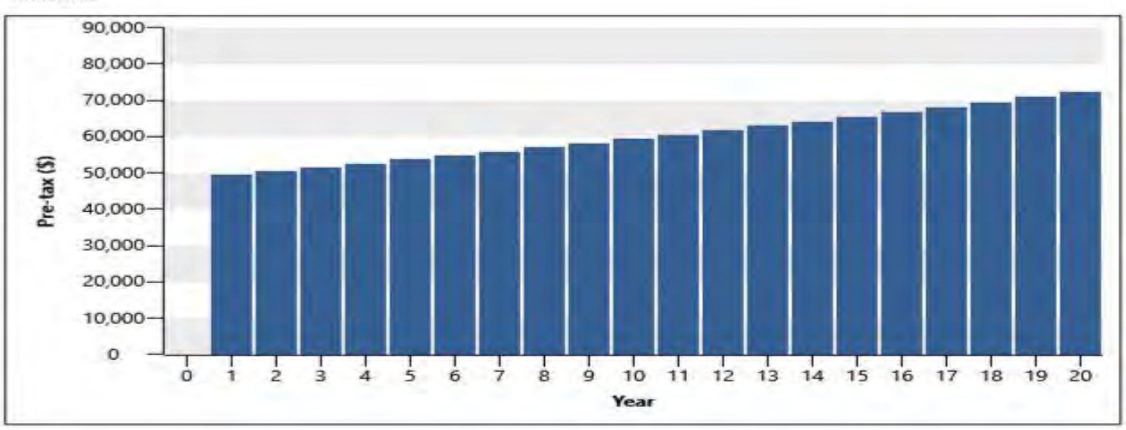
Power system - Total		
Capacity	172	kW
Electricity	487	MWh
Hydro turbine		
Capacity	128	kW
Electricity	371	MWh
Hydro turbine (1)		
Capacity	43.9	kW
Electricity	117	MWh

Notes

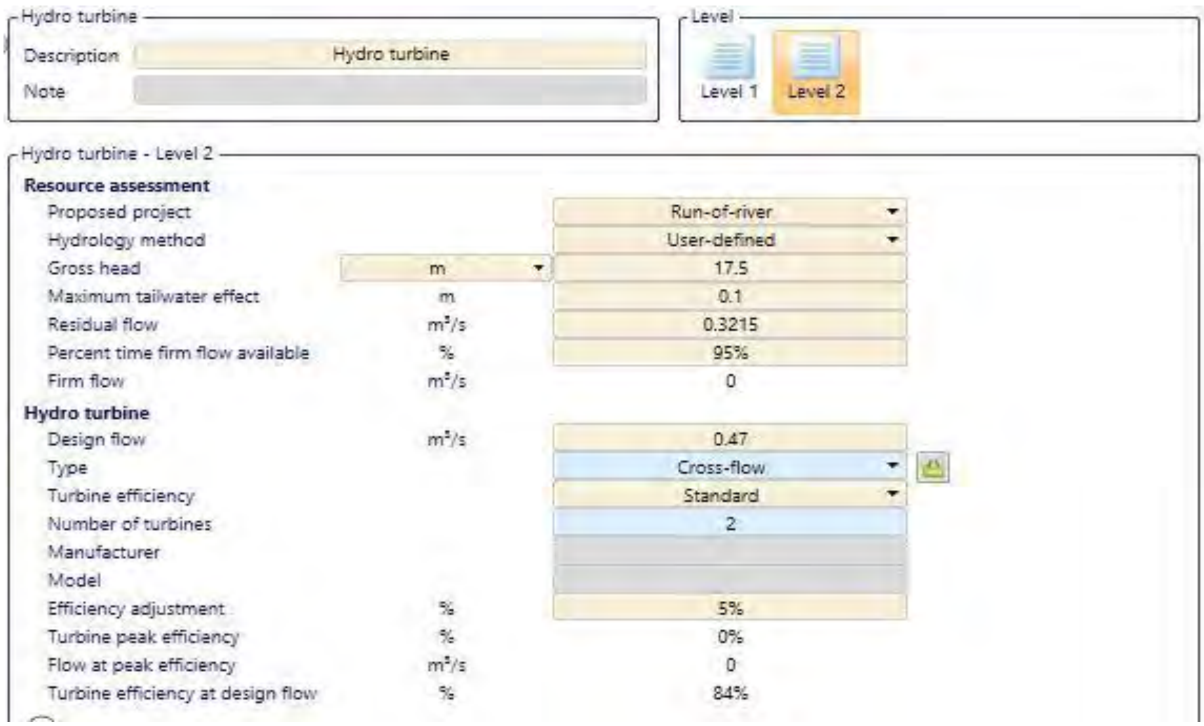
Appendix B2.7:

Cash flow

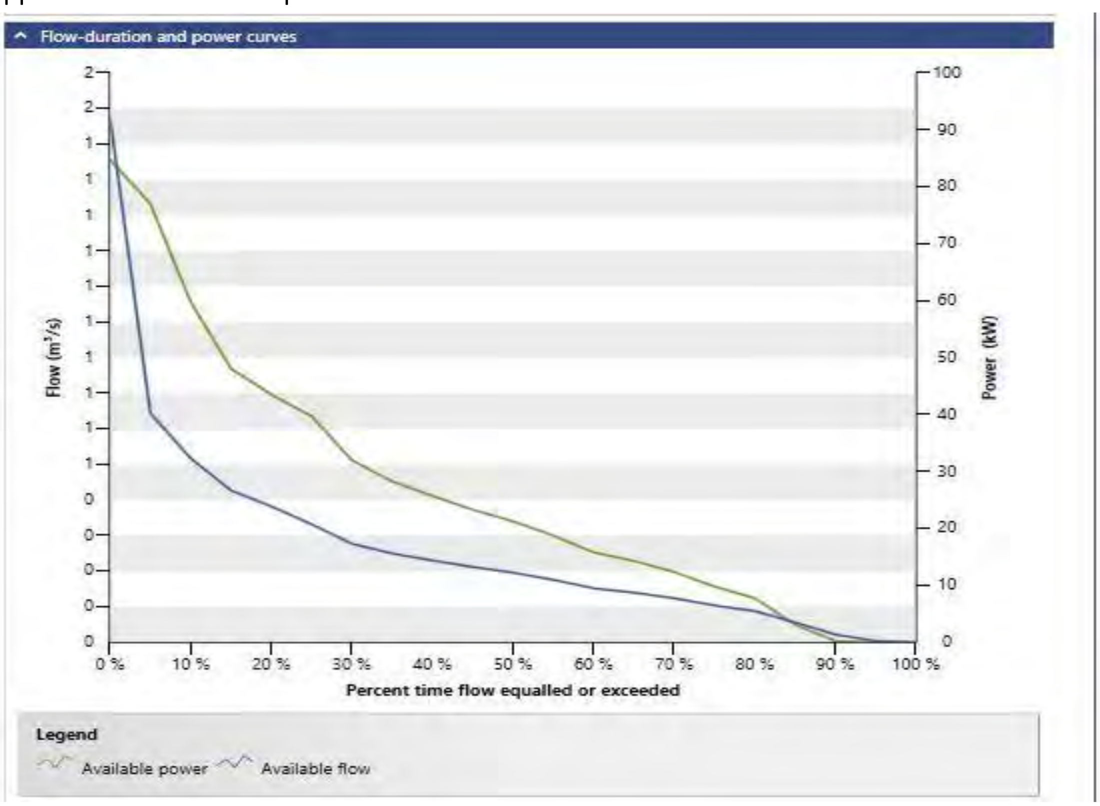
Annual



Appendix B3: hydrologic input parameter of Meskebet dam site



Appendix B3.1: flow and power duration curve



Appendix B3.2: summery of Meskebet micro hydro result

Executive summary

This report was prepared using the RETScreen Clean Energy Management Software. The key findings and recommendations of this analysis are presented below:

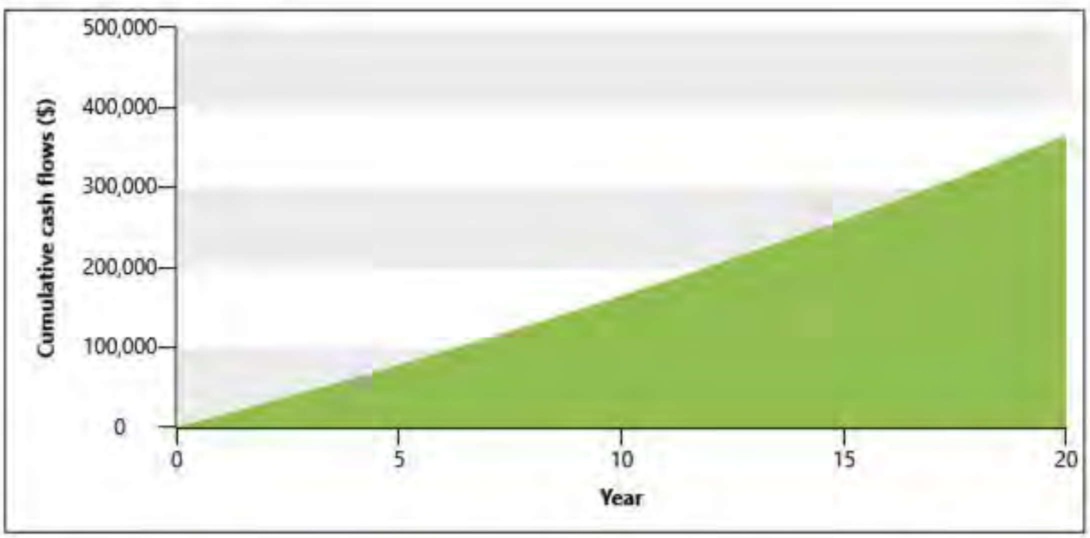
Target

	Electricity exported to grid MWh	Electricity export revenue $	GHG emission reduction tCO_2
Proposed case	147	14,715	1.2

AppendixB3.3: cash flow of the Meskebet dam site

The main results are as follows:

Cash flow - Cumulative



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Appendix 3.4: result estimated value of capacity factor, energy and cost

Losses			
Maximum hydraulic losses	%	2%	
Miscellaneous losses	%	1.5%	
Generator efficiency	%	93%	
Availability	%	94%	
Summary			Firm
Power capacity	kW	60.8	0
Available flow adjustment factor		0.8	
Capacity factor	%	27.6%	
Initial costs	$/kW		
	$		
O&M costs (savings)	$/kW-year		
	$		
Electricity export rate		Electricity exported to grid - annual	
	$/kWh	0.10	
Electricity exported to grid	MWh	147	
Electricity export revenue	$	14,715	

Appendix B3.5: turbine capacity

Hydro turbine		
Capacity	60.8	kW
Electricity	147	MWh

Notes

Appendix B4: hydrologic input for luelay wukro hydro development

Hydro turbine	
Description	Hydro turbine (1)
Note	

Level: Level 1, Level 2

Hydro turbine - Level 2

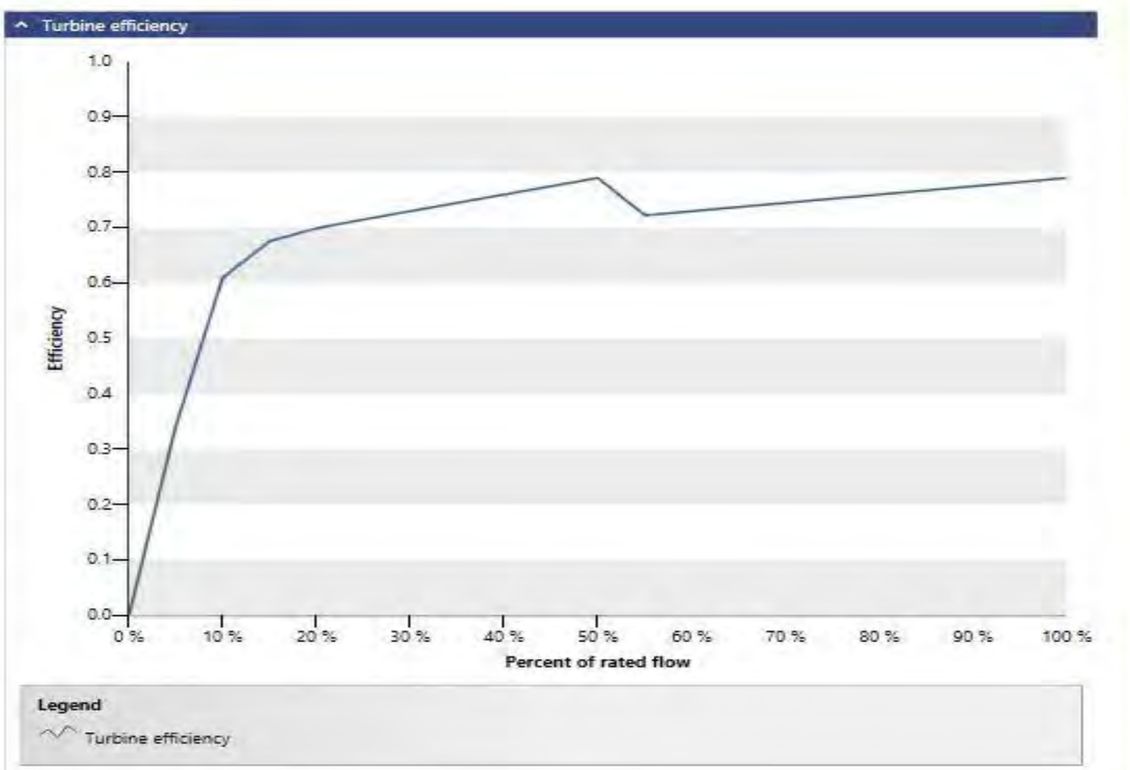
Resource assessment		
Proposed project		Run-of-river
Hydrology method		User-defined
Gross head	m	14.5
Maximum tailwater effect	m	0.1
Residual flow	m^3/s	0
Percent time firm flow available	%	90%
Firm flow	m^3/s	0
Hydro turbine		
Design flow	m^3/s	0.07
Type		Cross-flow
Turbine efficiency		Standard
Number of turbines		2
Manufacturer		
Model		
Efficiency adjustment	%	2%
Turbine peak efficiency	%	0%
Flow at peak efficiency	m^3/s	0
Turbine efficiency at design flow	%	81%

Appendix B4.1: stream flow and corresponding value of Turbine efficency

Flow-duration and turbine efficiency curve data

%	Flow m^3/s	Turbine efficiency	Number of turbines	Combined efficiency
0%	0.08	0.00	0	0.00
5%	0.07	0.00	1	0.34
10%	0.07	0.34	1	0.61
15%	0.06	0.52	1	0.68
20%	0.06	0.61	1	0.70
25%	0.05	0.65	1	0.71
30%	0.04	0.68	1	0.73
35%	0.04	0.69	1	0.74
40%	0.04	0.70	1	0.76
45%	0.04	0.71	1	0.77
50%	0.03	0.71	1	0.79
55%	0.03	0.72	2	0.72
60%	0.03	0.73	2	0.73
65%	0.03	0.74	2	0.74
70%	0.03	0.74	2	0.74
75%	0.03	0.75	2	0.75
80%	0.03	0.76	2	0.76
85%	0.02	0.77	2	0.77
90%	0.02	0.77	2	0.77
95%	0.01	0.78	2	0.78
100%	0.00	0.79	2	0.79

Appendix B 4.2: TURBINE EFFICENCY CURVE OF LUELY WUKRO



Appendix B4.3: output of luelay wukro

Losses			
Maximum hydraulic losses	%	2%	
Miscellaneous losses	%	1%	
Generator efficiency	%	93%	
Availability	%	95%	
Summary			Firm
Power capacity	kW	7.3	0
Available flow adjustment factor		0.9	
Capacity factor	%	44.6%	
Initial costs	$/kW		
	$		
O&M costs (savings)	$/kW-year		
	$		
Electricity export rate		Electricity exported to grid - annual	
	$/kWh	0.10	
Electricity exported to grid	MWh	28.4	
Electricity export revenue	$	2,842	

Appendix 4.4: energy and cost report

Executive summary

This report was prepared using the RETScreen Clean Energy Management Software. The key findings and recommendations of this analysis are presented below:

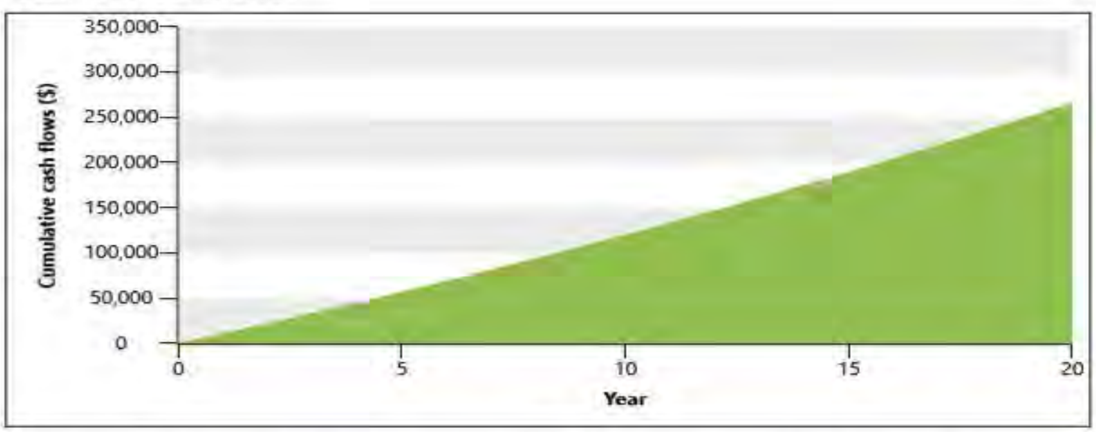
Target

	Electricity exported to grid MWh	Electricity export revenue $	GHG emission reduction tCO_2
Proposed case	107	10,730	50.6

The main results are as follows:

The main results are as follows:

Cash flow - Cumulative



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Appendix B4.5: total report of energy

Power system - Total		
Capacity	33	kW
Electricity	107	MWh
Hydro turbine		
Capacity	26.2	kW
Electricity	78.9	MWh
Hydro turbine (1)		
Capacity	7.3	kW
Electricity	28.4	MWh

Notes

Appendix B4.6: financial report of luelay wukro

RETScreen - Financial Analysis — **Subscriber: Viewer**

Financial parameters

General		
Inflation rate	%	2%
Discount rate	%	9%
Project life	yr	20
Finance		
Incentives and grants	$	
Debt ratio	%	70%
Debt	$	0
Equity	$	0
Debt interest rate	%	7%
Debt term	yr	15
Debt payments	$/yr	0
Income tax analysis		☑
Effective income tax rate	%	30%
Loss carryforward?		No
Depreciation method		Declining balance
Half-year rule - year 1	yes/no	No
Depreciation tax basis	%	100%
Depreciation rate	%	5%
Tax holiday available?	yes/no	No

Costs | Savings | Revenue

Initial costs			
Feasibility study		$	0
Development		$	0
Engineering		$	0
Power system		$	0
Balance of system & miscellaneous		$	0
Total initial costs	**100%**	$	**0**
Annual costs and debt payments			
Debt payments - 15 yrs		$	0
Total annual costs		$	**0**
Annual savings and revenue			
Electricity export revenue		$	10,730
CE production revenue		$	3,047,313
Total annual savings and revenue		$	**3,058,042**

Financial viability

Pre-tax IRR - equity	%	Positive
Pre-tax IRR - assets	%	Positive

Yearly cash flows

Year	Pre-tax	After-tax	Cumulative
#	$	$	$
0	0	0	0
1	3,058,257	2,140,780	2,140,780
2	3,058,476	2,140,933	4,281,713
3	3,058,699	2,141,089	6,422,803
4	3,058,927	2,141,249	8,564,051
5	3,059,159	2,141,411	10,705,463
6	3,059,396	2,141,577	12,847,040
7	3,059,638	2,141,747	14,988,787
8	3,059,884	2,141,919	17,130,706
9	3,060,136	2,142,095	19,272,801
10	3,060,392	2,142,275	21,415,076
11	3,060,654	2,142,458	23,557,533
12	3,060,921	2,142,645	25,700,178
13	3,061,193	2,142,835	27,843,013
14	3,061,470	2,143,029	29,986,042
15	3,061,754	2,143,228	32,129,270
16	3,062,042	2,143,430	34,272,699
17	3,062,337	2,143,636	36,416,335
18	3,062,638	2,143,846	38,560,182
19	3,062,944	2,144,061	40,704,242
20	3,063,257	2,144,280	42,848,522

Appendix: cash flow graph

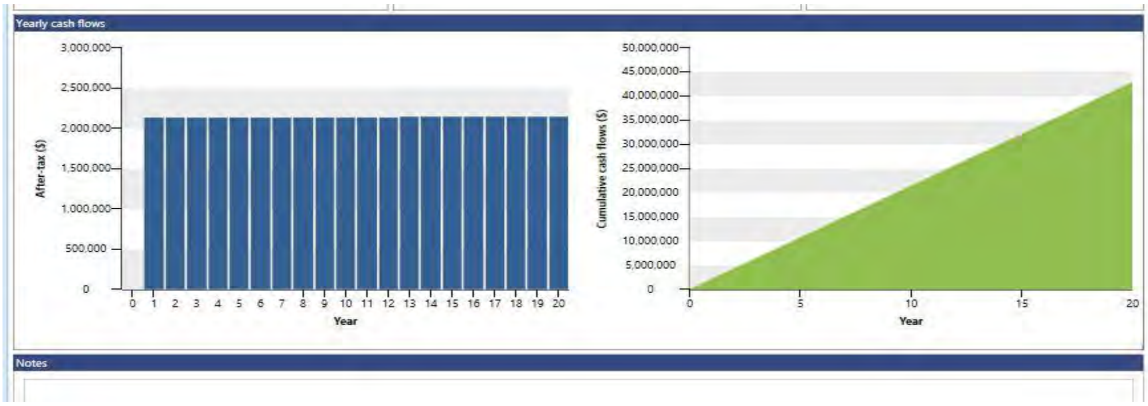


Table: stream flow data of the serenta river site

monthly flow of the serenta dam site(m^3/sec)													
YEAR	Jan	Feb	March	April	May	Jun	July	Aug	Sep	Oct	Nov	Dec	yearly average
1998	6.664282	5.500219	5.113202	3.245495	2.800023	3.098931	13.60496	23.50582	15.45117	6.59811	6.048143	6.2250353	8.1546157
1999	6.240058	5.438161	5.053564	3.963297	5.196052	8.447913	15.6874	25.55885	15.04483	5.478642	5.671878	6.561011	9.0284717
2000	6.703854	4.652555	5.017502	4.607854	6.473009	7.838431	15.30791	25.85144	15.25228	6.041262	5.617009	6.466033	9.152428
2001	0.309617	5.428923	4.621881	4.926204	0.126073	3.926365	13.13213	26.36333	15.65592	5.841481	6.270416	6.2296018	7.7359954
2002	6.035869	5.109664	5.184356	4.629083	6.101222	7.162245	18.17777	23.04992	13.68553	6.492014	6.873189	6.9195554	9.1183683
2003	7.086684	5.006231	4.928841	4.265125	6.235378	5.692195	16.58302	26.9526	15.54862	1.879548	1.879548	0.2206774	8.0232054
2004	6.747134	0.237403	0.005419	0.146303	0.00471	0.664068	8.877903	15.84929	7.618706	2.85	2.85	0.4705161	3.8601212
2005	0.268806	0.708186	0.198065	0.237268	0.14071	0.783568	10.46829	13.00611	11.57467	3.050819	3.067463	1.2735734	3.7314609
2006	1.022947	1.214462	0.703137	0.948422	2.586176	7.320229	16.28134	24.95008	14.28893	6.982324	5.214335	6.8217274	7.3611762
2007	6.467284	5.518713	4.964568	4.552271	6.211133	6.476078	18.04164	25.87825	14.21922	6.720045	5.904688	5.5294233	9.2069434

2008	2.214246	1.353401	2.064634	3.189193	5.757321	7.575415	17.33693	23.91401	14.74844	6.755626	6.449698	8.2913939	8.3041916
2009	16.95972	5.765748	4.854851	5.125655	16.33713	16.94335	45.27867	39.88069	24.35556	11.7229	11.7229	8.4927097	17.286658
2010	9.807806	10.25982	10.05406	10.20162	9.994677	19.15226	29.42932	37.82463	28.29419	12.41806	12.41806	9.2786129	16.594428
2011	8.343	9.291	8.481	7.823	9.347	8.920	16.528	35.112	24.628	9.173	9.173	9.623	13.037
2012	12.81639	10.71559	10.21048	9.700425	11.91845	11.95217	20.03938	32.98976	22.30824	8.962129	8.962129	4.5679355	13.761924
2013	9.332935	10.06442	8.218318	9.030462	9.238097	8.853343	19.40598	27.17061	13.45924	9.30785	9.447333	21.815582	12.945348
2014	18.8144	13.8913	12.92977	12.07322	15.5123	6.789495	17.17015	26.54642	15.28011	6.190672	6.593844	6.2741437	13.172151

Table: data transfer to serenta dam site

year	inflow(Q)(m^3/sec)	AREAOF GUG(m)	AREA UNG site(m)	TRANSFR SERNTA(m)
1998	8.15461574	219	36.1	1.344208348
1999	9.028471686	219	36.1	1.488254922
2000	9.152427992	219	36.1	1.508687902
2001	7.735995395	219	36.1	1.275202894
2002	9.118368298	219	36.1	1.503073496
2003	8.023205373	219	36.1	1.322546639
2004	3.860121196	219	36.1	0.636303083
2005	3.73146086	219	36.1	0.61509469
2006	7.361176216	219	36.1	1.213417632
2007	9.206943414	219	36.1	1.517674234
2008	8.30419161	219	36.1	1.368864462
2009	17.28665816	219	36.1	2.849535889

2010	16.59442788	219	36.1	2.735428522
2011	13.03660452	219	36.1	2.14895627
2012	13.76192411	219	36.1	2.268518083
2013	12.94534785	219	36.1	2.133913504
2014	13.17215081	219	36.1	2.171299745

Hydrological data of Tekeze near Miknetal station

Tekeze near Miknetal hydrologic recorded data(m)													
YEAR	Jan	Feb	March	April	May	Jun	July	Aug	Sep	Oct	Nov	Dec	AVG YRLY
1994	19.93549	10.00815	0.662839	6.755323	7.121387	24.49792	92.1548	894.4454	469.3702	9.67071	6.77742	0.462677	128.4885
1995	0.19	8.272029	26.22335	76.43881	13.50152	25.62132	557.4713	1178.945	352.724	39.96026	11.40662	8.213452	191.5807
1996	5.552258	16.99377	53.97142	39.84861	61.26174	139.9031	498.5222	1287.61	296.3398	63.23168	33.69482	20.65829	209.799
1997	7.486452	20.0657	22.7991	16.09179	30.41977	87.9081	453.9867	601.5817	108.6747	149.8522	60.45471	16.59045	131.3259
1998	4.214226	10.18995	2.623419	13.54205	39.95445	42.63255	759.9542	762.4316	799.6621	216.6142	88.25328	35.81029	231.3235
1999	37.57165	27.06292	17.99832	19.06466	21.17231	50.57675	715.2633	1424.349	869.0773	242.4704	88.34928	38.49081	295.9539
2000	10.52277	30.12626	19.34052	14.47935	9.893161	30.4938	352.1211	1350.572	349.1421	108.5019	37.39394	17.97332	194.2133
2001	15.15997	16.60791	14.02427	14.14673	9.859387	79.11399	760.5586	1588.498	406.4136	109.5268	31.65085	51.85658	258.1181
2002	87.6324	131.2278	123.8375	81.37315	29.81358	100.5978	362.1723	709.9444	320.2624	63.13626	39.63203	35.34006	173.7475
2003	24.57758	33.13033	25.55303	30.33957	20.91613	111.4654	515.8896	1450.952	497.184	148.4758	74.08913	49.05656	248.4691
2004	36.98168	34.83481	26.09997	39.70514	57.87845	166.6199	460.9764	985.6152	455.001	135.5819	98.44723	72.97881	214.2267
2005	108.1715	114.2665	137.5376	115.2317	94.71429	104.0352	715.1692	1118.221	442.2629	102.2758	51.65093	33.06026	261.3831

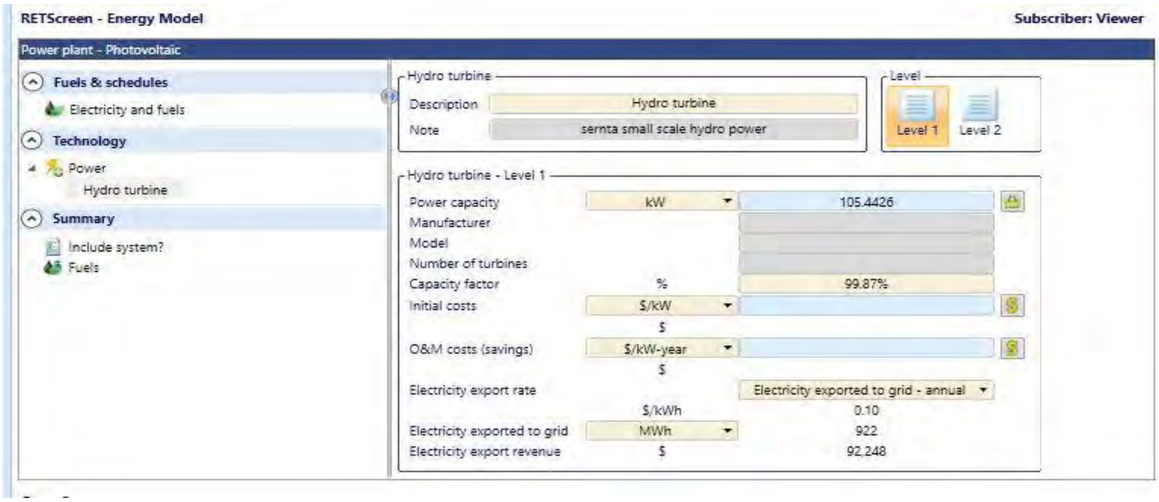
2006	87.37859	131.3028	130.0833	121.7549	79.15974	132.3262	578.5644	1768.582	459.5377	146.6375	64.2262	58.3798	313.1611
2007	98.38034	103.673	104.7016	108.4725	19.71097	166.14	1068.947	1495.166	1044.057	206.7462	58.78244	48.62605	376.9503
2008	112.374	134.9658	80.86301	23.98177	28.45866	108.9656	440.775	802.4228	393.4882	123.2978	102.749	83.96137	203.0252
2009	98.02213	107.5222	129.2372	119.8838	122.699	111.0891	334.4285	576.8184	205.9074	97.72319	97.59494	108.343	175.7724
2010	131.7757	178.1656	199.8815	156.1066	143.2504	163.9053	264.5325	614.1256	336.6749	164.0758	180.9532	130.0964	221.962
2011	203.3452	398.1299	543.1367	459.1981	727.9505	769.7442	718.9927	1022.714	461.8219	310.0204	292.6179	258.9389	513.8842
2012	290.422	296.4518	282.4064	293.3174	326.0542	338.0429	426.8804	1270.063	623.8004	323.4904	338.515	327.4463	428.0742
2013	317.3271	303.513	310.9257	346.8571	349.5126	360.7578	751.2543	928.6675	465.8224	294.9091	254.1914	253.689	411.4522
2014	291.7337	290.9145	305.5016	310.2536	315.5182	159.6463	561.7433	687.0986	562.8594	281.5579	234.0535	202.2067	350.2573
2015	207.6424	227.422	245.2358	235.3134	236.8338	133.6821	435.553	822.7685	435.0612	121.2679	114.0366	82.30563	274.7602

Table: Werie hydrologic record of Streamflow

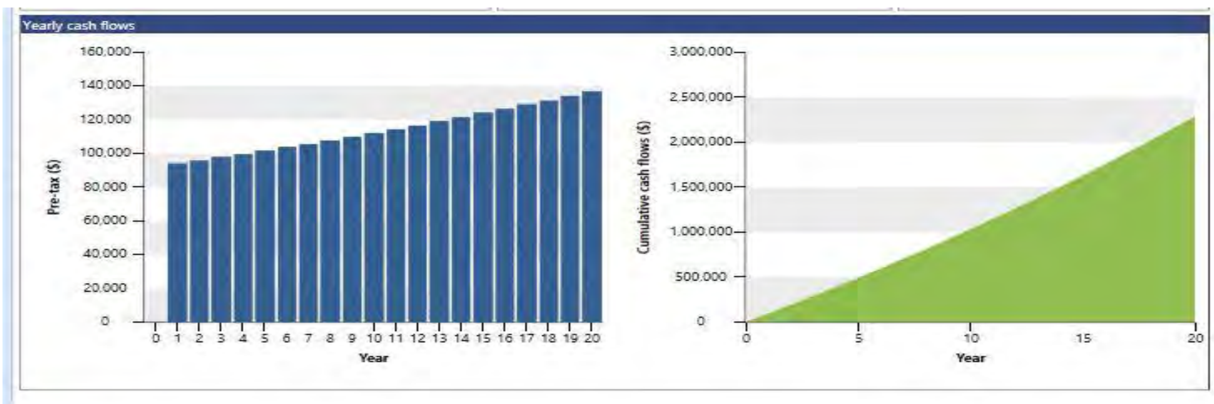
Monthly flow of the Werie hydrologic station records(m^3/sec)													
YEAR	Jan	Feb	March	April	May	Jun	July	Aug	Sep	Oct	Nov	Dec	AVG
1990	1.241491	1.187846	2.099002	5.288048	3.716928	10.64138	34.65516	42.38806	17.50028	5.924655	2.652747	1.476936	10.73104
1991	38.00436	28.53611	47.12397	191.0624	136.0477	345.8435	1031.092	1132.946	584.6216	149.5607	76.00306	44.28777	317.0942
1992	1.1432	1.039133	2.082868	4.99268	4.347306	10.65131	33.23038	45.0359	23.72014	4.453513	2.395288	1.507664	11.21662
1993	1.282621	0.983554	2.171124	5.337287	4.332538	12.11589	36.72878	41.09641	21.4173	6.067851	2.369843	1.442939	11.27885
1994	1.138671	1.070851	2.426512	6.19997	4.045351	11.335	34.56282	39.54633	19.8739	5.347117	2.581312	1.523137	10.80425

1995	1.138639	0.968469	2.692342	5.916067	4.299552	8.454508	37.27986	39.36288	23.1747	5.224408	2.57383	1.461339	11.04555
1996	1.23655	1.029354	1.856974	5.157125	4.128894	11.54752	34.36856	36.86296	19.41733	4.859426	2.239558	1.440274	10.34538
1997	1.202256	0.946667	0.761355	0.83163	0.435516	2.41936	43.33611	71.4839	13.19179	1.989479	1.523983	0.688684	11.56756
1998	0.682748	0.539246	0.472802	1.177828	0.765518	4.851454	36.46419	44.13816	25.75137	6.188079	2.591389	1.629727	10.43771
1999	1.169616	1.101708	2.272792	3.991982	4.708404	10.8605	37.55876	36.71983	22.81255	4.523392	2.766218	2.748	10.93615
2000	2.748	2.563673	2.748	2.831991	2.748	3.483747	4.729097	3.141645	3.563676	2.801419	2.73421	2.730032	3.068624
2001	2.723516	2.572635	2.659387	2.791219	2.671161	4.798713	22.97835	27.06012	15.99878	3.221484	2.410507	2.02529	7.659264
2002	1.630871	1.61061	1.337613	3.552138	0.965097	1.439933	12.76153	23.15674	5.083359	4.076968	1.832554	1.48171	4.91076
2003	1.412774	1.095747	0.593	2.942094	3.981161	7.163842	25.79733	31.78812	7.436544	1.64564	0.716211	0.391824	7.080358
2004	0.24176	0.273057	3.533362	3.35119	5.305756	11.43612	37.40293	38.33116	22.72635	5.480576	2.423368	1.447503	10.99609
2005	1.127725	0.961578	1.379089	2.628429	4.609	11.37243	33.82623	34.74991	19.71177	3.927621	2.25535	1.349098	9.824853
2006	1.2152	1.187427	1.790521	5.513773	1.73337	4.807825	53.86768	44.67395	14.14336	3.467839	2.117162	1.68771	11.35048
2007	38.5829	30.11056	58.66655	166.4447	43.0843	370.2286	1964.513	1980.073	1835.854	366.256	59.55098	44.279	579.8037
2008	1.048452	0.701126	0.57629	2.140243	2.506677	8.794583	35.5152	73.74348	24.87213	4.520935	2.164566	0.970355	13.1295
2009	0.459032	0.425203	1.254354	11.66208	5.160097	18.39589	82.87597	64.02662	32.18369	4.051323	1.104489	0.718129	18.52641
2010	0.594806	0.535104	1.439164	6.236931	3.198774	12.59025	44.37603	67.19375	31.9514	6.13741	6.778895	1.423815	15.20469
2011	0.674535	0.766082	2.90356	1.722607	9.309626	12.02337	51.82943	52.06016	32.52888	4.896204	2.395028	1.470511	14.38167
2012	1.150076	0.961115	2.203836	4.984323	4.426873	11.29997	38.86346	42.17318	21.79373	4.368439	2.202399	1.460507	11.32399
2013	1.177564	0.998671	2.783932	5.391859	3.543434	10.80997	39.8629	49.74801	23.0595	5.631295	2.619317	1.41416	12.25338

Annex d1: the RET SCREEN software result of the serenta dam



Annex d1.1: the financial graph of the serenta during the life of the project



Annex d1.2: the summery of the energy, cost and green gas emission (GHG)

Executive summary

This report was prepared using the RETScreen Clean Energy Management Software. The key findings and recommendations of this analysis are presented below:

Target

	Electricity exported to grid MWh	Electricity export revenue $	GHG emission reduction tCO_2
Proposed case	922	92,248	7.6

Annex 1.3: the financial report of serenta dam

RETScreen - Financial Analysis Subscriber: Viewer

Financial parameters

General		
Inflation rate	%	2%
Discount rate	%	9%
Project life	yr	20
Finance		
Incentives and grants	$	
Debt ratio	%	70%
Debt	$	0
Equity	$	0
Debt interest rate	%	7%
Debt term	yr	15
Debt payments	$/yr	0
Income tax analysis		☐

Annual revenue

Electricity export revenue		
Electricity exported to grid	MWh	922
Electricity export rate	$/kWh	0.10
Electricity export revenue	$	92,248
Electricity export escalation rate	%	2%
GHG reduction revenue		
Gross GHG reduction	tCO_2/yr	8
Gross GHG reduction - 20 yrs	tCO_2	151
GHG reduction revenue	$	0
Other revenue (cost)		☐
Clean Energy (CE) production revenue		☐

Costs | Savings | Revenue

Initial costs		
-	$	0
Total initial costs	$	**0**
Annual costs and debt payments		
Debt payments - 15 yrs	$	0
Total annual costs	**$**	**0**
Annual savings and revenue		
Electricity export revenue	$	92,248
Total annual savings and revenue	**$**	**92,248**

Financial viability

Pre-tax IRR - equity	%	Positive
Pre-tax IRR - assets	%	Positive
Simple payback	yr	0
Equity payback	yr	Immediate
Net Present Value (NPV)	$	987,785
Annual life cycle savings	$/yr	108,208
Benefit-Cost (B-C) ratio		
Debt service coverage		
GHG reduction cost	$\$/tCO_2$	-14,305
Energy production cost	$/kWh	10.000

Yearly cash flows

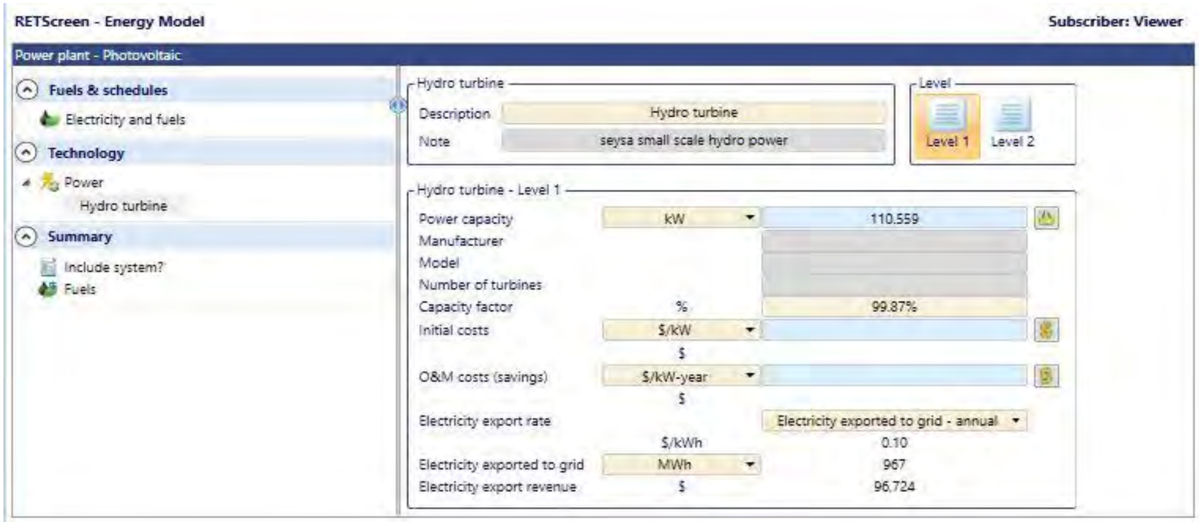
Year	Pre-tax	Cumulative
#	$	$
0	0	0
1	94,093	94,093
2	95,974	190,067
3	97,894	287,961
4	99,852	387,813
5	101,849	489,662
6	103,886	593,547
7	105,964	699,511
8	108,083	807,594
9	110,244	917,838
10	112,449	1,030,288
11	114,698	1,144,986
12	116,992	1,261,978
13	119,332	1,381,310
14	121,719	1,503,029
15	124,153	1,627,182
16	126,636	1,753,819
17	129,169	1,882,988
18	131,752	2,014,740
19	134,387	2,149,127
20	137,075	2,286,203

Annex d1.4: the turbine capacity of the and energy gained

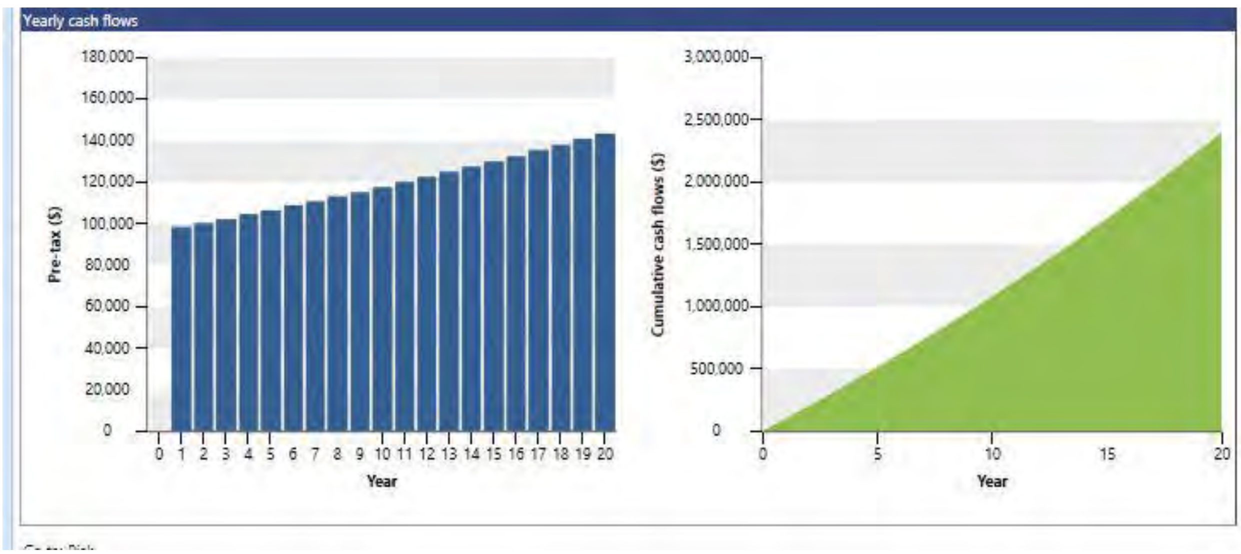
Hydro turbine		
Capacity	105	kW
Electricity	922	MWh

Notes

Annex d2: seysa dam RET SCREEN software



Annex d2.1: the finical output of seysa during the life of project



Annex d2.2: the energy, cost and green gas emission (GHG) of seysa

Target

Summary

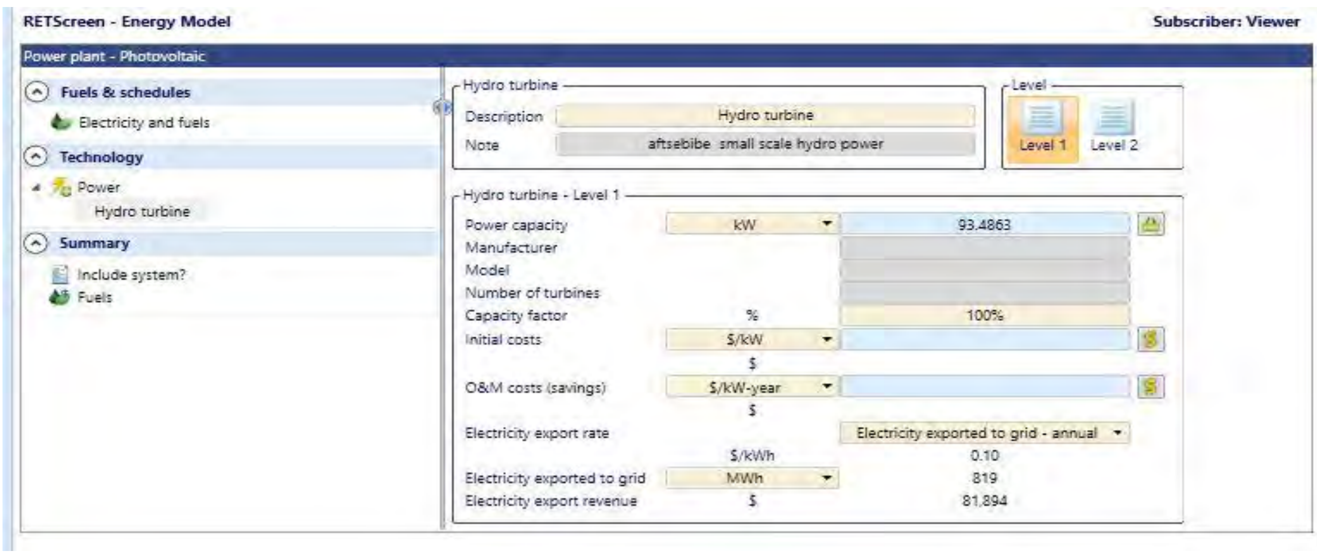
	Electricity exported to grid MWh	Electricity export revenue $	GHG emission reduction tCO_2
Proposed case	967	96,724	7.9

Annexd2.3: the turbine capacity and energy of seysa

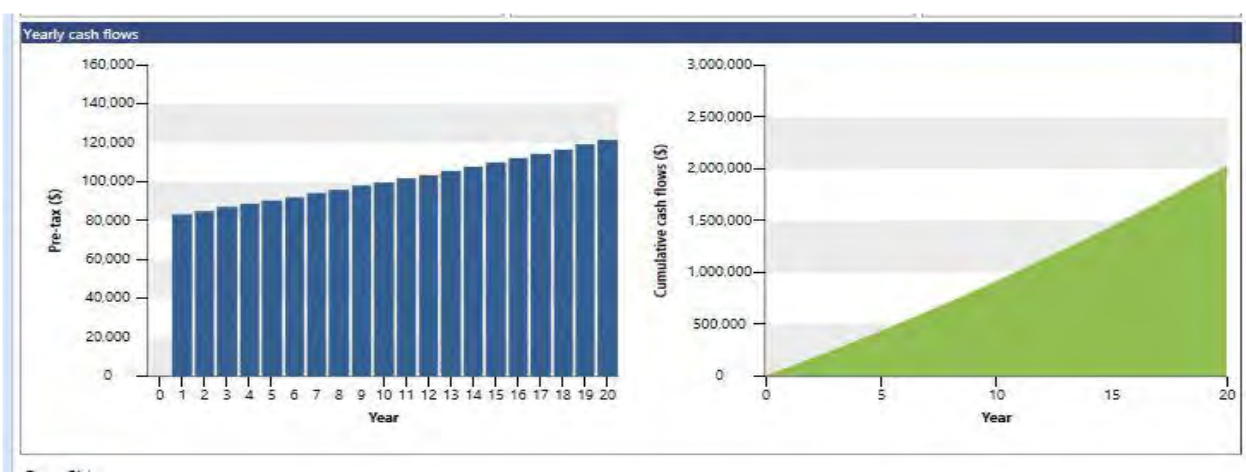
Hydro turbine		
Capacity	111	kW
Electricity	967	MWh

Notes

Annex d3: aftsebib dam result OF RET Screen software



Annex 3.1: finical graph of aftsebib dam



Annex d3.2: The power energy, cost and GHG of aftsebib

Executive summary

This report was prepared using the RETScreen Clean Energy Management Software. The key findings and recommendations of this analysis are presented below:

Target

	Electricity exported to grid MWh	Electricity export revenue $	GHG emission reduction tCO_2
Proposed case	819	81,894	6.7

Annex d3.3: capacity of turbine and energy

Hydro turbine		
Capacity	93.5	kW
Electricity	819	MWh

Notes

Annex d3.4: financial report of the aftsebib dam

RETScreen - Financial Analysis — **Subscriber: Viewer**

Financial parameters

General		
Inflation rate	%	2%
Discount rate	%	9%
Project life	yr	20
Finance		
Incentives and grants	$	
Debt ratio	%	70%
Debt	$	0
Equity	$	0
Debt interest rate	%	7%
Debt term	yr	15
Debt payments	$/yr	0
Income tax analysis		☐

Annual revenue

Electricity export revenue		
Electricity exported to grid	MWh	819
Electricity export rate	$/kWh	0.10
Electricity export revenue	$	81,894
Electricity export escalation rate	%	2%
GHG reduction revenue		
Gross GHG reduction	tCO_2/yr	7
Gross GHG reduction - 20 yrs	tCO_2	134
GHG reduction revenue	$	0
Other revenue (cost)		☐
Clean Energy (CE) production revenue		☐

Costs | Savings | Revenue

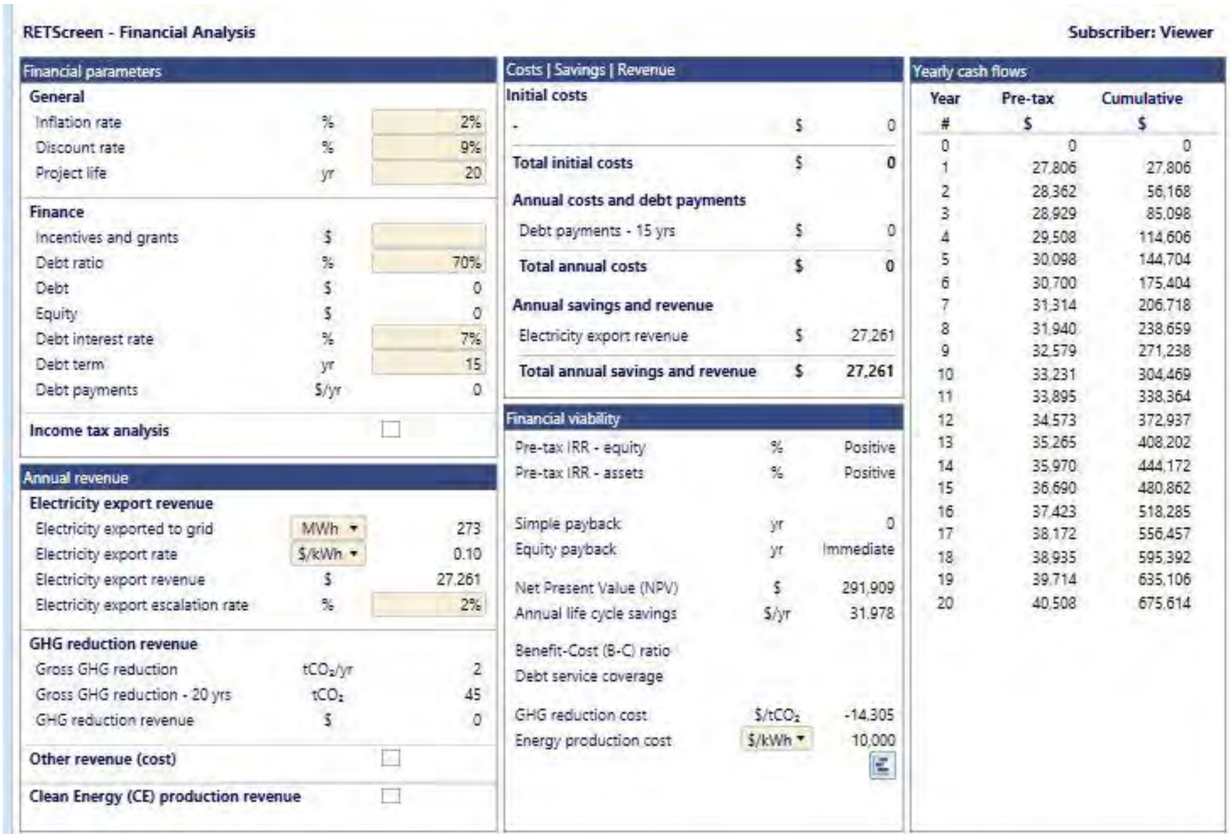
Initial costs		
-	$	0
Total initial costs	$	**0**
Annual costs and debt payments		
Debt payments - 15 yrs	$	0
Total annual costs	**$**	**0**
Annual savings and revenue		
Electricity export revenue	$	81,894
Total annual savings and revenue	**$**	**81,894**

Financial viability

Pre-tax IRR - equity	%	Positive
Pre-tax IRR - assets	%	Positive
Simple payback	yr	0
Equity payback	yr	Immediate
Net Present Value (NPV)	$	876,919
Annual life cycle savings	$/yr	96,063
Benefit-Cost (B-C) ratio		
Debt service coverage		
GHG reduction cost	$/$tCO_2$	-14,305
Energy production cost	$/kWh	10,000

Yearly cash flows

Year	Pre-tax	Cumulative
#	$	$
0	0	0
1	83,532	83,532
2	85,203	168,734
3	86,907	255,641
4	88,645	344,286
5	90,418	434,703
6	92,226	526,929
7	94,070	621,000
8	95,952	716,952
9	97,871	814,822
10	99,828	914,651
11	101,825	1,016,476
12	103,861	1,120,337
13	105,939	1,226,276
14	108,057	1,334,333
15	110,219	1,444,552
16	112,423	1,556,975
17	114,671	1,671,646
18	116,965	1,788,611
19	119,304	1,907,915
20	121,690	2,029,605



RETScreen - Financial Analysis

Subscriber: Viewer

Financial parameters

General		
Inflation rate	%	2%
Discount rate	%	9%
Project life	yr	20
Finance		
Incentives and grants	$	
Debt ratio	%	70%
Debt	$	0
Equity	$	0
Debt interest rate	%	7%
Debt term	yr	15
Debt payments	$/yr	0
Income tax analysis		

Annual revenue

Electricity export revenue		
Electricity exported to grid	MWh	273
Electricity export rate	$/kWh	0.10
Electricity export revenue	$	27,261
Electricity export escalation rate	%	2%
GHG reduction revenue		
Gross GHG reduction	tCO_2/yr	2
Gross GHG reduction - 20 yrs	tCO_2	45
GHG reduction revenue	$	0
Other revenue (cost)		
Clean Energy (CE) production revenue		

Costs | Savings | Revenue

Initial costs		
-	$	0
Total initial costs	$	**0**
Annual costs and debt payments		
Debt payments - 15 yrs	$	0
Total annual costs	$	**0**
Annual savings and revenue		
Electricity export revenue	$	27,261
Total annual savings and revenue	$	**27,261**

Financial viability

Pre-tax IRR - equity	%	Positive
Pre-tax IRR - assets	%	Positive
Simple payback	yr	0
Equity payback	yr	Immediate
Net Present Value (NPV)	$	291,909
Annual life cycle savings	$/yr	31,978
Benefit-Cost (B-C) ratio		
Debt service coverage		
GHG reduction cost	$/$tCO_2$	-14,305
Energy production cost	$/kWh	10,000

Yearly cash flows

Year	Pre-tax	Cumulative
#	$	$
0	0	0
1	27,806	27,806
2	28,362	56,168
3	28,929	85,098
4	29,508	114,606
5	30,098	144,704
6	30,700	175,404
7	31,314	206,718
8	31,940	238,659
9	32,579	271,238
10	33,231	304,469
11	33,895	338,364
12	34,573	372,937
13	35,265	408,202
14	35,970	444,172
15	36,690	480,862
16	37,423	518,285
17	38,172	556,457
18	38,935	595,392
19	39,714	635,106
20	40,508	675,614

Fig: capacity curve of seysa dam

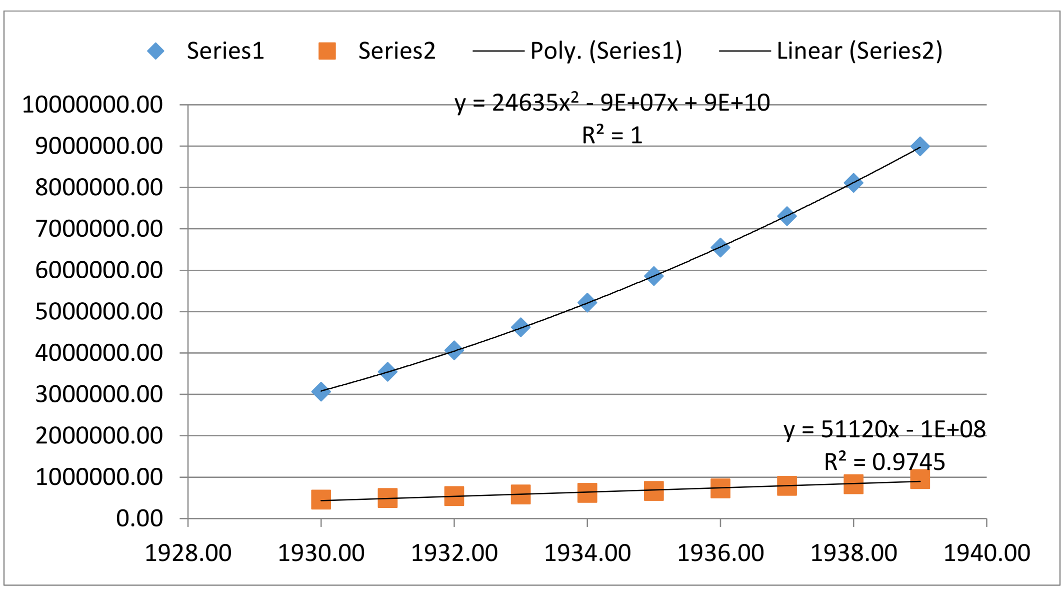


Fig: capacity curve of the serenta dam

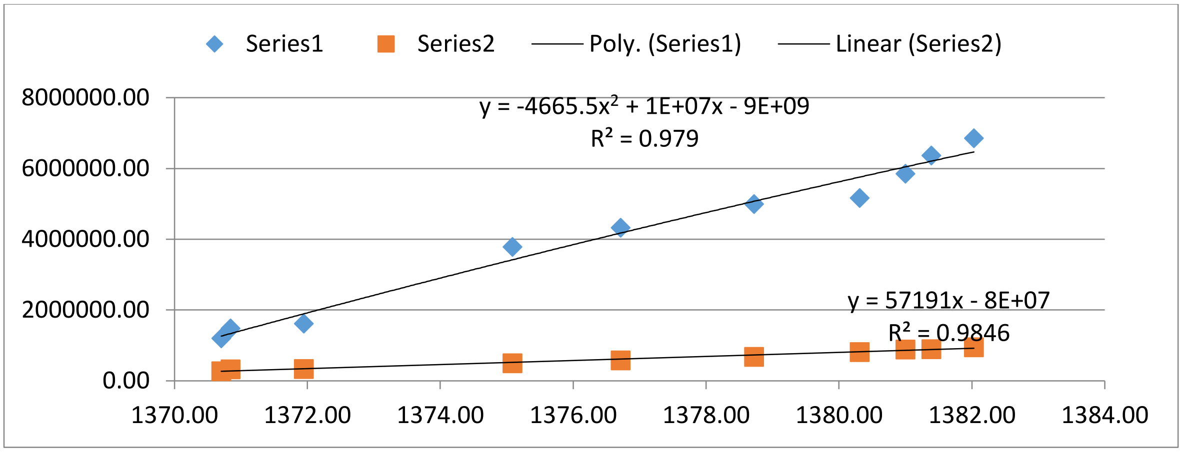


Fig: Aftsebib capacity curve of aftsebibe dam

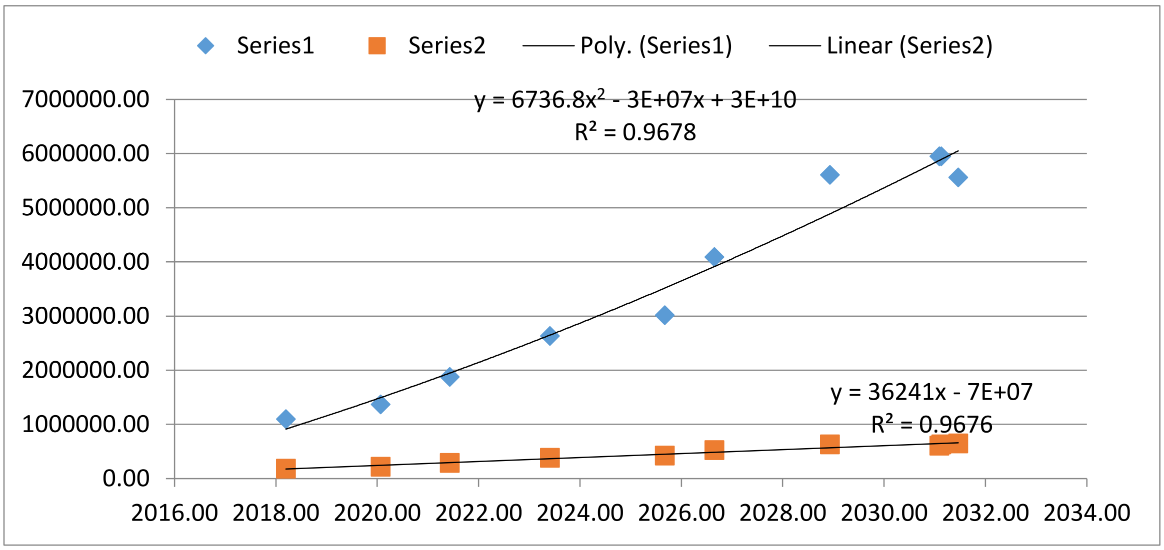


Fig: migorzo capacity developed curve

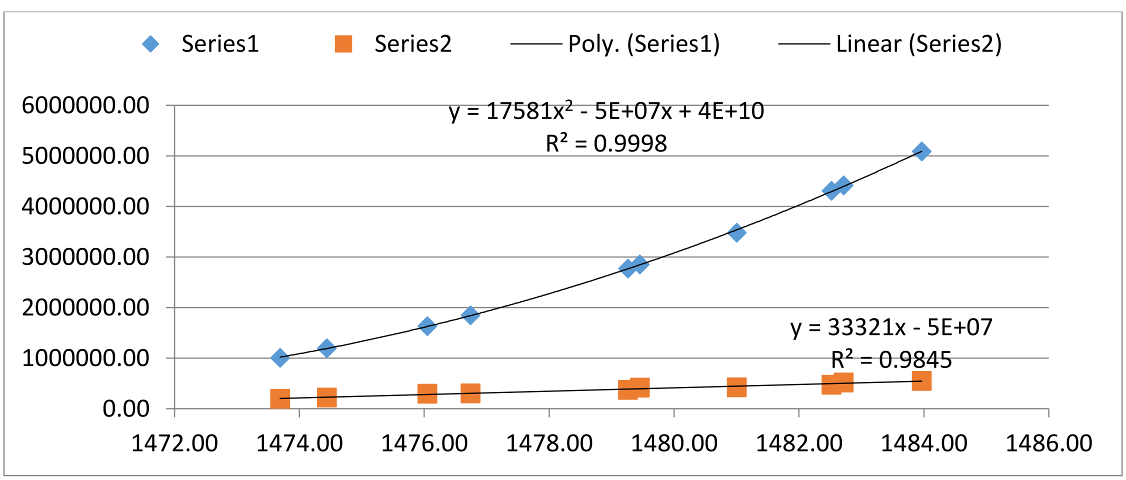


Table: migorzo estimated power, energy and cost calculated

Elevation(m)	Volume(Mm3)	Area (sq.km)	Month	Q m3/s	Month	**DAYS**	**Inflow**	**Outflow**	**m3/decade**
1473.692	*1010727.67*	*198,325.01*	Jan	0	10	31	0.01223	0.687713	1841971.778
1474.441	*1197843.69*	*224,668.39*	Feb	0	11	28	0	0.387375	937138.2222
1476.051	*1634486.41*	*297,233.05*	Mar	0	12	31	0	0	0
1476.74	*1849257.76*	*308,715.86*	Apr	0.0025416	1	30	0	0.393963	1021153.333
1479.262	*2777311.69*	*377,900.63*	May	0.0094235	2	31	0	0.723798	1938619.444
1479.452	*2858781.18*	*419,188.14*	Jun	0.2380542	3	30	0	0.980859	2542386.667
1481.003	*3481908.46*	*425,446.09*	Jul	0.5248584	4	31	0.00254	0.672966	1802470.889
1482.519	*4315142.75*	*480,022.89*	Aug	0.5969052	5	31	0.00942	0.170024	455393.4444
1482.716	*4417116.97*	*518,873.90*	Sep	0.3386667	6	30	0.23805	0	0
1483.965	*5088826.78*	*556,072.52*	Oct	0.0122281	7	31	0.52486	0.068844	184391.4444
			Nov	0	8	30	0.59691	0	0
			Dec	0	9	31	0.33867	0	0
Dead storage level		1473				minimum flow	0		
1472.5	canal level					max flow	0.59391		

Volume 1	**Elevation** (m)	**Area**	**Gross head(m)**	**Head Loss**	**net head(m)**	**Efficiency**	**Power**	**Energy**	**cost**
4417116.97	1482.866242	510000.235	10.36624	0	10.36624	0.9	62.94198	0.046829	32311.89
4417115.16	1482.866238	510000.0844	10.36624	0	10.36624	0.9	35.45394	0.023825	16439.28
4417114.22	1482.866235	510000.0064	10.36624	0	10.36624	0.9	0	0	0
4417114.22	1482.866235	510000.0064	10.36624	0	10.36624	0.9	36.05691	0.025961	17913.07
4417113.2	1482.866233	509999.9214	10.36623	0	10.36623	0.9	66.24447	0.049286	34007.26
4417111.26	1482.866228	509999.76	10.36623	0	10.36623	0.9	89.77158	0.064636	44598.52
4417108.72	1482.866221	509999.5483	10.36622	0	10.36622	0.9	61.59207	0.045825	31618.91
4417106.92	1482.866217	509999.3989	10.36622	0	10.36622	0.9	15.5612	0.011578	7988.499
4417106.49	1482.866216	509999.3631	10.36622	0	10.36622	0.9	0	0	0
4417107.11	1482.866217	509999.4144	10.36622	0	10.36622	0.9	6.300821	0.004688	3234.59
4417108.33	1482.866221	509999.5161	10.36622	0	10.36622	0.9	0	0	0
4417109.88	1482.866224	509999.6449	10.36622	0	10.36622	0.9	0	0	0
							31.16025	0.272626	188112

Table: Serenta hydro power production

Elevation (m)	Volume(Mm3)	Area (sq.km)	Month	Q m3/s	Month	**DAYS**	**Inflow**	**Outflow**	**m3/decade**
1370.706	1194884.59	272233.5733	Jan	0	9	31	0.33037	1.024254	2743362.222

1370.845	1478674.197	325104.6733	Feb	0	10	28	0.04365	0.576942	1395737.777
1371.948	1612148.523	330952.3264	Mar	0	11	31	0	0	0
1375.085	3786034.407	491640.8785	Apr	0.008234	12	30	0	0.586754	1520866.666
1376.714	4326465.732	575367.0774	May	0.021304	1	31	0	1.077996	2887305.555
1378.721	4993667.725	674819.9665	Jun	0.248	2	30	0	1.460854	3786533.332
1380.31	5165544.292	810867.2685	Jul	1.142209	3	31	0	1.002289	2684531.112
1381	5855297.068	880778.3258	Aug	1.312087	4	31	0.00823	0.253228	678245.5565
1381.389	6367388.959	893923.6375	Sep	0.330372	5	30	0.0213	0	0
1382.033	6853103.776	950599.1207	Oct	0.043646	6	31	0.248	0.102533	274625.555
			Nov	0	7	30	1.14221	0	0
			Dec	0	8	31	1.31209	0	0
Dead storage level		1362.63				minimum flow	0		
1358						max flow	1.31209		

Volume 1	**Elevation** (m)	**Area(m^2)**	**Gross head(** m)	**Head Loss(** m)	**net head(** m)	**Efficiency**	**Power**	**Energy(GW)**	**cost of energy(BIRR/KW)**
6367388.96	1381.552442	888133.6927	23.55244	0	23.55244	0.9	212.988	0.158463	109339.5298
6367387.1	1381.552438	888133.4672	23.55244	0	23.55244	0.9	119.9719	0.080621	55628.5588

6367385.81	1381.552435	888133.3106	23.55244	0	23.55244	0.9	0	0	0
6367385.81	1381.552435	888133.3106	23.55244	0	23.55244	0.9	122.0123	0.087849	60615.69181
6367384.29	1381.552432	888133.126	23.55243	0	23.55243	0.9	224.1633	0.166778	115076.4913
6367381.4	1381.552426	888132.7756	23.55243	0	23.55243	0.9	303.7763	0.218719	150916.0871
6367377.62	1381.552418	888132.316	23.55242	0	23.55242	0.9	208.4203	0.155065	106994.6459
6367374.93	1381.552412	888131.9902	23.55241	0	23.55241	0.9	52.65728	0.039177	27032.14176
6367374.28	1381.552411	888131.9105	23.55241	0	23.55241	0.9	0	0	0
6367374.33	1381.552411	888131.9172	23.55241	0	23.55241	0.9	21.32124	0.015863	10945.47021
6367374.72	1381.552412	888131.9645	23.55241	0	23.55241	0.9	0	0	0
6367377.68	1381.552418	888132.3239	23.55242	0	23.55242	0.9	0	0	0
							105.4426	0.922534	636548.6167

Table: seysa dam site power, energy and cost estimated value

Elevation (m)	Volume(Mm3) 10^6	Area (sq.km)10^5	Month	Q m3/s	Month	DAYS	Inflow	Outflow	m3/decade
1930	3.06635865	4.575509	Jan	0.181673	11	31	0.20	0.82	2183168.80
1931	3.5427834	4.952986	Feb	0.217112	12	28	0.16	0.45	1096697.28
1932	4.05895965	5.370539	Mar	0.231819	1	31	0.18	0.63	1675323.08
1933	4.6165238	5.780744	Apr	0.218544	2	30	0.22	0.96	2494280.40
1934	5.21571465	6.203073	May	0.227105	3	31	0.23	1.36	3649783.76

1935	5.85780175	6.638669	Jun	0.281871	4	30	0.22	1.63	4213557.60
1936	6.55073235	7.219943	Jul	0.978171	5	31	0.23	1.08	2893314.32
1937	7.3040493	7.846396	Aug	1.930683	6	31	0.28	0.61	1621923.72
1938	8.1076769	8.226156	Sep	0.856518	7	30	0.98	0.54	1405088.40
1939	8.9938857	9.49802	Oct	0.286111	8	31	1.93	0.02	48341.40
1940	9.9800874	10.226014	Nov	0.195166	9	30	0.86	0.00	0.00
1941	11.05521636	11.27656513	Dec	0.160009	10	31	0.29	0.71	1895121.76
Dead storage level						minimum flow	0.16		

Continuous

Volume 1*10^3	Elevation*10^3	Area*10^6	Gross head	Head Loss	net head	Efficiency	Power	Energy	Cost of energy
11.06	1.94	10.75	1942.562100	0.00	1942.56	0.90	13979.71	10.40	7176626.33
8.99	1.94	9.16	1939.440504	0.00	1939.44	0.90	7762.52	5.22	3599327.25
8.99	1.94	9.16	1939.440503	0.00	1939.44	0.90	10710.53	7.97	5498359.59
8.99	1.94	9.16	1939.440501	0.00	1939.44	0.90	16477.76	11.86	8186152.70
8.99	1.94	9.16	1939.440498	0.00	1939.44	0.90	23333.49	17.36	11978479.70
8.99	1.94	9.16	1939.440493	0.00	1939.44	0.90	27835.69	20.04	13828768.33
8.99	1.94	9.16	1939.440488	0.00	1939.44	0.90	18497.29	13.76	9495769.87

Table: aftsebibe power and cost determined value

Elevation (m)	Volume(Mm3)	Area (sq.km)	Month	Q m3/s	Month	**DAYS**	**Inflow**	**Outflow**	**m3/decade**

2018.197	1.10E+06	180951	Jan	0.1322829	10	31	0.10476	0.530093	1419800
2020.07	1.37E+06	219124	Feb	0.0337023	11	28	0.02429	0.524306	1268400
2021.434	1.88E+06	287801	Mar	0.0505538	12	31	0	0.994213	2662900
2023.406	2.63E+06	380046	Apr	0.1588238	1	30	0.13228	1.310185	3396000
2025.677	3.02E+06	422371	May	0	2	31	0.0337	1.4375	3850200
2026.654	4.09E+06	525525	Jun	0.5567934	3	30	0.05055	1.037037	2688000
2028.931	5.61E+06	629763	Jul	1.221155	4	31	0.15882	0.284722	762600
2031.091	5.95E+06	603338	Aug	1.3913499	5	31	0	0.306713	821500
2031.127	5.95E+06	629763	Sep	0.2324093	6	30	0.55679	0.190972	495000
2031.467	5.56E+06	649188	Oct	0.104758	7	31	1.22115	0	0
			Nov	0.0242943	8	30	1.39135	0	0
			Dec	0	9	31	0.23241	0.690972	1850700
Dead storage level		2014				minimum flow	0		
2013	out let location					max flow	1.4375		

Continuous

Volume 1(m^3)	**Elevation(m)**	**Area(m^2)**	**Gross head(m)**	**Head Loss**	**net head(m)**	**Efficiency**	**Power**	**Energy(GW)**	**cost**
5.95E+06	2031.27482	651003.6603	18.27482	0	18.27482	0.9	85.52959	0.063634	43907.47
5557206	2030.320296	616410.8669	17.3203	0	17.3203	0.9	80.17728	0.053879	37176.6

5557204.79	2030.320293	616410.7595	17.32029	0	17.32029	0.9	152.0359	0.113115	78049.16
5557202.13	2030.320287	616410.5232	17.32029	0	17.32029	0.9	200.3546	0.144255	99536.16
5557199.07	2030.320279	616410.2523	17.32028	0	17.32028	0.9	219.8236	0.163549	112848.6
5557195.31	2030.32027	616409.9186	17.32027	0	17.32027	0.9	158.5844	0.114181	78784.73
5557192.76	2030.320264	616409.6917	17.32026	0	17.32026	0.9	43.5399	0.032394	22351.64
5557192.42	2030.320263	616409.6617	17.32026	0	17.32026	0.9	46.90273	0.034896	24077.99
5557191.6	2030.320261	616409.5888	17.32026	0	17.32026	0.9	29.20358	0.021027	14508.34
5557192.55	2030.320264	616409.673	17.32026	0	17.32026	0.9	0	0	0
5557195.82	2030.320272	616409.9632	17.32027	0	17.32027	0.9	0	0	0
5557199.42	2030.32028	616410.2833	17.32028	0	17.32028	0.9	105.664	0.078614	54243.67
							93.48463	0.819543	565484.4

Fig: cost of seysa dam

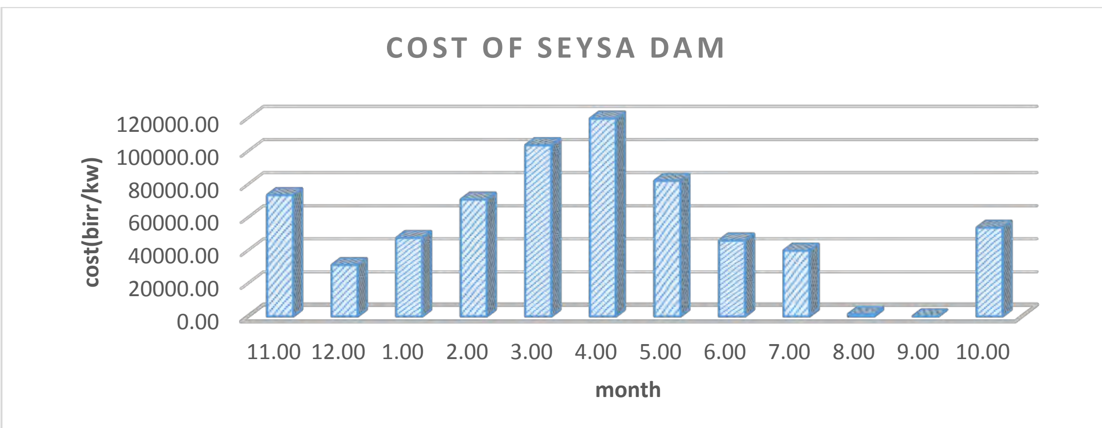


Fig: cost of aftsebibe dam

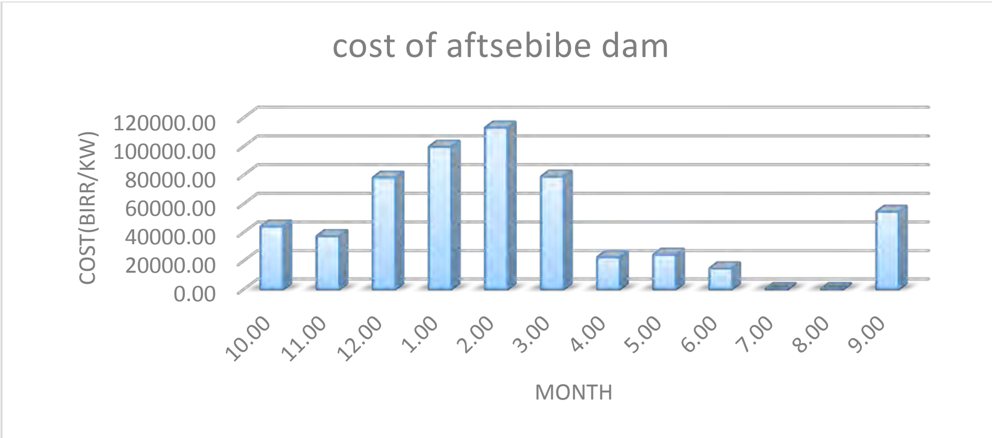


Fig: cost of the migorzo dam