UNIVERSITY of RWANDA

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DEPARTMENT OF MECHANICAL AND ENERGY ENGINEERING

MASTER OF SCIENCE IN RENEWABLE ENERGY

Master's Thesis

TOPIC:

"Assessment of existing Pico hydro power plant in powering remote area in Rwanda (case study: Mudasomwa Pico hydro power plant)"

A thesis submitted in partial fulfillment of the requirements for the award of Master of Science in Renewable Energy.

Submitted by:

MUKWINDI Uwineza Nicole (Ref.No: 217036740)

Supervisor:

Dr Ernest MAZIMPAKA

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DECLARATION

I, NICOLE UWINEZA MUKWINDI, declare that this thesis is my original work and has never been submitted to any university or institution.

Signature…………………….. Date ………………………..

Nicole Uwineza MUKWINDI

This thesis has been submitted for examination with our approval as the university supervisor:

Signature: …………………. Date …………………

Dr ERNEST MAZIMPAKA
University of Rwanda

DEDICATION

As well as everything that I do, I would be honor to dedicate this final research to my lovely little heaven family especially my beloved husband Fraterne and my son Yan for their obedience which provides me a constant source of joy and pride.

ACKNOWLEGEMENTS

The completion of this research project could not have been possible without the participation and assistance of so many people whose names may not all be enumerated.

I am using this opportunity to express my gratitude to everyone who supported me throughout this research project. Thanks go to all those who, closely or remotely, physically or morally helped me during this research project.

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I would like also to thank my project supervisor **Dr Ernest Mazimpaka** and all the people who provided me with the facilities being required and conductive conditions for my research project, especially Thanks goes also to HOBUKA Ltd staff for providing all supports to complete my research project on Mudasomwa Pico hydro power plant.

May the almighty God reward you accordingly!

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EUCL: Energy Utility Corporation Limited

EDCL: Energy Development Corporation Limited

REG: Rwanda Energy Group

MININFRA: Minister of infrastructure

kW: Kilo Watt

MWh: Mega Watt Hour

ABSTRACT

Hydro power plants can be classified according to many aspects among others we can mention production capacity, type of dams and so on...

Hydropower plant with minimum production (0-100kW) normal benefits in terms of investment cost because its low, and also the design is easy and simple compared to mini hydro and large hydro power plant.

Research and project are being done to reduce cost in the design, installation, Operation and Maintenance of hydro power plants, this is done as well as on Pico hydro power plants.

The only purpose is to reach even to the poorest people living in remote area or isolated to the main grid.

In my research, a case study of Mudasomwa Pico hydro power plant (34kW) has been taken, the power plant is being constructed in hilly and remote area, between Remera and Uwumusebeya Cells. This site is around 20 km from the nearest national grid and 1 km from the nearest road.

In the villages nearby, people lives normal life as other people in remote villages around the country, their life is based on agriculture, they have schools around, health center, churches and Small shops.

The people in villages are excited to be connected to the power plant, some are still having difficult to understand how it works because it will be their first time to live in an electrify world.

The life of the villagers before being connected to electricity was examined, a visit was done, as well as interviews and taking notes, the projection of what will be their future life after being connected including the improvement of education sector, reducing pollution, advancement in agriculture and creation of small business was revealed.

My research has a purpose to show how such plants improve the wellbeing of local population and to recommend the Government of Rwanda and private sector to boost and attract the number of investment in powering remote and rural area through localizing all remote area with potential streams and population.

This energy may be used not only for lightning but also in agriculture development (mainly irrigation) as well as preparing agriculture production from raw material to final products

CHAPTER I: INTRODUCTION

1.1 INTRODUCTION

Rwanda is developing country and is landlocked between Uganda, Tanzania, Burundi and DRC in Eastern Africa. The country is equipped with renewable energy resources. Currently, the overall capacity to generate electricity in our country is 221.1 MW it's come to more than 40 power plants, more percentage is hydro. Only 0.9% of the available capacity is imported while the rest is domestically generated. 46.4 % is from hydrological resources, and thermal sources (Fuel and peat) with 33.4%, Methane Gas (13.8%) and Solar (REG, 2019). Small hydro-power in particular has a significant potential for rural power supply with many remote zones rivers unexploited. (power, 2000)

The highly request for electricity is continually developing. Accessibility of useable power in the form of electricity has taken essential component of our daily lives. World trend shows that the demand for electrical energy in developing countries in particular normally grows at a rate faster than the rate at which generation can be ensured. The consequent ever-escalating gap between demand and supply of electricity therefore poses a challenge in technologically developing and advanced countries. (power, 2000)

Around the world, more than 1.2 billion people lack access to basic electricity service. The majority of those people are living in rural or isolated areas within the lower group. Steep costs and remote terrain often make it impractical or even impossible to extend the electric grid.

Energy access in general, and electricity access in particular, are widely recognized as essential to achieve development goals. In 2010 the United Nations has defined universal energy access as: "access to clean, reliable and affordable energy services for cooking and heating, lighting, communications and productive uses"

Our country is sacred with a geography including many hills and streams which present massive opportunities for the development of hydropower. There has been an increasing comprehension that electrification through mini/micro hydropower plants (MHPP) can play an important role in increasing the generation capacity in Rwanda as well as promoting the socioeconomic development of remote rural areas. Nowadays, the majority of the mini/micro hydropower plans in Rwanda have been promoted through public schemes, which are financed by the Government of Rwanda (GoR) or by international development partners and operated by the public utility. (EWSA, 2004)

Obstacles linked with hydropower development and operation in Rwanda is mainly the low participation of private sector in the development and operation of the plants. To overcome this, the Government have decided to develop and then transfer them to the private sector for operation, this incentive is expected to boost their participation as the involved risks will be minimized. Another issue is topography at the River banks which is responsible for soil erosion and landslides causing extensive siltation and sedimentation of the water bodies. The silt and sediments flow downstream and reach the turbine as slits and sediments with the potential to damage the mechanical parts of the turbines. Since this was identified, there has been a countrywide campaign to protect all the river banks by planting trees and grasses, and seasonal cleaning of rivers where possible**.** (EWSA, 2004)

At this time, 51% Rwandan houses have access to power, connected to the national grid (37%) or through off-grid systems (14%). As the target is 100% access to electricity, a national electrification plan has been elaborated to ensure that this target is reached in 7 years (by 2024). As the Government of Rwanda is promoting alternative sources of electricity such as solar home systems, a parallel policy has been approved to encourage people to make productive use of the power on the national grid, in order to bridge the demand-supply imbalance, while making economic sense of future energy investments. In 5 years (by 2022), 100% productive users will be connected.

The national Policy's approach on access to Electricity is that 52% of national population will be connected through grid extension while 48% will be connected through Off-grid. Currently off-grid connection is at 14%. **(MININFRA, 2019)**

When you travel around Rwanda, there are water streams (small rivers) and are not being exploited, there are also trading centers with high concentration of people not always far from these water streams that are not connected to the grid, and this allows to put small turbines and build distribution lines cheaper than extending the main grid.

Pico hydro is the hydro electricity generation methods with the maximum electric output less than 100KW. The recent improvement and innovations in Pico hydro technology have made it an easily available economic source of power even at remote places around the globe. This is a very versatile power source that could be used to generate AC electricity. Light bulb, radio, television and other similar electronic devices can be easily operated by using the Pico hydro power. (Jamal, 2015,August)

1.2 PROJECT DESCRIPTION

Pico hydro power plant is a form of renewable energy resources (hydro power plant), which is obtained from flowing water.

To create energy, water required to be flowing, water falling by gravity force, its potential energy converts into kinetic energy. This energy of the flowing water turns blades or vanes in a hydraulic turbines, the form of energy is changed to mechanical energy. The turbine turns the generator rotor which then converts this mechanical energy into electrical energy and the system is called hydro-electric power station. (Jamaludin, JANUARY,2013)

Pico hydropower system of small size profits in terms of price and easiness from different approaches in planning, design and installation than those which are applied to large hydro power. On a global scale, a very substantial market exists for Pico hydro system.

Several reasons are involved for the existence of this market.

- Hydro power plant with Pico size are easy to transport and install.
- For Pico hydro only small water flows are needed so there are many suitable places.
- The construction processes and design principles can be easily learned.
- Wisely calculated Pico Hydro schemes have a lower cost per kilowatt than solar or wind.

Mudasomwa Pico hydro Power Plant is one of the power plant which is ongoing project to power a remote area, a rural place in Nyaruguru district.

The place is in Ruheru Sector in Village called cyivugiza and Gitwa, The area to be powered is far of 20km from main grid and 265 Households are excited to be connected on grid.

The village has a hospital which use diesel generator, to lighten the house at night people use kerosene or candles which not only cause pollution but also expensive to them.

Near The place, there is a river which is being exploited to address all those issues,
The plant is expected to have a capacity of 34kW with a flow of 0.11m3/s and a head of 50m.
The plant will be located between Remera and Uwumusebeya Cells, Ruheru Sector.

How this project will be benefit to villagers especially and to the government in general, what will be the change after having electricity in the area.

1.3 PROBLEM STATEMENT

This research is conducted to show how potential Pico hydropower plant can help people in remote area to access electricity and to develop themselves.

Today, people in remote area are lack access to modern energy supply. They have insufficient lighting, no clean stoves for cooking food, no power tools for work or/and no communication devices.

The Government of Rwanda envisages transitioning from a developing country to a middle-income country. To achieve this goal, the country is targeting to access 100% electricity connectivity by 2024. Currently only 221.1 MW of installed generation capacity are available. According to the International Energy Agency (IEA), Rwanda's national electrification rate is estimated at 30% (12% in rural areas, 72% in urban areas).

When rural, isolated and remote communities' access to electricity, the effect on people can be intense for example: Children got encouraged to go to school because they have lighting, Kerosene tradition lamps which generate pollution are no longer used, enlightening people's work hours and health, people have more time to earn money or build home-based businesses.

In the rural area, many people make their life from agricultural and small informal businesses, They need energy and especially for taking advantage of additional income opportunities.

Pico hydropower plant will help people in remote area to access electricity and to develop themselves.

For living, people needs primary activities mainly in rural area we can mention phone charging, listening to radio, small shops, barber shops, small workshop, lighting for children to revise the courses, schools, hospitals, bars etc..

All these activities need electricity, many remote and rural area have small rivers that we can take advantage on them to produce electricity.

1.4 OBJECTIVES

1.4.1 General Objectives

The general objective of this project is to analyze and study the feasibility of using Pico hydropower plant to supply electricity to the remote area of Rwanda. (Case study: Mudasomwa Pico hydro power plant/ Nyaruguru district)

1.4.2 Specific Objectives

1. Study Technical and cost Problem on the site
2. Examine the living condition of people before the project and enumerate what will be the benefit after the project
3. Screening to government the potential we have to exploit the rivers either to use it in powering remote area or in irrigation system

1.5 SCOPE OF WORK

Mudasomwa Pico hydro power plant is a plant which is under construction, I took this project a case study to prove that even in other area in Rwanda can be powered using small rivers, the irrigation system can also be Improved using small rivers.

During my project research:

- Design of electric grid for our country Rwanda will not be part of this project research.
- The issues hydro power plant system control and stability won't be included in this project.

CHAPTER II: LITTERATURE REVIEW

2.1 INTRODUCTION

According to Maher hydro power history started nearly 2000 years ago when the Greeks used water wheels to grind wheat into flour. In the 1700's, hydropower was broadly used for milling of lumber and grain and for pumping irrigation water. Appleton, Wisconsin became the first operational hydroelectric generating station in the United States, in 1882, producing 12.5 kilowatts (kW) of power. The total electrical capacity generated was equivalent to 250 lights. Within the next 20 years roughly 300 hydroelectric plants were operational around the world. The invention of the hydraulic reaction turbine created the sudden expansion of hydropower. Nowadays, generating electric using hydro power become well-proven technology, relying on a non-polluting, renewable and indigenous resource; also can integrate easily with irrigation and water supply projects. (Maher, 2000)

2.2 HYDRO ELECTRIC HISTORY

Humans have used falling water to provide power for grain and saw mills, as well as a host of other applications. The first use of moving water to produce electricity was a waterwheel on the Fox River in Wisconsin in 1882; two years after Thomas Edison unveiled the incandescent light bulb. The first of many hydroelectric power plants at Niagara Falls was completed shortly thereafter. Hydropower continued to play a major role in the expansion of electrical service early in this century, both in North America and around the world. Contemporary Hydroelectric Power plants generate anywhere from a few kW, enough for a single residence, to thousands of MW, power enough to supply a large city. Early hydroelectric power plants were much more reliable and efficient than the fossil fuel fired plants of the day. This resulted in a proliferation of small to medium sized hydroelectric generating stations distributed wherever there was an adequate supply of moving water and a need for electricity. As electricity demand soared in the middle years of this century, and the efficiency of coal and oil fuelled power plants increased, small hydro plants fell out of favors. Most new hydroelectric development was focused on huge "mega-projects" (Maher, 2000)**.**

The majority of these power plants involved large dams which flooded vast areas of land to provide water storage and therefore a constant supply of electricity. In recent years, the environmental impacts of such large hydro projects are being identified as a cause for concern. It is becoming increasingly difficult for developers to build new dams because of opposition from environmentalists and people living on the land to be flooded. This is shown by the opposition to projects such as Great Whale (James Bay II) in Quebec and the Gabickovo-Nagymaros project on the Danube River in Czechoslovakia (Maher, 2000)

The Pico hydro is hydro power with a maximum electrical output of one hundred kilowatts (100kW). Hydro power systems of this size benefit in terms of cost and simplicity from different approaches in the design, planning and installation than those which are applied to larger hydro power.

Recent innovations in Pico-hydro technology have made it an economic source of power even in some of the world's poorest and most inaccessible places. It is also a versatile power source. AC electricity can be produced enabling standard electrical appliances to be used.

Common examples of devices which can be powered by Pico-hydro are light bulbs, radio and televisions.

2.3 RWANDA ENERGY SCENARIO

Currently, the total installed capacity to generate electricity in Rwanda is 221.1 MW from more than 40 power plants, mainly hydro. Only 0.9% of the available capacity is imported while the rest is domestically generated. By generation technology mix, 46.4 % is from hydrological resources, followed by thermal sources (Fuel and peat) with 33.4%, Methane Gaz (13.8%) and Solar (2%). (www.reg.rw)

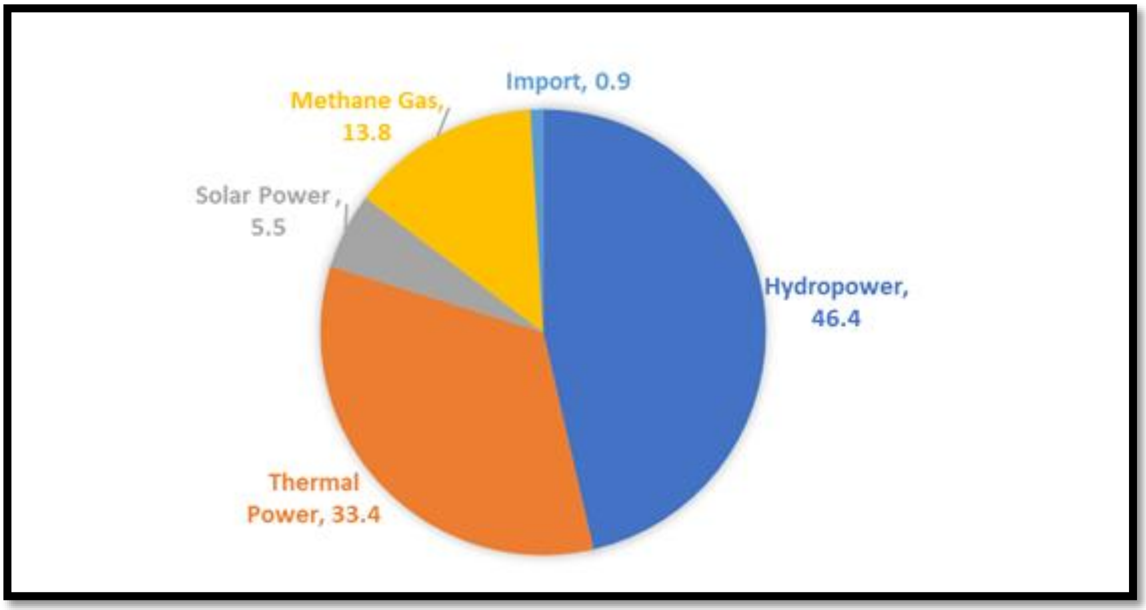

Figure 1: *Currently Total Capacity*

As part of the efforts to increase the current capacity, a number of projects to build new power plants are underway and will add more capacity on the existing national grid by the year 2024. These include among others Hakan peat to power plant which will add 80MW in 2020, Rusumo Falls Hydropower plant (26MW in 2021), Rusizi III (48.3MW in 2023), Symbion (50 MW in 2022) and Nyabarongo II (43.5 MW in 2024).

These projects are expected to considerably reduce the usage of expensive sources (fuel) and change the generation technology mix as indicated in the graph below:

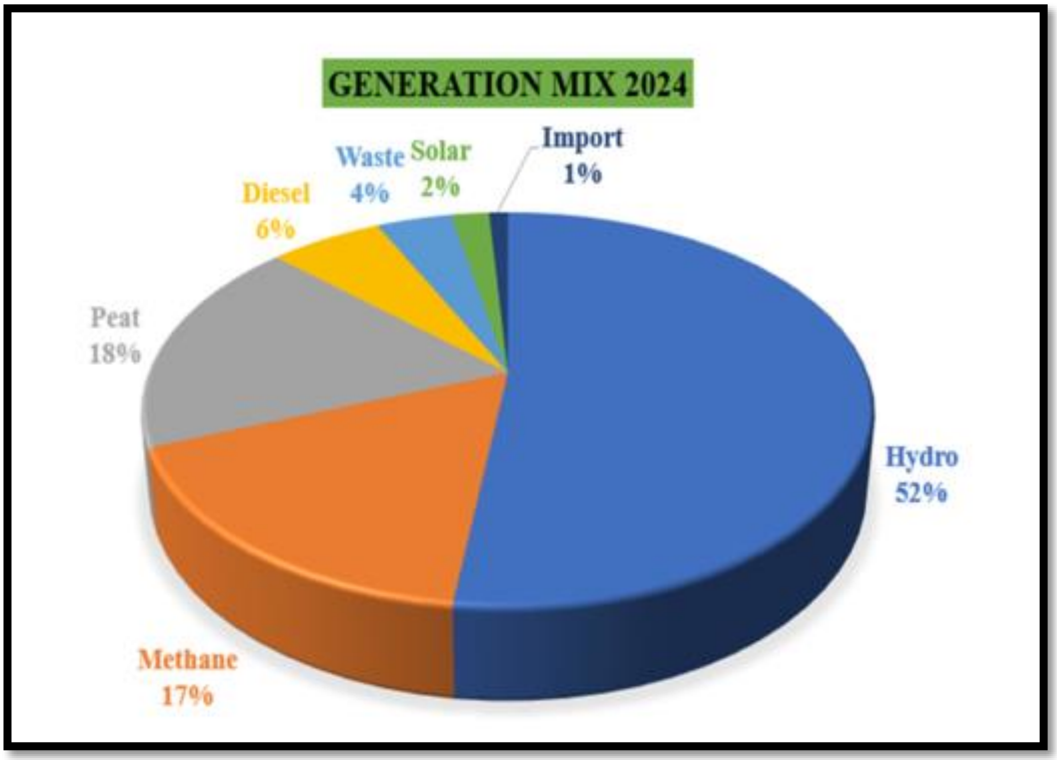

***Figure 2**: Generation mix 2024*

Off-grid micro hydropower plants

Currently, 11 micro hydropower plants MW exist in Rwanda as isolated networks. These plants were originally developed by the GoR, and handed over to private sector management to increase the private sector contribution in energy generation. GoR has recently leased out these sites to private investor to better operate, upgrade and connect them to the grid.

2.4 RURAL ELECTRIFICATION IN RWANDA

Cumulatively, for the last 7 years, a total of 16,162 kilometers of distribution network has been constructed across the country, in a bid to extend electricity producers to the end user. Of these, 5,590 km (35%) are Medium Voltage lines while 10,572 km (65%) are low voltage distribution lines. (REG, 2019)

Below map shows current existing and ongoing electricity distribution lines (Medium Voltage lines) as well as ongoing site.

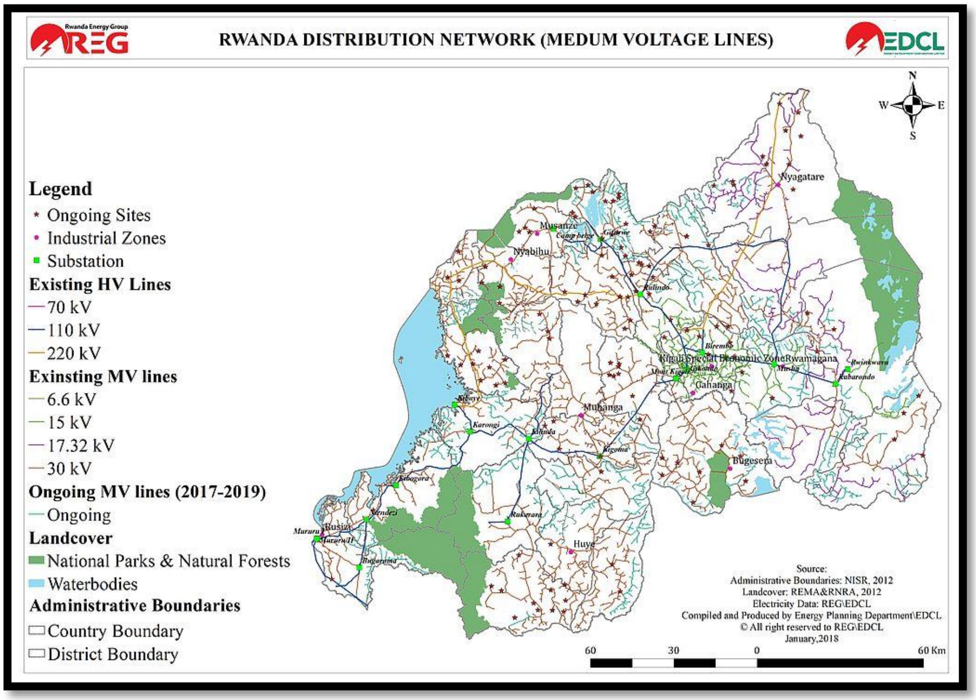

Figure 3: Rwanda's distribution network (source REG)

The Government developed rural electrification strategy in 2015 with the objective of ensuring that Rwanda’s households have access to electricity through the most cost effective means by developing programs that will facilitate both the end users to access less costly technologies and increase private sector participation in the provision of these solutions.

The four distinct programs in the strategy include; the provision of basic solar systems as a basic necessity to the less privileged population under Ubudehe 1, the establishment of a risk mitigation facility that will support the private sector, mechanisms that will increase, the development of mini-grids in suitable locations and the continued rollout of the Electricity Access Rollout Programme (EARP).

➢ **Energy Acess and consumption in Rwanda**

Rwanda Energy Mix

The modern energy sector access has grown on an outstanding pace. The access rate increased from 10% in 2010 to 13% in 2012 to 28.6% in 2016 to 43% in 2018.

As of January 2019, the total access to electricity in Rwanda is 51% whereby 37% of all households in Rwanda are connected to the national grid and 14% off grid mainly via solar energy. Average monthly household consumption of electricity is 20.8 kWh nationwide, 29.2 kWh in urban areas, and 9.9 kWh in rural areas**.** The number of on-grid connections has grown more than 10 times over the last 10 years (Figure 4).

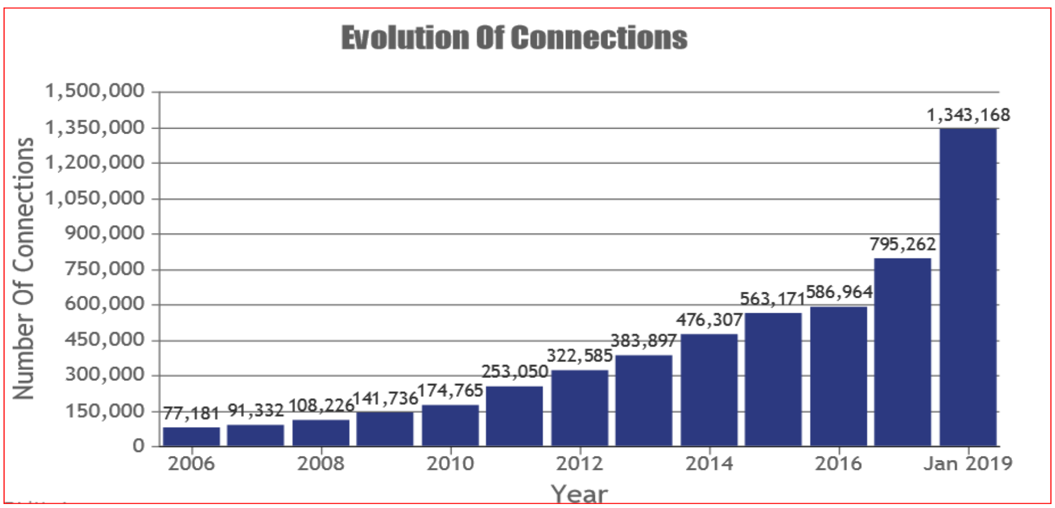

***Figure 4**: Evolution of electricity access by connection*

Source : Rwanda Energy Group (REG)

According to the National Strategy for Transformation approved in 2017, the Rwandan government has set a target to achieve 100% electrification by 2024 with 52% through grid connections and 48% through off-grid solutions.

As per January 2019 energy statistics are desegregated per district and province is as follows.as follow:

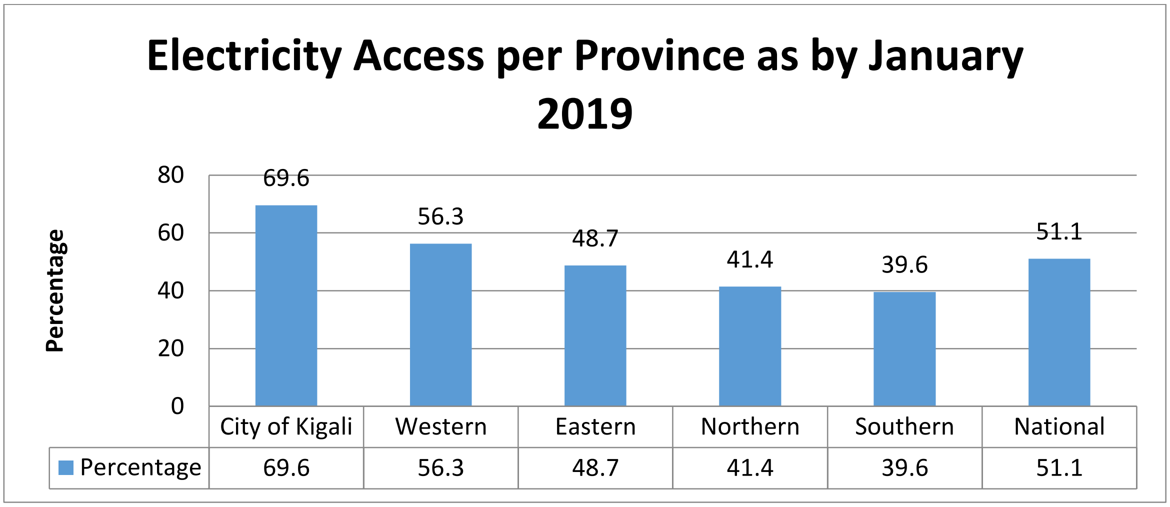

Figure 5: *Electricity access per province*

Source: EUCL, January 2019

Access per district in figure 6

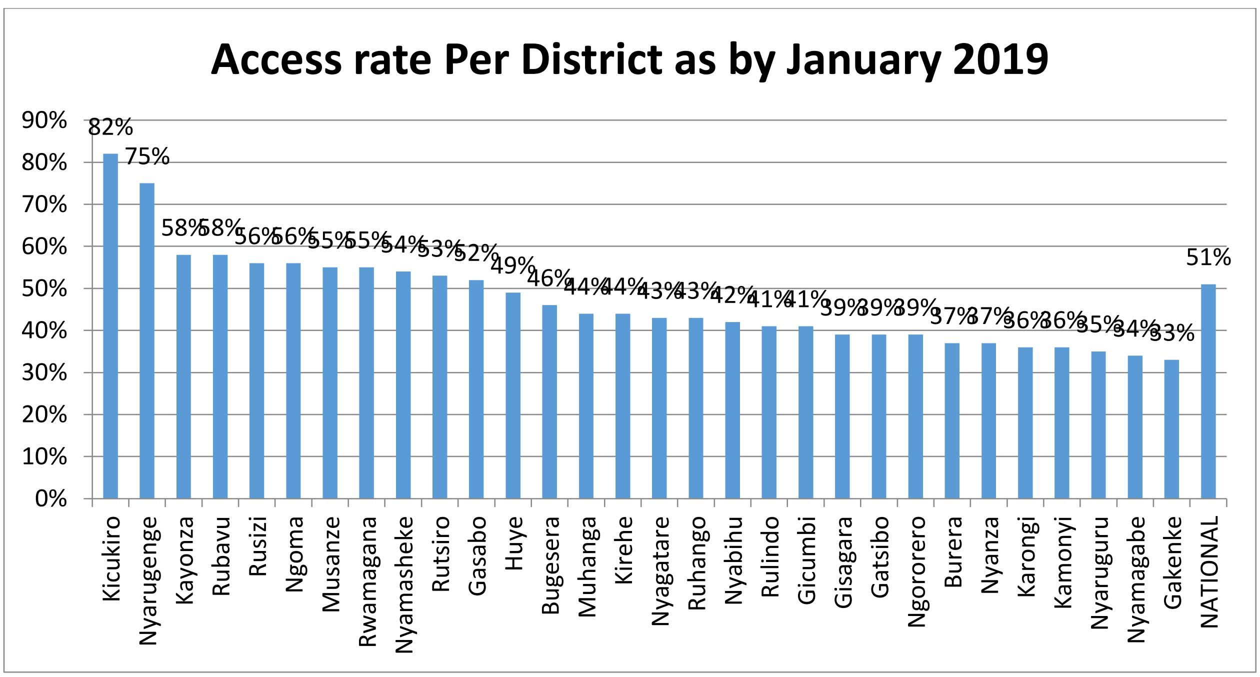

Figure 6 *Electricity access per district as per January 2019*

Source: EUCL, January 2019

2.5 DESIGN OF POWER PLANT AT MUDASOMWA PICO HYDRO POWER PLANT

2.5.1 Introduction

The energy of a hydropower system is captured from moving water for some valuable determination. Most of the place you can find streams and mountains, without polluting the air or water hydropower is a low-cost electricity to remote area. Also, hydropower is an advanced technology; for many years ago people gained energy from falling water. The power from hydro is still being extracted on many different ways to resolve many needs, even a small grain-grinding facilities to huge hydroelectric dams that provide electricity to entire cities. (Kapoor, 2013)

The hydropower plant can be listed referring to the size of power it produces:

Classification of Hydropower Plant.

Power Class

More than 10 MW Large

Less than 10 MW Small

Less than 1 MW Mini

Equal to 100 kW Micro

Less than 100 kW Pico (Kapoor, 2013)

Pico-hydro is a reference to define the smallest systems explaining hydroelectric power generation under 100kW. A Pico power technology can offer a small, isolated community with tolerable electricity to power televisions, radios, and light bulbs among other appliances.

2.5.2 Principle of Operation

The Power from hydro is obtained by taking the potential energy from water over difference height. The energy from the water is transformed to mechanical energy and can be used directly or can be changed to electrical by a generator. The term head, H, symbolize the quantity of pressure in the water. It measures to actual height difference the water travels. Power, P, is the energy converted over time or the rate of work being done. (Kapoor, 2013)

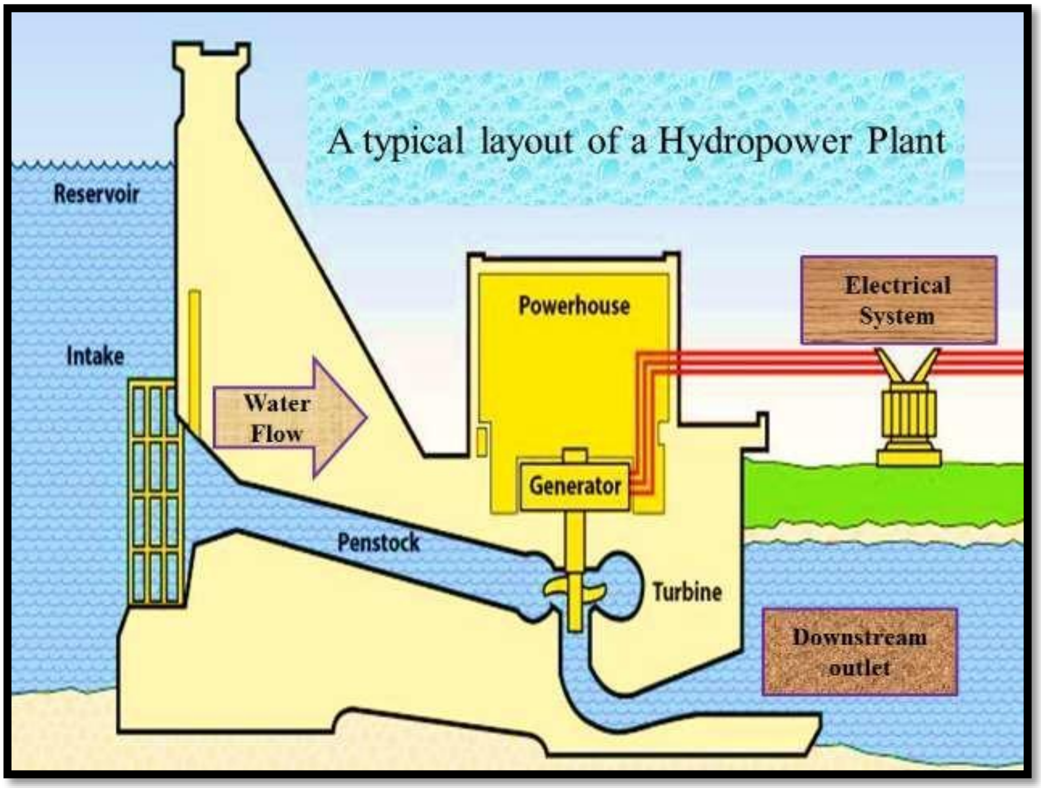

Figure 7: A typical layout of Pico hydro power plant

- **Dam:**

The most important component of hydro power plant is dam. To build a dam on a big river that has a meaning quantity of water throughout the year is applicable. The height of the river must be considered while building a dam to get the maximum possible potential energy from water. (Kapoor, 2013)

- **Water Reservoir :**

The place behind the dam where water is stored is called reservoir. The rest of the dam structure must be located high than the water in the reservoir and water in the reservoir agrees just how much potential energy the water possesses. When the height of water is higher, its potential energy is high too. When the position of water is high in the reservoir it enables it to move downwards naturally. (Kapoor, 2013)

- **Intake and Control Gates:**

Inside the dam there is the gates built on it. Through these gates water, you can release and control water from reservoir. They are called inlet gates because water enters the power generation unit through these gates. The water flows due to gravity through the penstock towards the turbines when the control gates are opened. We find potential as well as kinetic energy in the water flowing through the gates.

- **Penstock** :

The long pipe or the shaft commonly called penstock carries the flowing water from the reservoir towards the power turbine, and generator.

Due to its height, the water in the penstock has kinetic energy from motion and potential energy. The total amount of power generated in the hydroelectric power plant depends on the height of the water reservoir and the amount of water flowing through the penstock. The amount of water flowing through the penstock is controlled by the control gates. (Kapoor, 2013)

- **Water Turbines :**

Water flowing from the penstock is allowed to enter the power generation unit, which houses the turbine and the generator. When water falls on the blades of the turbine the kinetic and potential energy of water is converted into the rotational motion of the blades of the turbine. The rotating blades causes the shaft of the turbine to also rotate. The turbine shaft is enclosed inside the generator. In most hydroelectric power plants there is more than one power generation unit. There is large difference in height between the level of turbine and level of water in the reservoir. This difference in height, also known as the head of water, decides the total amount of power that can be generated in the hydroelectric power plant. There are various types of water turbines such as Kaplan turbine, Francis turbine, Pelton wheels etc. The type of turbine used in the hydroelectric power plant depends on the height of the reservoir, quantity of water and the total power generation capacity.

- **Generators:**

It is in the generator where the electricity is produced. The shaft of the water turbine rotates in the generator, which produces alternating current in the coils of the generator. It is the rotation of the shaft inside the generator that produces magnetic field which is converted into electricity by electromagnetic field induction. Hence the rotation of the shaft of the turbine is crucial for the production of electricity and this is achieved by the kinetic and potential energy of water. Thus in hydroelectricity power plants potential energy of water is converted into electricity.

- **Electronic Controller:**

An electronic controller is connected to the generator. This matches the electrical power that is produced to the electrical loads that are connected and stops the voltage from changing as devices are switched on and off.

- **Mechanical load**: The mechanical load is a machine connected to the turbine shaft using a pulley system so that the power can be drawn directly from the turbine. The rotating force of the turbine runner can be used to turn equipment such as grain mills or woodwork chinery.

- **Distribution System :**

It connects the electrical supply from the generator to the houses or schools. This is the most extensive part of the system. (Kapoor, 2013)

2.5.3 The design of the Mudasomwa Pico hydropower plant

Mudasomwa power plant was designed to help people from Cyivugiza and Gitwa village to come from remote area and black area to a lightning area, a developed area.
The cost of Mudasomwa was 200 000 dollars from shareholders and investors (HOBUKA ltd).

When I visited the power plant, they were ready for installing turbine machine and battery inside power house.

Main party of Mudasomwa Pico hydro power plant

The design of Mudasomwa Pico power plant is similar to the design of other small power plants

1. **Dam and intake :**

The construction of the dam or intake is normally done near the river where water is flowing. The intake has a trash rack which prevents branches, trees, stones and debris to enter in the conduit to prevent any harms of turbine.

When the pipe system has to be empty, intake gate is designed to let off the water delivery. A small gate is settled for drainage of the leakage through the main gate.

Mudasomwa river Dam

Civil Works for Intake

The intake is built main with rubble masonry works with a small quantity of reinforced concrete on the weir. 2 steel gates (manually operated) were installed and are fabricated locally. Unfortunately, this rubble masonry works is questionable on its resistance against water force and maintenance cost can be high and frequent.

Canal or Channel

From intake the water is conveyed through an open canal up to the reservoir. Open canals are usually made of masonry or PVC pipe for Pico project or concrete and steel pipes for big project.

Mudasomwa PP, the canal is built with burnt bricks masonry with smooth surface inside and water is conveyed. The challenge, is that with time the canal can face issues of leakages.
The channel has the following dimensions:

The length of the canal: 400m
Width: 0.75m
Height: 0.50m;
Wall thickness: 0.20m and
Longitudinal Slope: 2m/1000m

Figure 8: *Canal/ Channel at Mudasomwa pico hydro power plant*

Forebay tank and spillway

Figure 9: Forebay tank Mudasomwa Pico hydro power plant

The Forebay is built with rubble masonry works with smooth surface inside to allow flow of water and minimize leakages. Considering the size of the project, this is the optimum construction method that can be adopted for such type of plants.

Forebay is composed of:

- Flushing channel for cleaning purpose to remove sediments.
- A drain and flushing gate.
- Penstock gate to regulate the inflow
- Spillway for excess of water and safety
- Trash rack at the end of the sand trap to prevent solid and other waste material to enter in the penstock and damage the turbine.
- The longitudinal bed slope: 1m/30m

Penstock and power house

Figure 10: *Power house at Mudasomwa Pico hydro power plant*

Length of penstock: 120m;

No. of pipes (buried): 20 pieces; PVC pipes of PN 16 (nominal pressure);

Section of diameter: 0.200 m

The powerhouse is built with; rubble masonry for foundation, burnt bricks for walls, reinforced concrete for machine foundation and lintels and corrugated sheet with steel trusses for the roof. Ground pavement is smooth cement mortar.

Turbine Pelton Coupling The runner is directly mounted to the generator shaft Generator: Synchronous 50KVA 240/400V 1500RPM Control and protection system Electronic load controller will be installed with a ballast load.

Below is a table for civil works costs incurred during construction of Mudasomwa Pico Hydro power plant:

***Table 1** : Cost of civil works at Mudasomwa Pico hydro power plant*

Serial	**Items**	**Quantity**	**Unit Price (rwf)**	**Total Price (rwf)**
1	Rubble masonry	184 m^3	53,100	9,770,400
2	Reinforced concrete	17.3 m^3	280,000	4,844,000
3	Steel gates	5 pieces	256,100	1,280,500
4	Penstock pipe (PVC)	20 pieces	317,386	6,347,720
5	Corrugated sheet	22.8 m^2	4,300	95,030
6	Steel for truss	Lump sum	280,000	280,000
7	Entrance door-Steel	1piece	220,000	220,000
8	Contingencies	Lump sum	1,845,600	1,845,600
9	Total manpower cost	Lump sum	2,363,830	2,363,830
10	Overheads cost	Lump sum	2,740,140	2,740,140
Total cost for Civil works				**29,787,220**

2.5.3 Different innovation of Pico hydropower plant made recently

1. *DESIGN OF 5KW PICO HYDRO POWER PLANT USING TURGO TURBINE*

The Turgo turbine is an impulse turbine shown in fig below. The runner of turgo turbine look like a Pelton runner split in half. This turbine is used in medium head and high head of water. This is widely used in pico hydro power plant because the cost of the turbine is low.it can easily manufacture in minimum cost. Turgo turbines are mostly used in those days in rural areas electrification in pico hydro power plants. (Vipin, 2017)

Figure 11: *Design of Turgo turbine for 5kW*

DESIGN OF 5KW PICO HYDRO POWER PLANT BASED ON TURGO TURBINE CALCULATION:

Preparing the site data of power plant

Hg = Gross Head
Hj = Jet Head
Hn = Net Head
P = Pressure
ρ = Density of water
Vj = Velocity of Jet
D = Dia of runner
d = Dia of jet
Hf = Loss of Head
Q = Discharge of stream
U = Circumferential velocity

Ns = Specific Speed of turbine

g = gravity

nt = efficiency

Pj =jet power

Ps = shaft power (power output)

Cv = coefficient of velocity

N = speed of runner (rpm)

T = Torque

a. Calculation of the Net Head

For the pico-hydro scheme, hydraulic head H can be calculated at any location where elevation z, pressure p, and velocity v are known using

Hg = p/ρg+ v2/2g+z

The net Head Hn = Hg - Hf

Hg = The gross head which is the vertical distance between water surface level at the intake to the turbine Hf = Total Head losses due to open channel.(12)

These losses approximately equal to 6% of gross head

The jet Head

Hj = Cv2 Hn

b. Calculation of water flow rate

The water flow rate can be calculated by the measuring the river or stream flow velocity and its cross sectional area, then

Q=A×V A= Area of channel

V=Velocity of stream

c. Calculation of Power

P= ρ* g*Q* Hj Where ρ is the density of the fluid and g is gravity.

d. Calculation of the Turbine Speed (N)

The Correlation between the specific speed (Ns) and the Net Head is given

Ns= 85.49×√Nj/Hn.243

Where Nj =No. of jet N= Ns*Hn5/4/√P

e. Runner Design:

The mean velocity of the free jet emerging from the nozzle of the turbine is determined from the net head, by the equation

$$V_j = C_v\sqrt{2gH_n}$$

At the best efficiency point the circumferential speed of the runner is connected with the jet velocity via the relation.

$$U = (0.46\text{-}0.47)*V_j$$

Hence the Diameter or runner is

$$D = 60*U/\pi N$$

Where N is the speed of runner in rpm.

f. Diameter of Nozzle or Jet

$$d = \sqrt{4Q/\pi V_j}$$

g. Number of Buckets

$$Z = 15 + D/2d$$

h. Efficiency of turbine

Torque $T= Q*D*(V_j - U)$ Power transferred by the turbine shaft

$$P_s = 2\pi NT/60$$

Efficiency $\eta_t = P_s/P_j$ (12)

The most important part for this project is planning as install ability in resident house. There are many factors that determine the suitability of the system. This includes:

1. The amount of power available from water flow in the pipelines. This includes water pressure, volume of water available and friction losses in the pipelines.
2. The type of turbine and available generator type and capacity.
3. The type and capacity of loads to be supplied by the Pico Hydro.
4. The cost of developing the project and operating the system (Jamaludin, JANUARY,2013) (13)

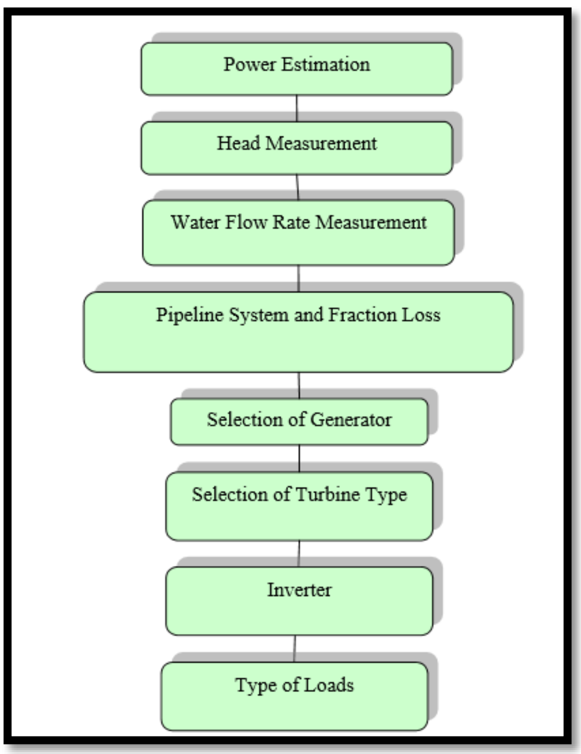

***Figure 12**: A procedure to plan pico hydro power system*

Power estimation

Potential energy is a kind of stored energy and the energy of position. The water in a water tank on top of a house is example of potential energy. The stored energy in the tank is converted into kinetic energy (motion) as the water flows down a large pipe call penstock and spin the turbine. The turbine spins a shaft inside the generator, where magnets and coils of wire convert the motion energy into electrical energy through a phenomenon called electromagnetism.

These are the step of water flow:

1. Water in a tank on top of a house flows through a filter that filters dust or sediment in the tank.

2. The water travel through a pipe called a penstock and been blast by high pressure water jet.

3. The force of the water spins a turbine at a high speed.

4. Water flows out of the penstock (Jamaludin, JANUARY,2013)

Head measurement

Head rate is very important parameter in hydropower. It is a measure of falling water at turbine which is calculated from begins of penstock to the turbine at the bottom. When determine head, we should observed static head first. This is due to the fix high of water tank in our house. For most of resident house, the high of water tank is 3-4 meter from ground.(13)

Water flow rate measurement

In fluid dynamic studies, water flow rate is the volume of fluid which passes through a given surface per unit time. The SI unit is m3 s-1 (cubic meters per second). In US Customary Units and British Imperial Units, volumetric flow rate is often expressed as ft3/s (cubic feet per second). (Jamaludin, JANUARY,2013)

3. DESIGN AND DEVELOPMENT OF PICO-HYDRO GENERATION SYSTEM FOR ENERGY STORAGE USING CONSUMING WATER DISTRIBUTED TO HOUSES

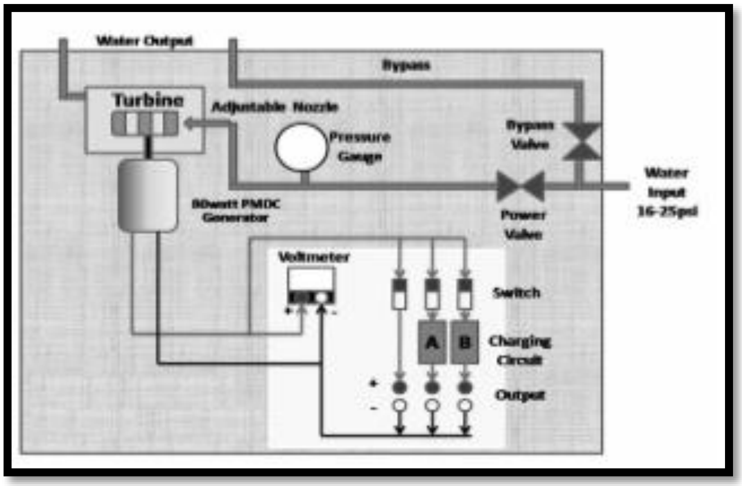

Figure 13: *Layout of proposed pico hydro power plant*

In general, the major concern in the development of the proposed pico-hydro system are civil works for small scale piping system or penstock from the consuming water outlet to the turbine and fabrication of the turbine (blades and drive shaft). Both parts determine the functionality and performance of the proposed system.

The piping system of the Pico hydro system is provided with a bypass pipeline via a “Bypass Valve” to reduce the wear and tear effect of the generator. When consumer not use this system, they can bypass the water flow by closing the “Power Valve” to the turbine and opening the “Bypass Valve” to the bypass pipeline. Therefore, the generator will not operate all the time until it is required by the user.

4. PROSPECT OF A PICO HYDRO POWER PLANT BASED ON IRRIGATION PUMP IN PERSPECTIVE OF RURAL AREAS IN BANGLADESH

This project proposes a design of a PHP in a village of Bangladesh. An irrigation pump, generally used to irrigate a farming land, is used as the main source of water for the PHP. Instead of a water reservoir, the pump is installed a few meters above ground level to account for the head of the water. The water from the pump is then driven through a pipeline (penstock) towards a specially manufactured Pelton turbine. The turbine is the prime mover of the shaft of the PMG. The hydro power which rotates the turbine is thus converted to electrical energy by the PMG.

Finally the electrical energy produced by the PMG is stored in one or multiple batteries using a simple battery charging circuit. And in the process, a very negligible amount of the original extracted water is lost, and thus the water continues its venture for irrigating the farming lands. (Naushad, 2011)

CHAPTER III: RESEARCH METHODOLOGY

3.1 INTRODUCTION

The purpose of my study is to assess already established Pico-hydro project in order to know if really it contribute to the development of the remote and rural area. To assess the Pico hydro power plant and its potential, three procedure may be taken into consideration technical, financial and social impacts.

Technical analysis establishes the site selection and technical problems evaluation.

Economic analysis looks on calculations of total investment cost and benefit of the feasible projects.

Social impact is assessed using the response of villagers to the questionnaires regarding what they think on the quality of life when usage of tradition cooking stove and kerosene compared to the electricity from the already established Pico-hydropower project.

3.2 RESEARCH METHODS

3.2.1 Analyze Technically

While analyzing Technical aspect we based on issues concerning the problems that can occur while producing electricity, we also look on flow obstacles such as loose leaves and branches as well as the uncontrollable flow rate of water that can occur while running generators.

Also, the system performances, durability of equipment, the quality of power, and technical maintenance should be considered. Following site topography at many mountain area, it is difficult to the durability of equipment, maintenance should be emphasize

3.2.2 Analyze Economically

To analyze the aspect economically I will look on how villagers have increased their income and reduced their expenditures before and after the projects has started on operation. On either side, the expense that has been reduced is a profit gained

From the cost of fuel that were used for the diesel engine in the past and the Pico-hydro system's maintenance cost. For total system feasibility evaluation, a comparison of total outcomes and the total cost of the project are conducted. In addition, all the benefit of the project can be redirected by the ratio of the outcomes and total project investment cost.

3.2.3 Analyze socially

To analyze the project in social aspect, I will take consideration the impacts of villagers' quality of life before and after the project.

The assessment of Pico hydro power plant requires as a preliminary stage data collection for the project work to be carried out effectively. This include the number of house that are connect on the power plant, the benefit of the people accessing the Pico hydro, then I did evaluation of the villagers' quality of life through questionnaires focusing on the change they think will happen when they will start using of electricity.

3.2.4 Site visit

According to electricity accessibility published by Energy Development corporation limited in year 2015-2016 , Nyaruguru and gicumbi district were among districts with low accessibility, this is because of the remote area and hills found in these districts.

District of Nyaruguru

Nyaruguru is in Southern Province of Rwanda. the capital city is **Kibeho**, this is commonly visited by catholic church and is used as a pilgrimage site.

It has 14 sectors commonly called imirenge in Kinyarwanda:, Nyagisozi ,Busanze, Kibeho, Mata, , Kivu, Ngera, Ngoma, Munini, Nyabimata, , Muganza, Ruheru, Cyahinda, Ruramba and Rusenge.

Name	Status	Population Census 2012-08-15
Nyaruguru	**District**	**294,334**
Busanze	Sector	27,190
Cyahinda	Sector	21,377
Kibeho	Sector	21,456
Kivu	Sector	17,719
Mata	Sector	13,900
Muganza	Sector	19,208
Munini	Sector	15,994
Ngera	Sector	22,440
Ngoma	Sector	22,950
Nyabimata	Sector	16,953
Nyagisozi	Sector	18,275
Ruheru	Sector	35,599
Ruramba	Sector	17,126
Rusenge	Sector	24,147

Figure 14: *Nyaruguru population 2012*

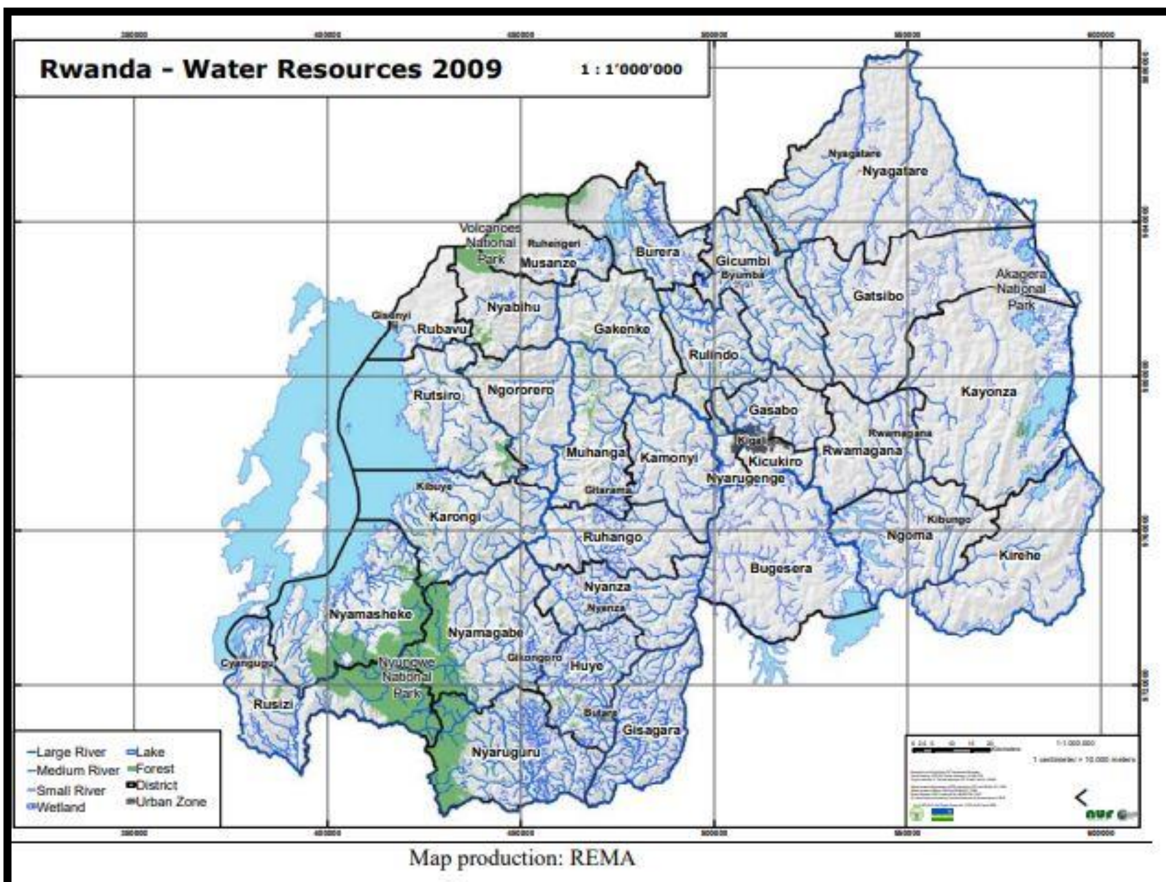

Figure 15: *Rwanda's water ressources network 2009*

In nyaruguru the rivers are large and many. We can list among others:

- The Giswi river feeded by Nshili river,
- Then Nshili river feedeed by Agatare river
- The Akanyaru river feeded by Simbuka river feeds
- Etc..

3.3 MUDASOMWA PICO HYDRO POWER PLANT PROJECT IN PROCESS

3.3.1 Location of Mudasomwa pico hydro power plant

The Mudasomwa project is situated in Nyaruguru District, Ruheru Sector, between Remera and Uwumusebeya Cells. The site is around 20 km from the nearest national grid and 1 km from the nearest road, the target village to power has a total of 625 households and the total population is estimated to be around 2500 people.

The project Mudasomwa Pico-hydro power plant is one such attempt by MUDASOMWA MINI GRID Ltd. The plant is estimated to have a capacity of 34kW with a flow of 0.11m3/s and a head of 50m.

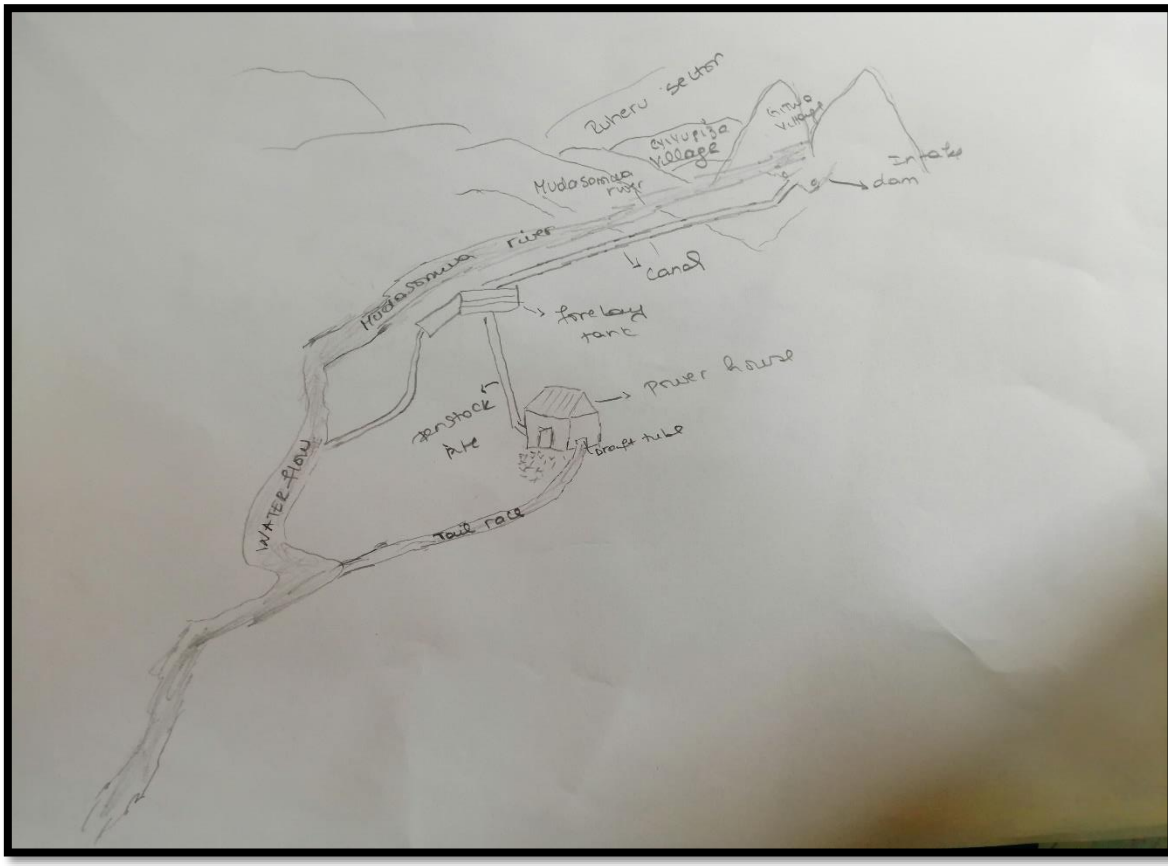

Figure 16: Layout of the plant (Mukwindi,2019)

Mudasomwa river is located between uwumusebeya and Remera cell, to reach the site of the power plant you have to cross Kibeho sector, Munini Sector,Busanze Sector and final Ruheru sector.

Figure 17: Way to Ruheru sector

Some of the cells in ruheru sector aren't remote area, they are connected on grid even the installation of public lighting are ongoing,

But all people in Munini sector or Busanza near the grid are not connected some be subject to poverty and others on attitude (I grow up in this area, I never saw my parents with electricity and they were well, healthy, why should I spend my money on the things that I won't need, said by Mudacumura a 56 old man).

In Ruheru sector, Remera Cell, cyivugiza and Gitwa village the grid doesn't reach because it's a hill area, it's almost 20km far from the transmission line.

To reach the area is complicated because the road isn't well maintained with motorcycle it's about 2 hours from Nyaruguru district

Figure 18: *A road on the way to Cyivugiza and Gitwa Villages (Mukwindi,2019)*

3.3.2: Life at Cyivugiza and Gitwa villages

The villages have almost 650 households though 250 household near from the power plant. They have church, schools, health center, small shops all don't reach on grid and will be an advantages to be connected on the power plant.

People living at the village are most Farmers (they live from agriculture), we find a big tea plantation, sorghum plantation, millet plantation, potato etc…

Figure 19: Agriculture activities at Cyivugiza Village(Mukwindi,2019)

Most of the house has 1 living room and 2 bedroom, they are designed in similar as these houses below:

Figure 20:
Typical design of the house at Cyivugiza and Gitwa Villages(Mukwindi,2019)

The village are in hilly area and people are living in umudugudu.

During the day, except cultivation they just sit to wait for next day, their living life is the same as the life of most people living in different remote areas in our country.

When the living life is depending on agriculture only, we don't have development because after harvesting we need to prepare the harvests to final products, drying packaging and transporting.

Figure 21: *Tradition drying used at 2 villages (Mukwindi,2019)*

This is lucky of development, this is lucky of other area emphasis.
Energy as well as electricity is one of the tools to develop a village.

The village has a primary school, so 98% of the children attend school, because of lucky of electricity they don't use computer nor other electronic tools to educate the children.

3.4 DATA COLLECTION

The community living in Mudasomwa village constitutes the key market of the electricity from Mudasomwa power plant. The main sources of the income of potential customers are agriculture, and livestock raising. The average monthly earning for the people living in the concerned area is around 50,000 Rwandan francs per month obtained mainly from Agriculture. The center consists of various business activities such as hair cutting salon, phone charging, bars and shops, churches and health centers.

The electricity generated after deployment of the power plant will be distributed among 260 households, 6 bars, 6 small shops, a sector office, 2 schools, 3 cassava mill, a health center, 3 churches and 4 barber shops, 1welding workshop and 1 carpentry workshop.

3.4.1 Energy consumption at Cyivugiza and Gitwa Villages

Table 2: *Energy consumption before being connected*

<table>
<tr><th></th><th>Quantity</th><th>/house hold/day</th></tr>
<tr><td rowspan="5">HOUSE HOLD</td><td rowspan="4">260</td><td>1 candle</td></tr>
<tr><td>1 Kerosene lamp</td></tr>
<tr><td>torch</td></tr>
<tr><td>telephone</td></tr>
<tr><td>5</td><td>Solar kit (mobisol)</td></tr>
<tr><td rowspan="2">BARS</td><td rowspan="2">6</td><td>3 candles</td></tr>
<tr><td>1 Kerosene lamp</td></tr>
<tr><td rowspan="2">SMALL SHOPS</td><td rowspan="2">6</td><td>3 Candles</td></tr>
<tr><td>1 Kerosene lamp</td></tr>
</table>

At present, candles and oil lamps are the main sources of light at night. Majority of the households are using candles, torch and oil lamps as a source of energy to light their houses. A few other households use torch to light their houses. The churches are using the batteries, which are carried over long distance for charging.

Only 5 households are using solar home systems in this area. Two households are using the solar kits from Ignite power and three households are using Mobisol kits. The owners of smallest set of Mobisol has to pay Rwf 399/day for a period of three years. The high daily payment is a holdup, which limits a number of households towards access to Solar Home System

CHAPTER IV: DATA ANALYSIS AND DISCUSSION

4.1 INTRODUCTION

While analyzing power plant performances with the benefits of people who will be connected to the power plant three methods in chap III have been used, it include **Technical** analysis, **Economic** analysis and **social** analysis.

Assessment of energy expenses before having electricity and what will be the cost of energy after having electricity were analyzed:

4.2 ASSESSMENT OF DATA COLLECTED

4.2.1 Assessment of Energy cost used at two villages before electricity connection

***Table 3**: Energy cost at the 2 villages before connecting to electricity*

	Quantity	/house hold/day	Unit cost	Total cost/day
HOUSE HOLD	260	1 candle	50	13 000
		1 Kerosene lamp	100	26 000
		torch	100	26 000
		telephone	100	26 000
	5	Solar kit (mobisol)	399	1 995
BARS	6	3 candles	300	1 800
		1 Kerosene lamp	100	600
SMALL SHOPS	6	3 Candles	300	1 800
		1 Kerosene lamp	100	600
TOTAL				**97 795 Rfw**

One candle costs Rwf 100 which amounts to a weekly expenditure of Rwf 700. On average, household spends Rwf 10 500 per month for lighting their houses at night.

Charging a battery costs Rwf 1000 plus the transportation cost, entities using the batteries can spend as much as Rwf 15,000 per month.

The community charges their phones at an Rwf 100 thereby spending around Rwf 1500 per telephone on a monthly basis. For those who have radio, they use batteries that cost them Rwf 700 on a weekly basis.

In their daily live, this money could be used to do other things if they could have power.

The people in village spend average of 2,933,850 Rwf per month for power.

4.2.2 Assessment of power Demand at cyivugiza and Gitwa villages

A survey done on 250 households at Gitwa and Cyivugiza Village, 1 school Ecole Primaire Remera, 1 church ADEPR Remera and a community church SEIRA (on appendix) and small business activities shows the number of light lamp needed and other equipment which will consume electricity.

Table 4: *Energy demand by clients from villagers per day*

category name	**number of clients**
House Holds	250
Cassava mill	3
Bars and Restaur ant	6
Churches	3
cell office	1
Health center	1
school	1
	265

Table 5 Energy demand by villagers

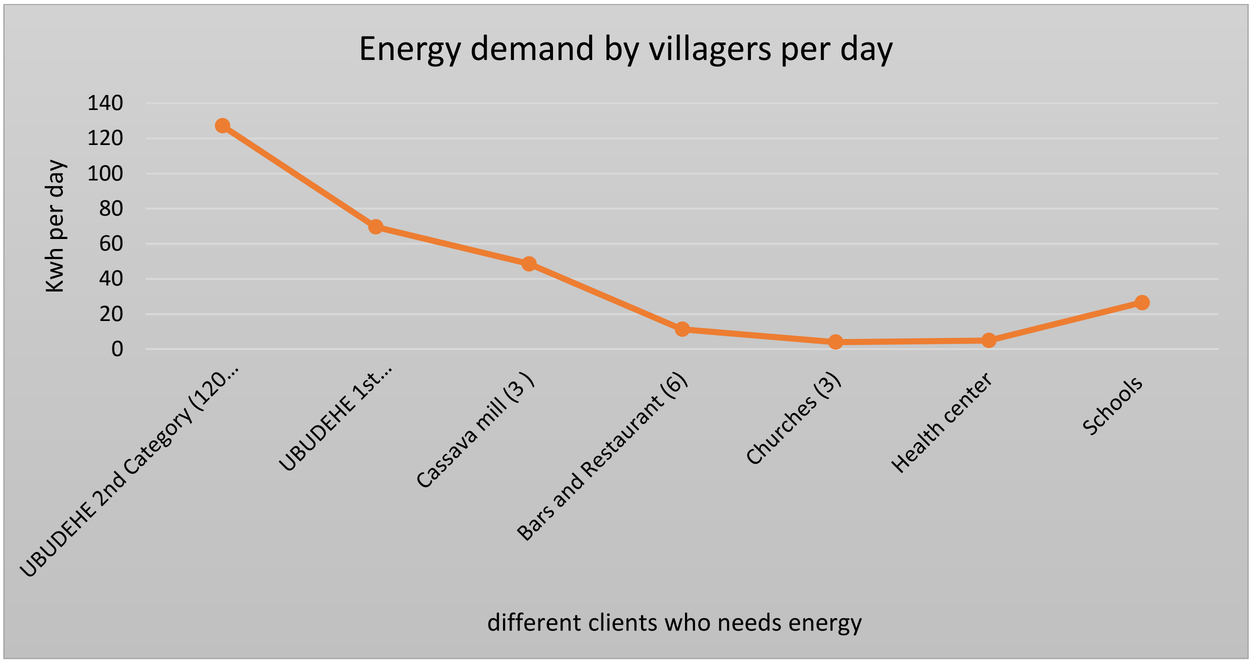

Table 6: Energy demand at 2 villages

	Total Watthours needed a day	Energy needed a day(Kwh)
Ubudehe 2nd category (120 HOUSEHOLD)	127,200.00	**127.20**
Ubudehe 1st category (130HOUSEHOLD)	69,600.00	**69.60**
Cassava mill (3)	48,588.00	**48.59**
Bars and Restaurant (6)	11,376.00	**11.38**
Churches (3)	4,020.00	**4.02**
Health center	4,992.00	**4.99**
Schools	26,530.00	**26.53**
	292,306.00	**292.31**

The villages demand is about 300 **kWh** a day and this will be **9 MWh** needed a month

4.3 COST OF ENERGY DEMAND BY VILLAGERS

REG (Rwanda Energy Group)'s energy tariffs are:

Consumption (kWh) block/month	FRW/kWh (VAT exclusive)
[0-15]	89
[>15 – 50]	182
>50	189

Figure 22 Rwanda Energy Tariff (Source REG)

Suppose that, the power plant consumers will pay on the normal cost of REG customers

Then:

In a daily basis, the villagers will have to pay:

The first 15 kWh of the month will be paid at 89 Rfw/kWh

15 - 50 kWh at 182 Rfw/kWh

50 - 300kWh at 189 Rfw/kWh

It means:

54,773 Rfw will be a daily payment on electricity to the power plant.

4.4 ANALYZE OF MUDASOMWA PICOHYDRO POWER PLANT PERFORMANCE

4.4.1 TECHNICAL ANALYSIS

The power plant Operation and Maintenance, when producing electricity some issues may occur like flow obstacles etc., are all technical issues to assess

- *Power plant O&M*

Following The flow measurement at the site that was done over a length of three years using the floating leaf method as it is simple and applicable with local material and following results were obtained: The low, medium and high flow are 0.11 m3/s, 0.13 m3/s and 0.15 m3/s respectively and the head is estimated to be 50 meters. The plant will have an installed capacity of 34kW.

Q1=Flow rate 1 = 0.11 m3/s
Q2=Flow rate 2= 0.13 m3/s
Q3=Flow rate 3= 0.15 m3/s

The head available is 50 m.

Technical data:			
Turbine:			
Units	pc.	1	
Gross Head	HB	46,56	m
Nominal net head	H_N	44	m
Nominal discharge	Q_A	0,1	m^3/s
Max. Turbine output	P_T	38,2	kW
Turbine speed	n_1	1000	rpm
Runaway speed	n_D	1800	rpm
Jet circle diameter	D_1	260-270	mm
Width of buckets:	B_2	90	mm
Number of buckets:	z	18	
Number of nozzles	-	5	

Figure 23: *Turbine specification*

OUTPUT AND EFFICIENCY TABULATION

Q_T [%]	Turbine Discharge [m^3/s]	Net Head [m]	Turbine Efficiency [%]	Turbine Output [kW]
50%	0,050	45,0	86,0	19,0
100%	0,100	44,0	88,5	38,2

Figure 24:*Efficiency of the turbine*

According the turbine specification, the Gross head will be 46.56m with flow rate of 0.1m3/s and efficiency of 88.5 at 100%.

Installed in the workshop on the turbine.

Units	Pc.	1
Make		European
Generator output	kVA	43
Generator voltage	V	400
Power factor	-	0,85
Ambient temperature	°C	40
Altitude max.	m	2500
Connection	-	Star
Voltage regulation accuracy	%	+/- 1
Voltage adjusting range	%	+/- 5
Generator speed	rpm	1000
Overspeed	rpm	1800
Frequency	Hz	50
Insulation class	-	H
Temperature rise	-	Class F
Protection	-	IP23
Cooling	-	IC01
Type	-	V1
Bearing type	-	roller bearing
Bearing life time	h	100.000
Automatic voltage regulator	-	included
Specification standard	-	IEC 60034
Shaft rotation	-	optional
Phase sequence	-	right
Cable outlet	-	optional
Painting	-	RAL 3000

Accessories:

- *Manual re-greasing nipples*
- *Bearing designed for lifetime >100.000 hours*
- *Terminal box with cable outlet*

Generator efficiencies:

Load	Power factor cos ϕ= 0,80	Power factor cos ϕ= 1
100%	88,1%	90,1%
75%	88,5%	90,5%
50%	86,5%	88,5%
25%	84,0%	86,0%

Figure 25:*Generator Specification*

The generator is attached on turbine with the specification above (fig22).

- *Operation of the power plant:*

Operating hours and production through out of year:

Table 7 Operation hours and production throughout a Year

MUDASOMWA Pico HP								
Annual energy productic								
operating time(days)	flow rate (m3/s)	head(m)	theorical power (Kw)	turbine efficienc y(%)	generato r efficienc y (%)	power production(Kw)	energy produced (kWh)	
4	0.110	46.56	50.24	0.85	0.88	**37.58**	**3,607.84**	
18.00	0.110	46.56	50.24	0.85	0.88	**37.58**	**12,627.45**	
37.00	0.110	46.56	50.24	0.85	0.88	**37.58**	**17,137.25**	
55.00	0.130	46.56	59.38	0.85	0.88	**44.41**	**19,187.16**	
73.00	0.130	46.56	59.38	0.85	0.88	**44.41**	**19,187.16**	
91.00	0.120	46.56	54.81	0.85	0.88	**41.00**	**17,711.22**	
110.00	0.120	46.56	54.81	0.85	0.88	**41.00**	**18,695.18**	
128.00	0.120	46.56	54.81	0.85	0.88	**41.00**	**17,711.22**	
146.00	0.100	46.56	45.68	0.85	0.88	**34.17**	**14,759.35**	
164.00	0.100	46.56	45.68	0.85	0.88	**34.17**	**14,759.35**	
183.00	0.050	46.56	22.84	0.85	0.88	**17.08**	**7,789.66**	
201.00	0.050	46.56	22.84	0.85	0.88	**17.08**	**7,379.68**	
219.00	0.050	46.56	22.84	0.85	0.88	**17.08**	**7,379.68**	
237.00	0.100	46.56	45.68	0.85	0.88	**34.17**	**14,759.35**	
255.50	0.110	46.56	50.24	0.85	0.88	**37.58**	**16,686.27**	
273.75	0.130	46.56	59.38	0.85	0.88	**44.41**	**19,453.65**	
292.00	0.130	46.56	59.38	0.85	0.88	**44.41**	**19,453.65**	
310.25	0.110	46.56	50.24	0.85	0.88	**37.58**	**16,460.78**	
328.50	0.050	46.56	22.84	0.85	0.88	**17.08**	**7,482.17**	
346.75	0.050	46.56	22.84	0.85	0.88	**17.08**	**7,482.17**	
365.00	0.110	46.56	50.24	0.85	0.88	**37.58**	**16,460.78**	
							296,171.02	**kWh**
							296.17	**MWh**

During one year, the power plant is able to produce more than **296.17 MWh** despite the losses that can occur.

This sufficient to cover the energy demand.

- *Maintenance of the Pico hydro power plant*

When running a hydro power plant we don't need diesel, Heavy fuel oil or other type of fuel compared to other thermal power plant.

But, to operate and maintain the power plant we don't find much difference as they all have to run, produce and have a long life. Power plants can remain for a long life if the maintenance and operation are followed perfectly. The hydro power are most utilize because not only being an indigenous energy resource but also renewable energy.

The operation and maintenance of a hydro power plant must be done following the manual and instruction of the manufacturer.

In general, people who runs a micro-hydro power plants should know the following rules:

- O& M people has to be professionally in conduction of operation and maintenance of a plant complying with the work plans, rules and regulations.
- Operators to avail their power plant have to be in familiar with the power plant equipment or corrective and preventive functions. Furthermore, they must also be aware of measures against various accidents for prompt recovery.
- The daily and routine maintenance should be applied. When they find some troubles or accidents, they must inform a person in charge and try to remedy the situation.
- Operators must try to prevent any accidents. For this purpose, they should repair or improve facilities preventively as necessary.

In general, Pico-hydro power plants can be operated even in case of flood. However, when the river becomes a muddy stream and if there is possibility that sand and soil come into facilities, operation of the plant should be stopped and the intake gate should be closed. After flood, operators must inspect all facilities, and try to recover operation as soon as possible.

Figure 26: *A long canal open channel (Mukwindi,2019)*

The above picture shows how risk the canal can face during rainy season, flood, and muddy can be formed a long way of open channel.

This should be avoided by planting glasses and trees to prevent erosion of soil.

Figure 28 Intake of Mudasomwa Pico hydro power plant

Figure 27: *Intake of Mudasomwa pico power plant*

- *Reliability of the power plant and safety of the equipment*

The power plant will need 2 operators to work in shift, preferably should be trained people and living in village nearby.
The security guard also will be hired with 2 cleaners to keep the plant clean and safe

The power plant will be managed by the **shareholders**: people who wants to be connected to the power plant has made a company where by everyone has to pay 58000Rfw,
48 000Frw as connection process fees and 10 000Frw as a share in the company.
This will help the people to take care of the power plant and maintain it as its own property.

4.4.2 ECONOMIC ANALYSIS

In analyzing the economic aspect of the power plant, I have focused on energy burden and also on income of the villagers before getting electricity and after being connected.

- *The income to the villagers:*

The people living in 2 villages are agriculture based population, they earn money from their agriculture activities.

The average total amount earn by every household in the village is almost 50 000Rfw/month

- *Energy burden of one villager*

Energy Burden represents the percentage of the income of a household comparing to the energy expenses in the house (All kind of energy are considered).

A survey done on one household shows different kinds of energy used by a household in Cyivugiza and Gitwa villages:

Lightening: 250 Rfw /day

Cooking: No cost allocated as they use woods and traditionally stoves

Charging mobile phones and radio: 200Rfw/day

The total expenses on energy in a monthly basis are: 450Rfw*30= **13 500Rfw**
As the income is **50 000Rfw,**

The Energy burden is: 13 500/50 000 = 0.27 or 27%
If cooking and other energy activities were considered, the findings will show that the energy burden to the villagers is very high vs their monthly revenue.

4.4.3 SOCIAL ANALYSIS:

The quality of life of people living at Cyivugiza and Gitwa Villages will be improved in a great way.
After analysis I have found that:

1. Electricity lighting helps the household to no longer use torch, kerosene lamps etc.,, This reduce pollution as well as home expenses
2. The after school revision hours for student increase from 30min to 2 Hrs and it reduces the risk for children to have eyes and throat problem
3. Electricity also gives people access to information as it encourages people to buy Radios, TVs, digital Mobile phones etc.
4. The last but not least, electricity decrease expenses as we have seen that people spend almost 2,000,000 Rfw a months before having electricity but with electricity they could spend 1,700,000 Rfw

CHAPTER V: CONCLUSION AND RECOMMANDATION

5.1 CONCLUSION

As Rwanda has a target to be 100% connected by 2024, we can't achieve this target without cooperation of Government, investors, shareholders and researchers.

Rwanda is a hilly country which make it have a many remote areas and off grid areas.
Off grid power plant will help not only increase the connectivity but also contribute to their development.
As mentioned in my research Pico hydropower plant are simple to adapt, Government should put effort in developing those power plants wherever it's possible.
The work carried at Mudasomwa Pico hydropower shows that remote area in Rwanda near the rivers can be powered and be developed.
The development of this Pico hydro power plant is easy and simple, the production also 260MWh per year is sufficient for people living in 2 villages and will allow them to develop projects which will benefit and increase their revenue.
The connection of electricity will also increase the potential of people to access information, to promote education and to facilitate the target of Rwanda for rural electrification.

5.2 RECOMMANDATION

The landscape and the climate in Rwanda are very prone for hydro power generation mainly Pico hydro power plant, we should take advantage of that and develop all our rivers tiny, small and large for our development and to also save the planet.

Bigger hydro requires bigger demand/consumption and therefore must be connected to the main grid with PPAs (Power Purchase Agreement) which are currently not available or very difficult to get.

As we know when you travel around Rwanda, there are water streams and are not being exploited to the fullest. In addition our high population density is an opportunity in this case as there are trading centers with high concentration of people not always far from these water streams and this allows to put small turbines and build distribution lines cheaper than extending the main grid.

The only challenge is the purchasing power of our people which is still low but it is not static either which shows potential growth in consumer's electricity spending as long as there are productive usage activities linked to the mini-grids. There are ways to stimulate the demand if we partner with groups that support local entrepreneurs in the rural areas.

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APPENDICES

1. Questionnaire for people who wants to be connected at Mudasomwa Pico Hydro power plant 7th January 2019

1. Family name
   Amazina y' umukuru w'umuryango?...
2. How many people do live in your family?
   Abantu bangahe utunze mu muryango wawe?...
3. What is the ubudehe category?
   Icyiciro cy'ubudehe cyanyu ni ikihe?...
4. Do you know how electricity is produced and transmitted?
   Uko amashanyarazi atangwa nuburyo akorwamo urabizi?...
5. Do you have children, if yes how do they do their homework? ***Ufite abana. Niba yego, Nigute basubiramo amasomo ?..***
6. What is your daily activities?
   Ni akahe kazi ukora ka buri munsi? ....
   ....
7. How much do you gain per month?
   Ni angahe wunguka ku kwezi?
   …………………………………………………………………………………………
8. What do you use to lightening your house?
   Niki wifashisha mukumurika inzu yawe iyo hatabona? ………………………………………………………………………………
9. What do you use while cooking?
   Niki ukoresha iyo utegura amafunguro y'umuryango wawe? ………………………….
10. How much do you spend in a month for energy?

    Ukoresha amafranga angahe mukwezi mubyerekeye ingufu? ………………………….
11. What do you expect after having electricity?

N'izihe mpinduka witeguye Numara kubona amashanyarazi? ………………………….
…………………………………………………………………………………………………
………………………………

2 One of the Survey done by Hobuka company at Remera sector at 9th March 2017

3\. AKARERE KA NYARUGURU
UMURENGE WA RUHERU
AKAGARI KA REMERA

URUTONDE RW'ABAKENEYE UMURIRO W'AMASHANYARAZI MU KAGARI KA REMERA MURI PHASE YA I

Nº	AMAZINA	I.D	UMUDUGUDU	AKAGARI	AMATARA YAKORESHA	
1	MINANI Innocent	1196580022793011	GITWA	REMERA	6	
2	NDABAKURANYE Timote'	1195480014845 18	GITWA	REMERA	7	
3	KAGWIRE Vitalienne	1197470035175043	GITWA	REMERA	6	
5	NYIRARUBUMBA Immaculée	1197670035936080	GITWA	REMERA	4	
6	NYIRARUBUMBA Immaculée	1197670035936080	GITWA	REMERA	4	
7	NTAWUHUNGUKUGISHA Joseph		GITWA	REMERA	5	
8	TWAGIRAMUNGU Grégoire	119758003326 1005	GITWA	REMERA	11	
9	NYANDWI Frédéric	1197780038431059	GITWA	REMERA	4	
10	NYIRANDIHANO Domitille	1196570022791043	GITWA	REMERA	4	
11	BAPFAKURERA Jean	1196180018489047	GITWA	REMERA	5	
12	MUKANTWARI Xavérine	1197370033754039	GITWA	REMERA	5	
13	BARABWIRIZA Vincent	1196780023597061	GITWA	REMERA	6	
14	BIHOYIKI Vincent	1199280202140081	GITWA	REMERA	6	
15	NSHIMIYIMANA Viateur	1197680035934000	GITWA	REMERA	6	
16	NSANZIMANA Emmanuel	1198580064545003	GITWA	REMERA	5	
17	UWOBIKUNDIYE E	1198780037745090	GITWA	Remera	5	
18	HABIMANA Vianney	1193580018032061	GITWA	REMERA	8	
19	RIBANJE Maurice	-	GITWA	REMERA	5	
20	URIHO Jean de Dieu	1198080057177089	GITWA	REMERA		
21	BIHEMYIMANA Filemin	1196980026853098	GITWA	REMERA		

No.	AMAZINA	I.D	AMATARA AKENEYE	AKAGARI	UMUDUGUDU	UMUKONO
45	NYANDWI Frédéric	1197780038431054	8	REMERA	CYIVUGIZA	
46.	BARABWIRIZA Vincent	1196780023537061	4	REMERA	CYIVUGIZA	
47.	MUKARUGWIRO Venantie	1196570024700047	7	REMERA	CYIVUGIZA	
48.	NDINDABAHIZI Augustin	1195780017679021	4	REMERA	CYIVUGIZA	
49.	MUTANGANA Innocent	1198080057167001	4	REMERA	CYIVUGIZA	
50.	KAMBEKENE Emmanuel	1196880029328087	6	REMERA	CYIVUGIZA	
51.	MUNYANEZA Charles	1198080057164040	12	REMERA	CYIVUGIZA	
52.	UWIRAGIYE François	1197880046890062	7	REMERA	CYIVUGIZA	
53.	SINUGOMWA Paul	1195580016011683	9	REMERA	CYIVUGIZA	
54.	HABINTWALI Mathieu	1197080030666087	9	REMERA	CYIVUGIZA	
55.	SEKAMANA Claude	1198280012746048	8	REMERA	CYIVUGIZA	
56.	SEKAMANA Claude	1198280012746048	8	REMERA	CYIVUGIZA	
57	UWIRAGIYE Joséphine	1196470024704097	5	REMERA	CYIVUGIZA	
56.	MURIHANO Callixte	1197080060635000	5	REMERA	CYIVUGIZA	
57.	HAKORIMANA Samuel	1198380062543059	5	REMERA	CYIVUGIZA	
58.	UWIMANA Claude	1198780057736047	5	REMERA	CYIVUGIZA	
59.	KANANI Fabien	1198980055457046	5	REMERA	CYIVUGIZA	
60.	BARAYAVUGA Emmanuel	1196780023677074	6	REMERA	CYIVUGIZA	
61	KAMAGAJU Joséphine	1194670007558047	4	REMERA	CYIVUGIZA	
62.	BUKURU Venantie	1194870001446012	6	REMERA	CYIVUGIZA	
63	MBASIGIYIMANA Joséphine	1197470035167029	4	REMERA	CYIVUGIZA	
64	NKURYENGORO Emmanuel	1196580022281004	7	REMERA	CYIVUGIZA	
65.	MINANI Samuel	1197380033743059	5	Remera	CYIVUGIZA	

3 Number of people to be connected

category name	number of clients
House Holds	250
Cassava mill	3
Bars and Restaur ant	6
Churches	3
cell office	1
Health center	1
school	1
	265

4 Different calculation on energy needed

household

UBUDEHE 2nd Category (120 HOUSEHOLD

equipment	Number in use	power (W)	Total power (W)	Hrs/day	watthrs/day	TT Watthour per 120 household	Hours	
Lamps	4	11	44	10	440	52,800.00	05-06h	18h-22h
Cell phones	2	5	10	2	20	2,400.00	05h-07h	
Radio	2	10	20	12	240	28,800.00	05h-17h	
TV	1	120	120	3	360	43,200.00	18h-21h	
					1,060.00	**127,200.00**		

UBUDEHE 1st Category(130HOUSEHOLD)

equipment	Number in use	power (W)	Total power (W)	Hrs/day	watthrs/day	TT Watthour per 120 household	Hours	
Lamps	4	11	44	10	440	52,800.00	05h-06h	18h-22h
Cell phones	2	5	10	2	20	2,400.00	05h-07h	
Radio	1	10	10	12	120	14,400.00	05h-17h	
					580	**69,600.00**		

Cassava mill (3)

equipment	Number in use	power (W)	Total power (W)	Hrs/day	watthrs/day	TT Watthour per 3 cassava mills	Hours
Lamps	3	11	33	12	396	1188	18h-06h
3 phases motor	1	3000	3000	4	12000	36000	08h-12h
1 phase motor	1	1000	1000	3	3000	9000	13h-16h
ceiling fan	1	100	100	8	800	2400	08h-16h
						48,588.00	

Bars and Restaurant (6)

equipment	Number in use	power (W)	Total power (W)	Hrs/day	watthrs/day	TT Watthour per 6 bars and resto	Hours
Lamps	3	11	33	12	396	2376	18h-06h
TV	1	120	120	10	1200	7200	12h-22h
DVD Player	1	30	30	10	300	1800	12h-22h
						11,376.00	

Churches (3)

equipment	Number in use	power (W)	Total power (W)	Hrs/day	watthrs/day	TT Watthour per 3 churches	Hours
lamps	10	11	110	4	440	1320	18h-22h
TV	1	120	120	6	720	2160	15h-21h
DVD Player	1	30	30	5	150	450	13h-18h
MICROPHONE	2	5	10	3	30	90	17h-19h
						4,020.00	

Cell office

equipment	Number in use	power (W)	Total power (W)	Hrs/day	watthrs/day	TT Watthour 1 cell office	Hours
Lamps	4	11	44	3	132	132	17h-20h
TV	1	120	120	4	480	480	14h-18h
Computer	3	150	450	10	4500	4500	07h-17h
Printer	1	50	50	10	500	500	07-17h
						5,612.00	

Health center								
	equipment	Number in use	power (W)	Total power (W)	Hrs/day	watthrs/day	TT Watthour 1 Health center	Hours
	Lamps	6	11	66	12	792	792	18h-06h
	Computer	1	150	150	15	2250	2250	07h-22h
	Printer	1	50	50	9	450	450	09h-18h
	electronic equipmnt	3	50	150	10	1500	1500	07h-17h
	phones	3						
							4,992.00	

Schools								
	equipment	Number in use	power (W)	Total power (W)	Hrs/day	watthrs/day	TT Watthour 1 Health center	Hours
	Lamps	15	11	165	12	1980	1980	18h-06h
	Computer	10	150	1500	15	22500	22500	07h-22h
	Printer	1	50	50	9	450	450	09h-18h
	electronic tools	3	50	150	10	1500	1500	07h-17h
	phones	10	5	50	2	100	100	16h-18h
							26,530.00	

5 Site visit pictures