UNIVERSITY OF TWENTE.

Neverland organic farm

University: University of Twente
Supervisor: Joy Clancy

Host organization: Neverland Organic Farm
Mentor: Tina Marshall

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Let the water run

Design and implementation of a micro hydropower project in Tumianuma, Chirusco valley, Ecuador

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Preface

Around the world many people live in areas where streams and rivers are located. Water is an important source of life, what everyone will agree. Also in the Chirusco valley in Ecuador water is highly valued. Even though there is a lot of water available, no water can be spoiled. This mindset is already there from way before the Inca's, where the indigenous people valued water as the most important source of life.
Besides using the water for drinking, the force of the water can be used. Streams and rivers are potential sources of energy for lighting, communication and processes industries. This natural resource can be exploited by the building of small hydro-power schemes. The water in the river will be borrowed and not be consumed. The force of the water can make a turbine run which can be transferred to the generator that will convert it into electricity. And then you will have a green source of energy.
The Neverland farm, located in Tumianuma in the Chirusco valley, started building such a micro-hydro scheme three years ago. By the time I came to work on this project they got new funds and new hope to finally finish this project. Being a student from Sustainable Energy Technology, University of Twente, I was highly interested in renewable energies and especially the application in rural areas. I worked on the engineering aspects of the micro hydropower scheme but also helped with the building of it. Furthermore I researched what social impacts it can have. Having electricity in this rural area may have major effects. Traditional farmers may come back to their original homes, because a more comfortable lifestyle is possible. In this way the traditional way of organic farming can be continued with the help of sustainable energy.

In this report are the research and conclusions I made during my internship about the micro-hydro project. This report is just one of the fruits my internship produced. Without the help of many people it would not have been succeeded.
First I would like to thank my supervisors; Dr. Joy Clancy from the CSTM faculty of the University. I can learn a lot of things from all her experiences in rural areas. And Tina Marshall from the Neverland farm in Ecuador. I was more than happy to live together on her farm for a while and experience everyday a totally different day. I can learn from her great ambitions.
I was very happy to meet Hydro Engineer Nelsson and Electrical Engineer Bob. With them I could look and talk about the technical parts. Also a great thanks to Engineers F. van 't Hul and J.F. van 't Hul. They initiated this project and where still involved and very enthusiastic to give very good support from the Netherlands.
Many thanks to Patricio, the permanent local employee, who worked very hard on the site every day. Due to his experience in construction work we were able to make good designs together. Also thanks to his wife, Alba, the cook, and Davey.
Thanks to all the people living in the valley, where I could go to and having nice conversations with in English; Hans, Jay, Caroline, Walter and Susan. Also thanks to all the people in Tumianuma, including all the interviewees.
Furthermore I would like to thank all the volunteers coming from all over the world, who were at the farm during my stay, and helped with the hard physical work. Digging holes, removing rocks, pushing donkeys... Thanks Rico, Chris, Reuben, Jeremy, Aude, Scott, Mattheu, Constance, Beany, Leah, Alejandro, Chris, Axel, Lisa, Jenna, Tommy, Reint, Renée, David, Sarah, Matt, Anders, Josefine, Ilona and Dominique. It was great to do it all together and also to be at the farm together.
As last I want to thank my husband, Bouke Pieter, who was with me in Ecuador and supported me during hard and good times. He also helped with his GPS and using QuantumGIS to make the maps.

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Annegreet Ottow-Boekeloo

Abstract

Neverland is an organic farm located in Tumianuma, in a small valley in the parish of the province Loja in the Andes region. In the remote area of this valley is a lack of electricity and people are moving from their traditional farmer places to the village. Neverland wants to provide a micro-hydropower installation for the nearby rural households. In 2008 they started building a micro-hydropower system of 4 kW, for the farm itself and for the households around the farm. Due to financial allocation problems the system is still not working. This year they got some new funding, so the project could be resumed. My tasks were to continue with this project and help with the design and practical realisation of the plant, which is the technical part. Besides this I did a social part and conducted a survey among the people in the valley.

Environmental setbacks lead to a lot of extra work and resulted in a still not finished power plant. But due to this extremely weather, some weak places in the canal could be found and reconstructed. However, there are some parameters that could be designed and constructed. This includes the penstock, which is installed and supported by 8 pillars, which are made of concrete and strengthened with rebar. The construction is calculated to both withstand forces when the pipe expands as well as contracts. The foundation of the powerhouse is constructed and protected for the nearby river.

The expected total peak power is calculated to be 2.7 kW, which is below the expected generated power of 4 kW. Three different groups of houses are made which will be connected to the three different phases. With the most optimized design in both balance of energy-use and financial costs, the total wire length that is needed is 6.3 km. The maximum voltage drop, with an aluminium wire of 7mm in diameter, will be 17 V.

Most of the people are really enthusiastic to receive electricity in the valley. If there is electricity they say they will come back to the valley and have a farmers living again. Besides having electricity, another important necessity that turned out is potable water.

Some people are not really interested in having electricity from the hydro plant, because they already use solar power. The general perception is that the positive effects of this project is that the families will come back in the valley and have a traditional farmers life. No real negative effects are expected, if it is properly organised regarding agreements and maintenance.

For a good continuation of this project I suggest that a good system is found to do the maintenance. Someone should be in charge to be responsible for the basic maintenance of the system, like cleaning the filters. Furthermore the local people need to be educated in how to handle this system. I think it is also important to organise meetings among the local people that will be connected to the system, to keep them informed and hear their ideas. In this way they are more part of the system which will result in a more sustainable whole in both using and maintaining the system.

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1. Introduction

This is the report of my internship with Neverland, where I focussed on a micro hydropower project in Tumianuma, Ecuador. The purpose of this report is to give the results and the conclusions of this internship of 10 weeks. It can help with the further construction and finishing of the micro hydro plant. And also gives some understanding in the expected social effects of the hydropower project.
In this introduction you first find some basic information about Neverland. A short introduction on the micro-hydro project and my task therein, followed by the structure of this report.

1.1. Neverland

"Always living in a tree house, never hesitating to stop anything to play Indians and pirates, licking my plate when the food was gooooddd. Sharing my life with other lost boys, and girls, who want to play and live happily and simply." - Tina Marshall

Neverland is an organic farm located in Tumianuma, in a small valley in the parish of Vilcabamba in the Andes region. The farm is named after Neverland in Peter Pan, the idea of never growing up. Neverland wants to share a more sustainable way of living.
Neverland is a leader in the field of teaching organic farming. They raise awareness from all over the world via the WWOOF-program. WWOOF is a worldwide network of organisations who link volunteers with organic farmers to live, learn and share organic lifestyles (WWOOF, 2012). It combines this leadership with a social role for the local area, to support the less fortunate of the parish (Neverland, 2012).

1.2. Hydropower

"It can run but never walks,
has a mouth but never talks,
has a head but never weeps,
has a bed but never sleeps.
A river."
- J.R.R. Tolkien

Micro hydro is a type of hydroelectric power that harnesses small-scale energy from falling water. Micro hydropower is often used in remote areas where the electricity grid does not exist. Typically they provide power to just one rural industry or one rural community. They range in the size from 200 W, enough to provide lighting to a group of houses, to 300 kW, which can be used for small factories and the supply of an independent local mini-grid (Harvey, 1993). Micro hydro systems provide poor communities in rural areas with an affordable, easy to maintain and long-term solution to their energy needs.
In the remote area of the Chirusco valley is a lack of electricity, what made Neverland think of hydropower. Neverland wants to provide a micro-hydropower installation for the nearby rural households, so other people can profit of generating electricity. In 2008 they started building a micro-hydropower system of 4 kW, for the farm itself and for the households around the farm. Due to financial allocation problems the system is still not working. This year they got some new funding, so the project could be resumed.
My tasks were to continue with this project and help with the design and practical realisation of this plant. Besides this I conducted a social survey among the people living in the valley.

1.3. Structure of the report

After this introduction the second chapter will give some background information. Some general principles of a micro-hydro system and the status of the project before I started to work on it are given. Also the living conditions of the local families in the region will be explained.

Chapter three is the problem definition followed by the research questions. After that a chapter about the methodology to answer these research question.

The results of this research are divided in a technical part (chapter six) and a social part (chapter seven). This is followed by the conclusion and as final chapter some recommendations for the future ending of this project.

In the Appendices you find a country study of Ecuador. Besides that some deeper calculations, sketches and tables I used. The chapter 'Results' will refer sometimes to the appendices, for more information.

2. Background information

The first paragraph in this chapter is about the general principle of a micro-hydro system, which will be used on the Neverland farm. It also tells the status of the project before I started to work on it. Furthermore it is important to understand the living situation of the people. Therefore the second paragraph is about the livelihood circumstances in the surroundings of the Neverland farm.

2.1. Power from water

There are a lot of different hydropower schemes. The micro-hydro system to be used is based on the "run of the river". These systems do not require a dam or storage facility and are therefore a low-cost way to produce electricity, with low environmental damage. The water is diverted from the river into a channel through a settling basin, which helps to remove sediment that could harm the turbine. Then the water flows into the forebay tank and drops it downhill via a pipeline, called the penstock. When the water reaches the bottom it drives a turbine which is designed to provide electricity. The major components of the micro-hydro scheme are schematically given in Figure 1.

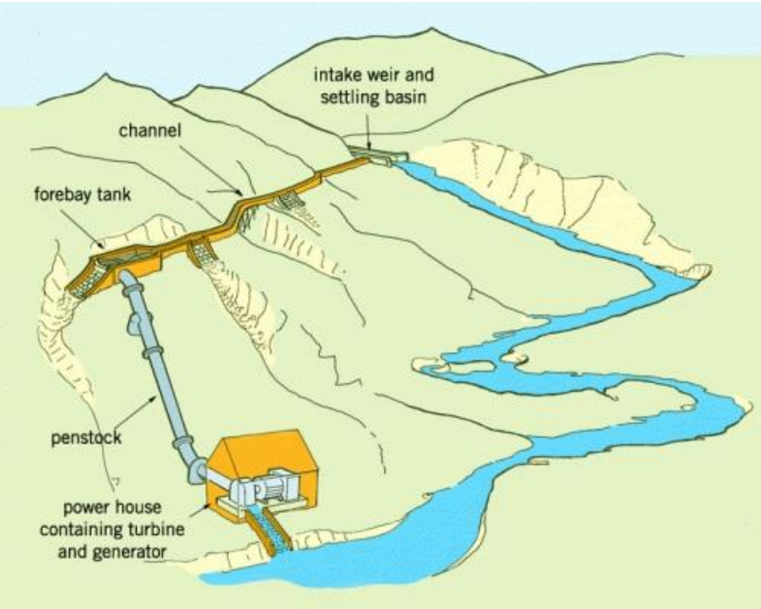

Figure 1 - Major components of micro-hydro scheme (Practical Action, 2012)

A turbine converts energy, in the form of falling water, into rotating shaft power. However centrifugal pumps can also be used as turbine, which is called a "pump as turbine" (PAT). Neverland will also use a PAT for their micro-hydro system. Pumps are manufactured in large quantities for water supply and irrigation purposes in many countries. In contrary to turbines, of which there may be no local manufactures. PATs are therefore less expensive and locally available, especially in developing countries. Furthermore standard pumps are simple and do not require highly qualified mechanics for maintenance, which make it more appropriate for the Andes region (Chapallaz, Eichenberger, & Fischer, 1992) .

A large part of the micro-hydropower system is already designed and installed at Neverland. This includes the intake and settling basin, the channel and the forebay tank. The turbine and generator are already chosen and also the switchboard is assembled. The main parts which have still to be done are the installation of the penstock with supports, the powerhouse with the installation of the PAT (Pump as Turbine) connected to the generator and the ballast loads as well as the installation to the users.

2.2. Livelihood circumstances

The micro-hydro system is not only built for the Neverland farm but also for the surrounding households. These households will get some of the electricity that is produced, which means that they also have to work with this technology. Therefore it is important to know the context of these villagers and the problems they face. Furthermore it is important to know the living situation of the villagers because I have to work with the local people.

I will describe the current situation in Tumianuma with the sustainable livelihood approach. This approach is a way to improve understanding of the livelihoods of people. The livelihood framework indentifies five types of capital upon which livelihoods are built: human, natural, financial, physical and social capital (DFID, 1999). I will focus on the problems related to the implementation of a hydropower installation. The information is mainly coming from the Neverland farm and a report of J.F. van ‘t Hul (Hul, J.F. van 't, 2009).

2.2.1. Human capital

In Ecuador primary school is free of any costs, so most of the people complete this, also in the valley. Not all the families can pay the cost of secondary school. At secondary school most children drop out at the age of 15. 75% of the people from Tumianuma finish secondary school, only a view people went to a higher level of education after secondary school. The language spoken at school is Spanish.

There is no knowledge of renewable energy or the understanding about hydro power with the inhabitants. In the area there is no other example of hydro power.

Most of the families are farmers, but there are also some tourists’ jobs possibilities in Vilcabamba. All the children help their parents on the farm. The knowledge how to farm is passed on from generation to generation.

Migration is a problem in the mountains. Many young people are leaving for finding better economic possibilities somewhere else. In the Chirusco valley this is visible because of the 12 farms, 8 are lead by people older than 60.

2.2.2. Natural capital

The Neverland farm is located in Tumianuma, near Vilcabamba in the Chirusco valley. This valley has mild year-round climate, lush green scenery and fresh mountain air. The mountain that overlooks the valley and its two rivers is the Mandango. Also called as sleeping Inca of which it is said to protect the area and its inhabitants from natural disasters.

The Andes region is full of streams, rivers and waterfalls. The water is safe to be used as drinking water. There is a big difference in the amount of water between the dry and the rainy season. This can be a problem for the micro-hydro system during the dry months. The rain season is normally from November till April, so it is really dry in September.

2.2.3. Financial capital

Most people have their own small farm for generating income. The working on the farm is done by the whole family. Most farmers earn their money with the growing of coffee and fruit, which are harvested from September till October. Neverland helps these farms with becoming certified biodynamic farmers, which will increase their income. The income of the agriculture production is just enough for basic living needs and the secondary school fees for the children.

The people of Tumianuma have access to banks, but there is no real credit-culture due to high interest rates. Especially the elderly prefer to bury all their money.

2.2.4. Physical capital

Tumianuma is accessible by an old road from Vilcabamba to Quinara. There is a bus connection to these places, but the frequency of the bus is low. The Neverland farm itself can be reached in a half our walk through the mountains from Tumianuma.

The farmers in the valley of Tumianuma live and work on their small farm. Some families own donkeys or horses, where others have to rent them for the harder work on the farm. The farmhouses consist often of two rooms, built from clay or mud. There is no access of electricity, but clean drinking water is available from the river.

In contrary to the valley, the people in the village Tumianuma itself are wealthier. Their houses are made of bricks and they have access to electricity, which makes it possible to have some electrical appliances like lights and a television.

2.2.5. Social capital

Most families are formed by two parents and three to five children. In the village the role of the man is to earn the money and the role of the woman to care for the children and the house. On the farms in the valley both man and woman are working on land to produce income. In some families the women has the financial overview to keep the family running. But often the women are not trusted with money because of the macho culture.

The social coherence in the communities is high. This is also the case for the micro-hydro project; everyone offers to help even if there is no believe in the outcome of the project.

The Catholic Church plays a big role in the social life. The priest is a well known and high ranked person. If he supports a project it has a higher chance of getting supported by the villagers too.

3. Problem definition

The report is divided in a technical and a social part. In this chapter you can read the problem definition of both these parts.

3.1. Technical

As told before, a large part of the micro-hydropower system was already designed and installed. This includes the intake and settling basin, the channel and the forebay tank. The turbine and generator are already chosen and also the switchboard is assembled. The parts that still need to be installed or designed are listed in the following paragraphs.

3.1.1. Penstock and supports

The first step that needs to be done is the design of the penstock. The penstock is the pipe which conveys water under pressure to the turbine. It is one of the major expenses in the total micro-hydro budget and it is therefore worthwhile to optimize the penstock design. For support the penstock needs to have pillars and foundations. The dimensions of these supports need to be calculated and the supports have to be constructed. The pipe needs to be stable and should withstand several forces.

The pump to use as turbine has already been selected. The diameter of the penstock (8 inch) needs to be reduced at the entrance of the PAT to 3 inch in a certain way. It also needs a bend.

3.1.2. Filtration system

It is very important to get the debris out of the running water system, for not destroying the PAT. The tanks already have a good sediment filtration but still particles bigger than 5 cm can pass through the PAT. Therefore some kind of filtration system must be installed.

3.1.3. Powerhouse

A powerhouse must be constructed to enclose and protect the associated equipment. The powerhouse floor must support the weight and pressure of the entering water, the PAT and other equipment. It should also already contain the bolts to install the pump and the turbine with.

3.1.4. Switchboard

The purpose of the switchgear is to isolate the power supply when necessary and also to have some control over the electrical power flow. There is already a switchboard installed, with replaceable fuses, but this has been 3 years ago. It needs a complete rewiring and the fuses must be checked.

3.1.5. Ballast loads

Electricity is always produced when there is a continuous flow of water trough the turbine, even if there is no usage. For not destroying the generator a system has to be made which can store or use the excess of the produced electricity. The Neverland farm does not want to have batteries on their farm. Therefore other ways of ballast loads must be designed.

3.1.6. Wiring to houses

The energy to be generated should be divided in such a way it will match to the user's needs. Therefore the expected energy use of the future electrified households should be calculated.

The energy output will be in three phases. Therefore the houses need to be divided in three more or less equal groups.

Finally the electricity must reach the farm and several houses in the neighbourhood. For this you need to know the exact places of the houses to be connected, to know the length of cable you need. Another thing that must be taken into account is the thickness of the cables and the fuses in the houses.

3.2. Social

The traditional farmers are more and more leaving from the valley to live somewhere else. In this way the traditional way of farming is becoming less practiced. Whether or not these local people prefer to live in the valley is not clear.

When the hydropower system is ready to run, the electricity will be used by the farm, but also by the local families in the valley. It is not clear what they think about this project and if they see it as a positive change. Another important question is if the people are willing to help with the maintenance. Also what kind of appliances they are planning to use.

Another interesting thing to know is the perceptions people have about the changes the electricity will bring to their life.

4. Research questions

The research questions are divided in two groups. The first one is the technical questions. The second one is the social questions. The questions are divided in sub-questions.

4.1. Technical

If there was enough time I could have answered the question: “What is the performance of the installed micro-hydropower plant?”. However, the system was far from finished when I had to leave Ecuador. Mainly because we had a lot of setbacks due to the environment, like forest fires and flash floods. There was also a lack of funding and therefore the investigation for ballast loads and the purchase of it has been delayed. That is why I removed these research questions and only left the one I can answer now.

WHAT ARE THE APPROPRIATE PARAMETERS TO REALISE A MICRO-HYDROPOWER PLANT OF 4 KW IN THE CHIRUSCO VALLEY?

- What is the optimized penstock design?
    - How many pillars are needed, to prevent bending?
    - How thick must the foundation be for a stable construction?
    - What is the most efficient manner to implement a special order reduction from the penstock to the entrance of the PAT?
    - What kind of filtration system is needed?
- How thick must the platform of the powerhouse be to support all the equipment?
- How can the switching box be made ready for use?
- What is the best configuration to wire to houses?
    - How can the 3-phase system be in the best balance?
        - What is the expected energy use when the households are connected to the system?
        - What are the geographical locations of the houses to be electrified?
    - What length and what type of transmission lines are needed?
        - What is the voltage drop along the line?

4.2. Social

ARE THERE ANY SOCIAL EFFECTS EXPECTED AFTER THE INSTALLATION OF THE MICRO-HYDROPOWER PLANT?

- Why are farmers leaving out of the Chirusco valley?
- Where do the people prefer to live?
- What are the most important things for the local families to have a comfortable living?
- Is there trust in the system?
- What is the perception of the people, how will electricity in the valley change their lives?

5. Methodology

In this chapter the methodology is described, which is used to answer the research questions.

5.1. Technical

Before the practical realisation could take place, a good design and working plan have been made and the materials are ordered. Every step is discussed with Tina Marshall. When the constructing of the parts started, several local workers and volunteers at the farm helped with the work. I also worked with a local hydro engineer and an electrical engineer. Furthermore I had contact with H-Energiesystemen B.V. who initiated this project and helped with some calculations (H-Energiesystemen B.V., 2011). The design of the different parts is being made with the help of some hydro design books: “Micro-hydro design manual” (Harvey, 1993) and “Mini and micro hydropower schemes” (Rodríguez & Sánchez, 2011).

5.1.1. Penstock and supports

The diameter of the penstock was already chosen to be 8’’ and also already purchased (Hul, J.F. van 't, 2009). Supports are needed to support the weight of the water and the PVC above the ground and to constrain movement of the penstock. The supports are made from concrete pillars with a concrete foundation. To ensure low maintenance costs the supports of the penstock are placed on stable slopes to find firm foundations. The supports are designed to withstand both upwards and downwards forces so it is stable to hold the penstock. The diameter reduction from the penstock to the entrance of the PAT has been made, with having the degree of angle in mind. The reduction and the angle are ordered and made by a local water company.

5.1.2. Filtration system

For the filtration system some metal screening filters can be placed every 20 metres along the canal. The filters can be pulled up and cleaned. Before the entrance to the penstock another screening filter must be placed with a really fine mesh. The filters can be welded from metal rebar. The filters still need to be installed.

5.1.3. Powerhouse

The platform for the powerhouse is generally made of concrete. The powerhouse must be constructed above flood stage. The loads are calculated to ensure a strong enough platform. The powerhouse itself can be made of anything. The cheapest option in the Chirusco valley is adobe bricks. The powerhouse itself still needs to be build, the foundation is finished.

The PAT must be installed and placed on the platform of the powerhouse. The generator must also be installed on this platform. The PAT and the generator still need to be installed.

5.1.4. Switchboard

The switchboard has been checked with the help of the electrical scheme, given in Appendix D Figure 14. A multimeter is used to check the connections. The fuses are replaced. Furthermore the box has been ordered more logically and provided with nameplates so it is easier to recognize for the persons who will continue with this project and connect the switchboard to the system. The reordered switchboard can be seen in Appendix D Figure 15.

5.1.5. Wiring to houses

There are two groups of users who will make use of the hydropower installation; the people that already use electricity (from solar power) and the people who don’t have electricity at all. The energy use of the first group of people was easily found by asking which appliances they already use. Furthermore this group was asked

which appliances they like to use if there is more energy available. The second group of people are also asked which basic appliances they would expect to use if they have electricity.
For the wiring to the houses, the distances must be known. This can be measured with a GPS. The application 'Quantum GIS' is used to make maps and calculated distances.

5.2. Social

For the social part I interviewed 18 different people, varying in age from 26 to 83. Of these people were 7 female. Nearly all the people who are or who were living in the valley were interviewed. Some of them were at other places for a while, so were not available for interviewing. Besides these people I also interviewed some other family members and other people who are involved. This includes the president and the vice-president of Tumianuma.
The interview was done in a semi-structured way. In this way I could ask new questions brought up during the interview, as a result of the interviewees response. It was not possible to arrange interviews in different focus groups, for example male and female.

6. Results technical part

6.1. Penstock

6.1.1. Supports

The penstock is the tube that carries water under pressure from the forebay tank to the turbine. In our case we use high pressure PVC pipes with a diameter of 20 cm. These materials where already bought three years ago, when the project started. The advantage of PVC with regards to steel pipes is the lower cost, light weight material and anti-corrosive properties. Also the installation is much simpler since no welding equipment is needed. However, steel pipes can withstand greater pressure but with this small system, with a total head of around 11 m, PVC will fulfil.

The PVC pipes we use have flexible unions that do not require glue to joint. The socket has an incorporated rubber ring with a steel core where the pipe end fits is directly. Only a layer of lubricant is applied. The joints are watertight and can resist loads from horizontal and vertical tractive forces. (Supreme, 2007).

For the calculations I used some fixed values, including the flow design, gross head and physical and mechanical characteristics of the used material. These fixed design values can be found in Table 1.

Table 1 - Fixed design values

Total gross head	H_b	11.7	m
Flow rate	Q	0.05	m^3/s
Length of pipe segment	L_i	6	m
External diameter pipe	D_e	0.2	m
Internal diameter pipe	D_i	0.183	m
Wall thickness pipe	t	0.008	m
Density PVC	ρ_{PVC}	1435	kg/m^3
Modulus of elasticity PVC	E_{PVC}	$3 \cdot 10^8$	$kg/\ m^2$
Maximum yield stress of PVC	σ_{PVC}	625	kg/cm^2
Moment of inertia penstock	$I_{penstock}$	$2 \cdot 10^{-5}$	m^4
Density concrete	$\rho_{concrete}$	2400	kg/m^3
Friction coefficient between soil (gravel stratum, not dense) and concrete	$\mu_{s/c}$	0.6	
Admissible bearing capacity of the foundation soil	σ_T	3.00	kg/cm^2

The penstock cannot be buried because of the design and the difficult terrain. Pillars are needed to support the weight of the water and the PVC above the ground. The supports are made from concrete pillars with a concrete foundation. I calculated the stresses which are involved; when the pipe expands and when it contracts. When the pipe expands the force of the friction between the pipe and the block are upwards. When the pipe contracts the force is directed downwards in the direction of the pipe. If the supports are designed to withstand these forces it is stable to hold the penstock.

The calculations for the supports are given in Appendix A 'Penstock'. Also the wall thickness is verified and the friction loss calculated. A short summary for the design is that there were 4 foundations made, with a surface of 1 m^2, with a depth of at least 0.5 m for the first foundation and 0.25 m for the other foundations. On each of these 4 foundations a pillar is made of 0.3 by 0.3 m with different heights. The foundations and pillars are made of concrete; consisting of sand, stones, rocks, cement and water. The pillar will be strengthened with rebar in the concrete. With this set-up I calculated that the bending of the tubes will be 7 cm. Together with engineer Nelson we decided to build more pillars to prevent bending. So then we made 4 more pillars, which means that the tube will have a support at every 3 metres. The last 10 metres will not have any pillars, because there the tube will be in the ground.

6.1.2. Penstock connection to the PAT

A sketch of the connection can be seen in Figure 2. The reduction will be from 8 to 3 inch at the end of the penstock and is of the same PVC material as the penstock itself. The valve is also made of PVC but the angle is made of iron and will be 19 degrees. With the installation the pieces can be cut at the right length, so the angle will perfectly match with the pump as turbine. It can then be connected with nuts and bolts.

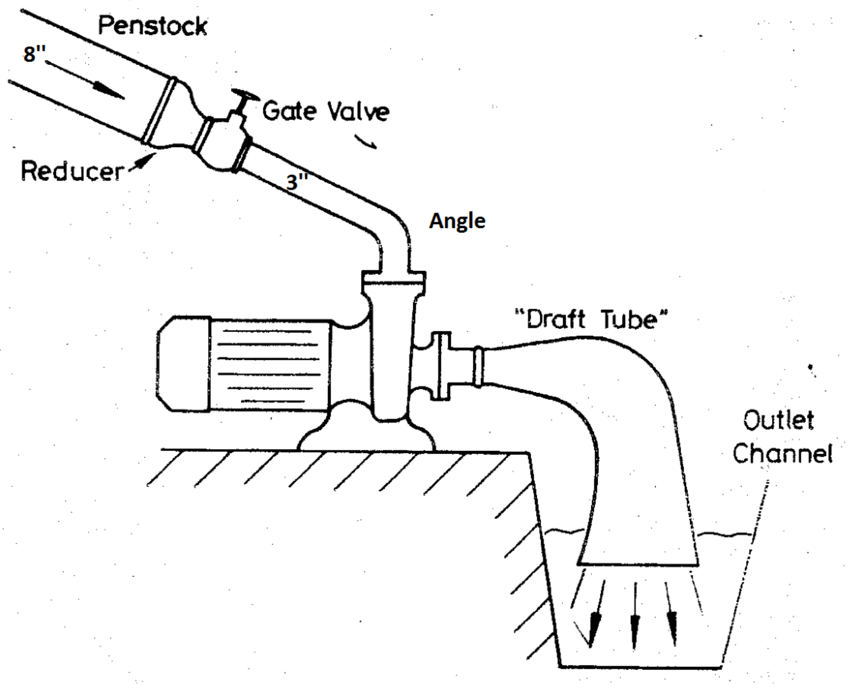

Figure 2- Sketch of the penstock connection to the PAT

Valve

It is recommended to have a valve at the bottom of the penstock so it can be emptied. The turbine can be uncoupled by closing the valve. The valve we used is a gate valve which cannot be closed quickly. This is because otherwise large pressure surges can occur in the penstock which will lead to damage. The valve is inserted immediately before the PAT, after the reduction.

Outlet

An expanding pipe (draft tube) will be used to increase the diameter of the pipe where it discharges the water into the outlet channel. The water in the outlet channel will be at atmospheric pressure; therefore it must be large enough and with a slope to take away the full flow from the PAT. The expanding pipe will lead the water out of the powerhouse and there it will flow in the outlet channel, which returns the water back into the stream.

Air vent

Usually an air vent is placed at the top of the penstock to avoid vacuum collapse of the penstock. This can happen while it is emptied or when the penstock mouth is accidently blocked. In our case it would be difficult to install an air vent because the first tube was already installed. But to avoid vacuum collapse the following things should be taken into account. First the forebay tank should be covered, so no rocks can enter and block the tube. Also filters must be placed at the entrance of the forebay tank, so again no rocks can enter and block the system. The second thing is, when the penstock must be cleaned or for other reasons be emptied the entrance of the tube should not be blocked to stop the water flow. The water flow can be stopped in the first sediment basin by closing the channel with wooden boards. In this way potential incoming air can always flow out of the penstock via the entrance of the tube.

6.2. Powerhouse

The powerhouse will not only be a house for the machines, but there will be another floor on top of that for other purposes. It might be a small greenhouse with air heaters as ballast load. This means that the foundation and the walls must be strong enough not only to hold the machines and the weight of the penstock but also the weight of another floor.

Another really important thing to keep in mind is the creek. The creek is running really close to the powerhouse. In the rainy season this will be even closer. There might be times that the creek will flood the powerhouse. Although it might happen every 100 years, it can be this year already. So we have to protect the house for this river really strong. Furthermore it also needs to bear seismic motions. Keeping this in mind I designed the foundation.

The hole is 2 metres deep and around 2 by 2 metres wide. The lowest layer will consist of huge rocks (which can be more than 1 m) enclosed with concrete[1]. This will be a layer of 1 metre. On top of that will be a layer of 30 cm with only small stones (not bigger than 20 cm) with concrete. The upper layer will only consist of concrete with rocks not bigger than 2 cm.

In each corner of the hole is a long square rebar, which will reach to the top of the house. Above ground level it will be boxed in concrete (like the pillars). Around 10 cm below ground level an armament net is placed (with darns of 15 cm). At the sides of these net horizontally square rebar is placed, to reinforce the walls. The armament net will be tightened to the horizontally and vertically placed rebar.

On top of the ground level an extra 'box' of concrete is made for the machines. When there is water leaking in the powerhouse it will not reach the machines, because of this higher box. The underlying floor is made with a small angle so the water will flow to one side of the powerhouse where it is connected with tubes to the outside. This 'box' is 15 cm high and 115 by 75 cm. It has a basket of armament (also with darns of 15 cm). This net will be connected to the net underneath.

The bolts for the machines are reinforced in the concrete. This will be normal bolts, but at the end 3 pieces of rebar are welded to have an anchor which will be strong in the concrete. To ensure the bolts come exactly at the right place a wooden mould has been used were the bolts are connected at the top. This mould is removed later when the concrete was hardened.

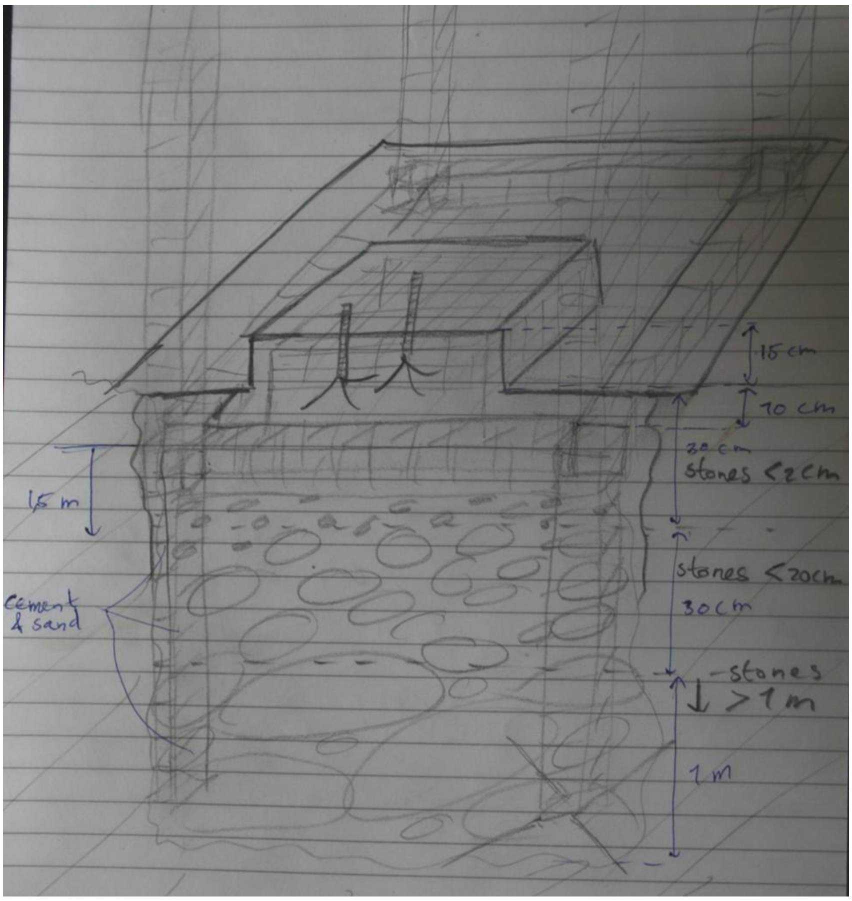

Figure 3 - Sketch of foundation for powerhouse

[1] with concrete I mean the mix of Portland cement, sand, small stones (not bigger than 2 cm) and water

6.3. Wiring

6.3.1. Energy use

The overview of the expected energy use can be found in Table 2. The extensive version can be seen in 'Appendix B Energy use'. As you can see the total expected peak power is 2.7 kW, which is far less than the expected generated power of 4 kW. This means that every household can use more energy than they expect to use. Or maybe new households can be connected to the system.

Table 2 - Expected energy use

House	Peak power [W]
Tina	285
Cuisina	181
Wooden house	26
Large dorm	57
Bodega	193
Hans	19
Jay and Caroline	304
Lucho Medina	241
Pesantes-Armijos	241
Manuel Medina	262
Abad	290
Delgado	255
Walter	350
Powerhouse	15
Total	**2719**

6.3.2. Three phases

The generated power will be 4 kW, which means there will be 1.3 kW per phase. The line voltage will be 110V, which means each phase has a current of 12 A.

Each house will be connected to one of these phases. All the houses must be divided in three equal groups (3 phases), with a total maximum use of 12 A. In this way you have a balanced system.

Because the wiring is an expensive part of the system it is also good to look at the geographical locations of the houses. Each different phase starts from the powerhouse and then goes to the rest of the houses, which means that at some routes different wires are passing. By looking at the geographical locations I tried to find groups with the least length of wire. For example, you use less wire if you put the farthest houses on one phase together, instead of dividing them to different phases.

I made three groups of phases in the most optimized design regarding balance of energy-use and costs (length of wire). These groups of houses approximately consume about the same and are on a geographically logical route. In Table 3 until Table 5 you can find the division I made for the different phases. The 'maximum use' is what the fuses in the houses should be. So in example Tina should have a fuse of 6 A, and therefore can maximum use 6 A. If she uses more, the fuse will break.

In 'Appendix C Wiring' you can find geographical sketches in Figure 7-Figure 10 of the different phases how they will be wired. The wiring for the neutral will run from the powerhouse and from there to every other house, from all the different phases.

Table 3 - Phase 1

Phase 1	Expected use [A]	Maximum use [A]
Tina	2,6	6
Wooden house	0,2	1
Hans	0,2	1
Jay and Caroline	2,8	4
		12

Table 4 - Phase 2

Phase 2	Expected use [A]	Maximum use [A]
Cuisina	1,6	4
Large dorm	0,5	2
Bodega	1,8	2
Lucho Medina	2,2	3
Powerhouse	0,1	1
		12

Table 5 - Phase 3

Phase 3	Expected use [A]	Maximum use [A]
Pesantes-Armijos	2,2	3
Manual Medina	2,4	3
Abad	2,6	3
Delgado	2,3	3
		12

A special remark on the third group is that they only exist of local farmers and none of these households have electricity now. This means that the energy consumption will slowly increase, but not as fast as the other groups. They have to save money to purchase appliances, which will take a certain amount of time. I expect that it increases more slowly than the other groups. This means that especially in the beginning, the groups are in a good balance. But maybe in 10 years, when their energy consumption is increased or when there are coming more farmers back to the valley, they should be connected to another group.

6.3.3. Transmission lines

The transmission cables are an insulated group of conductors that transfers the generated power from the powerhouse to the users along the line.

An underground cable is safer and also more protected than an overhead line. Especially in this rural area where rocks are often falling from the mountain and fires will burn the mountain. However, it is more labour-intensive to bury the cable. The total length of the different phases can be seen in Table 6, this is based on the sketches of the different phases, by drawing straight lines for having the most efficient way.

Table 6 - Total cable length

	Length [m]
Neutral	2689
Phase 1	539
Phase 2	792
Phase 3	2355
	Total: 6375

It is important to select the right conductor size to keep the voltage drop low between the two ends of the cable. Normally the voltage drop in micro hydro schemes should stay within the limit of 4-11% (Harvey, 1993). The voltage drop over a certain length of power cable can be calculated from:

$$V_{drop} = \frac{I \cdot \rho \cdot l_{cable}}{A} \qquad [1]$$

ρ is the electrical resistivity in Ωm, l_{cable} the length of the cable and I the rated current. The rated current which will flow through each cable, generated by the generator, will be 12 A. There is already bought some stranded aluminium wiring with a diameter of 7 mm. The calculation I made are based on this wire, with an electrical resistivity of aluminium of $2.82 \cdot 10^{-8}$ Ωm (Raymond, 1998). The results can be seen in Table 7. In 'Appendix C Wiring' you can find in Figure 11-Figure 13 the voltage drop numbers in the geographical sketches.

Table 7 - Voltage drop

	House	Distance from powerhouse [m]	Voltage drop [V]	Voltage [V]	Percentage of voltage drop [%]
Phase 1	Jay & Caroline	550	5	105	4
	Tina	440	4	106	4
	Wooden house	380	3	107	3
	Hans	270	2	108	2
Phase 2	Lucho Medina	780	7	103	6
	Bodega	560	5	105	4
	Cuisina	370	3	107	3
	Large Drom	400	4	106	3
Phase 3	Delgado	1930	17	93	15
	Abad	1540	14	96	12
	Manuel Medina	1440	13	97	12
	Pesantes-Armijos	1100	10	100	9
	Walter Moora	990	9	101	8

As can be seen in Table 7 the voltage drop is higher than 11% in phase 3, this is so high because of the large distances and the low source voltage of 110V. When a system with a source voltage of 220 V had been chosen the maximum drop would have been only 4%.

You can solve this problem by using a bigger aluminium wire in the third phase. However, you can also choose to work with a lower voltage. For normal household appliances this would not be a problem. The limits of minimum voltage are that motors starts to draw more current and run hotter, therefore heavily loaded motors will have a shorter life (is significant at 6% below rated voltage) (Harvey, 1993). Besides that lights and heaters will have reduced power.

7. Results social part

18 different people were interviewed, varying in age from 26 to 83. Of these people were 7 female.
There are roughly three groups of people were is written about. The local people, the villagers or the families are the Ecuadorian people who are living in Tumianuma. The farmers are also Ecuadorian people who are living in Tumianuma but used to live in the valley. The western or foreign people are the non-Ecuadorian people, most of them coming from the United States, who choose to live in the valley.

7.1. Residence

There are five houses in the valley which are most of the time inhabited. The people who are all the time living there are all western people. The local people are all living in Tumianuma. Some of them lived in the valley before, but left their house to live in the village Tumianuma. They left most of the time because of the woman or the children who want a more comfortable living style. Some of them still have a house in the valley where they work during the day on the land and sleep in the village. In Figure 4 you can find the percentages of interviewees in the different resident places.

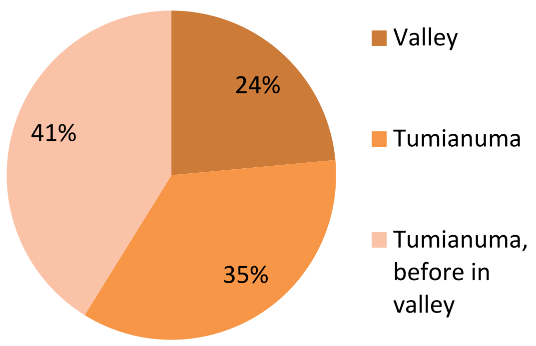

Figure 4- Residence place of interviewees

7.2. Projects image

All the interviewees had heard about the project and all the locals are very positive about it and say it is a good idea. They think it is a good way to lent the water from the river and use it to generate electricity. All of them agree that environmentally it has very low impacts. All the local people pointed out it is a very cheap way to generate electricity and see it as a free form of having energy. One of them saw such a kind of system somewhere else, so he knows it should be working.
All the foreign people are a bit more sceptical about the project. They also think it is a great project with low environmentally impacts but they also see some drawbacks. They are pointing out that it is a very costly project with a lot of unknowns. They are questioning themselves why it is such a big project, where it is now the question how to consume all the generated electricity. It sounds strange for them to find a way to ballast the system and to find appliances which can be used as ballast load[2]. The question is now how to use all the electricity in a beneficial way and therefore the need to purchase submersible water heaters to use as a ballast load and get rid of the electricity.

[2] The system is continuously producing electricity. Ballast loads are used when not all the electricity is consumed, for example during the night. In this case the switching box will switch to the ballast loads who can consume this electricity. These ballast loads can be every kind of appliance that needs electricity. The total amount of ballast loads that are needed is the same as the total power of the system; 4 kW.

7.3. Personal benefits

In Figure 5 you can see whether being connected to the hydro power network will have personal benefits for the people or not.

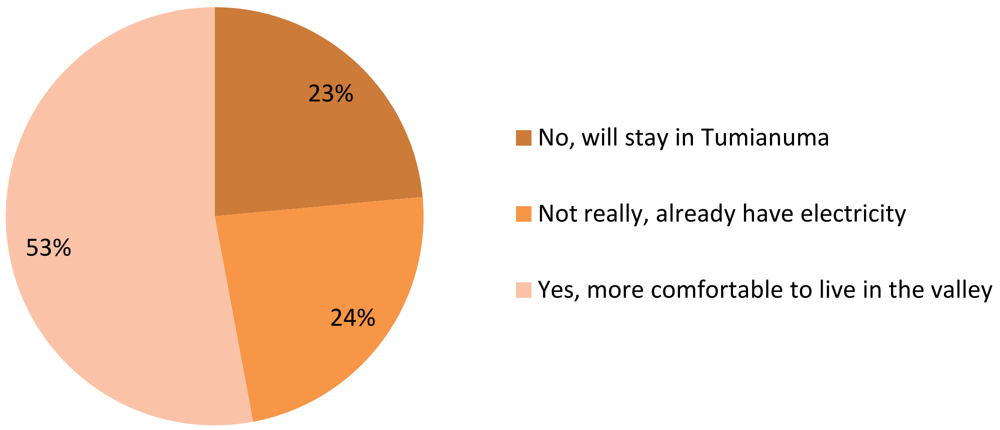

Figure 5 - Personal benefits of having electricity

For most of the people there is a personal benefit for they will go back and live in the valley. It is more comfortable to live there with having electricity, especially during the night to have some light. Two people mentioned that if there is electricity they will not have fear anymore during the night when living there, because they have lights or can install an alarm system. Another personal benefit is that they can actually live on the place where they prefer to live. They like to live on a more quiet and peaceful place where there is much more space. Also they will come back and start the traditional farming life again, what they actually love to do. Some are mentioning that there is only a personal benefit if the electricity is for free.
For all the western people it is not really a personal benefit to be connected to the system. One person only wants to use it for a few lights, but if the hydro was not here, he would use solar power. The others already use solar power, and do not want to use more electricity. One interviewee was saying that if you have more energy, you can use more appliances and then you will get these appliances which will perpetuate. And such a system was exactly where they were running away from. They do not want to rely on electric goods or having a regulated life by electronics. They would rather balance their live with what is available. One of the foreigners does not want to be connected at all. He would rather have that all the electricity goes to the locals, because he can afford it to provide his own energy with solar panels.

7.4. Expected effects

7.4.1. Positive

70% of the local people I spoke to, want to move to the valley if there is electricity. The really old people will stay in Tumianuma, because it is much better to access. But the children and the children of these people, who used to live in the valley, really like to come back and do farming activities. Some are also saying that the other family members will go there more often when they live there. Besides the men, also the women prefer to live there.
All the people agree that if the electricity will go to the families it will be positive for the valley. It will improve the living quality. Mostly all of them think people will come back and live in the valley. Only one of the foreigners does not think they will come back to have a farming living because it is not accessible by streets.

7.4.2. Negative

The major part of the interviewees does not see negative effects. Their reasoning is that if everybody wants it, there will not be any negative effects.
One of the non-Ecuadorian people is mentioning that the maintenance system does not seem viable. It is a huge responsibility which cannot rely on all the people together, because then nobody feels responsible. It needs a kind of set-up for a good consistency. It would be good for the valley if you make it a job opportunity, where someone is responsible. If the maintenance system is not working, one negative effect could be that the system is not working most of the time.
The local people are really afraid of being charged money at some time. That is what also happened in the village; suddenly the prices for electricity increased tremendously. One local asks the question what happens if Tina dies, or if she sells her farm. Then the negative effect for the locals can be that the new owner has totally different plans with the hydro power system and he does not want to share the electricity or will charge money. If everyone now is investing and making effort in living there and will lose it afterwards it will be a huge negative effect.

7.5. Appliances

All the people want to use or are using the electricity for lights. The local people are also talking about radio and television. Four of them also want to have a refrigerator to keep meat and vegetables fresh. One person is mentioning an alarm system, which again points out the fear some people have in living there without electricity.
The foreigners are more against the use of using more appliances. One of them lived for years without electricity. The rest of them already have solar panels for their basic needs as lights and a laptop. They adapted their living style with not having much appliances. However, one of them wants to buy a solar refrigerator to keep the milk of the goats cool.

7.6. Payment

If you want to sell electricity in Ecuador you need to be an electrical company. This is really difficult to realise with all the paper work and it is very expensive. Tina chose to leave all the paperwork and therefore she needs to give the electricity away for free. However, if all the families get free energy their property value will increase. People are more likely to buy a house with electricity then without. But if the local families sell their houses in the valley to others (can be people from somewhere else of the region or western people), it is in contrary with the aim of this project: keeping the local farmers in the valley. Therefore the people in the valley will not get the electricity as a gift but they will lend it from Tina. The people will get electricity in change for their help with the building of the plant and all the maintenance work. A good agreement must be made with all the conditions. Of course they can sell their property, but not with the electricity. Tina will be the owner of the electricity and she can easily close the connections.

7.7. Maintenance

All of the people who want to be connected to the electrical system are willing to help in the maintenance. Some of them suggested that it can be the same as it is now with the water system in the village. Especially during the wet season the filters needs to be cleaned a lot of time and people can help with the physical work or they can pay a guy who will do the maintenance. When it needs some bigger maintenance they organise a minga; gathering a lot of people and do the work together. They are all willing to discuss together and make a plan for doing the maintenance.

7.8. Water

Because of the semi-structured interview it appeared that besides having electricity, potable water was an equally important condition for the people to come back and live in the valley. The potable water for the

village passes over the farms along the line, which means that these houses do not have potable water and need to get their water from the river. The wet season brings the difficulties of river water with a lot of sediment and in the dry season there are fewer streams so the water is further away.
There is a possibility to use the old water pipes for a new connection to the houses. This can be connected to the forebay tank of the hydro power system, which will ensure the pressure. With some cleaning filters potable water can be realised also for the farmers.

8. Conclusions

Technical

There are still many parameters that need to be done to realise the micro-hydropower plant of 4 kW. This includes the building of the powerhouse, the installing of the reduction and the bend to the PAT, the installing of the generator to the switchbox, the purchasing of ballast loads and the installing of the transmission lines to the houses. Also the filtration system needs to be installed, but the design is already made. The appropriate parameters that are designed and constructed are listed below.

Partly due to environmentally setbacks, major floods and mudslides, a lot of extra work needed to be done. But due to this extremely weather, weak places were found in the canal. These places are reconstructed and protected with an overpass, so the rocks and the mud can pass the canal.

Penstock

The penstock is installed and is supported by 8 pillars. These pillars are made of concrete and strengthened with rebar. The pillars are based on a foundation, where the dimensions depend on distance between penstock and soil. The construction is calculated to both withstand forces when the pipe expands as well as contracts. The maximum bending sag is 4 mm.

The penstock connection to the PAT is made of an 8 to 3 inch PVC reducer, followed by a valve and after that an iron angle which can be connected to the pump. The outlet is an expanding pipe that will discharge the water into the outlet channel.

Powerhouse

The powerhouse self is not constructed yet but the foundation has been made. The foundation is designed to withstand the forces of not only the machines, but also another floor. Furthermore it had to be protected against the river. The foundation is made in different layers, starting with huge rocks and ending with concrete and small stones. A basket of armament has been made to put the machines on. The bolts for the machines are reinforced in the concrete. The pump as turbine and generator can easily be attached to the foundation, but first the powerhouse needs walls and a roof for protection. The switching box is reordered and ready to connect to the system.

Wiring

The expected peak power is 2.7 kW, which is below the expected generated power of 4kW. This means that every household can use more energy than they expect to use, or that new households can be connected to the system. Three different groups of houses are made which will be connected to the three different phases. With the most optimized design in both balance of energy use and costs, the total length of wire that is needed is 6.3 km.

With transmission lines made of aluminium, 7mm in diameter, the maximum voltage drop will be 17V. Although it is above a 10% voltage drop, it only occurs to the three furthest houses. Assuming they will only use household appliances this will not be a problem.

Social

Most of the people are really enthusiastic to receive electricity in the valley. A lot of people moved to town because there were no resources to make life comfortable, which makes it difficult to live in the valley. With electricity they will come back to the valley and live there. The local people want electricity for just making their life a little bit easier, with having lights and radio all the day. It is also a reason for their children not to leave from this area and come back and work in this area on a traditional farmer way. Besides having electricity another important necessity is potable water, which is now difficult to access in the valley.

There are people who are not very interested in having electricity in the valley because of several reasons. The very old people will not come back to the valley, because it is still difficult to access. There are also some people from other countries living there, who do not really need the electricity. Most of them already have their own solar panels and they would rather give the water power to the local people who cannot afford it.

The general perception is that the positive effects of this project are that the families will come back in the valley and have a traditional farmers life. No real negative effects are expected, if it is properly organised, regarding agreements and maintenance.

There were no remarkable differences observed in the opinion of the male and female or the younger and elder people.

9. Recommendations

In this chapter you find some recommendation for a good continuation of the micro hydropower project.

Wiring

I divided the houses among the 3 phases. If you want to change these groups you should be aware of two different aspects which influence the outcome. First is the length of the wire, which can increase dramatically if you change the groups. Keep the geographical sketches as a reference. The second aspect is that the total amperages per phase cannot exceed the 12 A. So the houses connected to one phase, should have an aggregate size of the fuses of 12 A. You can easily change a suggested fuse of 1 A to 2 A, but then you should also lower a fuse in the same group of another house from for example 4 A to 3 A, as long as the total is 12 A. In this way you ensure safety. Per phase the total amount of wire is calculated, but this is based on straight lines to have the most efficient way. In practice you will not be able to lay the cables in the most efficient way and therefore there is a good chance you need more wire.

Maintenance

It is important to realise that the system needs a lot of maintenance. It will not need 'difficult' maintenance that much but it will need some 'easy' maintenance. With this I mean the cleaning of the filters, especially during the wet season when a lot more debris is taken by the river. The filters needs to be unclogged, but it is not to say how often this must happen. I think especially in the beginning it is important that someone is having a look everyday from the powerhouse, to the penstock all the way up to the end of the canal, just to see how it looks and what must happen. Then you can make a plan how often things must be cleaned.
Furthermore it is important that someone is responsible for the maintenance. With all the people together it is not going to work. Maybe all the connected people can give a little bit of money to one person, who will be responsible in example to clean the filters every day. If it is on a voluntary basis, it will always be the same people fixing the work, which can lead to quarrels. Or no one is feeling it is their time to go.

Education

The local people need to learn that this system is different in handling than the local grid. The difference is that hereby there is less energy and every house has a fuse that is much lower in amperage than a normal local grid connection. This means that you cannot have an 'endless' amount of appliances turned on. For example the television and the blender cannot be turned on together (depends on the fuse if this is possible). This should not be a problem because you will only use the blender for a short moment. And if it happens it is still not a real problem because the fuse will only break, which can easily be repaired by switching it on again. But to avoid frustrations and not understanding why it happens maybe some educational illustrations can be made. These can illustrate which of the appliances can be or cannot be turned on together. They can hang these illustrations in their house which will make the system easier in use.

Meetings

I was really amazed during the interviews that nobody was disappointed that the system was still not working, while electricity was promised three years ago. But I think that due to the interviews the people started thinking about it again and they really wondered when it will be finished. It is really important that you stay connected with the people and keep them informed. Maybe it is good to start having meetings once in a while. During these meetings you can talk about which places will be connected. Discuss about a maintenance plan, maybe give people responsibilities. And you can also learn them about the effects of having limits to the amount of electricity. An important thing of these meetings, besides keeping them informed, is that the people have a voice and can give their ideas and their side of the story. Furthermore if the local people are included and have more part of in system it will be more a sustainable whole; in both using and maintaining the system.

Agreement

For both the peoples perspective as from the perspective of the farm it is important that an agreement is made that is signed by both parties. In here you can clearly state that the electricity is not a gift, but a lending system in change for maintenance. Also that it will not increase the property value of the land owners. So the right of the farm is that you can decide to remove the electricity if they sell their land.

From the interviews it turned out that the people are afraid what will happen if money is charged, or what will happen if someone else will be the owner of the system. If the people now invest in living there and helping with the maintenance there should be a right that they will have electricity. These kind of regulations can be clearly noted in an agreement.

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Appendix A Penstock

Stability of the supports

To verify the stability of the supports I checked the bending of the pipe, the sliding and the stability of the foundation soil; described in the next paragraphs.

Bending

The weight of the pipe and the water per linear metre are given in Table 8 . Each pipe is 6 m and the total pipe length is 37 m.

Table 8 - Weight of the pipe

Weight of the pipe	W_t	7.3	kg/m
Weight of the water in the pipe	W_a	26.3	kg/m
Total weight of one pipe	W	33.6	kg/m
Weight of total pipe length and water to be supported	W_{ta}	201.8	kg

If the pipes are supported at every joint the admissible bending stress is calculated to be 17 mm. The maximum sag is calculated to be 71 mm, which means that the pipes will bend 5.4 cm more than allowed. This can lead to problems if the penstock will not be support better, but in first instance the manufacturer of the pipes said it will be no problem.

$$\delta_{admissible} = \frac{L_i}{360} = 16{,}67\ mm \qquad [2]$$

$$\delta = \frac{5 \cdot W \cdot L_i^4}{384 \cdot E \cdot I} = 71.09\ mm \qquad [3]$$

For the stability of the support the vertical stress moments (stabilizing moments) needs to be bigger than the horizontal stress moments (bending moments) at the same point. The condition is given below.

$$Condition: \frac{\sum stabilizing\ M}{\sum bending\ M} \geq 2 \qquad [4]$$

The calculations are done for both pipe expanding and pipe contraction. The horizontal and vertical stress moments are calculated for a pillar of 0.3 by 0.3 m standing on a foundation in the ground. The height of the pillars can be found in the second column of Table 9 and Table 10. For pillar 5 and 6 there is no height because at these points the penstock will reach the ground. This means that for the last 12 metres no support is needed. As you can see in the last column the moments all apply to the condition with the assumed fundament width, depth and pillar height.

Summarizing is that there need to be made 4 foundations, with a surface of 1 m^2, with a depth of at least 0.5 m for the first foundation and 0.25 m for the other foundations. On these foundations a pillar needs to be made from 0.3 by 0.3 m with different heights. The foundations and pillars will be made of concrete, consisting of sand, stones, rocks and cement. The pillar will be strengthened with a rebar in the concrete.

Table 9 - Verifying the stability of the support when the force of friction moves upwards

Pillar	Height	Mass Pillar	Fundament width	Fundament depth	Mass fundament	Bending M	Stabilizing M	Check >2
	m	kg	m	m	kg	kg/m	kg/m	
1	2,7	583,2	1	0,5	1200	-415,8	1220	2,93
2	1,23	265,68	1	0,25	600	-189,4	650	3,43
3	1,6	345,6	1	0,25	600	-246,4	718	2,91
4	0,95	205,2	1	0,25	600	-146,3	598	4,09
5	0	0	0	0	0	-	-	-
6	0	0	0	0	0	-	-	-

Table 10 - Verifying the stability of the support when the force of friction moves downwards

Pillar	Height	Mass Pillar	Fundament width	Fundament depth	Mass fundament	Bending M	Stabilizing M	Check >2
	m	kg	m	m	kg	kg/m	kg/m	
1	2,7	583,2	1	0,5	1200	65,46	1275	19,47
2	1,23	265,68	1	0,25	600	29,82	705	23,64
3	1,6	345,6	1	0,25	600	38,79	773	19,92
4	0,95	205,2	1	0,25	600	23,03	653	28,37
5	0	0	0	0	0	-	-	-
6	0	0	0	0	0	-	-	-

In consideration with engineer Nelsson, who came to the site to see what we were doing, we decided to also make pillars in the middle of every pipe. This means that the penstock will have support every 3 m. The admissible bending sag is now calculated to be 8 mm and the maximum bending sag is 4 mm. The maximum sag is now lower than the admissible sag, so it is a better design.

Sliding

If the sum of the horizontal forces in the supports is greater than the frictional resistance of the soil, the block will slide. Therefore we have the following condition:

$$Condition: \sum F_x < \mu_T \cdot \sum F_y \quad [5]$$

μ is here the coefficient of friction between the soil and the concrete. The type of soil is of the kind gravel stratum, with a dense ground, which gives a friction coefficient of 0.6 (Rodríguez & Sánchez, 2011).

The first pillar will be the most critical for sliding, because it is the largest. The calculation of F_x and F_y, when the force of friction moves upwards, and applying the condition gives:

$$154\,kgf < 0.6 \cdot 1929\,kgf \quad [6]$$

$$154\,kgf < 1157\,kgf \ldots OK \quad [7]$$

When the force of friction moves downwards, the condition gives:

$$24\,kgf < \ -1196\,kgf \ldots OK \quad [8]$$

So for both situations the concrete will not slide from the soil.

Stability of the foundation soil

The base of the concrete block exerts a pressure on the soil. The base area must be big enough such that it is less than the bearing capacity of the soil. It must apply the following condition:

$$Condition: \sigma_T > \sigma_{max} > \sigma_{min} \quad [9]$$

σ_T = admissible bearing capacity of the foundation soil

σ_{max} = maximum bearing capacity transmitted to the foundation soil

σ_{min} = minimum bearing capacity transmitted to the foundation soil

The maximum and minimum bearing capacity are given by the following formulas:

$$\sigma_{max} = \frac{R_y}{A}\left[1 + \frac{6e}{b}\right] \quad [10]$$

$$\sigma_{min} = \frac{R_y}{A}\left[1 - \frac{6e}{b}\right] \quad [11]$$

Calculating this and verifying with the condition gives for pipe expanding:

$$3\,\frac{kg}{cm^2} > 0.99\,\frac{kg}{cm^2} > \ -0.60\,\frac{kg}{cm^2} \ldots OK \quad [12]$$

And for pipe contraction:

$$3\,\frac{kg}{cm^2} > 0.67\,\frac{kg}{cm^2} > \ -0.27\,\frac{kg}{cm^2} \ldots OK \quad [13]$$

The shape and pre-established dimensions of the support comply with all three stability conditions when the pipe expands as well as contracts.

Verifying wall thickness

The penstock must be strong enough to withstand very high pressures which can be a result from sudden blockage of the water flow. These high pressures are temporary and known as surge pressures, see Figure 6. A negative pressure wave destroys the penstock by inward collapsing and a positive wave destroys the penstock by bursting it. The wall thickness should be suitable to accommodate the negative and positive pressure waves. To reduce the risk of very fast stoppage of flow, and thereby reduce the risk of large surge pressures, a slow-closing valve should be used.

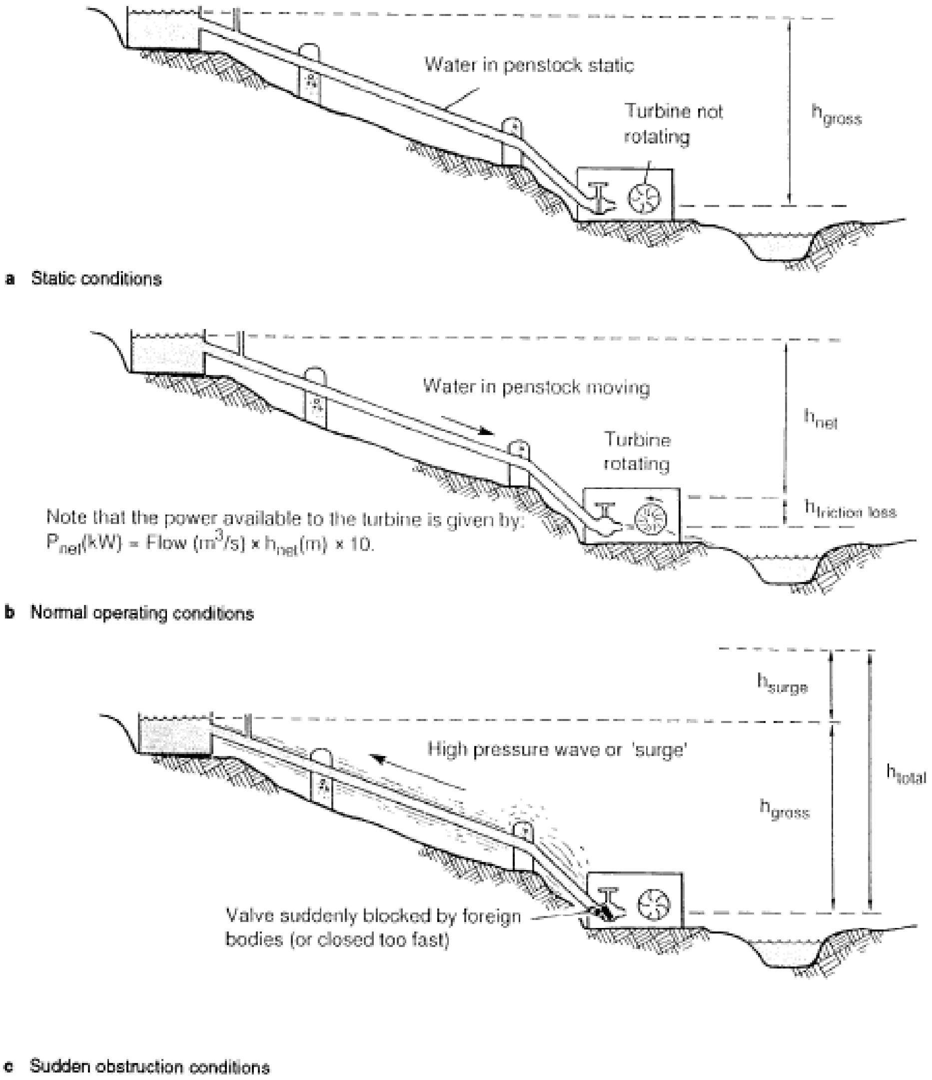


Figure 6 - Surge pressure and friction loss (Harvey, 1993)

Besides the surge pressure thinner walls of the pipes must also withstand the thinning while in service, caused by corrosion or manufacturing defects. As the tubes where already bought the only thing I can do is verifying the wall thickness. The method I used makes use of a safety factor, recommended is a safety factor of 3.

The surge pressure can be calculated by the following formula:

$$\Delta h = \frac{a \cdot V}{g} = 71\ m \qquad [14]$$

The pressure wave propagation speed, a, depends on the diameter, thickness and material of the pipe, which is calculated as following:

$$a = \frac{1400}{\sqrt{1 + \frac{2.1 \cdot 10^9 \cdot d_i}{E_{PVC} \cdot t}}} = 365\ m/s \qquad [15]$$

The method I used makes use of a safety factor, which can be calculated as following:

$$f_s = \frac{t \cdot \sigma_{PVC}}{5 \cdot h_T \cdot d_i \cdot 10} = 7.5 \qquad [16]$$

In which h_t is the surge pressure head plus the gross head. Recommended is a safety factor of 3. The calculated safety factor of 7.5 means it is a bit overdesigned, but the wall thickness is at least fairly safe.

Friction loss

The penstock will have friction losses and losses due to turbulence. Under normal operating conditions the netto head is the gross head minus the head losses, see Figure 6. The head loss can be calculated with:

$$h_p = h_f + h_t \qquad [17]$$

h_f = head loss due to friction in the interior wall of the pipe
h_t = head loss due to turbulence when the water enters the pipe, at section changes, in curves, valves, etc
The head loss due to pipe wall friction can be calculated by:

$$h_f = 0.08 \cdot \frac{f \cdot L_i \cdot Q^2}{d_i^5} \qquad [18]$$

The friction factor, f, can obtained using the Moody's diagram. The friction factor is found to be 0.015 for the 20 cm tube. With this the head loss is calculated to be 0.09 m in each 20 cm tube section. At the reduction the head loss increases to 0.79 m.
The head loss due to turbulence is depending on the velocity of the water and a factor, K, associated with the bend or obstruction:

$$h_t = \frac{V^2}{2g}(K_{entrance} + K_{bend} + K_{contraction} + K_{valve}) \qquad [19]$$

The velocity of the water can be calculated with the formula underneath, and is 1.9 m/s in the 20 cm tube. The velocity increases to 9.9 m/s at the reduction.

$$v = \frac{4Q}{\pi d_i^2} \qquad [20]$$

The turbulence losses are very high at the end, where the reduction, the valve and the bend are. This is because the velocity of the water is much higher at the smaller diameter; furthermore the K factor is high where the bend, the valve and the contraction are.
The total head losses in percentages can be easily calculated to divide the sum of the friction and turbulence losses with the gross head, which is 11.7 m in this case. An overview of the losses can be found in Table 11.

Table 11 - Overview of the friction and turbulence losses in each section

Section	h_f [m]	h_t [m]	h_p [m]	Total head loss
1	0.09	0.09	0.18	1.5 %
2	0.09	0	0.09	0.7 %
3	0.09	0	0.09	0.7 %
4	0.09	0	0.09	0.7 %
5	0.09	0	0.09	0.7 %
6	0.09	0	0.09	0.7 %
7	0.79	3.03	3.82	32.6 %
Total	**1.32**	**3.12**	**4.44**	**37.9 %**

Appendix B Energy use

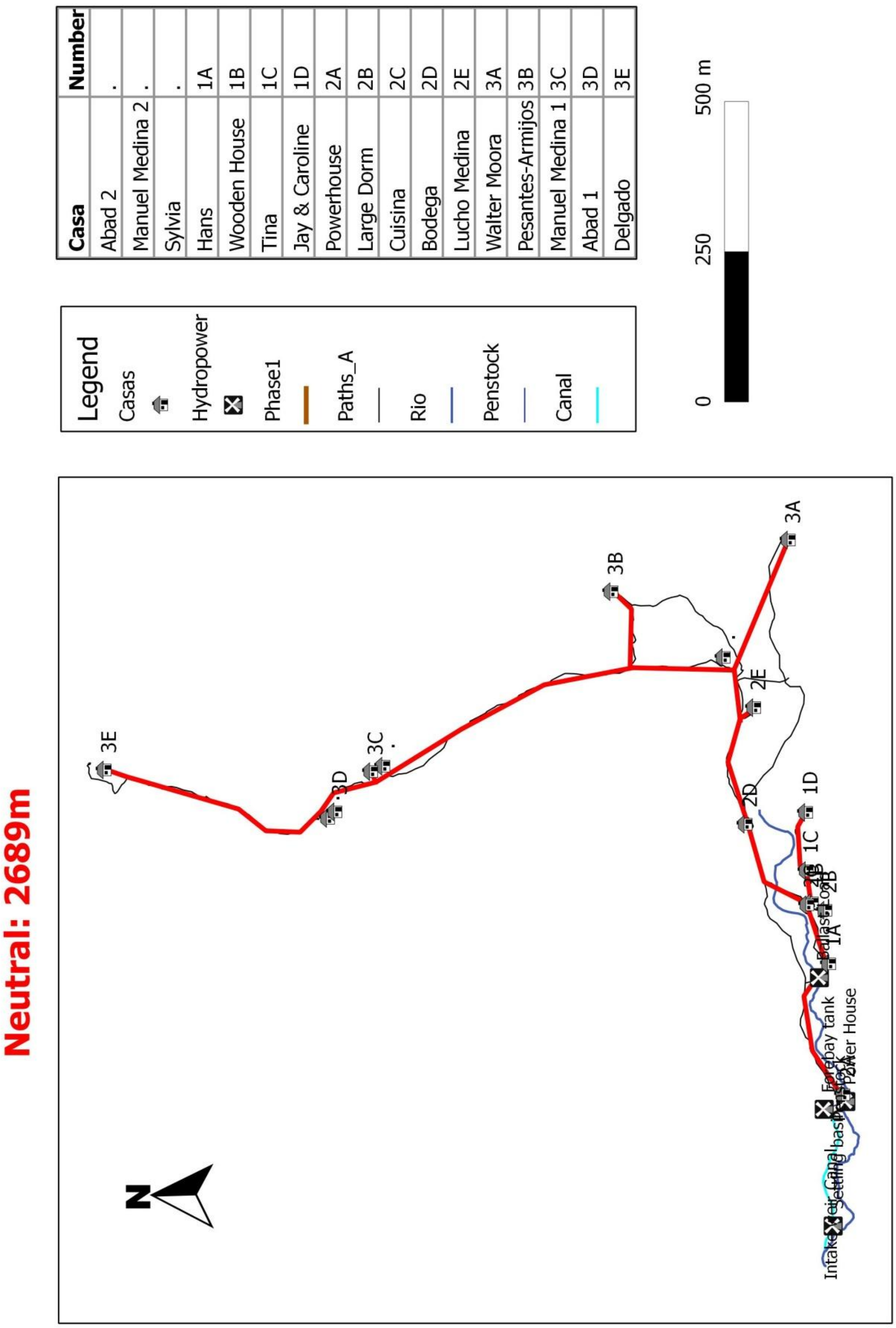
Table 12 - Expected energy use (extensive version)

House	Appliance	Power [W]	Number	Time of use [h]	Daily consumption [Wh]
Tina	Battery charger	3	1	24	72
	Mobile charger	5	1	5	25
	Laptop	60	2	7	840
	Lights	7	6	4	168
	Radios	3	2	24	144
	Speaker	9	1	3	27
	Router	60	1	24	1440
	Refrigerator	40	1	24	960
Total		**285**			**2716**
Cuisina	Radios	3	1	12	36
	Lights	7	4	5	140
	Blender	150	1	1	150
Total		**181**			**326**
Wooden house	Lights	7	3	3	63
	Charger	5	1	12	60
Total		**26**			**123**
Large dorm	Lights	7	6	3	126
	Charger	5	3	12	180
Total		**57**			**306**
Bodega	Lights	7	4	3	84
	Charger	5	3	12	180
	Blender	150	1	1	150
		193			**414**
Hans	Lights	7	2	4	56
	Radio	5	1	3	15
Total		**19**			**71**
Jay & Caroline	Lights	7	12	4	336
	Laptop	60	1	3	180
	Blender	150	1	1	150
	Charger	5	2	12	120
Total		**304**			**786**
Lucho Medina	Blender	150	1	1	150
	Charger	5	1	4	20

	Laptop	60	1	3	180
	Lights	7	3	4	84
	Radio	5	1	4	20
Total		**241**			**454**
Pesantes-Armijos	Blender	150	1	1	150
	Charger	5	1	4	20
	Laptop	60	1	3	180
	Lights	7	3	4	84
	Radio	5	1	4	20
Total		**241**			**454**
Manuel Medina	Blender	150	1	1	150
	Charger	5	1	4	20
	Laptop	60	1	3	180
	Lights	7	6	4	168
	Radio	5	1	4	20
Total		**262**			**538**
Abad	Blender	150	1	1	150
	Charger	5	1	4	20
	Laptop	60	1	3	180
	Lights	7	10	4	280
	Radio	5	1	4	20
Total		**290**			**650**
Delgado	Blender	150	1	1	150
	Charger	5	1	4	20
	Laptop	60	1	3	180
	Lights	7	5	4	140
	Radio	5	1	4	20
Total		**255**			**510**
Walter	Blender	150	1	1	150
	Charger	5	1	4	20
	Laptop	60	2	3	360
	Lights	7	10	4	280
	Radio	5	1	4	20
Total		**350**			**830**
Powerhouse	Alarm	5	1	1	5
	Motion sensor	3	1	24	72
	Light	7	3	3	63
Total		**15**			**140**

Appendix C Wiring

Figure 7 - Geographical sketch of the neutral wiring



Casa	Number
Abad 2	.
Manuel Medina 2	.
Sylvia	.
Hans	1A
Wooden House	1B
Tina	1C
Jay & Caroline	1D
Powerhouse	2A
Large Dorm	2B
Cuisina	2C
Bodega	2D
Lucho Medina	2E
Walter Moora	3A
Pesantes-Armijos	3B
Manuel Medina 1	3C
Abad 1	3D
Delgado	3E

Figure 8 - Geographical sketch of phase 1

Casa	Number
Abad 2	.
Manuel Medina 2	.
Sylvia	.
Hans	1A
Wooden House	1B
Tina	1C
Jay & Caroline	1D
Powerhouse	2A
Large Dorm	2B
Cuisina	2C
Bodega	2D
Lucho Medina	2E
Walter Moora	3A
Pesantes-Armijos	3B
Manuel Medina 1	3C
Abad 1	3D
Delgado	3E

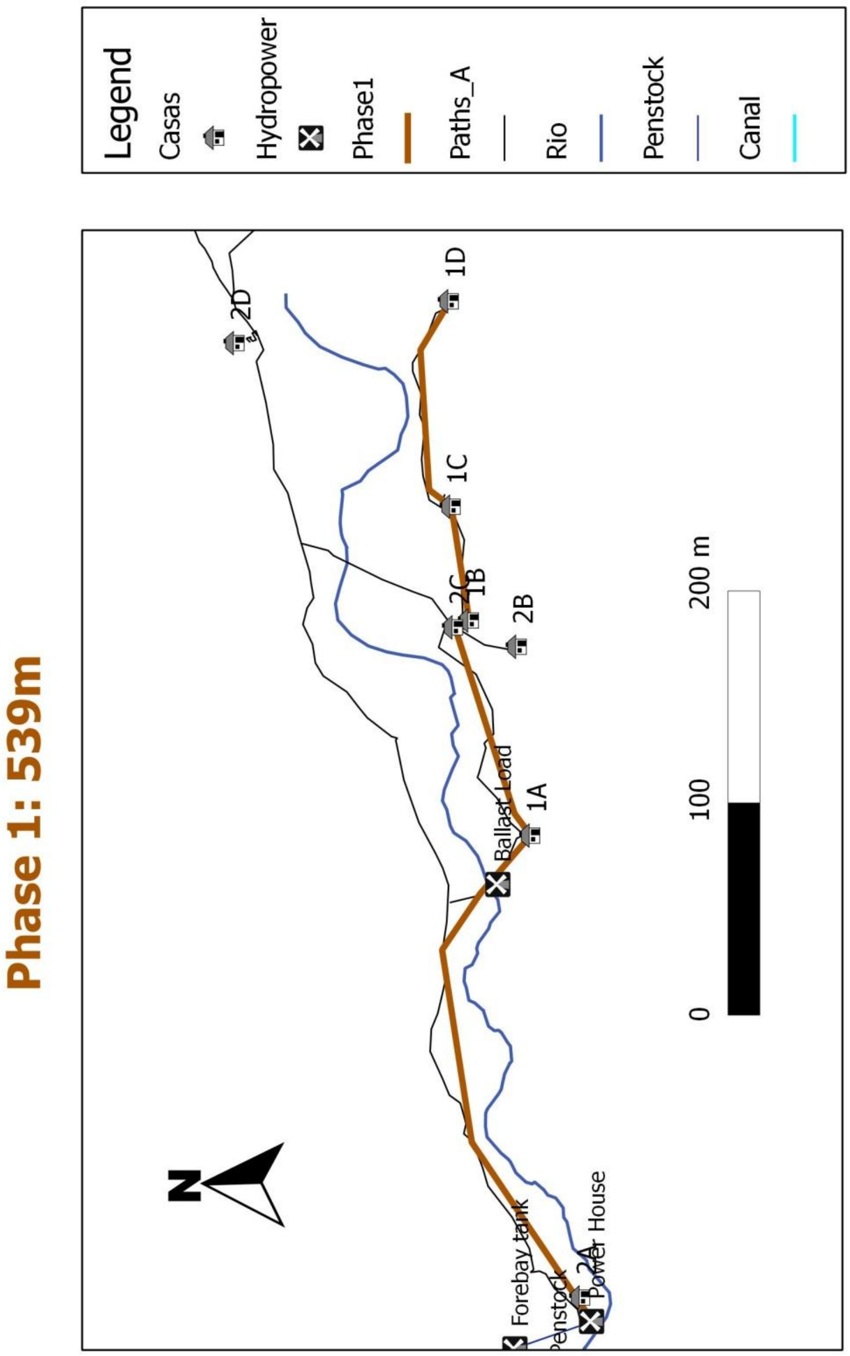
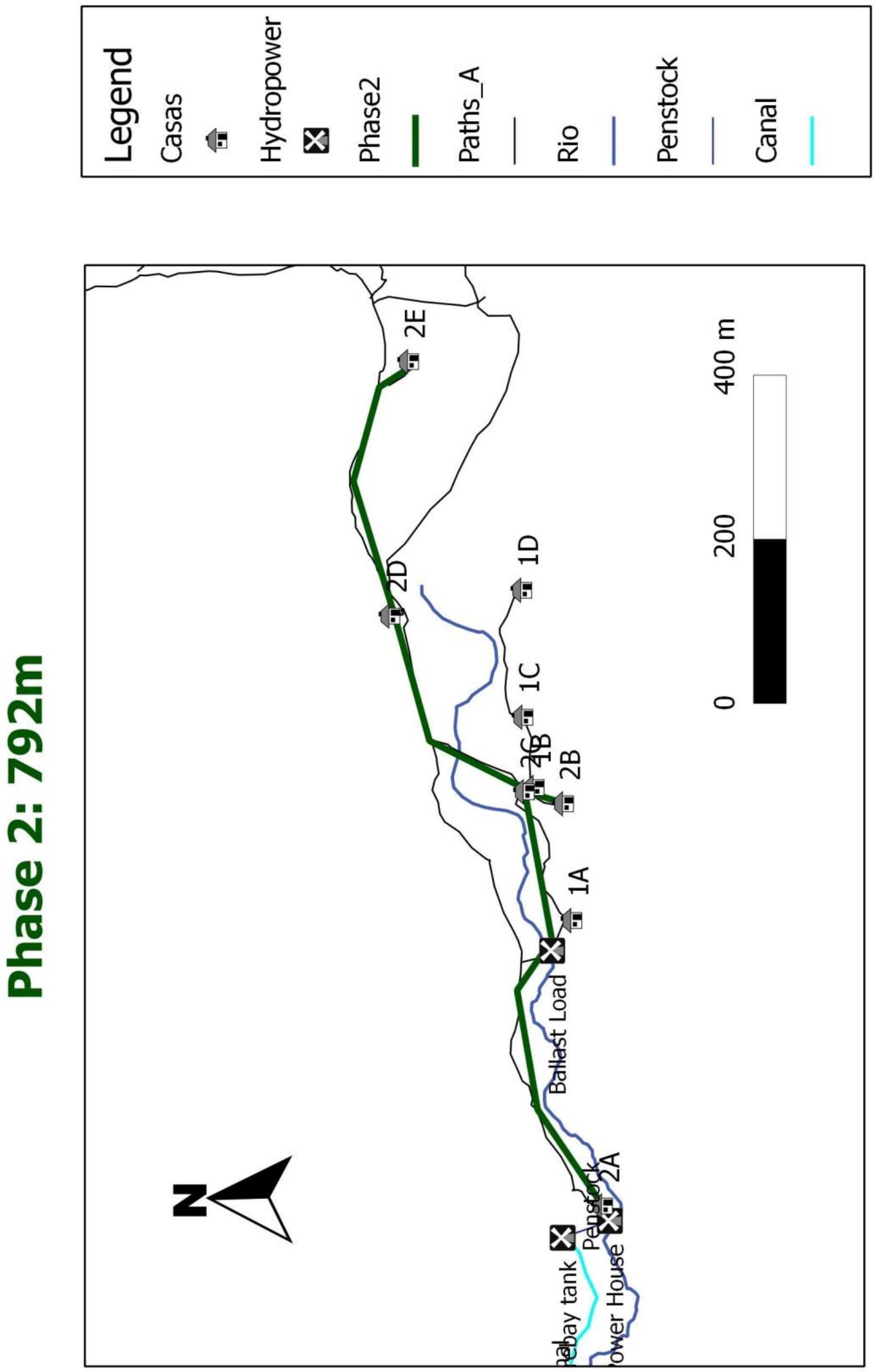


Figure 9 - Geographical sketch of phase 2



Casa	Number
Abad 2	.
Manuel Medina 2	.
Sylvia	.
Hans	1A
Wooden House	1B
Tina	1C
Jay & Caroline	1D
Powerhouse	2A
Large Dorm	2B
Cuisina	2C
Bodega	2D
Lucho Medina	2E
Walter Moora	3A
Pesantes-Armijos	3B
Manuel Medina 1	3C
Abad 1	3D
Delgado	3E

Figure 10 - Geographical sketch of phase 3

Casa	Number
Abad 2	.
Manuel Medina 2	.
Sylvia	.
Hans	1A
Wooden House	1B
Tina	1C
Jay & Caroline	1D
Powerhouse	2A
Large Dorm	2B
Cuisina	2C
Bodega	2D
Lucho Medina	2E
Walter Moora	3A
Pesantes-Armijos	3B
Manuel Medina 1	3C
Abad 1	3D
Delgado	3E

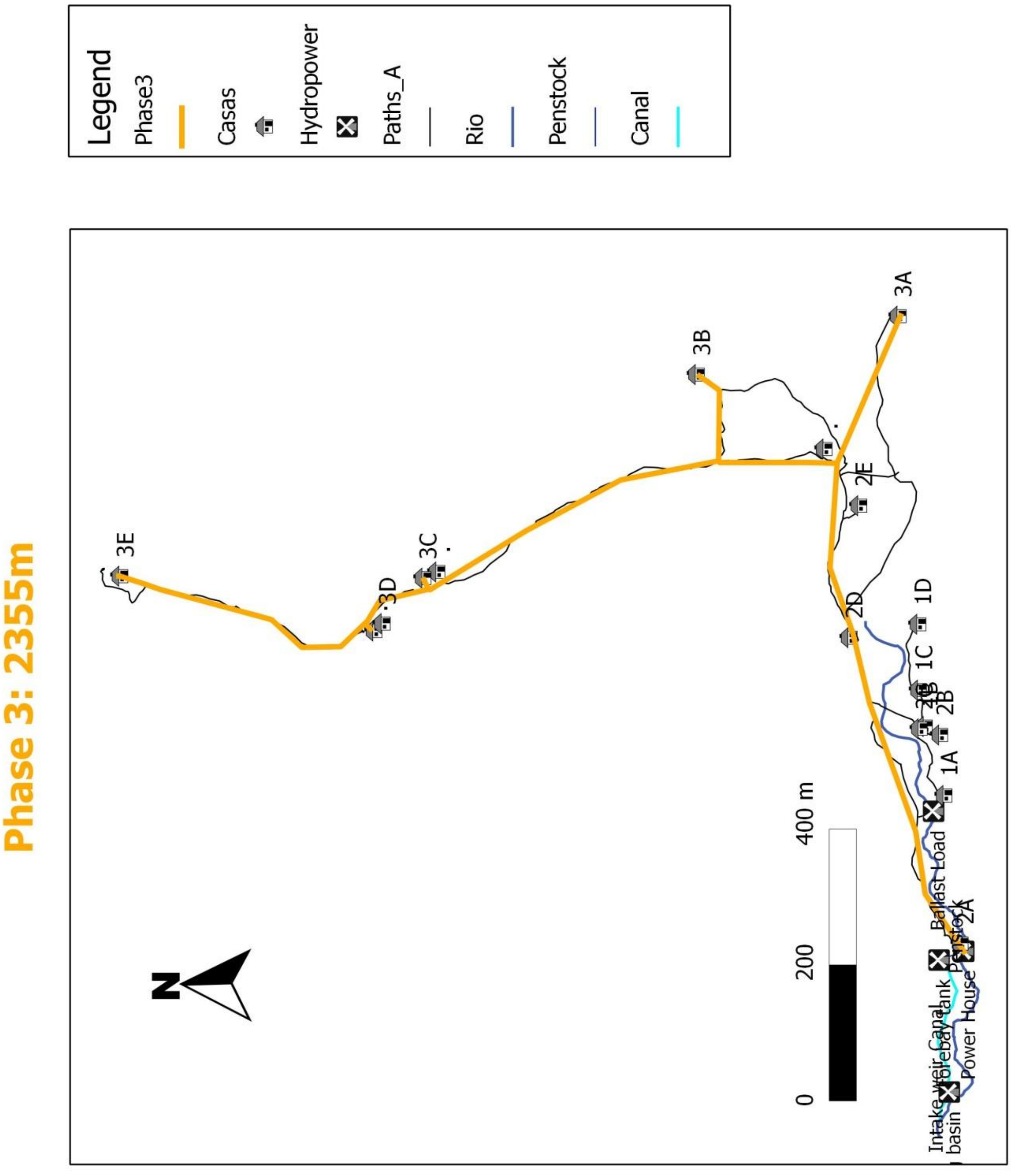
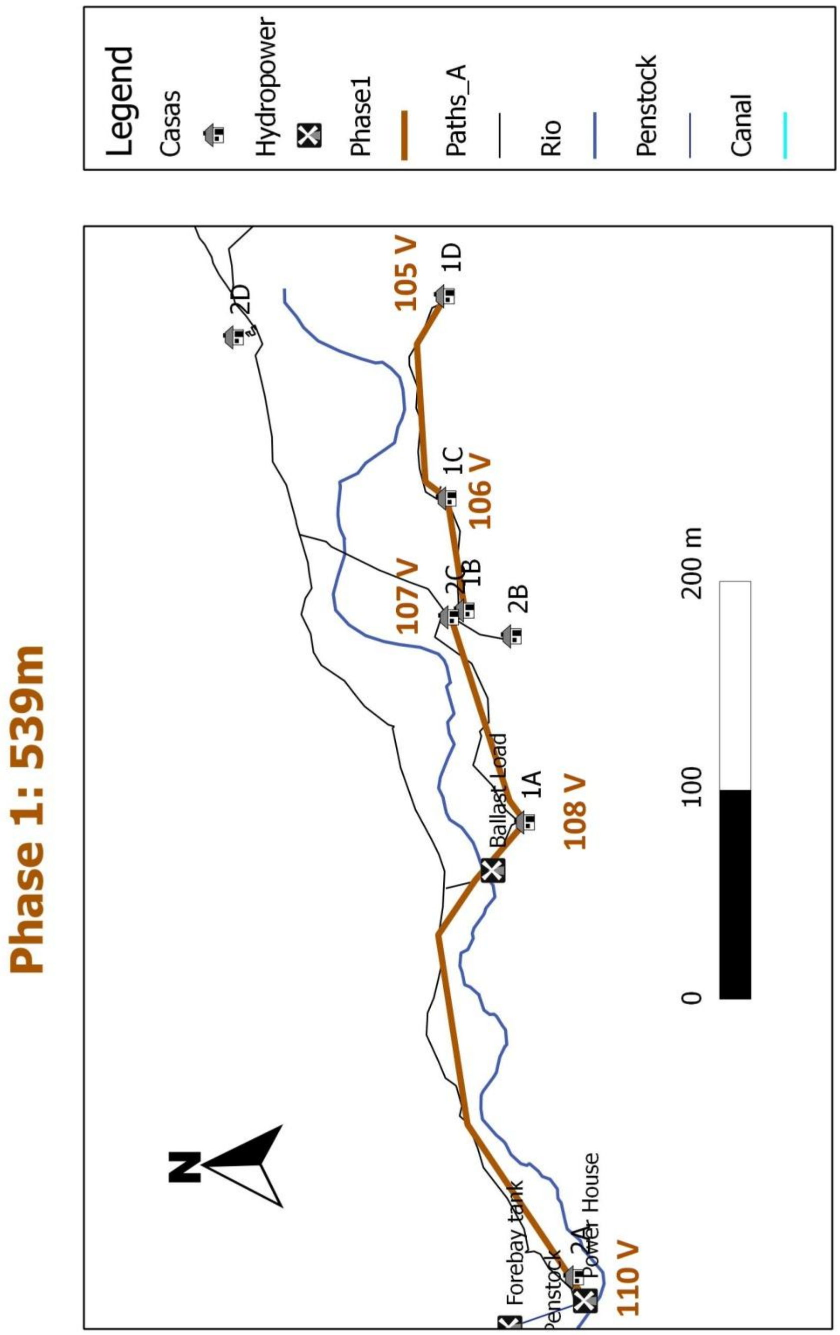


Table 13 - Distances table to each house, in metres[3]

	Abad	Ballast load 1	Ballast load 2	Bodega	Cuisinas	Delgado	Hans	Jay & Caroline	Large dorm	Lucho Medina	Main road	Manuel Medina	Pesantes-Armijos	Powerhouse	Tina	Walter Moora	Wooden house
Abad	x					410					20	150		1540			
Ballast load 1		x												10			
Ballast load 2			x		120									230			
Bodega				x	180					210				560			
Cuisinas			120	180	x		110							370	60		10
Delgado	410					x								1930			
Hans					110		x							270			
Jay & Caroline								x						550	110		
Large dorm									x					400			30
Lucho Medina				210						x	30		430	780			
Main road	20									30	x	20	140			240	
Manuel Medina	150										20	x	630	1440			
Pesantes-Armijos										430	140	630	x	1100			
Powerhouse	1540	10	230	560	370	1930	270	550	400	780		1440	1100	x	440	990	380
Tina					60			110						440	x		50
Walter Moora											240			990		x	
Wooden house					10				30					380	50		x

[3] This table is based on the geographical sketches for the different phases (see Figure 7-Figure 10). The numbers are rounded.

Figure 11 - Voltage drop along phase 1



Casa	Number
Abad 2	.
Manuel Medina 2	.
Sylvia	.
Hans	1A
Wooden House	1B
Tina	1C
Jay & Caroline	1D
Powerhouse	2A
Large Dorm	2B
Cuisina	2C
Bodega	2D
Lucho Medina	2E
Walter Moora	3A
Pesantes-Armijos	3B
Manuel Medina 1	3C
Abad 1	3D
Delgado	3E

Figure 12 - Voltage drop along phase 2

Casa	Number
Abad 2	.
Manuel Medina 2	.
Sylvia	.
Hans	1A
Wooden House	1B
Tina	1C
Jay & Caroline	1D
Powerhouse	2A
Large Dorm	2B
Cuisina	2C
Bodega	2D
Lucho Medina	2E
Walter Moora	3A
Pesantes-Armijos	3B
Manuel Medina 1	3C
Abad 1	3D
Delgado	3E

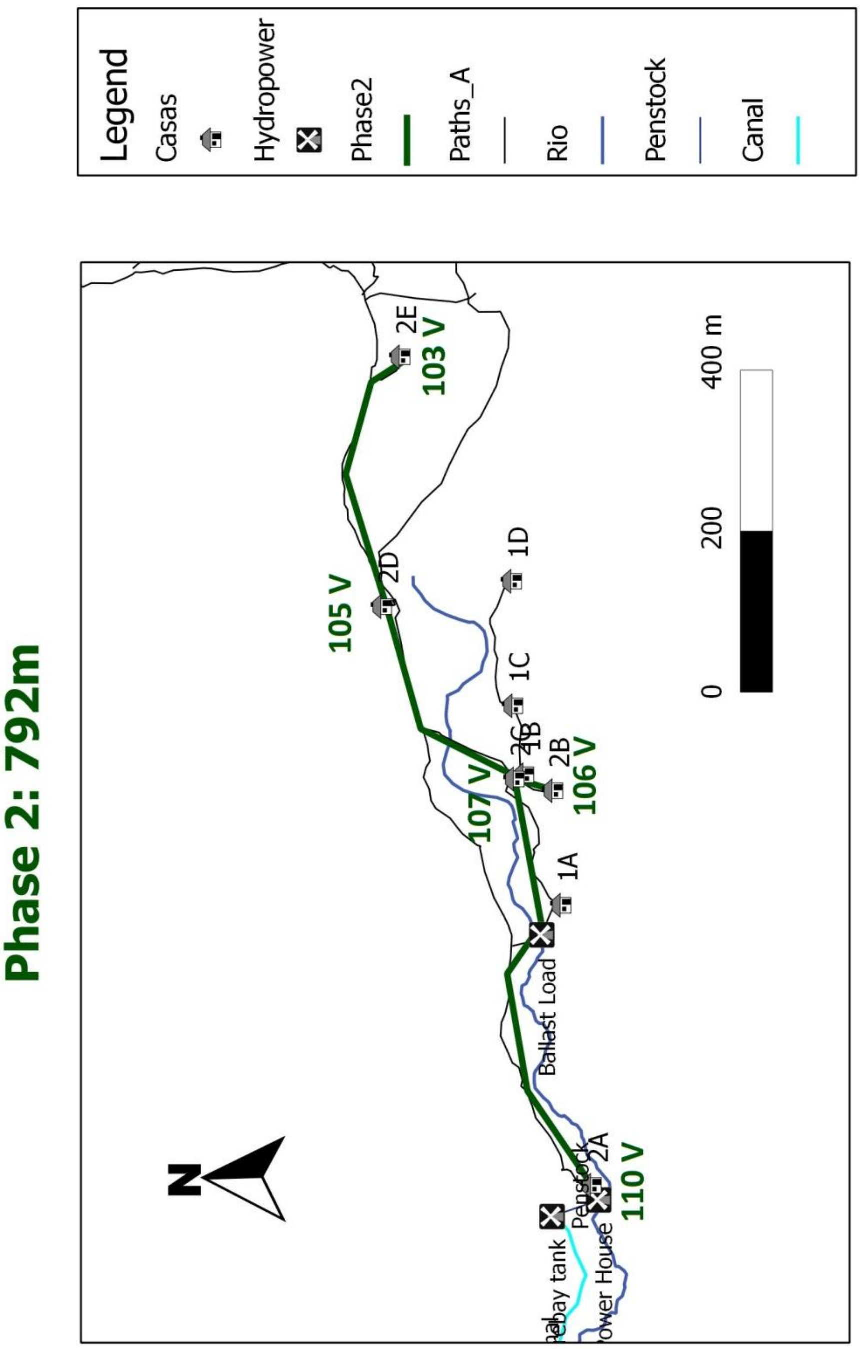
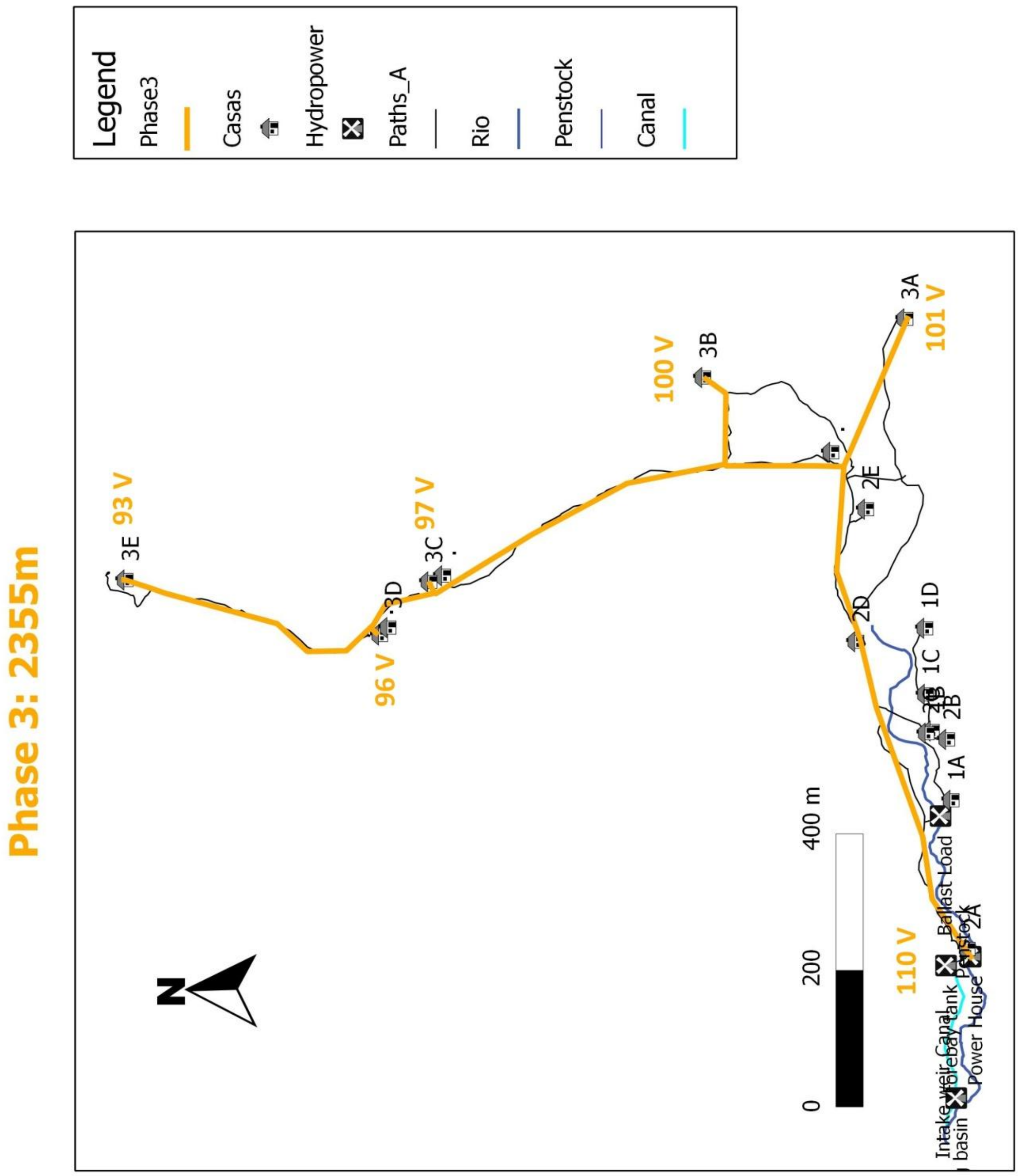


Figure 13 - Voltage drop along phase 3

Casa	Number
Abad 2	.
Manuel Medina 2	.
Sylvia	.
Hans	1A
Wooden House	1B
Tina	1C
Jay & Caroline	1D
Powerhouse	2A
Large Dorm	2B
Cuisina	2C
Bodega	2D
Lucho Medina	2E
Walter Moora	3A
Pesantes-Armijos	3B
Manuel Medina 1	3C
Abad 1	3D
Delgado	3E



Appendix D Switching box

Figure 14 - Switching box electrical scheme (H-Energiesystemen B.V., 2011)

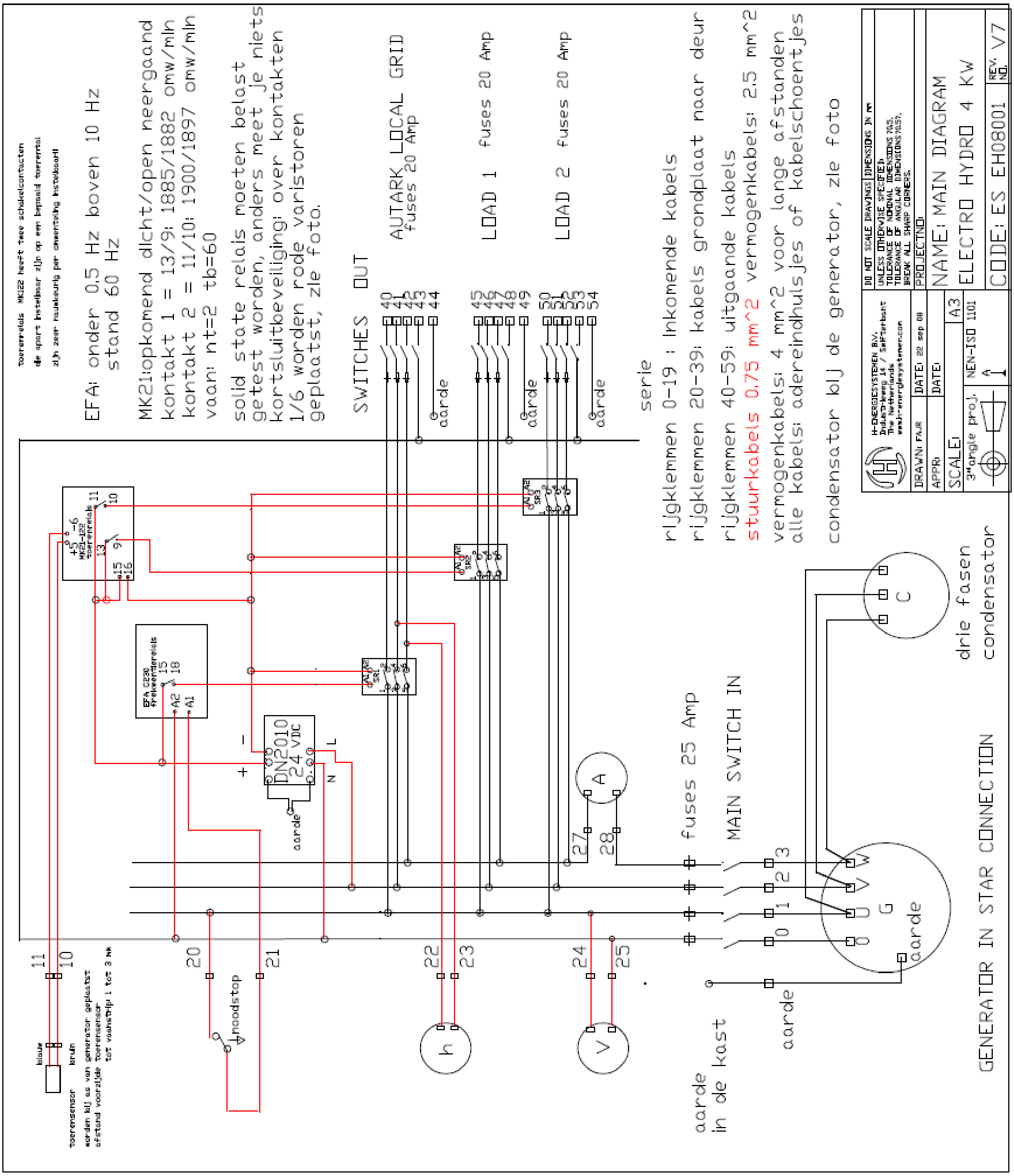
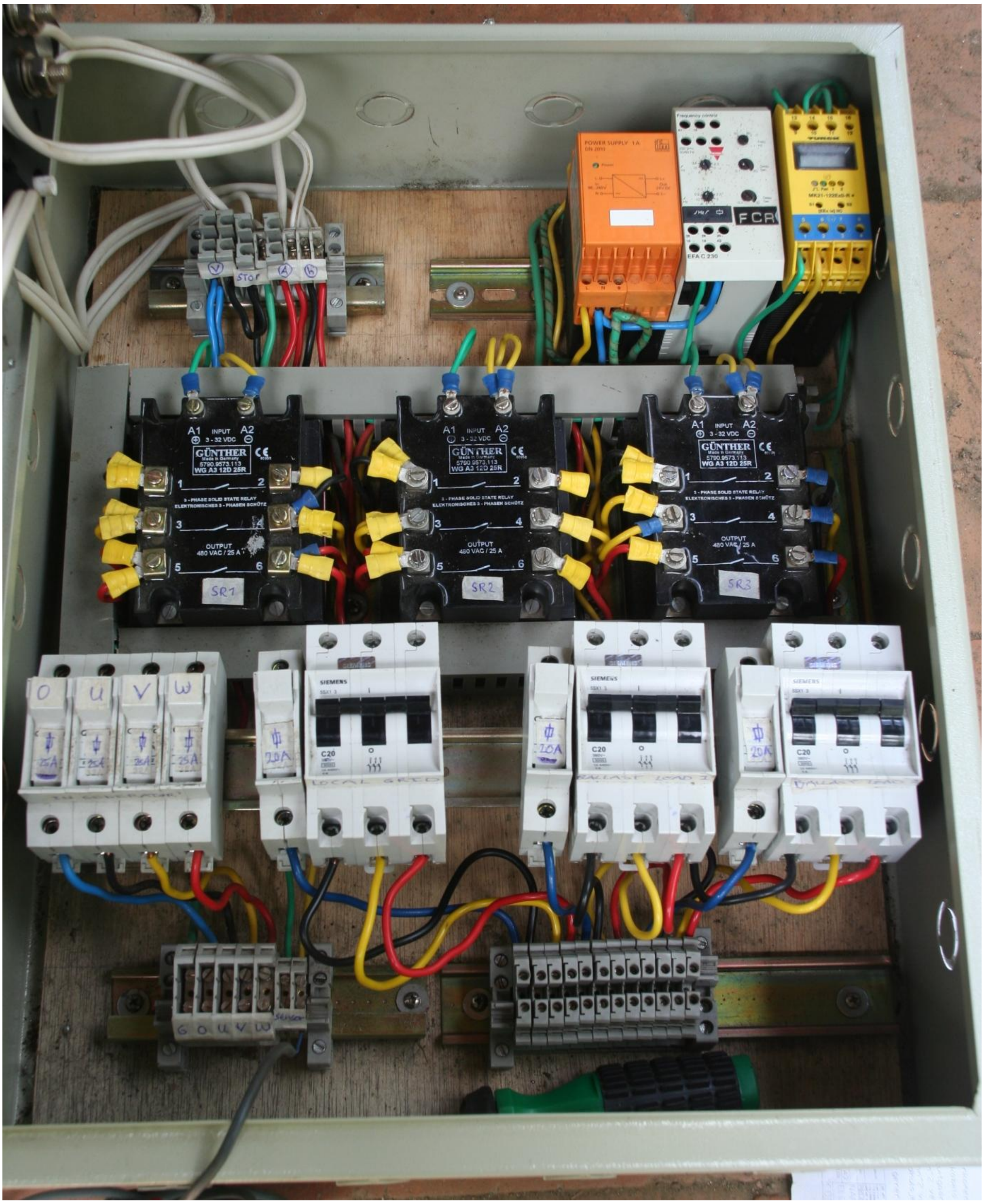


Figure 15 - Switching box in real (reordered)



Appendix E Country study

In this chapter a country study of Ecuador is given, with special attention on the rural energy sector. The most relevant information of Ecuador is given in Table 14. The general information of Ecuador is mainly derived from The World Factbook (CIA, 2012).

Table 14 - Statistics of Ecuador (CIA, 2012)

Geography	Area	Total	276,841 km^2[4]
		Water	5%
	Land use	Arable land	5.71%
		Permanent crops	4.81%
		Other	89.48%
People and society	Population	2011 estimate	15,223,680
		Density	52.5/km^2
	Ethnic groups	Mestizo	65%
		Amerindian	25%
		Spanish and others	7%
		Black	3%
	Religions	Roman Catholic	95%
		Other	5%
	Literacy[5]	Total population	91%
		Male	92.3%
		Female	89.7%
	Life expectancy	Total population	75.94 years
Economy	GDP (PPP[6]) 2011	Total	$ 129.1 billion
		Per capita	$ 8,600
	Below poverty line	Population	28.6%
	Electricity	Production	16.88 billion kWh
		Consumption	14.92 billion kWh

Geography

Ecuador, officially the Republic of Ecuador, is located in South America. A map is given in Figure 16, with Tumianuma marked in green. Ecuador straddles the equator, from which it takes its name. It is bordered by Colombia on the north, Peru on the east and south and the Pacific Ocean in the west. The Galápagos Islands in the Pacific also includes Ecuador, 1,000 kilometres west of the mainland. The capital city of Ecuador is Quito, but the largest city is Guayaquil.

The climate is tropical along the coast and becoming cooler inland at higher elevations. The Andean highlands are temperate and relatively dry while the Amazon jungle lowlands also have a tropical climate. Because of its locations at the equator, Ecuador experiences little variation in hours of daylight during the year. Sunrise and sunset occur each day at the two six o'clock hours.

The terrain is plain along the coast (costa), flat to rolling in the eastern rainforest areas (oriente) and with central highlands in the Andes region (sierra). The highest mountain is in the Andes with Mount Chimborazo of 6,267 m.

The natural hazards are frequent earthquakes, landslides, floods, periodic droughts and volcanic activity. The volcanic activity is concentrated along the Andes Mountains. The latest volcanic eruption was from the Tungurahua in August 2012.

[4] Includes Galápagos Islands
[5] Definition: age 15 and over can read and write
[6] Purchasing Power Parity

Figure 16 - Map of Ecuador (UN, 2004)

Demography

Ecuador has more than 15 million inhabitants, divided into various ethnic groups. The largest group (65%) are the Mestizos, descendants of Spanish colonist and indigenous people. Ecuador is one of the countries in America with the largest amount of indigenous people of the Americas, the Amerindians (25%). The minority in Ecuador includes Spanish and Afro-Ecuadorians.

The majority of the population lives in central provinces, the Andes Mountains or along the coast. The tropical forest region is sparsely populated.

Approximately 95% of Ecuadorians are Roman Catholic. In rural areas indigenous beliefs and Catholicism are syncretised.

History

Ecuador became a part of the northern Inca Empire in 1463. The official language of this empire was Quechua. The Spanish took over the rule in 1533. The Spanish colonization endured for nearly 300 years. In 1563 Quito became a seat of Spanish colonial government and in 1717 it became part of the Viceroyalty of New Granada. The Ecuadorian War of Independence was fought from 1820 to 1822, between several South American armies and Spain. Guayaquil became the first city in Ecuador to gain its independence from Spain in 1820, followed by Quito in 1822. Ecuador joined the federation of Gran Colombia, which were territories of the Viceroyalty – New

Granada (Colombia), Venezuela and Quito. In 1830 this republic fell apart and Ecuador became an independent republic.
The Liberal Revolution of 1895 in Ecuador was a period of radical, social and political upheaval. The Radical Liberals, led by Eloy Alfaro, started the revolution which resulted in a reduced power of the conservative land owners of the highlands. It also resulted in new infrastructure projects, such as the construction of a railway between Quito and Guayaquil.
In the beginning of the 20th century Ecuador had a long-lasting dispute with Peru, about the control over territory in the Amazon basin. In 1941 the first war with Peru broke out, which officially became to an end with the signing of the Rio de Janeiro Protocol in 1942. A border skirmish between Ecuador and Peru in 1981 was followed by a full-scale warfare in 1995. The war was fight at the headwater of the Cenepa River, which territory was claimed by both countries. In 1998 Ecuador and Peru reached a comprehensive peace agreement.
Since the eighties several presidents aimed to fight corruption and to flourish the Ecuadorian economy. Most of them have not succeeded. In April 2005 the most recent coup committed, President Lucio Gutierrez was ousted by the parliament and had to make room for his Vice President Alfredo Palacio. On October 1, 2010 a state of emergency was declared after President Rafael Correa escaped from an attempt by rebellious policemen to abduct him.

Government

Ecuador is governed by a democratically elected President, every four years. The current President is Rafael Correa, he is settled in the presidential Palacio de Carondelet in Quito. The President is both the chief of state and head of the government. The Vice President is Lenin Moreno. The next elections will be held in 2013. The executive branch consist of 25 ministries. Ecuador is a member of the United Nations and several other groups.
Ecuador is divided in 24 provinces, each with its own administrative capital. Their civil law is based on the Chilean civil code with some modifications, which is based on several West European civil legal systems.\
The national symbol is the Andean condor, which symbolize the power, greatness and strength of Ecuador. The flag of Ecuador can be seen in Figure 17. It consist of three horizontal bands of yellow, blue and red with the coat of arms in the centre of the flag. The yellow colour represents sunshine, grain and mineral wealth. Blue represents the sky, sea and rivers. Red represents the blood of patriots spilled in the struggle for freedom and justice. The flag retains the three main colours of the banner of Gran Columbia.

Figure 17- Flag of Ecuador (OLSTARS, 2010)

Economy

Ecuador suffered a severe economic crisis in 2000, as result of a banking crisis, with GDP contracting by 5.3%. Poverty increased significantly. The currency was changed to the stronger US dollar. Dollarization, high oil prices, remittance and increased non-traditional exports helped to stabilize the economy. Between 2002 and 2006 they experienced an average growth of 5.2% per year.

Half of the country's export earnings are from petroleum resources. In the agricultural sector Ecuador is a major exporter of bananas. Other agriculture products includes coffee, cocoa, rice, potatoes, manioc (tapioca), plantains, sugarcane; cattle, sheep, pigs, beef, pork, dairy products; fish, shrimp and balsa wood. The import commodities are industrial materials, fuels and lubricants and nondurable consumer goods.

The industry is concentrating on petroleum, food processing, textiles, wood products and chemicals. Due to Ecuador's high water potential, power generation is also a potential sector which is starting to be developed.

Energy sector

The electricity rate in Ecuador is 92.2%, the population without electricity is 1.1 million (IEA, 2011). The share of total primary energy supply (TPES) can be seen in Figure 18, with a total energy supply of 11,352 ktoe (OECD/IEA, 2011). TPES is the total share where the energy is coming from in the first place, so not from the plug. The renewable resources in Ecuador are significant, with mainly hydropower and the recent appearance of wind turbines.

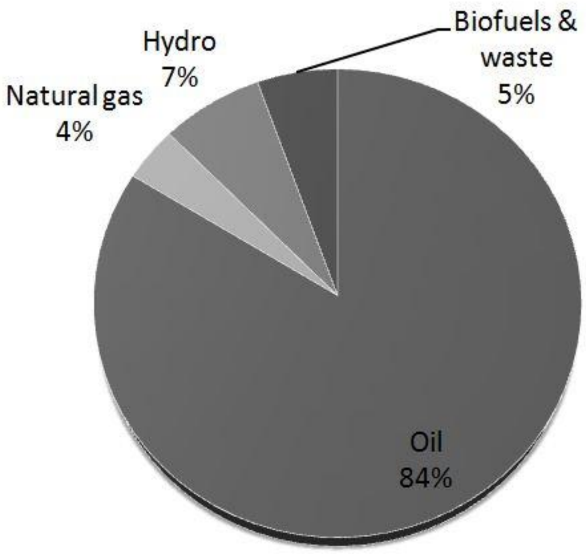


Figure 18 - Share of total primary energy supply of Ecuaor in 2009 (OECD/IEA, 2011)

Energy policy

For the Ecuadorian government, energy is a strategic sector as demonstrated by different programs and plans they made. The Ministry of Electricity and Renewable Energy (MEER), is the principle agent in the sector. MEER established a system for energy planning in "Policies and Strategies for the Energy Matrix Change in Ecuador". Currently 43% of the production of all electrical energy comes from hydraulic energy. In the energy matrix the goal for 2020 is to produce 80% hydroelectricity of all available energy on a national level, eliminating the use of fossil fuels (MEER, 2008). Remarkable is that the government has decided to install mainly large hydroelectric plants. They are not talking about the huge environmental impacts it will have in the local area. In addition the homelands of native people will be destroyed.

Other most important actions and programs in the renewable energy sector can be found in Table 15.

Table 15 - Most important actions and programs in the sector of renewable energy and efficiency in Ecuador (Tech4CDM, 2009)

Energy Matrix	Strategy so that so that hydroelectric energy will reach a level of 80% of all available energy.
Dignified rate	Tariff to low income homes, to benefit those users who practice reasonable.
Euro-solar Program	Offers rural community access to the electrical network, a source of renewable electric energy for community use.
Energy saving Light bulbs	Substituting six million incandescent light bulbs with glowing compact fluorescent ones.
High Voltage Hydroelectric Plants	High voltage hydroelectric projects such as the Coca Codo Sinclair with 1500 MW of power, Soplador (500 MW), Mazar (160 MW) and Baba (42 MW).
Rural electrification	Projects with residential solar energy systems in the provinces of Esmeralda, Napo and the Isla Santay.
Energy Efficient Public Buildings	Promotion for energy savings in public buildings.

Rural energy sector

According to the census and housing statistics in 2001, the electrification rate in the rural sector reached 79%. The urban sector was 91% and the national coverage was 89%. The estimated coverage in 2009 was 85.7% in the rural sector, 92.7% in the urban sector and 90.4% as national coverage. (Tech4CDM, 2009)

In the isolated regions of Ecuador is renewable off grid technology the only viable solution, due to geographical limitations. Due to distance and low populations, network extension is not a viable economic option. The renewable technology based on isolated systems, or mini-networks is variable in scale and offered services. Some advantages they cover all includes on-site energy generation, flexibility to adapt to different areas, optimized use of natural resources, easy installation, minimum maintenance costs and respectful for the environment.

Besides the advantages there are also several barriers to rural electrification, which are summarized below (Tech4CDM, 2009). There is no real solution to remove these barriers, but there are steps that can be taken to overcome these barriers, which are listed below.

- *Technical adequacy of equipment*
  The equipment is typically designed under conditions that are very different then the reality in these rural areas. Problems are often arising with the operation and maintenance.
  Solution: Joint collaboration between manufacturers and local sector.
- *Lack of qualified workers*
  There is a lack of qualified project developers, installers and maintainers. This results in bad quality systems which can lead to operational failure.
  Solution: Share the knowledge. I.e. the development of training programs between international engineering firms and local engineering agencies.
- *Lack of replacement pieces*
  Remote areas have insufficient access to replacement pieces for an uninterrupted energy service.
  Solution: Use local or national parts which can be replaced more easily. Furthermore improve and implement the current international regulations or standards for the renewable energy industry.
- *Inadequate use to apply international quality and safety standards*
  Often low quality of components are used (wherein the standards have not been applied), which prevents long term functioning and safety.
  Solution: Improvement of industrial standards for rural electrification.
- *Socioeconomic aspects*

There is a lack of knowledge and trust in the communities to change their technology type. Due to the low electrification level and high poverty index. There is also lack of trust.
Solution: Design informative programs regarding functioning, maintenance and benefits.

- *Lack of awareness and knowledge*
  There is lack of awareness, understanding and information by legislators, providers, project managers and final users. There is also lack of social awareness.
  Solution: Training for capability, handling and operation, maintenance and equipment management.
- *Lack of physical infrastructures*
  The rural areas are isolated and difficult to access.
  Solution: Increase access through creation of roads.