Opportunities for Sustainable Community Development of Ward 10 in Honde Valley

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SUSTAINABLE COMMUNITY DEVELOPMENT OF WARD 10 IN HONDE VALLEY

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Executive Summary

Within the framework of the Project of the Year (POY) course provided by the InnoEnergy MSc SELECT program 2016-2017, a team of eleven Master Students from Royal Institute of Technology and Polytechnic University of Catalonia chose to devote their efforts to the Ward 10 Community in Honde Valley, Zimbabwe. The team members agree that the aspect of elaborating solutions for the sustainable development of a community was a significant determinant in their choice of this challenge. The project is presented by Fortune Development Centre (FDC) which is based in Samaringa in the Honde Valley, with a counterpart in Sweden. FDC aims to improve the living conditions of the population in the Honde Valley, focusing on Ward 10.

The project encompasses a wide range of topics which require careful attention to the socio-economic and geographical constraints that influence the feasibility of any project. The main objectives of the project are the sustainability of the community in the long run, the introduction of innovative technology with the social acceptance of locals, the identification of a long run development strategy that will lead to the improvement of the quality of life. Once the needs of the community were evaluated and aggregated in terms of priority and potential impact, the team proceeded to a literature review of similar case-studies in sub Saharan Africa rural areas, synthesizing information about different kinds of interventions and technologies, along with their social and environmental implications, risks and economic viability-sustainability.

Following two field trips and the evaluation of the actual conditions in Ward 10, the main focus has been identified on the following topics:

- Water supply harmonization, purification and sanitation
- Sustainable and clean energy access
- Roads and infrastructure improvement
- Agriculture
- Community services
- Ecotourism

During the trips, the team had the chance to meet the locals and to establish contacts with them, confronting the different opinions and understanding the features of the local culture. A questionnaire has been delivered to the local population to understand their interest in the proposals, and measurements on the water quality have been performed and analysed in the laboratory of Land and Water Department at KTH.

For each of these areas, the team identified some proposals, evaluated from the technical, social, ecological and financial point of view. The project aims to identify a path of awareness and acceptance of local population, enhancing local business opportunities and job creation. Moreover, some potential partners for the proposed solutions are suggested and mentioned, in order to give a tool to the customer to implement the solutions of interest, find investors and funding opportunities and approach local authorities to reach agreements on the future cooperation.

Abbreviations

Abbreviation	Significance
AD	Anaerobic Digestion
ARI	Acute respiratory infections
BCS	Battery charging station
BVIP	Blair Ventilated Improved Pit
CAD	Centralized anaerobic digestion
CCT	Controlled Cooking Test
COPD	Chronic obstructive pulmonary disease
CWF	Colloidal Silver Impregnated Ceramic Water Filter
FDC	Fortune Development Centre
FDI	Foreign direct investment
GDP	Gross domestic product
GHG	Greenhouse Gases
HDPE	High-density polyethylene
IE	InnoEnergy
IEEE	Institute of Electrical and Electronics Engineers
KTH	Kungliga Tekniska Högskolan
LED	Light-emitting diode
MDG	United Nation Millennium Goals
MSW	Municipal Solid Waste
NGO	Non-Governmental Organization
NPV	Net Present Value
PET	Polyethylene terephthalate
POY	Project of the Year
PV	Photovoltaic
RBZ	Reserve Bank of Zimbabwe
SAZ	Standard Association Zimbabwe
SHS	Solar home systems
SODIS	Solar Water Disinfection
SSA	Sub-Saharan Africa
SWOT	Strength, Weaknesses, Opportunities, Threats
TDI	Tolerable daily intake
UN	United Nations
UNWTO	United Nations World Tourism Organization
UV	Ultra Violet
WBT	Water Boiling Test
WHO	World Health Organization
ZESA	Zimbabwe Energy System Authority
ZETDC	Zimbabwe Electricity Transmission and Distribution Company
ZINWA	Zimbabwe National Water Authority

Table of Contents

List of figures

List of tables

Credits

We want to take the opportunity to thank all the people who directly participated and helped in the project, providing useful information, equipment, suggestions.

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1 Introduction

Energy has a strong role when it comes to development of communities, societies, nations and whole cultures. On the one hand energy is one of the most important anthropogenic needs, because it is strictly related to a wide range of primary needs, and even more important is that in a future world everybody has this access, in order to be able to develop and grow. On the other hand, the problem of electrification must be solved without jeopardizing the environment. Walking this thin line and finding the perfect sustainable solution in terms of social, economic and environmental aspects is a major challenge the students are learning through the Project of the year in Energy Systems Analysis in an Environomical Context.

The synergy between these three pillars of sustainability is one of the main challenges in the project of the year (POY) in Zimbabwe. Contrary to the expectation this project being an Energy System Analysis in Environomical Context, it turned out to be a sustainable community development project with a strong socio-economic aspect.

The community of Ward 10 which is analysed in terms of sustainable development and entrepreneurial opportunities. The main client on our case is the Non-Governmental Organization (NGO) Fortune Development Centre (FDC), which is operating in this area since many years. Aside from a couple of basic details, e.g. the number of citizens or the existence of a very basic power grid, no further information could be obtained. Even more important was to undertake a field trip on site and gather as much information as possible about the area, the water and grid system. But also, the examination of the community and their response to an external intervention was a very important aspect of the excursion.

The wide range of topics which needs to be considered in this project resulted in a separation of topics (refer Figure 1).

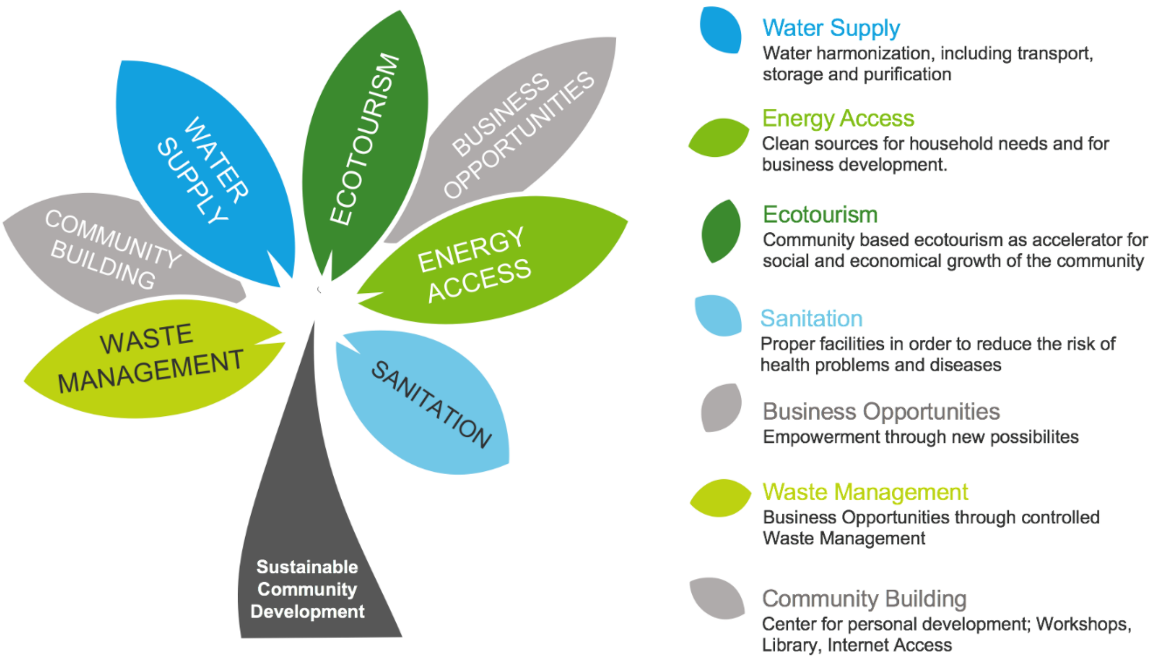

Figure 1: Different branches of sustainable community development

1.1 Objectives of the project

Today there is a huge gap between the opportunities available to rural communities in Africa and Europe. The ultimate scope of the project is to balance this gap by providing improvement in the quality of life for one community in Zimbabwe, Ward 10, in the long run. This rural area has a lot of potential to harness local natural and human resources to become self-sufficient.

The project aims to create a strong sense of community, while providing employment opportunities, in particular for the younger part of the population. Therefore, the objective is to empower the community of Ward 10 with technical knowledge and infrastructure to unleash all the potential of the local natural and human resources. Rather than with the mere supply of financial aid, the goal is to help the people start a path of self-development towards the most sustainable way, without completely overturning their social and economic behaviour. The team has tried to develop a project that would rely as less as possible from external helps, but instead would be as economically independent as possible. The mentioned skills have to be provided following a logic of the highest priority level, that has to be set by the working team together with all the stakeholders. In this phase, it has been revealed as a crucial aspect to listen to the needs of people, in order not to make the mistake of imposing unwanted or unnecessary changing to the community's habits.

In the future, if successfully implemented, this project could be used as a model for the development of nearby areas and, more generally, could be part of the African Renaissance. All the proposed solutions are focused on the involvement, the empowerment and the pursuit of happiness of the community.

It is necessary to specify that the report will give a broad overview on what the main problems in different areas of focus are, how to find sustainable solutions and what are the potential benefits of the proposals. However, since the project is expected to last for at least 10 years, the report is just the beginning of a long pathway for the community of Ward 10, and more insights are expected to come in the future, to have a continuous improvement and perfecting of the proposals.

1.2 The stakeholders

- InnoEnergy: institution of affiliation of the students working in the project, promoter of education, innovation and business creation in the sustainable energy sector. InnoEnergy has 27 formal partners, who are all shareholders in the company, and works with over 150 associate and project partners across Europe in the fields of education, innovation and entrepreneurship.
- Local Population of Honde Valley: Any important change cannot be possible without a significant involvement of the local population. Most of the solutions proposed will affect the everyday life of the inhabitants and, for this reason, they have to be gradually involved in the future developments of this project.
- Fortune Development Centre: FDC is divided in two branches, which operates separately in Sweden as fundraiser and fund manager and in Zimbabwe, directly in Honde Valley. FDC is present on local territory mainly as the figure of Jacob Chikuhwa, which is the leading personality of the Zimbabwean branch of the organization. However, while Jacob was born and raised in Honde Valley, he has spent more than 20 years living abroad before coming back, so he makes use of several local collaborators. The Swedish branch of FDC has been represented by Peter Dulley, who was also the person who has first presented the project to the team.
- Sweco: is the largest engineering consultancy company in Europe and Magnus Linden is the representative who provided the team some initial advices, regarding the Business Creation opportunities, and also important suggestions on the final draft of the project.

2 Methodology

The project was very challenging from the beginning due to the lack of data. The only information that have been used before the first field trip were the proposal presentation, a short statistics email and the few data available online. Since the area is remote, information gathered on internet were insufficient to work on detailed proposals.

In order to work in an efficient way, the time before the first trip has been dedicated to work on a general case of rural community development. A deep literature research of possible similar cases in Sub-Saharan Africa rural areas, involving different interventions and technologies, has been performed. In particular, some relevant areas of focus have been identified and analysed in deep by small teams, in order to understand how to go from the needs to the solutions, passing through appropriate technologies, social and environmental implications, risk analysis and economic viability-sustainability issues. More information has been gathered through the attendance of a KTH conference of Ray Larsen, co-founder of IEEE Smart Village[1], and contacting some experts with skype calls.

The team accepted the risk to work on aspects that, in the end, could have been not relevant in the specific case of Ward 10.

The two field trips focused on several aspects, that can be summarized in the Table 1:

Table 1: summary of the activities performed during the trips

First trip, December 2016 (end of the dry season)	Conditions of the water infrastructure, visiting the water source and the main tanks
	Status of development of the electric grid, availability, reliability, environmental impact, access for the population
	Mapping of the area
	First contact with the local community, meeting with the community leaders
	Status of the roads, transportation and mobility
	Cooking habits and local traditions
Second trip, April 2017, (end of the rainy season)	Water quality measurements
	Questionnaire for the population
	Local tea producer visits and biogas potential
	Local Waterfalls visit for ecotourism

The two field trips allowed the team to gather the necessary experience to reformulate and better focus the proposals, based on the specific needs of the population; the objectives of the project and considerations on the practical feasibility have been reshaped too. A specific risk analysis, as

[1] http://ieee-smart-village.org/

well, is performed for most of the proposals: in this project, without an accurate evaluation of the possible threatens and implications of the ideas, the failure risk could be very high.

A SWOT analysis of the project will be performed to evaluate the strengths, weaknesses, opportunities and threatens of the project.

The objectives of the timeframe analysis are to develop one or more possible development strategies, prioritizing different aspects according to the team suggestions and to the preference of the customer. The result will be a series of possible scenarios, to highlight the interdependency of the proposals, to forecast the state of development after a certain period and to provide a clear idea of what the final result could be.

Figure 2 shows the methodology scheme which has been developed throughout the first period of the project, while Figure 3 shows the one of the second period.

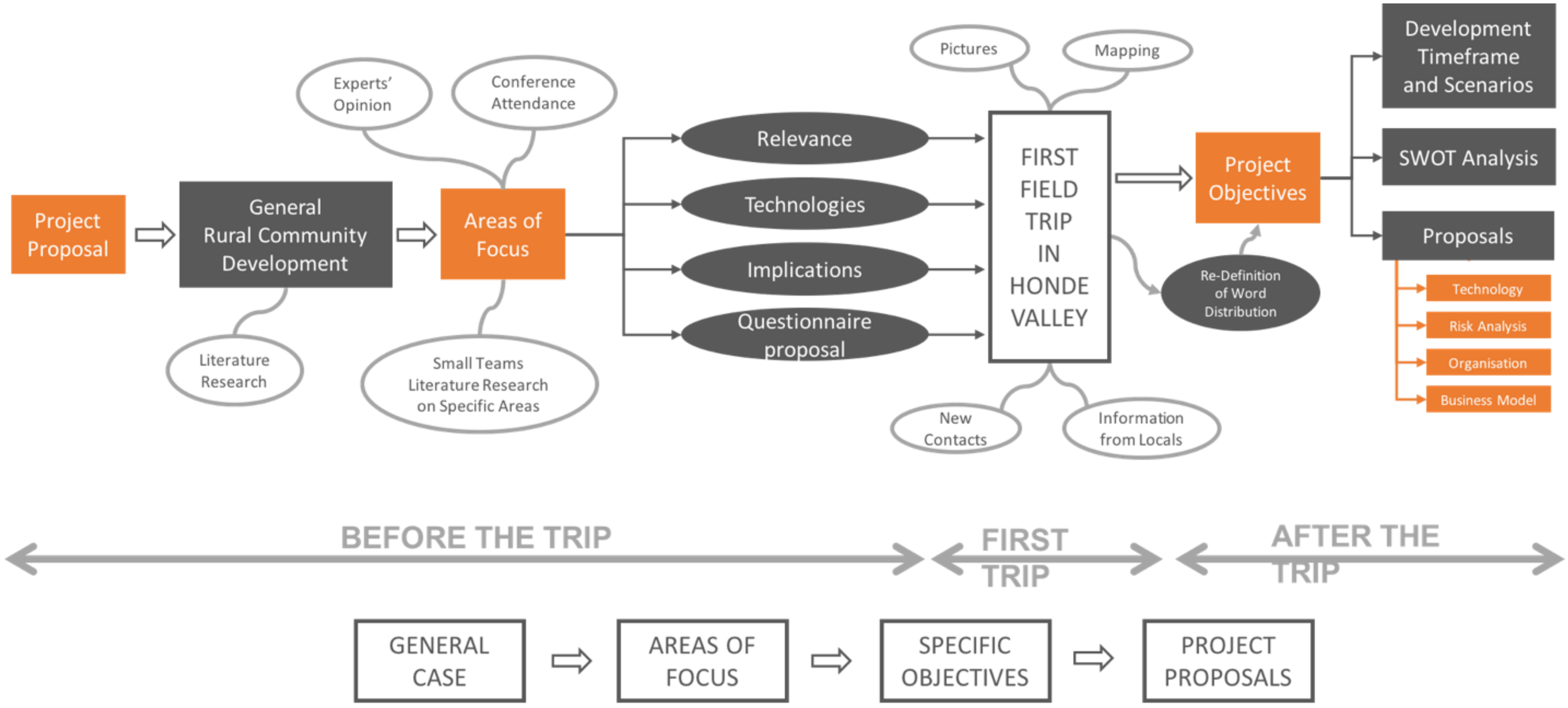

Figure 2: Methodology logical scheme, first period

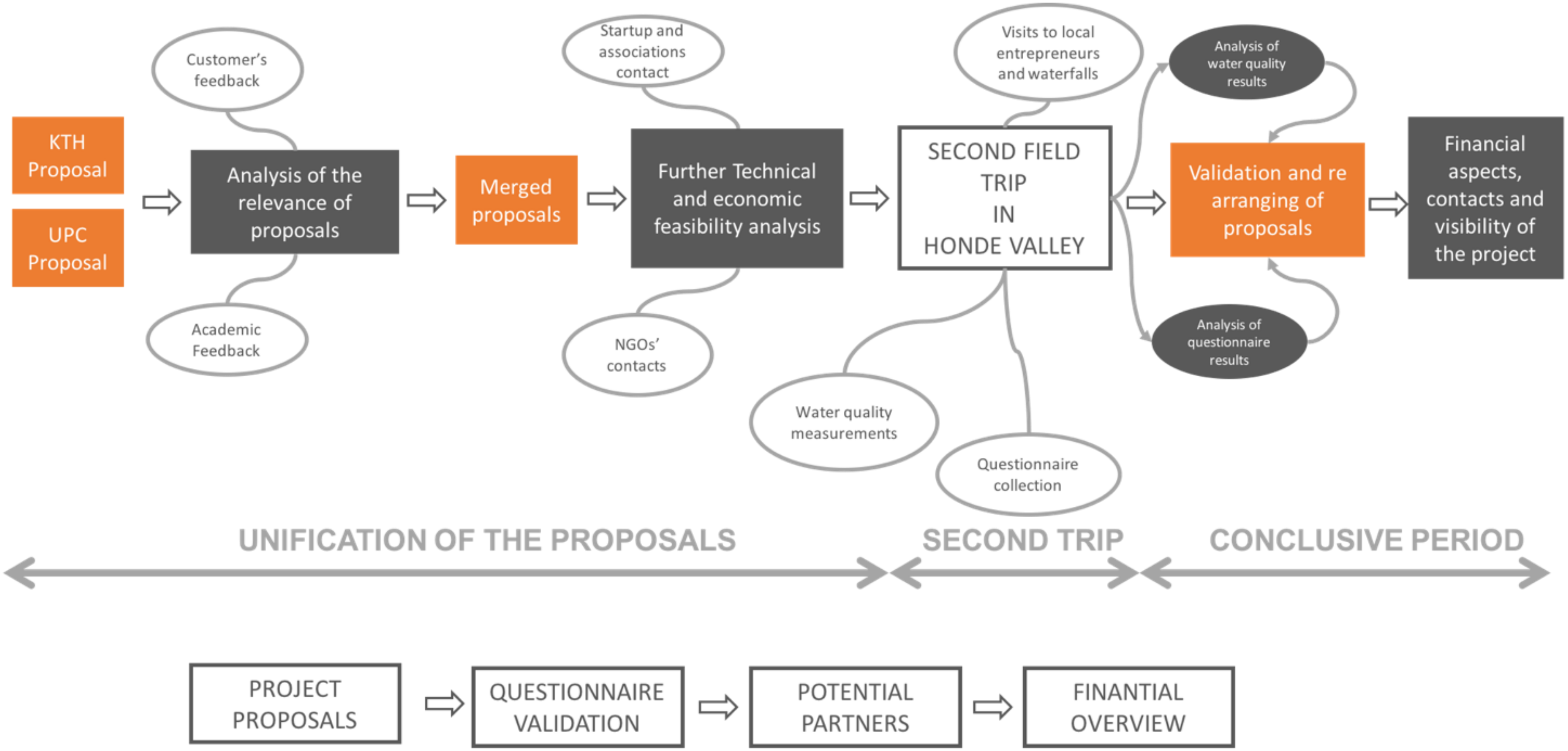

Figure 3: Methodology logical scheme, second period

2.1 SWOT analysis

The analysis of risk in this project is inevitable and needs to be treated carefully. The wide range of risk within this analysis has been identified using the methodology of the SWOT-analysis (Terrados, Almonacid, & Hontoria, 2007).

SWOT is an acronym and stands for Strength, Weakness, Opportunity and Threat. This matrix enables a straight-forward assessment of the situation and helps to write down every relevant information, which could be important for future decision-making. In Figure 4 the most important strengths, weaknesses, opportunities and threats for the overall project have been identified.

Figure 4: SWOT Analysis

2.2 Questionnaire for the local population

To validate the proposals and to understand the interest of local population in the proposed solutions, a questionnaire has been distributed. During the second field trip, FDC has organized a mingle with people coming from all the villages of Ward 10, in which the team of students facilitated the compiling of the answers. The questionnaire is a key information source to better understand the current situation and to change or better focus certain proposals. The criteria to write appropriate questions were:

- Covered and well distinguished as much areas of focus as possible;
- Clear and minimalist layout;
- Size limited to one single paper sheet, duplex printing;
- Double check of questions' possible impoliteness with FDC members before the delivery.

The full questionnaire is available in the Appendix 2: Questionnaire for Honde Valley.

The results of the questionnaire can be considered accurate concerning the representation of different ages and villages.

The drawback of the questionnaire is that the reliability of the answers cannot be proven without further analysis. Some specific aspects can have an impact on the results: since small groups of people compiled it together, there is the possibility that some of the answers have been chosen in common and repeated. Moreover, some of the answers, for example related to the distance from the closest water point, cannot be accurate, but can anyway be interpreted more from a qualitative point of view rather than quantitative.

91 people answered to the questionnaire, with 59% of responses of men and 41% of women. The average age of the respondents is 43 years old and 80% don't have a monthly income. From those who have a monthly income, 27% are farmers.

2.3 Water measurements

Presently there are no sources or studies describing water quality in Ward 10 and considering poor condition of the present water system, basic analysis of the water quality has been performed. Additional purpose of the analysis was to check whether some particular water parameters significantly surpass the general drinking water requirements, especially considering the fact that the water system was partially built from hazardous materials (e.g. water tanks roofs are made from asbestos). Lastly, the contaminated water resources can strongly impact on the human health and the environment.

During the second field trip to Zimbabwe, the group of students has been equipped with special water bottles in order to collect samples. These samples were collected in four different points. Detailed information about every sample have been presented in the Table 2.

Table 2: Samples description

Number	Time	Date	Elevation (m)	Location	Description
1	09:55	04.04.2017	979.66	18.60815 S; 32.77377 E	Ground Water Source
3	13:05	04.04.2017	1016.70	18.61546 S; 32.77224 E	Samaring Primary School (Borehole)
5	15:05	04.04.2017	928.70	18.59682 S; 32.76329 E	Honde Mission Clinic (Tank)
7	18:02	04.04.2017	972.39	18.60980 S; 32.77228 E	Bridge over Turumhu River

To check the presence of different constituents, three different samples were taken from every location: 50 ml of water, 25 ml additionally filtered water, 25 ml filtered water with a drop of HNO_3 to better preserve the sample. Samples have been labelled according to the place where they were taken, numbering them as 1, 1a, 2 for the first location, being them respectively filtered sample, filtered acidified, and unfiltered. Thus numbers of the samples presented in the Table 2 and Table 3 are 1, 3, 5, 7. All the samples have been transported to Land and Water Resources Laboratory at KTH, Stockholm where the following analysis have been performed: PH analysis, Conductivity, Alkalinity, Presence of phosphorus PO_4-P, chlorides, fluorides, NO_3^-, sulphates. All the obtained results have been collected and presented in the Table 3 in paragraph 3.1.2 together with the performed analysis.

2.4 Knowledge management

Considering the duration of the project, the question of appropriate knowledge management of the gained research and insights needs to be implemented. The fact that this project will take several years and will involve many people from different organisations requires an improved exchange of knowledge.

2.4.1 Website

The best way to guarantee transparency is the erection of a website, where the current situation, the scope of the project and the chosen technologies and approaches are described. This will reduce redundancy and help understand future generation why specific ways and technologies have been identified and other have been neglected.

Another important aspect is to raise the awareness of the existence of the Honde Valley. Within the project the area around Ward 10 has been mapped the first time in history. The data obtained through this work is now accessible online and can be used for future projects in the area.

Moreover, the website is a useful tool for funds acquisition. It will help to increase the transparency of the work done within this project, which might influence the funding in a positive way. This theory is based on the assumption, that NGOs or companies rather invest in a project which is transparent in its way of showing its progress. On the long run, the website might also help to establish community based ecotourism activities in the area, by simply increasing number of websites mentioning Ward 10 and Honde Valley. Figure 5 shows the website, which can be access through https://hondevalley.wordpress.com/.

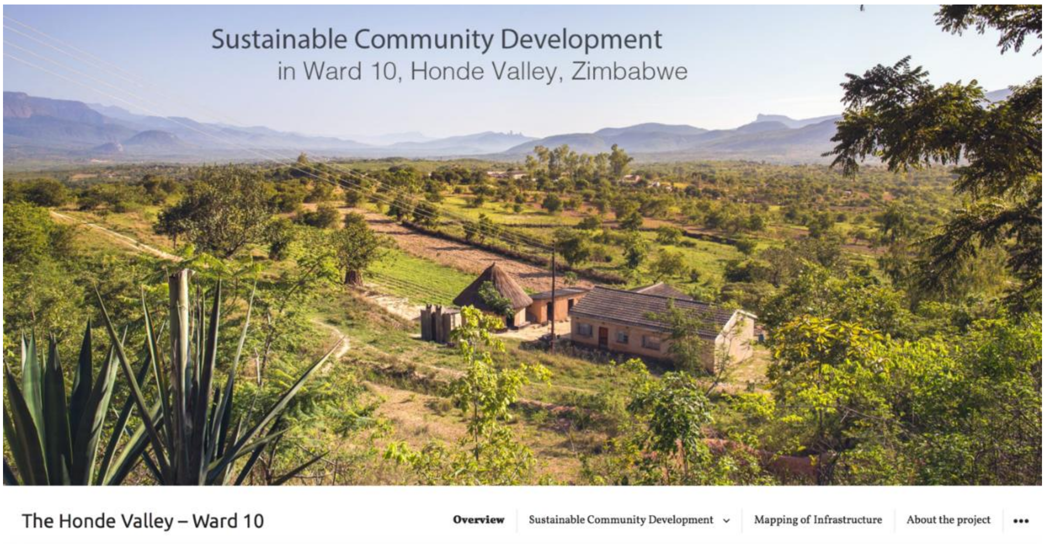

Figure 5: Screenshot of the created weblog

2.4.2 Mapping

The mapping of the infrastructure and the shared facilities of the Honde Valley and especially of the Ward 10 was a key area of focus. The area has not been documented in any of the public accessible geodatabases. Consequently, the allocation of information of the exact area was very difficult. Distances between important buildings or between villages, the condition of streets and altitude differences could not be analysed. This created, especially in the beginning of the project a huge amount of vagueness. Consequently, modern geo-locating hardware was used in order to verify satellite imagery in this area. The results have been implemented in the open source map collaboration, Open Street Maps (OSM) and publicly shared. This map now contains the following georeferenced information of Ward 10:

- Streets and their conditions
- Schools, Clinics, Business Centres
- Rivers and streams
- Pipelines and water tanks

Moreover, OSM gives free access to topographical maps. This enables an advanced examination of the area, concerning the demand of pumps within the water management system. It will also help to identify attractive areas for agriculture in terms of irrigation and solar radiance. In Figure 6 a screenshot of the status of the local map can be found.

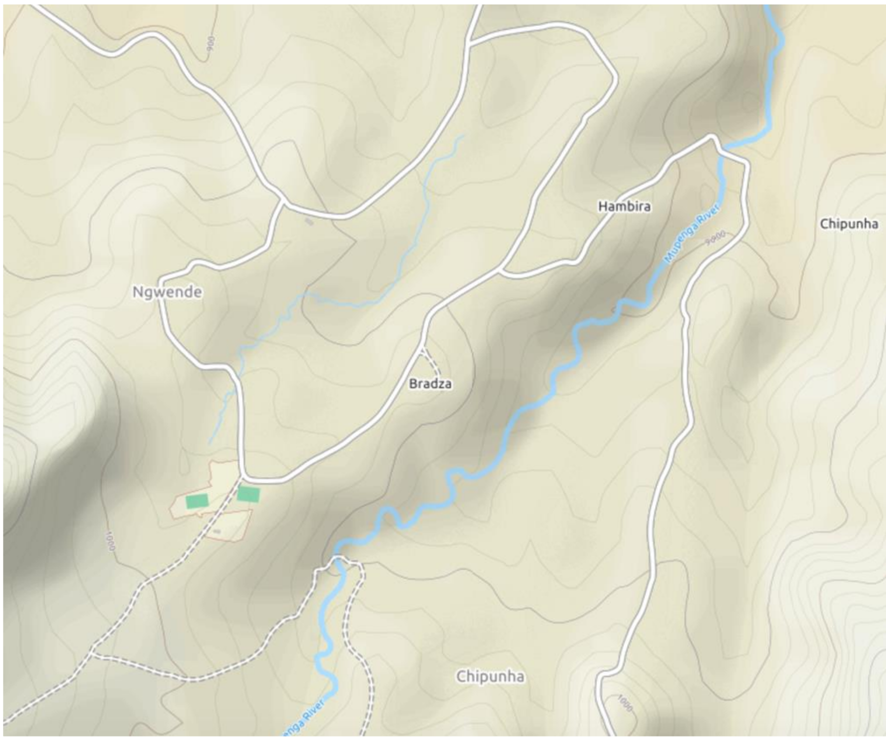

Figure 6: Screenshot, taken from Open Street Maps[2]

[2] https://www.openstreetmap.org/note/416857#map=16/-18.6114/32.7771&layers=N

3 Areas of Focus and Background

The following chapter describes the key elements identified for the socio-economic development of Ward 10, Zimbabwe. A brief summary of the current situation is also included.

3.1 Water supply harmonization and sanitation

One of the world's most urgent issues is lack of safe water, sanitation and hygiene. Water-related improvements are crucial to meet the development goals, reduce child mortality, and improve health in a sustainable way. Therefore, one of the major challenges considered in this project is to provide safe and clean water for everyday needs to people living in the Ward 10 area.

The term "safe water" is intended as a water without any forms of micro-organisms, chemical substances and radiological hazards that constitute a threat to health. Lack of basic water supply requirements leads to many serious or fatal diseases. According to World Health Organization requirements, daily safe water supply should be between 50 – 100 litres per person (WHO & Emergencies, 2005).

3.1.1 Introduction to the global water challenges

In the last decades, multiple international organization have tried to resolve the already mentioned issues but in practice the international water development sector continues to fall well short of its goals due to challenges for implementation such as:

- Insufficient financing and need for improved targeting and budgeting processes: Funding is not always targeted to those in need so it is necessary to improve priority-setting and targeting of development aid.
- Generating revenue through tariffs is often difficult. In most developing countries tariff structures for water, if they are applied, are insufficient to cover basic operation and maintenance.
- Governance: Deficient institutional and administrative structures, lack of political will, accountability and lack of stakeholder engagement.

3.1.2 Quality of water

Four main types of contaminants (U.S. Environmental Protection Agency, 2016) can be found in water:

- Physical: sediments, particulates and minerals
- Chemical: natural or artificial elements and compounds, such as salts, pesticides, metals, toxins
- Biological: pathogens such as bacteria, viruses, protozoa and parasites
- Radiological: elements emitting ionizing radiation

The methodologies for purifying water depend on the contained pollutants, thus the analysis and assumptions are necessary in order to choose the proper method. Additionally, it is possible to consider both large scale and small-scale depuration methods. Large scale methods allow to deliver water which has already been treated, while small scale ones are used by individuals or families to process small volumes of water for daily usage.

Current water treatment in Honde Valley

Considering the assurance of the proper water quality in Ward 10, several attempts have been made. Firstly, before the water intake there is a natural basin where sediments can settle down. However, due to the insufficient volume of the basin, especially during rainy seasons, this solution causes many troubles to the water system and its maintenance staff. Excess of the sediments and mud must be removed manually almost every day. Secondly, filters in the entrance of both water intakes prevent leaves and wood chops from coming into the pipe. Unfortunately, due to the poor construction of the filters itself (the holes in the net are too big and wide) many smaller objects can easily enter the pipeline. The construction of the pressure breakers helps in sedimentation and its removal.

Since above the main water intake there is no households it can be assumed only particulates (dust, sand, mud stones) and biological pathogens of various kind are present in the water. There are no factories or sources of pollution between the water sources and the villages. As well as that, there is no notice of any illnesses caused by heavy metals or radiations in the examined area.

Water analysis

As it was mentioned in the chapter 2.3, the following water analysis has been developed in order to get the general overview of the water quality present in the Ward 10, especially, whether some particular elements surpass the general water quality requirements. In order to introduce the following water analysis, several assumptions have been made:

- To increase the possibility of obtaining more versatile results the measurement locations have been chosen according to the presence of different types of the water sources; so that first sample represents shallow ground water source, third borehole, fifth water tank and for the seventh one water was taken directly from the river.
- No chemical and purification pre-treatment of the chosen water sources have been performed before taking the measurements.
- The analysed type of contaminants has been chosen based on the easiness of the laboratory tests as well as on the popularity of such methods
- The presence of the biological and radiological contaminates have not been checked during this analysis

All the obtained results have been presented in the Table 3 and described separately according to the WHO drinking water guidelines presented in the WHO guideline (WHO & Emergencies, 2005):

Table 3: Results of the water analysis

Number	pH	HCO3- (mg/l)	Conductivity (µS/cm)	Fluorides (mg/l)	NO3- (mg/l)	PO4-P (µg/l)	SO_4^{2-} (mg/l)
1	6.618	72.844	156.7	2.590	n.d.	68.314	13.510
3	6.808	101.761	232.000	7.530	n.d.	11.037	59.520
5	9.028	41.851	64.400	n.d.	n.d.	19.134	n.d.
7	8.869	57.958	101.600	n.d.	n.d.	0.525	n.d.

The pH abbreviation stands for the potential of hydrogen and generally describes the acidity or the alkalinity of the tested water sample. The pH scale ranges from 1– the most acidic to 14 – the most basic water solution. The value of 7 is recognised as neutral. The pH indicator is a very important factor because it can affect many chemical and biological processes in the water e.g. different organism flourish within different range of pH. Although pH usually does not influence consumers, the values recommended by the World Health Organisation for drinking water varying between 6.5 and 8.5 (WHO & Emergencies, 2005). Considering the obtained results, it can be concluded that shallow ground water, and water from Samaringa Primary School borehole meet the recommended standards. As for sample number 5 and 7 the obtained values are relatively high. It is important to notice that in both cases water is coming from the same river system that explain the similarity of the results. Additionally, in 75% of the cases the correlation between pH and HCO_3^- values can be observed. HCO_3^- that is an ion dissociated from the weak acid H_2CO_3 is adding acidity to the water sample, thus the higher level of HCO_3^- the lover value of pH can be observed. The phenomenon of the high pH value can be partially explained by the increased presence of the rock materials in the river which increase the basicity of the water (S. Manhokwe, I. Matiashe, & T. Z. Jombo, 2013). Nevertheless, more detailed on situ analysis should be performed to verify obtained results.

Conductivity of the water describes the ease at which an electric charge or heat can be pass through it. According to the (WHO guideline) the value of conductivity considering drinking water should not be higher than 400µS/cm. Thus, it can be noticed that all the tested samples are lower than this value. The highest value of 232 µS/cm has been obtained for the Samaringa School borehole. Additionally, it can be observed that the values are varying, however, this fact can be explained, since conductivity is a very sensitive parameter. It can be influenced by factors such as: water temperature, rainfalls or the geology of the area through the water flows.

Fluoride is a very common element that can be met in the Earth's crust. Traces of the fluoride can be easily found in many water sources on our planet. The higher concentration of this constituent can be found especially in the ground water sources. This feature can be also noticed among our results; the level of fluorides is the highest 7.53 mg/l in the Samaringa borehole and 2.59 mg/l in the shallow ground source. The most common concentration of fluorides in drinking water is around 0.5 – 1.0 mg/l, while the value recommended by WHO 1.5 mg/l. 50% of the obtained results exceed the recommended values, however, according to (Hall, 2004), the ground water sources might have increased the concentration of fluorides.

Considering the nitrates, these elements might be met both in ground and surface waters due to the agricultural activity. The (WHO World Health Organization, 1996) recommends that the value of 50 mg/l to be protected against methemoglobinemia or thyroid. However, this level can be additionally completed by consumption of vegetables which are one of the most common source of nitrates for humans. In any of the tested samples, the presence of NO_3 has been detected.

Phosphorus is one of the most abundant mineral on the Earth, in the water it is present in the form of ions. Phosphorus is one of the key elements necessary for growth of plans, even slight increase in its concentration can yield in a huge bloom of plants, especially algae are very vulnerable to the presence of this element. Additionally, increased amount of phosphates reduces the aesthetic value of the water. Considering the recommended quantities for all type of phosphorus, the value of 300 µg/l is mostly present in the literature (S. Manhokwe et al., 2013). Thus, all the tested samples fulfilled this standard, especially that only the presence of PO_4-P has been tested. Phosphorus has been detected in all the tested samples. The highest concentration was present in the ground water source 68.31 μg/l.

Acidic rains are considered to be one of the most significant sources of sulfates in ground waters, another possibility is the atmospheric deposition. Considering the health recommendation, the concentration of sulfates in the drinking water should not be higher than 500mg/l (WHO World Health Organization, 1996). As for the tested samples, presence of sulfates has been detected only in the sample number 1 and 3, respectively 13.51 mg/l and 59.52 mg/l.

<u>Summary</u>

The conducted analysis fulfilled its planned assumptions, it provided the overall information about the water presented in the Ward 10, however, the obtained results cannot be used to certify whether the water quality is good and can be drunk directly from the water source, without any pre-treatment. In order to clarify this issue, more detailed analysis should be performed, especially considering the number of taken samples. The total number of samples for every source should be higher, and the average concentration of every constituent should be calculated. Additionally, these samples should be taken and measured in situ, considering sampling before, during and after rainfalls (Hall, 2004).

Since, the conducted analysis does not include the biological tests, it is strongly recommended to use the basic method of purifying water such as boiling or clay filters before consumption. Another possibility is to test the water sample on the presence of the most popular biological contaminants by using simple, portable measurement equipment. The followings examples describe the common testing methodologies implied in developing countries:

- Presence/Absence(P/A) testing requires a sample (generally 100 mL) that mixed with a specific liquid can highlight the contamination of the water related to a specific pollutant. This testing requires a simple procedure, minimal equipment, a simple analysis procedure. Considering the drawbacks, there is a possibility of an erroneous respond when the sample contains low level of contamination, lack of quantitative results, application possible only when the pollutants present in the water are known. The average price is around 3-5 USD/test for the most common pollutant substances such as: E. Coli or coliform.
- Emerging Semi-Quantitative Method #1 is presently under development. The current design consists in a sole use plastic container that, incubated in a reusable incubator for 24 hours, will show the presence of E. coli. The price should be around 1 USD/test.
- Emerging Semi-Quantitative Method #2 is another low-cost (around 1-2 USD/test), easy to use portable test for E. coli and H_2S-producing bacteria. Unfortunately, the product is not yet commercially available.
- Most Probable Number with IDEXX is a procedure that allows to run multiple P/A tests while using the same sample. This methodology would deliver a highly reliable quantitative result using a simple testing and analysis procedure. The cost associated to each test would be around 5 USD, but an additional initial investment of 1500 USD should be considered for the analysis equipment.

3.1.3 Water supply in Honde Valley

Zimbabwe used to have some of the highest rates of access to water and sanitation in Africa. However, accordingly to the government, the access to adequate water supply has dropped to 46% and the sanitation to 30%. The deterioration of water and sanitation services resulted in a cholera outbreak in 2008-2009 that affected 100,000 people and caused 4,300 deaths (WHO & Emergencies, 2005).

The responsibility for the water resources management and water supply in the country is in charge of The Zimbabwe National Water Authority (ZINWA). The company supplies water to 538 stations that range in size and service around 3 million people.

The Honde Valley area is very rich of water resources of various kind: rivers, streams, aquifers and rainwater. However, inhabitants of all villages in Ward 10 have access to a rather haphazard and disorganized water system. Such situation produces many obstacles, difficulties and arguments among locals. There is not sufficient reasonable and trustable data providing information about availability and capacity of the water flows. Therefore, diagnosis of the real problems concerning the examined area can be difficult. Maps describing the Ward 10 are very poor in quality, thus planning and proposing any feasible solution is very challenging.

The main water source for Ward 10 is Mupenga River. It is a small size, torrential regime river, very dependable on the season of the year. During the dry season (usually in this region from April – May and September – November) the water flow is flowing partially underground. The over ground part is shallow and tiny. The smallest amount of water can be experienced between October and November because in these months the air temperature is the highest during entire year. The rainy season, usually from December up to the end of March results in huge and rapid rainfalls which strengthen the water flow. The majority of the stream is flowing over ground. The access to the water source is not simple: to get from Masere Business Centre to the main water intake, firstly approximately a 30-minutes-long car trip and then around 1 hour trekking trip is necessary.

3.1.4 Description of the system

Ward 10 water system was built in 2003 by Plan International in cooperation with Zimbabwe National Water Authority (ZINWA) that installed the existing pipeline system. In the beginning, ZINWA was responsible for all the operation and maintenance issues. Unfortunately, due to problems related to water bill payments, ZINWA decided to assign the management of the system to a community committee of Samaringa.

Currently, the water supply is completely free, and the maintenance is made by volunteers of the village committee. Their main task is to maintain the system in the proper condition, prevent from damages and provide a constant water flow to the local community. Another task, relies on removing cumulative sediments and sludge from the water intakes. This practise is extremely important during rainy season when water flow is high: sediments and sludge must be removed at least three times per week, while during dry season only once a week. There is also one person who is responsible for operating the steering valve. In case of absence another person must be informed.

Existing water system starts in the mountainous area at the Mupenga River (1196m above sea level), where two separate water intakes were installed. For the first one, a small concrete dam was built. The main task of the dam is to accumulate a certain amount of water, especially during dry season, and to be used as sedimentation basin. In the middle of the dam a metal pipe with the diameter of 110 mm is installed. The spring water coming from the mountain enters the pipeline through a rudimental metal array filter and then, by the use of gravity force, is transported to the inhabited area. The second pipe with the diameter of 90 mm also derives water to the areas below. Both metal pipes are running in parallel down for 1,3 km and eventually reach two separate pressure breaker tanks (refer Figure 7).

Figure 7: Main water tank in deteriorated conditions (top), water source in mountain (left), one main borehole (right) (photos by Leon Haupt and Sofia Gonçalves)

Next, the wider pipe continues to go straight while the 90 mm one is turning right and going towards the Manyonho village, where is spread into several pipes and provide water to the smaller tanks and water points which are placed inside the village. This water is manly used by the people living in the Cluster 4 containing Manyonho, Nyabadza and Mutsamba village. On the other hand, the 110mm pipe is passing by a steering valve and a big water tank. During day time, the valve is open and the water is flowing towards Samaringa and nearby villages, to satisfy daytime demand. Water is flowing also from the big water tank, and it's provided to Samaringa School Tanks, Samaringa Clinic, Maszere and Mutisi Business Centers and later to further villages. During night time, the valve is closed and the water is collected into the main tank.

Eventually, the water reaches the water collection points which are spread across the Ward 10; thence the water is collected to the private tanks and taken to the households by the locals. According to the calculations made by ZINWA the amount of needed water for the Samaringa Cluster is equal to approximately 390 m3/week while the estimated amount of water needed for the Matingo-Village Cluster (almost three times higher population) is about 310 m3/week. The entire water system has been presented on the Figure 8.

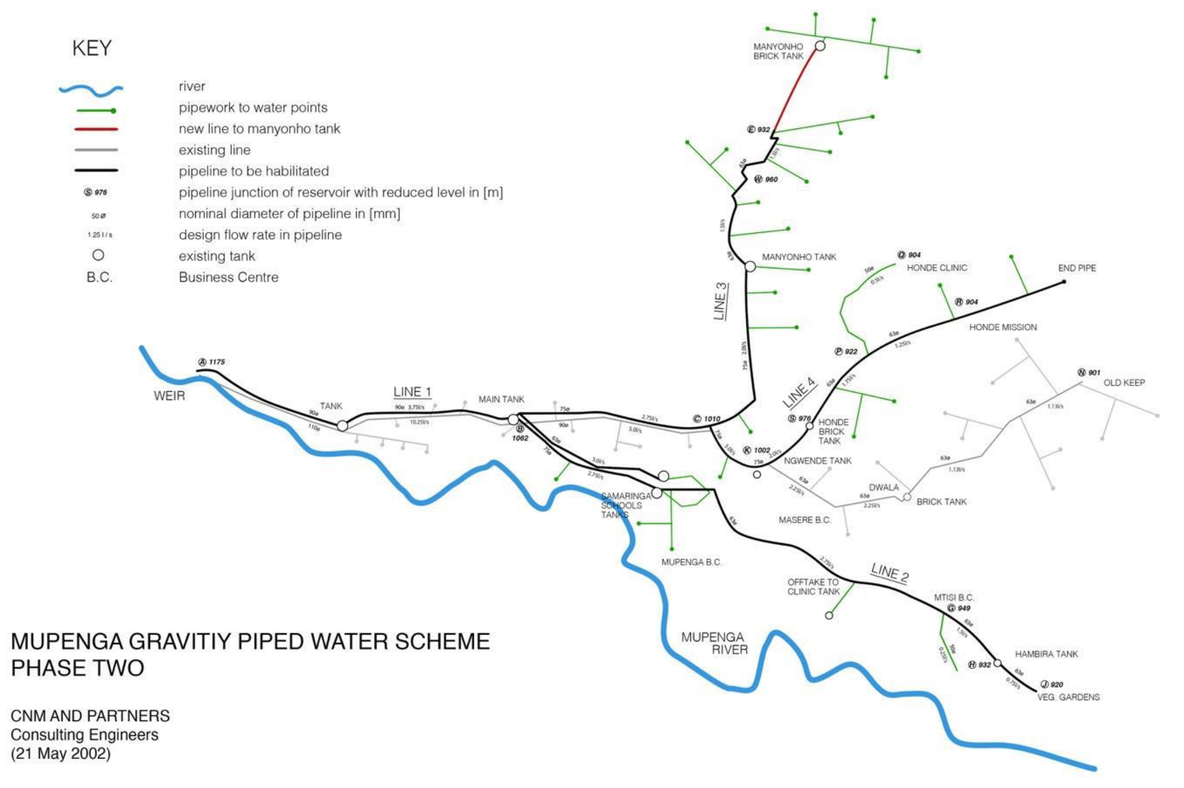

Figure 8: Digitalized version of the old water scheme; photo: Krzysztof Dzialo, Leon Haupt

In conclusion, in Ward 10, there is enough proof to believe that there are sufficient water resources with many homes having access to piped water. The problems are related both to the system itself and to the management of it. It is possible to summarize the main problems of the water supply as follows:

- It is not clear if the single water source is still enough for the population needs: no hydrological data are available so far;
- There are other possible sources in the valley that are not exploited at the moment, for economic reasons but also for the lack of equipment and infrastructures;
- The daily water storage capacity is not enough because many tanks are broken;
- The pipeline system is old, and leaking. An accurate scheme of the system, including the list and capacity of the tanks is not available;
- Lack of equity in the distribution of water: the water access is in series, and households living closer to the source have much more water than the other inhabitants downstream;
- Lack of information and awareness: the consumption is not controlled at all, so people with higher water availability tend to waste it, for example irrigating the fields also during the warmest hours of the day;

- Water is generally not purified, neither by the clinic. In some cases, this situation is due to the cost of purification, but it is possible that the problem could be related to the awareness of the risks.

3.1.5 Sanitation in Honde Valley

In Honde Valley there exist basic forms of sanitation, however, their condition and state of development is not satisfactory and should be improved. The biggest issue, which influences on all other sanitation problems, is lack of harmonised and safe water system. Hence the improvement of the entire water system is considered to be a long-term undertaking, there are some elementary steps which could be taken in order to provide a better life conditions to the community. In the paragraphs below these basic forms of sanitation are described basing mostly on interviews and observations made during the first and second field trip to Zimbabwe.

Health Care

Most of the information in this paragraph was provided by Mr Mongola who is a nurse in the one of the local clinic. According to his information the most common health issues in Honde Valley region are: pregnancy, diabetes, asthmatic attacks, malaria and colds. In order to get help, local people have access to two clinics located in the Ward 10 area.

First, bigger one – Samaringa Clinic belongs to the governmental organization. The clinic can treat 21 people simultaneously – 21 beds, and the personnel counts 7 people. This establishment is responsible for 3866 patients. In order to provide basic, medical services Samaringa Clinic has a poor access to the electricity which is supported by the PV installation. Unfortunately, due to battery damage the system is not working at the moment and there are not enough finances to repaired it. Clinic is taking water from the main water source and collect it in 5000l brick water tank. This amount is enough for 3 days of clinic's operation. The tank either requires a complete repair or should be replaced with the new one. According to Mr Mwongola the best solution would be the second option. Additionally, the tank's capacity should be increased up to 10 000l.

Second Clinics – Honde Mission Clinic belongs to the missionary organization. It is a smaller clinic, only able to treat 6 patients simultaneously – 6 beds. One of the personnel aim is to expand the clinic's capacity up to 15 places. Honde Mission clinic is responsible for 1782 patients. The clinic used to have access to the electricity with the usual monthly cost of 150 USD. The cost included the price for electricity needed to power the refrigerators, lights and possible internet access. Unfortunately, due to financial problems (8300 USD debt) the clinic has no access to the electricity at the moment. Thus, it is necessary to apply the temporary solutions instead such as: candles and gas-powered refrigerators. Similar to the first case, the water is also taken from the Mupenga river and transported to the 5000l metal tank. Due to extremely poor conditions of the tank, clinic had to buy a new, plastic 5000 l tank for 595 USD. The installation is planned for 2017 and will require some additional financial support for labour, pipes and maintenance of the system.

Main problems related to both clinics can be described as follows:

- Water standards – there is no overall water treatment for basic aspects such as: washing hands, laundry and cooking practises. Honde mission clinic used to use chlorine as a main water treatment method, however, due to financial reasons personnel had to stop this procedure. The chlorine was taken from Mutare city – almost 100 km from the clinic.

Presently, in order to cure patients properly, the clinic staff is forced to perform basic water purification methods such as boiling.

- Lack to the professional medical care – in both clinic there is no doctor, only nurses. In more serious cases patients are forced to visit Hauna District Hospital, (able to care 65 people simultaneously) which is around 17km far from the Ward 10. Vast majority of the roads in Honde Valley is damaged, thus entire trip may take more than 2 hours. Additionally, there is lack of any ambulance vehicle in entire Ward 10.
- Access to medical equipment and medications – need for basic medical treatment, vaccines, digital blood pressure machine, glucostix, glucometers, gynaecology equipment. Similar to the first case, the nearest pharmacy is also in the Hauna Business Centre – 17 km distance.
- Overall conditions – the standards of both toilets and showers are very poor. Only sub-standard Blair toilets are being used that can cause many troubles to both patients and the responsible personnel. There is a separate building for showers, however, its conditions are not satisfactory. Places for washing patients are connected with storage rooms for marinating equipment. Additionally, there is no enough space for all the patients. In Samaringa clinic two, very tiny rooms can be found with places for 12 women each. There is also a special place outside the clinic for pregnant women. Wild animals have very easy access to reach the clinic because there is no fence surrounding the facility.

Toilets and showers

The flush toilets in use in the western world use between 10 to 26.5 litres of water for every flush (Portland Regional Water Providers Consortium, n.d.). The most efficient still need 5 or 6 litres every time. It is clear that such devices are not possible to use in a place where even the amount of water for drinking is not granted.

In developing countries, open defecation is the common standard. Where toilets are present, they are simply holes in the ground with a pit collecting the sewage.

However, in the 1970s in Rhodesia (today Zimbabwe) a new concept of ventilation-improved pit toilet has been developed by the Blair Research Institute; in the following decades, the Blair toilet has spread and become very common in rural, underdeveloped areas.

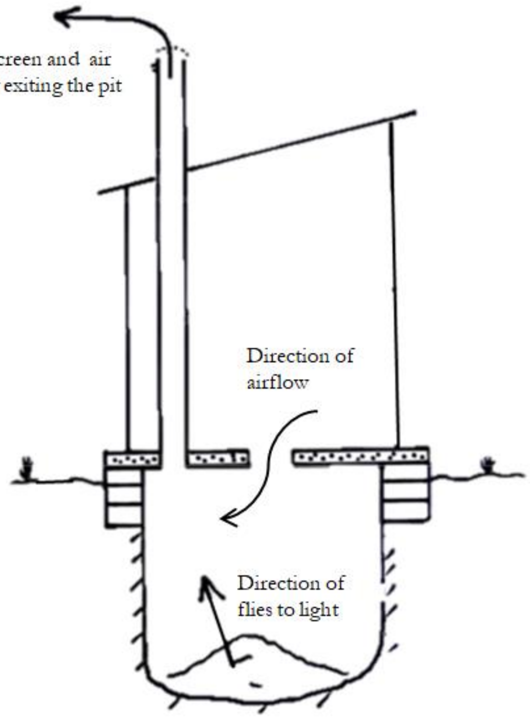

Figure 9: Blair Ventilated Improved Pit Toilet (Morgan, 2011)

BVIP (Blair Ventilated Improved Pit) toilets have a very simple scheme (refer Figure 9). The well for sewage collection is lined with bricks, and covered with a concrete slab in which two holes are present. The first aperture is for the squat hole, while the second one allows a ventilation pipe to expel the odour in the outside environment. Fresh air is sucked from the squat hole, allowing the toilet to be almost odour-free. Insects are attracted on the end of the ventilation pipe, where a net prevents them from entering the pit, thus avoiding the spreading of diseases that they can cause. The filling of the pit varies between 10 and 20 years depending on its capacity (Morgan, 2011).

Without water and a drainage system, Blair toilets are the best solution for sanitation purposes. They can be built very essentially and with cheap materials, and possibly upgraded in a second moment, by expanding them and building a brick superstructure, with a door, a seat, a lid and more comforts.

In the whole Honde Valley the most common type of the used toilets is standard blair toilet which is present close to every household and in public places e.g. business centre. The toilets are different between each other. The most developed ones have a proper sit and a toilet clap while the least advanced have only a hole inside. The main missing aspects are: lack of doors, lights and vans inside and lack of nets which could provide many insects from flying inside the toilet.

Considering showers, almost in every household there is a special, separate place where you can take a shower. Running water is not present, thus in order to take a shower there is a need of use a bucket of water. Like the toilets, basic equipment such as lights, mirrors, doors are missing.

In conclusion, as described above there are many aspects which can be improved in Ward 10 even without using very sophisticated solutions. Some basic technical improvements could brighten the life of people. The following suggestions of improvement of the already existing systems are listed below:

- Insert a fly screens/nets in the ventilation pit that would block insects to fly inside the latrine,
- Install a door/curtain to provide more security for the user and work to protect the interior of the toilets from insects,
- Install seats to provide more comfort for the users
- Install lighting system inside the toilets or close to the facility to make it more reachable during the night time and to give more security for the users.

The implementations are listed in order of the complexity and cost; the first is the cheapest one (less than 5$ per screen) and requires the least technical knowledge and the least time to be applied. The implementation of lighting system might require an off-grid generation system thus the cost may vary a lot for a specific facility.

The positive aspect is that the overall awareness and knowledge of need of such improvements is rising. Clinics are organising special health campaigns at least one a month for both villagers and schools. Also, investigation of health standards in the village is being checked constantly. All those activities are directed by people who are not payable for their work – volunteers.

3.2 Energy poverty and equity challenges

Access to Energy for all is one of the biggest challenges for the development of the world. UN Sustainable Development Goal number 7 is "Ensure access to affordable, reliable, sustainable and modern energy for all" (refer Figure 10).

Figure 10: Sustainable development goals (United Nations, 2015)

According to the World Energy Outlook report (International Energy Agency (IEA), 2016), 16% of the global world population don't have access to electricity, around 1.2 billion of people. Considering people without access to a sufficient quality electricity, this number is much bigger. More than 95% of them are located in Sub-Saharan Africa (SSA) and developing Asia, in particular in rural areas far from the main cities, where the national grid is too expensive to build.

Energy is linked with almost all aspect of human daily life (International Energy Agency (IEA), 2016): it is essential for the supply of clean water, sanitation, health care, lighting, cooking, heating, and is one key factor for economy but also social development and personal fulfilment. Electricity is needed for lighting, and for communication, lighting extend the hours per day of work or study, mechanical power is needed in agriculture for ploughing and for irrigation, or for textile manufacturing. It is evident that Energy is essential for all the goals envisioned by the UN, and when dealing with a community development, it must be one of the main pillars.

Despite of the fact that sub-Saharan Africa is rich in natural resources that could easily be exploited for electricity generation; still the region has the lowest electrification rates leaving around 621 million Africans without electricity (International Energy Agency (IEA), 2016).

Zimbabwe is facing a severe electricity shortage which started due to frequent power breakdowns since 1998 and became the country´s major economic challenge. Despite of this challenge, the government has paid least attention towards the investment in expanding the electricity generation capacity since 1980. The country´s demand has been rising due to several factors (R. Maasdorp, 2011). In addition, the energy demand is anticipated to escalate further due to population growth, improvements in manufacturing and agriculture sectors etc. The national electricity demand as of February 2016 was 2200 MW at daily peak compared to the production capacity of only 845 MW (Choruma, 2016). Currently, the country´s power is mainly supplied by two sources namely thermal and hydro with Hwange Thermal Power Station and Kariba Hydro Power Station, respectively being the principal power producers. Given this, Zimbabwe has a power deficit of 1355 MW or 62% of total energy demand. Because of lack of power generating resources, the industries are currently running at a capacity of 25-30%. In the next 5 years, it is assumed that the industry grows its capacity by 70%, and if mining and agriculture sectors continue to grow at current pace, the energy demand of Zimbabwe is anticipated to be double i.e. 4400 MW (Choruma, 2016).

3.2.1 Access to lighting

The lack of a reliable electricity grid affects access to clean lighting. The current alternative to electrical lighting sources is fuel-based lighting, such as kerosene lamps or candles that can create serious health problems with the fumes and fires in case of accidents. Moreover, it provides a very dim light with very low efficiency and it produces a different number of pollutants such as carbon dioxide and monoxide, nitrogen and sulphur oxides and volatile organic compounds, dangerous for either the environment or people's health (Ramchandra & Boucar, 2011).

This situation affects the productivity of nearly 25% of the world's population because basic activities are carried out in the dark with difficulty. An extension of the power grid to reach and electrify remote rural communities is very unlikely to happen due to the remoteness and isolation of the villages and the high investment cost that it will require. Therefore, an affordable solution to obtain better lighting is for instance the diffusion of renewable solar-powered lighting systems.

3.2.2 Honde Valley: Status of the grid

Honde Valley is currently fulfilling their energy needs almost entirely from hydro-energy resource because it's naturally blessed with water reserves and rivers. The fluctuations of electricity in Honde Valley are rare and the grid is able to fulfil the demand of the rural community. There are four hydropower plants[1] commissioned by Nyangani Renewable Energy (NRE)[3] which supply electricity to Honde Valley and also to the national grid.

[3] NRE is a private power producer, partially owned by the UK group "PGI Group Ltd", and operates mini-power plants in the eastern Highlands.

I. Pungwe B power station – is a mini hydro-power station with a capacity of 15,25MW and was commissioned in March 2015. Nyangani already operates four similar hydro power stations in Manicaland, feeding to the national grid.

II. Nyamingura – 1.1MW Scheme on Nyamingura River commissioned in 2010.

III. Duru – 2MW scheme on the Duru River commissioned in March 2013

IV. Pungwe – (stations A +B +C) which produces in total around 20MW, feeding to the national grid. Pungwe A, commissioned in January 2013, (2.8MW scheme) diverts water via a weir on the Nyamombe River through a pipeline and penstock down to the Pungwe River. Furthermore, 3.8MW Pungwe C scheme on the Chiteme River commissioned in March 2016.

The electricity is sold to the national company ZESA, Zimbabwe Energy System Authority, that is distributor and retailer (PGI Group Ltd, 2016).

The average price paid by ZESA for the electricity produced is 0.14 USD/kWh[4], while the retail price for the customers in Honde Valley is 0.1 USD/kWh. The retail price of ZETDC, Zimbabwe Electricity Transmission and Distribution Company, has been identified looking at some receipts of a villager: the price was specified and was constant for the last three years (refer Figure 11).

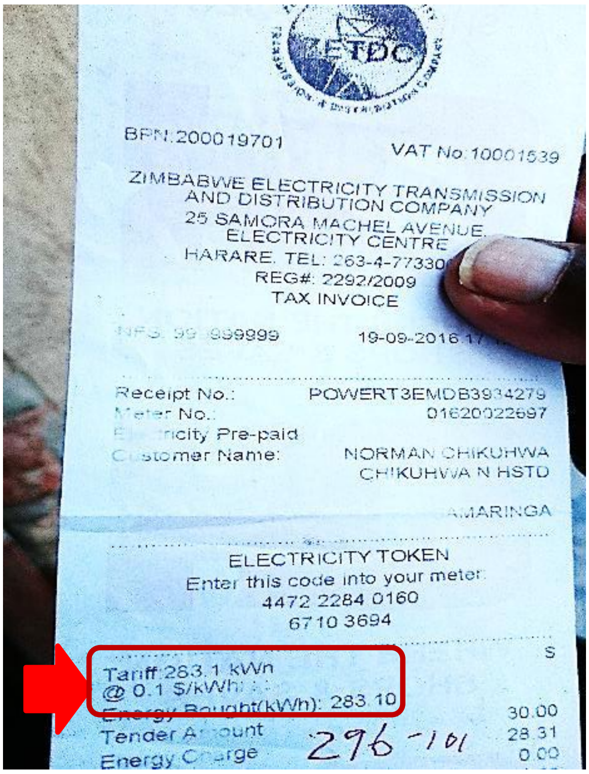

Figure 11: ZETDC electricity consumption receipt; photographer: Luigi Ghiani

[4] Information from Amos Kapenzi, Power Engineer employed at NRE (Nyangani Renewable Energy) and guide of the team to the hydropower plant, during the field trip of December 2016.

The electricity in the Valley is paid in advance: the meter shows how many kWh are available for the household consumption, according to the amount paid to ZESA.

Many houses are still not connected to the grid, and consequently don't have access to electricity. The school and the clinic of Samaringa are connected; in the school is also present internet connection via cable. The price of connecting to the national grid is 95 USD, with 16 m of electric wire included; for higher distances, the price can increase up to 160 USD. According to the opinion of locals, this initial investment is the biggest obstacle to a capillary electrification of the households: in fact, the price of electricity is not particularly high and it is considered affordable, while the connection to the grid is very expensive, especially for unemployed families or for subsistence farmers. This situation leads to some consequences: lighting is not present in many houses; in other cases, it is done with candles or liquid fuels, contributing to the Indoor air pollution.

The main appliances in the houses connected to the grid are light bulbs, fridge, sometimes television and radio. Electricity is also used to charge mobile phones. No air conditioning is used.

No electricity is used for the main water system: the water source is located in a very high position with respect to the houses. Some farmers use water pump fuelled with petrol for irrigation purposes.

3.2.3 Questionnaire results

In the questionnaire for the population some questions were related to the energy utilization and satisfaction. In particular, 57 people answered these specific questions, and the result is that 89.4% of them is strongly unsatisfied with the electricity availability they have, while only 3.5% is satisfied; the remaining part is slightly unsatisfied.

Regarding the electric appliances owned by the locals, in Figure 12 a summary is presented. In particular, it is remarkable that all the interviewed possess a mobile phone. This result is interesting because some of the proposals will be based on the assumption that the whole population can use the phone to pay with cashless money transfer based on SMS. It is also interesting to notice that the radio is still the most common media of information of the valley.

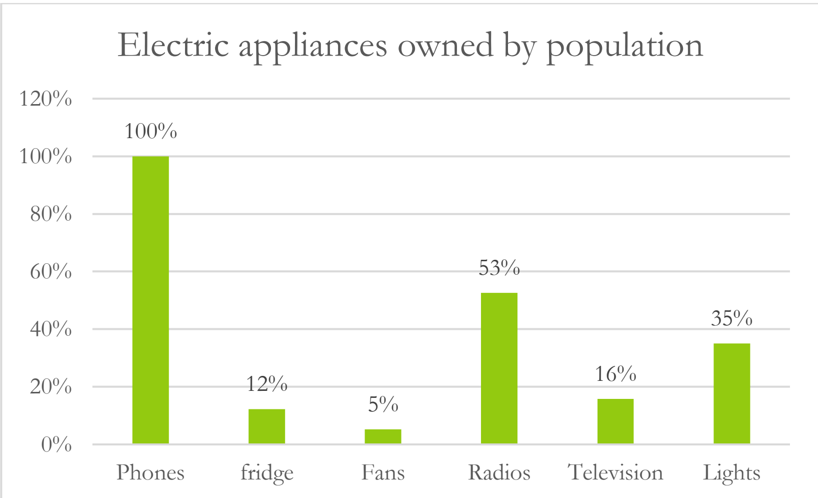

Figure 12: Electric appliances ownership

3.3 Access to clean cooking

Almost 3 billion people in the world (40% of total population), in developing countries, still rely on traditional solid fuels (Jagger & Jumbe, 2016), such as charcoal and firewood (also known as wood fuels), to cook every day. From the environmental point of view, firewood harvest contributes to deforestation and climate change: some areas, like Ethiopia, are facing severe problems of desertification, also due to industrial sector and international wood trade. In Sub-Saharan Africa (SSA), wood fuels are responsible for 75% of total wood harvesting (Jagger & Jumbe, 2016). Given that, the number of people that rely on firewood is expected to increase in the next decades, exacerbating the situation. In general, half of the total wood harvest of the world is used as fuel for cooking and heating, representing the 9% of the global primary energy supply (Bailis, Drigo, Ghialardi, & Masera, 2015).

When the wood is burned in open fire, which is the most common cooking way, the low quality of combustion lead to a big release of particulate and black carbon, or "soot". Black carbon has been recently identified as the second largest contributor to anthropogenic climate driver (between 35-42% of the total) after carbon dioxide emissions (Bailis et al., 2015). Several health threats are hidden in this cooking habit. Usually people cook inside their houses, with insufficient or no ventilation system. Therefore, cooking with biomass is the main responsible of indoor air pollution. Acute respiratory infections (ARI) among children under 5 years old include pneumonia, chronic obstructive pulmonary disease (COPD), chronic obstructive lung disease for women, and low birth weight. According to the World Health Organization (WHO), almost two million deaths per year (WHO World Health Organization, 2016) are associated to indoor air pollution; the same number of deaths caused by malaria and tuberculosis combined.

Regarding the impacts on society, fuel gathering activity consumes considerable time for the collectors (normally women and children) restricting them to perform other productive activities (e.g. income generation) and taking children away from school. In less secure environments, women and children are at risk of injury and violence during fuel gathering. The 'Children and Climate Change in Zimbabwe' study indicated that 50% of the children from rural areas and 40% in urban areas assisted their families in collecting firewood and there has been an increase in school children missing classes because of having to fetch firewood (Wickham, 2016).

Since this concern has become urgent in International community, a lot of effort has been put by UN and NGOs to improve the efficiency of cooking stoves which led to the creation of Improved Cooking Stove (ICS) programmes in most developing countries. Now the aim is to persuade the households for the adoption of an Improved Biomass Cooking Stove (ICS), a device that allows a more controlled, higher quality and insulated combustion, reducing both the consumptions and the emissions. A World Bank report cited 137 ICS projects in 41 developing countries initiated during 1981-1991(Barnes, Openshaw, Smith, & Plas, n.d.). These are clean, affordable and accessible cooking solutions that can dramatically reduce fuel consumption and exposure to harmful cook stove smoke, while providing economic opportunities in communities around the world. Yet, despite apparent benefits of improved stoves and a recent spate of 'dissemination' programs, many developing-country households have failed to adopt them for many reasons.

3.3.1 Honde Valley cooking traditions

The conventional way of cooking in Honde Valley is with solid biomass (firewood).

In their traditional homes (refer Figure 14), called Musha, they have separate round huts for the kitchen (refer Figure 13). Usually people cook inside these kitchens or outside when the temperature is warm. The kitchens have no exhausting system, just one or two windows.

Figure 14: Traditional round kitchens (Photos by Sofia Gonçalves)

Figure 13: Traditional households with round kitchens (Photo by Sofia Gonçalves)

Firewood has been used as a fuel since the beginning of mankind since it is renewable and relatively easy to produce, transport and store. From the trip, the group could observe the following:

- Fuel wood is used by majority of the households and is acquired by collection.
- Local people fetch firewood from the indigenous resources without having an idea about their monthly wood consumption (fuel) and quantity collected.
- Usually the wood collection activity is performed by women in charge of the cooking chores.
- There are no records of the number of weekly trips for gathering wood or the hours spent on collecting fuel per activity per week.
- The roundtrip distance (km) per collection activity has not been estimated usually, because of the fact that the collection is carried out from the surroundings of each household.

Traditionally, meals in the community are prepared three times a day (breakfast, lunch and dinner). In the morning tea is generally taken with bread. In urban areas, bread is bought from shops whereas in rural areas, people are used to bake their own bread. For lunch and dinner, a thick porridge (sadza) is prepared with relish that may include vegetables, meat (mainly chicken).

Currently, the stoves in use are either a 3-stone configuration or metal structures that support multiple pots and placed above the burning wood. Usually, woman cook using multiple pots and the fires are lit during several hours of the day. When asked during the trip, cooks responded that they don’t consider smoke inhaling in the kitchen a severe health problem because they are not aware of the health consequences.

Figure 15: Cooking stove in a household in Honde Valley (Photo by Sofia Gonçalves)

This type of cooking stove has disadvantages such as:

- Smoke and emission of unburned particles due to the low temperatures.
- Incomplete combustion.
- Slow pace of cooking, since the cooking pot does not sit in the hottest part of the flames, and a lot of heat is wasted and lost in the environment.
- High fuel consumption: usually a lot of fuel is consumed since not much heat is generated per unit of fuel: Higher Heating Value (HHV) between 14400 – 17400 kJ/kg. (Engineeringtoolbox.com)
- Injury risks: sparks of the fire pose an injury risk or even some flames can hit the cooker during the process.

Alternatively, the disadvantages in DV can be seen in a positive way as well:

- Open fires burn slow and do not require frequent attention which is an advantage if the cooker has other chores to be done simultaneously.
- Smoke can disperse mosquitoes;
- Smoke can be used to preserve food;
- During winters, the inhabitants can make use of the heat emitted to keep themselves warm.

Therefore, the development of improved cooking stoves is facing a dilemma; the same characteristics of the open fire can be seen as advantages for some and disadvantages for others.

3.3.2 Proposed solutions to clean cooking access

In 2015 and 2016, UNICEF Zimbabwe conducted two programmes on the use of improved cooking stoves which are cleaner, emit less smoke, are more efficient and use less wood with GOAL Zimbabwe. These programmes were conducted in Hurungwe and Mwenezi. Through these projects, women learnt to build the stoves themselves, and then went on to train ten other women within their community, and in some cases more (Wickham, 2016). Through these pilot programmes, UNICEF has reached 3,480 households so far (approx. 17,400 indirect beneficiaries). One of the stoves distributed within these programmes was the Tsotso Stove, a commercial product produced by a local engineering company, originally developed by David Hanlock in Zimbabwe in the '80s, and later by the Development Technology Centre (DTC) based at the University of Zimbabwe. This commercial product is by far the only commercially successful wood-burning stove in the region.

Non targeted participants have also adopted the improved cooking stoves, and volunteers will continue promoting the trainings together with raising awareness on the perks of using improved cooking stoves. Some participants are now selling the Tsotso stove to urban dwellers and growth points to generate income. Therefore, highlighting that these volunteers can now benefit from the establishment of their own micro business and income generation resulting from this programme.

To improve cooking conditions in Honde Valley, the simplest and appropriate solution is an improved cooking stove. The project of the stove should take into account several aspects related to traditions and habits of local population.

Tsotso Stoves

Among the desirable features of the stove is fast cooking, less smoke, and fuel economy. It has been estimated that the stove reduces the amount of wood needed to half. They cost around $40 and need only a few twigs to make a fire for cooking or heating (The Zimbabwean, 2014).

However, it has been criticised for damaging metal pots at the centre. Traditionally, people want to see the fire to be able to control it which is unfortunately not the case in metal pots due to its enclosed design (refer Figure 16). According to stove performance testing which was conducted throughout the programmes, the Tsotso stoves have reduced specific fuel consumption by as much as 39%.

Figure 16: Batch of Completed Tsotso stoves in Mwenezi Community (Wickham, 2016)

Clay Improved Cooking Stoves:

An example, of an ICS successfully implemented was the Firewood Jambar stove. ICS dissemination project is Foyer Amelioré au Sénégal (FASEN), which was initiated in 2006 in Senegal as part of the Dutch-German Energy Partnership Energising Development. In contrast to earlier ICS interventions, FASEN focuses on establishing a sustainable and autonomous market for ICS by performance testing, training of producers and distributors, and supporting communication and promotional campaigns. The ICS, originally developed in Kenya in the 1980s under the name Jika, distributed by GIZ and is also used in the present RCT is the Jambar. By December 2010, over 3,700 stoves had been produced and sold in the intervention areas (Bensch & Peters, 2012) (refer Figure 17). The ceramic improved stove is a standard-measure pottery kiln, where the fire is insulated by clay walls. It can be produced directly by local artisans, after an easy training. There is a complete manual available to guide artisans to build it step by step (Pour Personnes, 2011). It is a simple and cheap solution, the final price can be assessed between 0.76-3.81 € (Gunther Benscha, 2015). The stoves can be manufactured in the Clay Workshop already mentioned in the clay filters chapter. Cheapest stoves can cost less than 5 USD (Gunther Benscha, 2015) which is an affordable solution to start facing the problem of biomass cooking.

Figure 17: Jambar cooking stove("Global Alliance for Clean Cookstoves," n.d.)

Eventually, the stove can be combined with a sort of chimney, which could however be difficult to install, since the straw roof of the typical kitchen cannot be pierced without damaging the whole structure. Combining this product with clay filters, the potential market and product variation of the workshop can be expanded to make the business more profitable.

<u>Efficiency and technical functionality</u>

The efficiency of the stove is compared to the open fire three stones solution. From the technical point of view, the stove should be able to:

- Prevent fire accidents;
- Enable a better combustion in order to reduce indoor pollutants;
- Increase the efficiency of heat transfer to save fuel and reduce emissions;
- Be a stable, resistant and comfortable support for the pot.

The following Table 4 compares most important characteristics of the two stoves considered:

Table 4: Comparison of two possible solutions of IC: Jambar Stove and Tsotso Stove

Name	***Foyer Jambar à bois" in Senegal***	**Tsotso Stove**
Type	Portable, metal household stove with ceramic liner	Sheet metal. Fire grate and a removable bottom grid made from wire.
Production	3700 units	3480 units
Materials	Cladding: Scrap or new metal sheet, at least 0.6 mm thick Ceramic liner: Fired clay Binder: Cement and ashes	Sheet metal wire
Performance	45%	40% (more efficient)
Capacity	7-10 kg pots	n.d
Price	12 $ (2011)	40 $ (2014)
Estimated lifespam (years)	2	n.d
N° of Pots	3-4	n.d

In order to assess the technical performance of the stove, the design must be accurate from the engineering and material point of view, and it should be tested according to standardized performance tests, like the Water Boiling Test or the Controlled Cooking Test.

3.3.3 Questionnaire results

When inquired about the type of fuel used for cooking, the majority of the people claimed they collect wood from the surroundings. In Figure 18 and Figure 19 the results of the respective questions are shown.

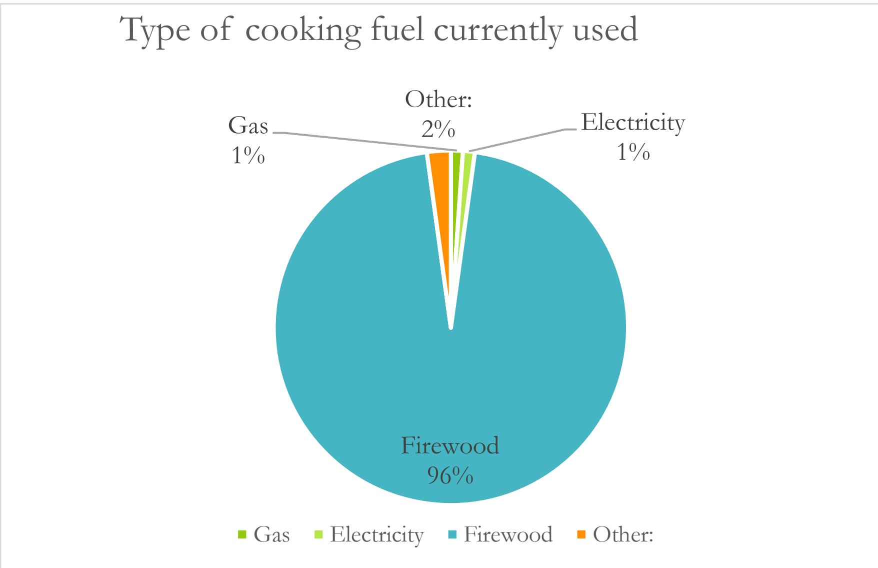

Figure 18: Results on type of cooking fuel used in Honde Valley

- On average, the answer to the monthly expense on cooking fuel is around 22,84 USD, and the maximum amount spent is 50 USD. There are 32 people answering they do not spend any money on wood.
- The walking distance to collect fuel per week is distributed in the following way:

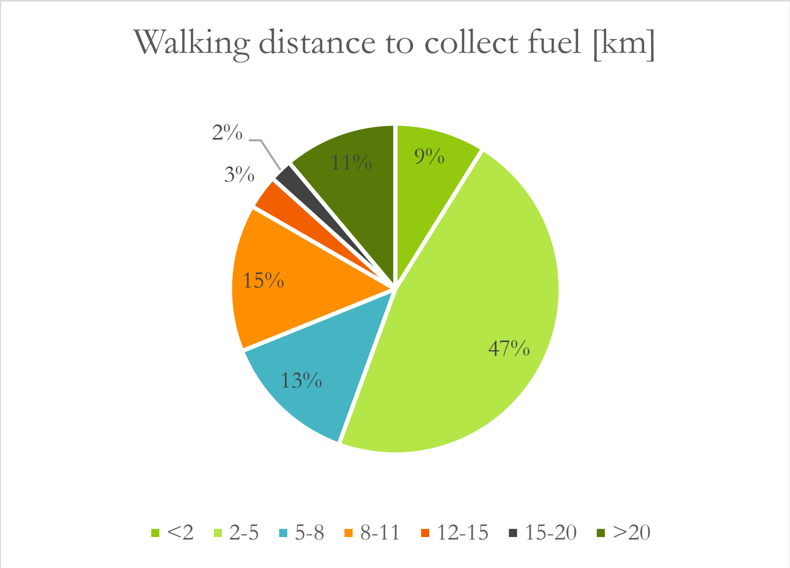

Figure 19: Results on distribution of walking distances per week in Honde Valley

The majority of people said that they usually walk around 2-5 km per week to collect fuel and the average time spent is around 10 hours per week. About the types of stoves used, most people answered Traditional/Fuel wood stove with 2 or 3 pots. Most people use the salting method to store food because they cannot afford fridge. Around 13 people, all from the same village (Manyonho), claim to have a Tsotso Stove, a type of ICS that has previously been implemented in Zimbabwe.

Considering the answers being honest and reliable during the questionnaire, 79 % of people answered that they would buy an ICS if it will provide better fuel efficiency, less smoke and greater safety. It can be concluded that the rural community is open to try a new option and the average price for the ICS was approximately 65$.

In order to achieve a successful implementation of one of the ICS, the first step is to create intensive awareness in the community regarding health consequences of using inefficient firewood stoves and about the need to adopt efficient stoves (wood savings, monetary, advantages to people). This mindfulness can create a sustainable motivation among the community. Moreover, awareness can be created through various means: Wall writings, posters, skits, plays, workshops, demonstrations, meetings, presentations, films, videos, press, etc. A better planning should be proposed for the next steps.

3.4 Roads, transportation and mobility

The trip of the first group to Honde Valley highlighted a very poor condition of the streets. Within Ward 10 villages only dirt roads are present. The road surface is not plain and many small rocks are present. Moreover, during the rainy season, the heavy rains dig grooves and form ponds that furtherly damage the surface and make it very difficult to pass through. Figure 20 provides a view of a typical road passage.

Figure 20: Roads in Ward10, Honde Valley [Photo by: Sofia Gonçalves]

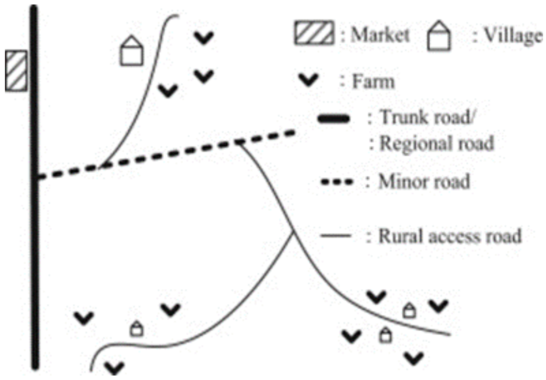

Figure 21: Scheme of the typical layout of the roads for a Rural Area. Ward 10 has a similar Layout, the black thick road being the paved one to Hauna (Fukubayashi & Kimura, 2014)

These conditions strongly limit the speed at which cars can travel as well as compromising the use of Intermediate Means of Transport (IMTs) that could be used for local population to increase their mobility, such as bicycles. IMTs are not very widespread within the community, mainly because of their cost. The price of a bicycle is averagely around $70, which is way too expensive for most of the families. During the visit, it has been clear that no motorized IMT was available within a reasonable ease of access (i.e. no motorcycle shop in the accessible markets and probably very expensive related to local average income anyway).

All the mobility of the community is based on walking and on combi buses. These are the only form of medium-long distance transportation in Ward 10. Travel with combi bus in the rural streets is very uncomfortable for the passengers, since they often carry passengers for more than the maximum capacity. The roads condition is a critical issue also for drivers, since an improved road would be faster to cover and it would limit damage to the buses. Combis are managed by private drivers and are currently used to reach bigger hubs, where more furnished markets are present and transportation to bigger cities is possible usually by means of other combis.

In the case of Ward 10, one of these bigger hubs is represented by Hauna village. The part of this village that has been visited during the trip is the market area, where several supermarkets, other than fruits and clothes stands, are located. The road to Hauna is unpaved for a first section, closer to the villages. As it is shown in Figure 21, from a certain point a paved road is reached and the travel can reach a higher speed (70-80 km/h). The overall time for a trip from Samaringa business centre to Hauna market area is about 1 hour and a half. From Hauna the combis have furthers destinations towards bigger city centres, like Mutare or Harare, such as it is explained in Figure 22.

Mutare is the closest big city to the people in Ward 10. It is the fourth biggest city in Zimbabwe and capital of the Manicaland District, that includes also Honde Valley. In Mutare, there is a bus station from where bigger touristic buses leave towards the capital Harare between other destinations.

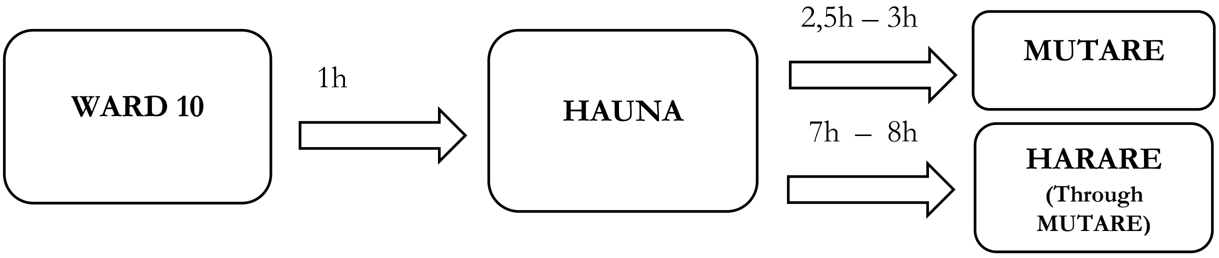

Figure 22: Scheme of Public Transport Time Distances. The time distance from Ward10 to Hauna could be decreased by improving the unpaved rural roads.

3.4.1 Objectives

Improve the quality of public transport

Public transport plays a crucial role in the system of a community, big or small. A good public transport grid can help to increase the number of trades between different areas and to favour the economic growth. Moreover, the services of public transport in Honde Valley are currently overloaded, with the situation leading to a heavy discomfort of the passengers and a faster deterioration of the vans.

Improve the quality of the streets

The condition of the streets is a crucial issue to all the stakeholders. Passengers, transport operators and regulatory authorities all consider road quality as a limiting factor for rural transport.
The poor conditions of the roads lead to:

- Long journey times;
- Overcrowded buses;
- Unreliable services;
- Higher fares;
- Poor access to health and education and to services in general.

Encourage the use of Private Means of Transport

Honde Valley is characterized by a general scarcity of the presence of IMTs. Motorcycles are no present at all, while bicycles are very rare, but still present in minor quantities. The causes of this situation have been individuated in the poor conditions of the roads, that does not encourage the use of any means of transport on two wheels, since it would be dangerous and uncomfortable to ride, and in the expensiveness of bicycles related to the average income of the community. While it would have to be preceded by a general improvement of the road conditions, the use of non-motorized means of transport, particularly bicycles, is individuated as the one with the highest potential to be sustainably encouraged in the valley, given the exaggerated expensiveness that motorcycles would have in the Valley compared to bicycles and to the average income.

3.5 Agriculture and farming

Mutasa district is located nearly 100 km north-east of Mutare, the fourth largest city in Zimbabwe, and a potential client for any produce from the Honde Valley. The valley is home to an estimated 1310 households located in 13 villages and agriculture is the main economic activity. From the 91 respondents to the questionnaire delivered to Ward 10 community members 89 (98%) responded having growing crop for domestic and commercial purpose (Figure 23). This fact has a great influence on the local nutrition, and as a result the local clinician reports that the population does not seem to suffer from malnutrition.

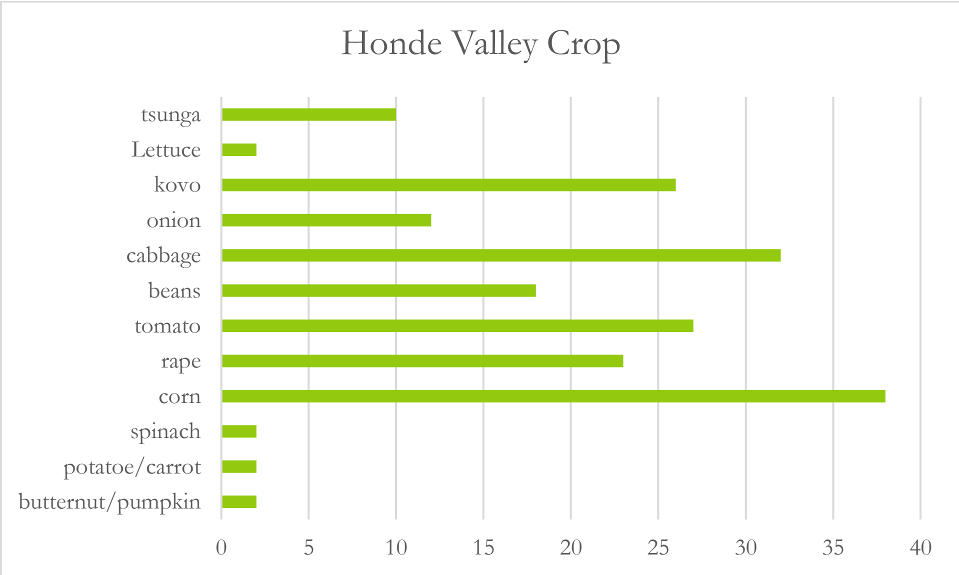

Figure 23: Crop in Ward 10

The land in Zimbabwe is classified into five agro-ecological zones (AEZ), where AEZ-I has the highest production potential and AEZ-V has the least. The Honde Valley is classified AEZ-I and therefore can be very profitable if cultivated properly (Ngongoni, Mapiye, Mwale, & Mupeta, 2006). Annual rainfall averages range between 850-1000mm, but falls mostly in the summer months (October-April).

In the Honde Valley, a great number of farmers are smallholders and a study in 2015 reported that many rely on external aid known as agricultural extension services, which is provided by a private firm under contract to a foreign donor. These services have many forms such as training and advice on farming practices, loans, and help accessing markets.

The results show that the outsourced extension service contributed to the farmer's income and expenditure and provided additional benefits such as better diets and health, improved product quality and employment. An analysis of the financial cost and benefit of the extension services suggested an annual net incremental benefit of 11,587 USD, representing a 30% return on the investment made by the donor to finance the service (Machilla, Lyne, & Nuthall, 2015).

Therefore, it seems that investing in agricultural practice in the fertile land of the Honde Valley could positively impact the economy by providing employment and income to the farmer sector.

3.6 Waste management

Waste management is not a purely technical issue. The political, socio-economic and environmental aspects also need to be accounted since it is based on the behaviour of the members of the community (Eugene & Busch, 2011). During the two field trips both teams identified a serious problem in the complete absence of a waste management system (Figure 24, Figure 25). From the various conversations with the locals and the survey analysis education appeared to be the biggest obstacle to be tackled in this field.

In fact, especially plastic waste, is considered of no value leading to improper and dangerous disposal practices such as littering and incineration. The situation is the same also in the schools and in the village clinic.

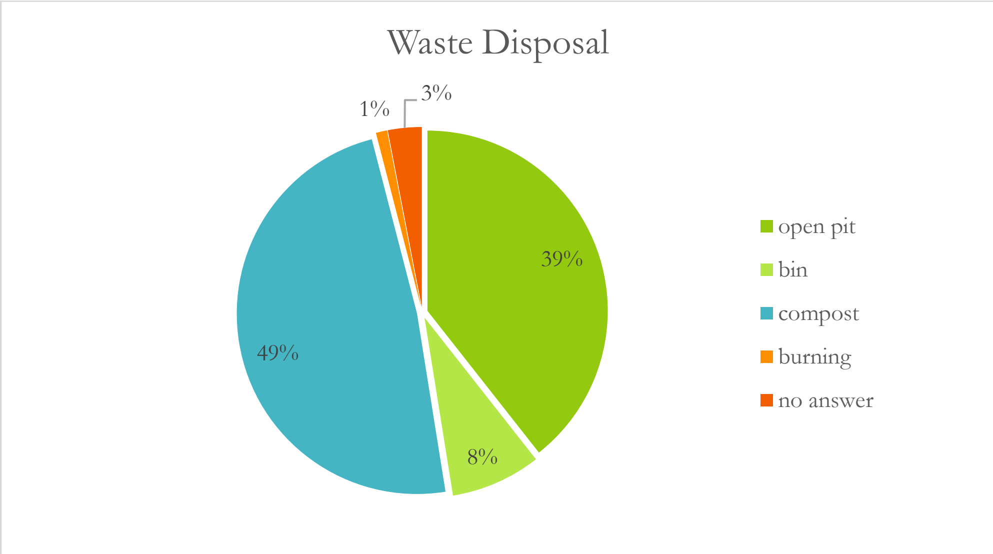

Figure 24: Waste disposal in Ward 10

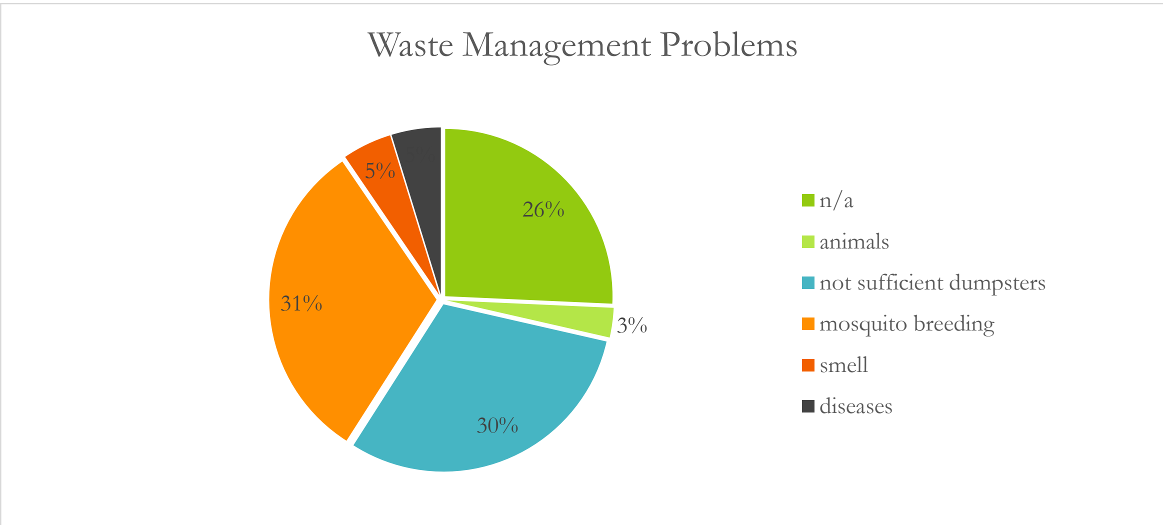

Figure 25: Problems related to waste management in Ward 10

3.7 Community Building and services

The community in Ward 10 uses an old Warehouse (refer Figure 26) with an area of approximately 330m^2 (30m x 11m). The venue is managed by a local committee. The usage is mainly for markets or small events for example speeches or presentations. The committee encourages the community to make more use of this building. In a meeting with the responsible community building manager the main needs for the building could be obtained. In the area of the Honde Valley, similar Community Buildings provides free water through a water reservoir. The water is for example used by farmers in order to wash their hands after the usage of fertilisers. The community building committee is working on volunteering basis and therefore generates no income. Consequently, required investments, for example for the mentioned water tank and a proper connection fully rely on donations.

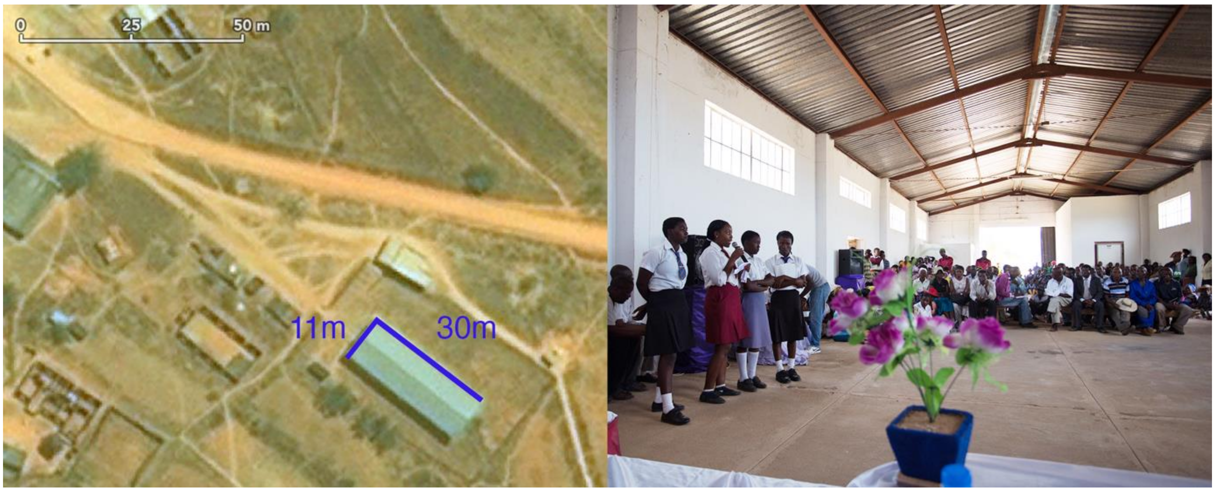

Figure 26: Arial view of the community building on the left (Source: Apple maps). Indoor view of the warehouse on the right; photographer: Leon Haupt.

4 Water system improvement

The following chapter presents a set of solutions related to the improvement of the water situation in Honde Valley. In particular, a payment and management system for water is introduced, together with technical solutions such as rainwater harvesting with roof systems and artificial ponds, advanced irrigation systems and clay filters for small scale water purification.

4.1 Water management

The current water management system, similarly to many others rural areas in Sub-Saharan Africa, is barely existing, being completely based on volunteer work. However, because of the dramatic situation of the water supply, critical modifications are crucial to make the system sustainable from the economic point of view.

In case of developing countries, it is primarily necessary to ensure the constant, safe water flow in the system; thus firstly, to fulfil this requirement, it is important to focus on the three main aspects: system assessment, operational monitoring and management plans. Properly organised plan should include many stakeholders including national and local governments, state-owned utilities but also NGOs & Donor Agencies. All of them should collaborate and control each other to obtain the best results and minimize the possibility of failure (World Health Organization, 2005) (Howard & Bartram, 2003).

Considering that in small community-managed water supplies operation and maintenance is handled by the community members with a limited technical knowledge and without any financial support, the water management system should be constructed focusing on the supply. Moreover, external help and guidance are necessary. According to WHO, two different concepts of approach to the problem are commonly used (World Health Organization, 2005):

a. System development for a particular technology available in the country,
b. Development of the guides that support the local development with examples which can be modified according to local conditions

In both cases, proper and detailed research about the analyse situation is fundamental. Additionally, to propose the most reliable, viable and sustainable solution, which will fit directly to the Honde Valley area, it is necessary that the opinion, behaviour and habits of the local community will be taken into consideration while planning the entire system. During the second field trip to Zimbabwe, a specially prepared questionnaire was successfully delivered to the locals. The paragraph 4.1.1 is presenting the results of the water harmonization part of the questionnaire. Properly organized water management plan should take into consideration: opinion of the future users of the system, locally available human resources and technology, rainfall data collection, results of the water quality studies, all the possible hazardous effects.

4.1.1 Current habits and public opinion

One of the most meaningful outcome of the questionnaire conducted during the second trip to Honde Valley is that 88% of the population inquired claims that their water supply is not sufficient.

The sources of drinking water in Honde Valley has been presented in Figure 27:

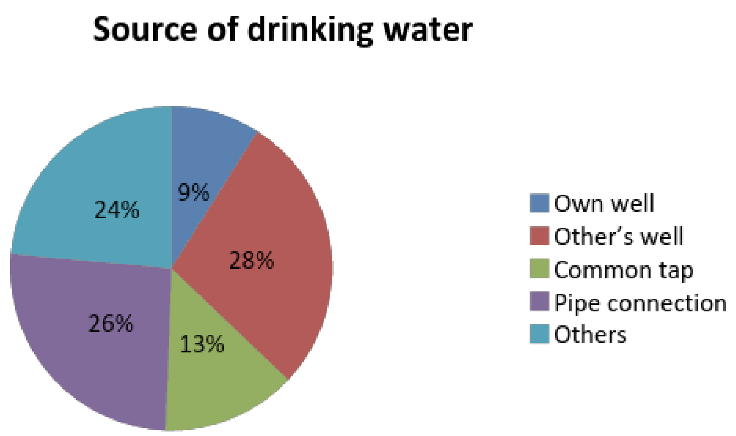

Figure 27: Sources of drinking water in Honde Valley

Other information regarding the water-related issues obtained from the questionnaire:

- Only 26% of the people (or households) has access to the pipe connection while the majority of the society is using wells (either their own or the neighbour's ones)
- When questioned about the walking distance from the drinking source, the average distance is around 739 m. The minimum distance is 3 m and the maximum 10 km
- 90% of people say they do not clean the water and only around 8% of the people say they boil the water for drinking purposes. The average water boiling process takes between 30 to 60 minutes
- When questioned what would be a reasonable price per month to pay for a clean water distribution point near their household, the average answer was around 15 USD/month. The maximum price proposed in an answer was even 150 USD/month, as stated by the workers of Honde Mission clinic. On the other hand, many people answered 0 USD/month.
- About the possibility of buying a water filter, 60% of the inqueries were open to buy a water filter and the average price that they would be available to pay would be around 31 USD.

4.1.2 Payment system

Calculation of water monthly fee/household

The first approach to calculate an approximate monthly water fee per household, was performed using data taken from local newspapers in Zimbabwe for a water fee in $/L of water, and values of the literature of standard minimum water consumption (drinking, cooking and cleaning) per person per day. The most recent value for a water fee for a rural/not urban area in Zimbabwe is of 0,0008 $/L of water (The Financial Gazette, 2017). Taking into account that the standard minimum amount of water per person (50-100 L/day), the group assumed a fixed amount needed of 60 L/person*day. Using these values, it was possible to estimate the minimum and maximum household's consumption per day and per month, and subsequently the respectively monthly fee, divided by class of family (number of family members). As it can be seen in Table 5, the water fee increases proportionally with the number of people per household.

Table 5: Calculation of minimum and maximum possible water fees per type of household (hh)

Nº of members in each family	Min household consumption per day (L)	Max household consumption per day (L)	Water fee min/month ($/month)	Water fee max/month ($/month)	Average price for type of household
1-2	60	120	1,44	2,88	**2,16**
2-4	120	240	2,88	5,76	**4,32**
4-6	240	360	5,76	8,64	**7,20**
Calculation taking into account an average consumption of 60 L water/person.day.					

This calculation on the possible water fees is used to complete a mathematical method (see Appendix 8: Water Monthly Costs) to estimate a fair water payment fee to be implemented through the population of Ward 10. This mathematical system is considering different factors to estimate the total cost of the system (taking into account factors such as: installation and O&M costs, the maintenance, disinfection with chlorine and the existence of a water team). In the analysis, the group estimated: the amount of water consumed per village (and cluster), the total amount of tanks needed to fulfil the need and the total monthly cost of each that will be then divided through the households in the area in form of a monthly fee.

Collection of water fee

Different approaches could be implied to collect the money through the local population: reactive financing (1), pay-as-you-fetch (2) or a monthly fee (3). Each of these methods has advantages and drawbacks ((RWSN), 2017). Option (1) consists in the local community, or the people exploiting the system, paying whenever the system breaks down or fail. Option (2) is based on the consumption, therefore it implies that at each water access point there will be a caretaker that will ensure people pay as much as they consume; the (3) is instead a periodical contribution from every member of the community. The proposed solution for the new improved system is a hybridization between a monthly fee and the pay-as-you-fetch. The monthly fee will guarantee the water team a base income through the full year. By paying partially on consumption it will be possible to reduce the fee making it more affordable to the entire population. The pay-as-you-fetch method will allow the water team to have a deeper knowledge on the water consumption of the population, therefore a first basic monitor methodology.

To introduce such a payment system, the population could decide to adopt a subscription method to the new improved water distribution system. By doing that, each interested household should provide the water team with some basic data (e.g. Number of members of the family, average water usage in buckets per day, etc). Once subscribed, each member of the family will be provided with a card (or a similar object) that will allow each member to withdraw a fixed amount of water every month, accordingly to their predicted consumption (shown in Table 5). Gathered this amount of water, it will be possible for the household to fetch more water from the system by paying an extra cost, based on the further consumption.

By the payment of the fee, the users will experiment a more stable water system with less periods of shortages due to technical issues, and at the same time a higher water quality. In fact, the water team will be responsible for a basic purification through chlorination in the distribution tanks.

To implement successfully this methodology, the water team should improve its current organization. A fixed number of water employees should be present in the area based on the dimensions of each of the 4 clusters. Moreover, for each of the new improved access water points, a caretaker should be present to monitor the water collection of the community. From our estimation, 11 people are required to monitor the status of the system. The payment of these employees would be guaranteed by the monthly subscription paid by the community members.

Possible pricing scenarios

An Excel model has been developed, starting from the general information provided by FDC. The entire population of Ward 10 has been grouped by villages and by clusters. For each cluster, the number of tanks required to satisfy the local domestic water demand has been calculated, assuming a daily water consumption of 60 litres/day/person. Together with plastic tanks, a shadowing system (i.e. a rooftop) will be installed. The data regarding the price and lifetime of the 10 000 litres tank have been taken from Figure 28. During the calculations, an interest rate of 3% has been assumed. Afterwards, the quantity of chlorine needed to purify the water stored has been estimated according to the WHO recommendation 5 mg/l (WHO & Emergencies, 2005). The price of chlorine has been assumed using commercial Zimbabwe data (Classifieds.co.zw, 2017) available on the website *Classified*, a Zimbabwian parallel of *eBay*. This price hypothesis is conservative, because private emails with Honde Mission nurse Mr. Mongola hint that the local price of chlorine might be lower than the assumed one. Finally, a figure regarding the number of employees that should monitor and maintain the new or improved water tanks has been proposed. Each water access point should be supervised by a caretaker during the operating hours (5h/day) to check that the water consumption from every user does not exceed the monthly threshold. This monitoring will be crucial to adapt the water distribution system to any new needs of the local population and to guarantee the system's fairness between all the consumers, and in a further time horizon will be automatised, for example with magnetic cards. Some extra workers have been counted to provide the periodical maintenance and the extra works the system could require. The wage of the water employee has been set to be in line with the average income of comparable works, approximately 300$/month.

Figure 28: Water tank prices of a local producer; photographer: Luigi Ghiani

Once the total monthly cost of the system is estimated, a pay-back time has been calculated, developing four different scenarios:

- Scenario 1 – the prices that every household pays are assumed as 150% of the estimated average monthly cost
- Scenario 2 – the average fee per household is assumed considering the average number of people per household - 2.62 (3433 people in 1310 households) multiplied by the minimum monthly price ($1,44/person) presented in Table 5. The overall price is equal to 3.77$/household.
- Scenario 3 – is similar to second scenario but every household pays the cost level of households between 2-4 people, which mean that the average number of people in household was rounded to 3. The overall price is equal to 4.32$/household.
- Scenario 4 – the monthly price is exactly the same as in the third scenario, but this time only half of the tanks have been installed. Then both total costs per month and costs per households are lower, resulting in higher revenues.

The fee for each household, was presented in Table 6 and used to calculate the different pay-back times in all the scenarios. The purpose of this analysis is to give an insight on the possible outcomes that can be expected by choosing a lower fee or a higher one, additionally it reflects the lifetime of the installed tanks and the income of the water employees.

In all the scenarios, the revenues have been calculated for different percentages of households participating to the payment system. A coloured scale has been set to highlight when the monthly revenue is higher than the monthly costs. It is possible to notice than in the first 3 scenarios, a high percentage of households agreeing to the payment system is necessary to have a positive return of the investment. Considering strategy number 4, in which costs are reduced and more distributed in time, only 40% of participation is already sufficient to cover the expenses, which anyway is still a quite high share. In this scenario, it is observed the highest monthly revenue per household - 2,74$ and the pay-back time of around 9 months with 80% of participation. The second most profitable scenario would be the first one, in which the price is based on the costs. In this scenario, the monthly revenue is almost half the cost - 1,51$ and the pay-back time of 2 years with 80% participation. Comparing second and third scenarios, although the monthly average revenue difference between them is $0,55, the pay-back time would increase to 10 years for scenario 2 and 2,5 years for scenario 3.

Table 6: Payment scenarios for water management system

PayBack Time Calculation	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Monthly fee	4,53 €	3,77	4,32	4,32
Average revenue per hh	1,51 €	0,75	1,30	2,74
Monthly Revenue with 10% participation	-3169,60	-3268,59	-3197,02	-1465,56
Monthly Revenue with 20%	-2576,27	-2774,23	-2631,10	-899,64
Monthly Revenue with 30%	-1982,94	-2279,88	-2065,18	-333,72
Monthly Revenue with 40%	-1389,60	-1785,53	-1499,26	232,2
Monthly Revenue with 50% participation	-796,27	-1291,18	-933,34	798,12
Monthly Revenue with 60%	-202,94	-796,83	-367,42	1364,04
Monthly Revenue with 70%	390,40	-302,47	198,50	1929,96
Monthly Revenue with 80%	983,73	191,88	764,42	2495,88
Monthly Revenue with 90%	1577,07	686,23	1330,34	3061,8
Monthly Revenue with 100% participation	2170,40	1180,58	1896,26	3627,72
Years to recover (80% participation)	2,11	10,83	2,72	0,83

4.1.3 Water team and water monitoring

One of most critical changes, is to allocate a Water committee team with assigned responsibilities. At the moment, there is a group of people in charge, but since the group members are not being remunerated, the provided services are not reliable. This situation must be implemented and accepted by the community and the elements of this team need to be paid for this work. Only after employing this team, the solution of the meter will be well functioning and organized. Therefore, priority should be given to either re-organizing the current team or forming a new one.

The roles devolved to the Water Committee team would be:

- Coordinate with authorised provincial departments, local authorities, academic centres, private sector and NGOs for scheme development and maintenance;
- Ordinary and extraordinary maintenance of the water system
- Act as a "point of call" for water users when issues of water management arise that they cannot resolve themselves;
- Manage water allocation and resolve minor conflicts (such as vandalism acts) within the community;
- Organise the collection of service fees for O&M;
- Report/share information with water users.

This team would be responsible for assigning a caretaker, whose responsibilities would be: regulate water inflow and outflow, organize cleaning and warn if repair is needed. There should be a mason with the necessary technical skills to perform repairs.

Another principal issue that must be taken into account is the monitoring for microbial pathogens that the water supply is exposed to. Removal of particles and chemicals from the water and general care of the water quality.

The number of members of the team depends on the financial support that can be provided to this group of people during the initial phase. This community based organization usually may need direct support by specialised agencies, such as FDC, or by local government. There is also the possibility to raise funds within the community but this depends on the willingness of water users to contribute with a fee. The overall description of this issue has been presented in the paragraph 4.1.2

Additionally, there is an idea to create a system to disseminate information about the water quantity available daily to the community. This system would be developed to track water tanker delivery and alert users to its availability and/or schedule so that they do not have to spend their day waiting for it. It was observed that people are often not able to define their needs and demands of water so this system would help them to obtain knowledge on that aspect. Since the water shortage is mainly problematic in the dry season because it does not arrive to all the boreholes spread through the wards, this solution would allow knowing the limited daily quantity arriving to the main tank. During the dry season, the water flow does not vary significantly because it is mainly dependent on the rain and the flow might be intermittent, so measuring the flow rate with a meter might not be very reliable. For this reason, either than the meter, the group thought about developing a visual solution, such as height marks on the main water tank as a first approach.

4.1.4 Increase the water flow in the system

Current water system does not provide enough amount of water to the community for all their purposes. According to the estimation made by Fortune Development Centre in collaboration with ZINWA technical team, total domestic water consumption in Ward 10 amounts to 1318 cubic metres as compared to a “projected storage requirement” of 2000 cubic metres. Total “water storage required per irrigation cycle” for the examined area is equal to 361 800 cubic metres. Additionally, the amount of used water is not distributed equally. It is possible to notice that some districts have a relatively high consumption; the reason for this is the presence of Samaringa High school, Samaringa Clinic and Masere Business Centre in those areas.

The need to increase current water flow in the system is clear. However, further research must be done in order to understand the variations of the rivers’ flows in the seasons. Nevertheless, it is reasonably sure that the flow present in the water system is not sufficient during the dry season, and measures must be taken both from a technical point of view and from a management side. Special consideration should be put on the development of a water grid as an occasion for employment creation: according to local sources, 81% of the young people in the area are unemployed (Chikuhwa, 2016).

Tanks

Water storage is strictly necessary, in order to match the natural water flow with the variable demand. The exact number of already existing tanks that can work is difficult to determine, thus many of them are not used because of their bad state of conservation. Also, the main water tank should be renovated together with Ngwende Tank, which because of its poor condition is not in operation at the moment. The Ngwende Tank, due to its capacity and strategic position could be extremely useful for the Ward 10 inhabitants. It is placed very close to many households and to the main community facilities. Additionally, it is on the top of the hill, thus there is no need for any electric devices to provide water to the households. Previous documentation can be very helpful during the installation process. The overall priority should be to repair and improve the possible biggest number of tanks: this will allow to provide a significant capacity with a relatively lower cost. In a second-time horizon, it is possible to consider building new tanks, both large in capacity and smaller ones for single households.

Wells and Boreholes

Samaringa is presently served by several wells. Part of them belongs to the community while others are private. Due to many damages, the proper estimation of their number and working period is difficult. However, there is an evidence that underwater streams are present in the area, so there is a possibility to repair old wells and boreholes or built new ones in a more proper location.

According to the NGO Water Wells for Africa, operating in Malawi and Mozambique, the average cost per well is 8,000 USD (Water Wells for Africa, 2017b). Such figure includes a preliminary study for drilling the hole and installing a pump, but also providing lectures about hygiene and sanitation, training and a technical-economical management for the well's maintenance. Each well serves approximately 2,000 people, which lead to an investment cost of 4.00 USD/person for clean water, for a useful lifetime of about 20 years.

In Samaringa area, the soil is quite hard and rich of stones, so the borehole digging process could be particularly expensive. A large well can be dug by hand, and lined with bricks and concrete. Otherwise, the well can be drilled or bored (Huffman & Miner, 1996). It is possible that renting a drilling rig will be necessary. In such case, the hole must be kept filled with water, both to prevent superheating of the drilling bit and to make the soil softer and facilitate the removal of the mud. Additionally, a compressor will be needed; air will be injected in the well to drive the drilling bit and to act like a pump for bringing the mud to the surface. Otherwise, a hand auger can be sufficient for small, shallow holes.

Depending on the diameter of the well, a casing can be done either with a plastic tube, with concrete or with bricks. A screen is necessary at the bottom of the pipe, to filter water from sand and debris.

The position of the well must be chosen carefully. Plants and trees can signal the presence of a shallow water table underground. As well as that, it is vital to keep a distance, as shown in Table 7, from toilets, muddy areas and septic tanks, to avoid contamination of the water (LifeWater Canada, 2016). The top couple of metres of the annular space outside the pipe should be sealed with bentonite or neat cement to keep the well sanitary.

Table 7: Possible sources of contamination (LifeWater Canada, n.d)

Distance (m)	Possible Source of Contamination
100	Garbage dumps/refuse piles, car repair or fuel (petrol) sales outlets, industrial operations/storage facilities etc.
50	Seepage pit or cesspool
30	Pit toilets, animal pens, barns, fields fertilized with dung
15	Septic tank, surface water body
7	Drain, ditch, house

All the mud inside the well must be pumped out, to clear the hole from all the debris and the drilling fluid. For small, shallow holes it is possible to use simply a bailer. After that, it is necessary to sterilise the hole with chlorine solution, and only then it is possible to pump again until when the water is perfectly clear.

A pump will have to be chosen, either electric (and connected to the grid) or manual. If the depth of the well is less than 8 m, a centrifugal pump is sufficient. Otherwise, to avoid cavitation problems, a sucker rod action piston pump or a submersible pump are needed. A suggested model of hand pump is the *Afridev Hand Pump*, which has a maximum lift of 45 m and a life of 20 years ((RWSN), 2016); all replacement parts are easily found in rural areas at affordable costs (Water Wells for Africa, 2017a).

<u>Pipes</u>

At the present state, there is only one pipe delivering water from the river to the village. However, several other streams are present in the area. The construction of at least one new pipe with an intake in one of those water sources should be considered.

New pipes can be built with various materials, such as copper, fibre-cement, plastics or stainless/galvanised steel. For technological limits and economic reasons some materials have been discarded; the two most promising materials are galvanised steel and High-density polyethylene HDPE. To avoid damages and abuses, such as not authorised derivations, it would be preferable for the pipe to pass underground, in a trench, however the cost of investment would rise significantly.

Galvanised steel pipes are durable and resistant. Particular attention must be paid when using underground pipes, since they can suffer from rapid corrosion in acidic soils. A coating can be applied, though. (American Water Works Association (AWWA), 2004)

Corrugated High-Density Polyethylene is a lightweight material, which allows for easier and less costly transportation and installation. It is not brittle, and therefore not susceptible to cracking during pipe handling and installation activities. It is resistant to abrasion, corrosion and chemical scouring, and its interior smooth surface has excellent characteristics for assuring low pressure drops in the pipeline (Bennett, 2003).

4.1.5 Risk Analysis

Risk analysis must be taken into consideration according to the solutions planned to be implemented.

Table 8: Risk classification

Index	Probability	Impact
1	Rare	Insignificant
2	Unlikely	Minor
3	Possible	Moderate
4	Likely	Major
5	Almost certain	Catastrophic

Risk is the product of P·I, and it results in a scale from 1 to 25. Preventive measures aim at reducing P, while Containment measures aim at reducing I. It is important to point out that preventive measures do not eliminate risk; they reduce the probability of a hazardous event, but a residual risk still remains and must be assessed (refer Table 8 and Table 9).

Table 9: Risk Analysis Water Supply

Potential hazard	P	I	Risk	Preventive measures	Containment measures
Lack of interest and of usage towards payment system	5	4	20	Education, convenient pricing	Hindering the use of other water sources not included in the system and not safe
Excess of chlorine	3	2	6	Education, providing measurement tools	Post-treatment analysis of the water
Inefficiency of purification	3	3	9	Constant supply of chlorine, quality measurements	Post-treatment analysis of the water; individual purification with ceramic filters
Lack of maintenance	3	4	12	Education, management and payment system	Good coordination of water team members
Insufficient water flow	4	5	20	Education; demand side management	Increase of storage capacity
Breaking of one pipe	1	5	5	Maintenance	Storage; supply of replacement components; verifying presence of retailers
Not sustainable costs	4	5	20	Dynamic nature of payment system	External funding, modifications of payment system, prioritisation of expenses
Payment system not enough widely spread	4	5	20	Better planning of the management aspects; information campaigns; involvement of local population	Protection of water sources from abusive collecting, encouraging measures such as discount for clay products

4.2 Rainwater harvesting

Due to very substantial rainfalls in the Sub-Saharan Africa, rain water harvesting (RWH) is a very efficient method for both collecting water for personal/domestic usage and for irrigation/cultivation purposes.

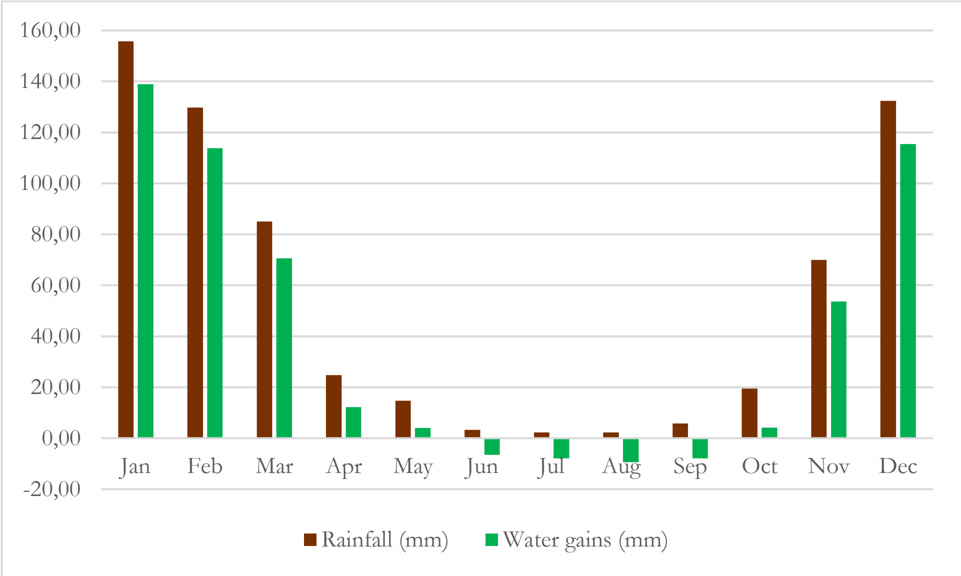

Figure 29: Rainfall and Evaporation Rate Distribution

Figure 29 shows the values of average daily rainfall and, using the evaporation (Eto) per month for Honde Valley, the daily gains, calculated as the difference of rainfall and evaporation ("Downscaled Data Download," n.d.). From the graph, it is possible to recognize that Zimbabwe has two different seasons: dry from November to March and then rainy from April to October. To optimize the usage of the water supplied from the rainy season, it is possible to consider the implementation of water storage systems fed with rainwater: rooftop collectors, employed mainly for domestic purpose, and ponds, particularly useful for farming. These two systems will both improve the water supply in the area and the condition of people living far from the water access points.

4.2.1 Ponds

Harvesting water with fishponds is a technology that has been already applied in many other similar regions of the World with successful result. This technology could help margin the problem of water supply and therefore increase the food harvested. The following criteria have been considered:

- The pond should be sized around 100 square meters of catching area (the shape would vary to adapt at the chosen area) and with at least 1 m depth to be effective.
- To maximize the benefits of the ponds, a plastic foil could be employed to remove any water seepage from the ground.
- During the dry season, the water collected in the pond can be employed to cover parts of the water needs of the farm. To maximize the water use, a simple drip irrigation system should be installed. Water distribution through the crops should be made by gravity; where this will not be possible the use of a small solar pump could be used to lift water to

a water tank on a stand about 2m high to enable sufficient pressure to operate the irrigation system.

- The pond should be built at least in system of two units. This would allow to clean harvest within 6 months
- The water should always have the proper qualities for the fishes: water should be green with algae (rule of thumb: when lower arm is immersed to the elbow the thumb should not be visible). To provide the proper nutrient levels to sustain algal growth a corner of the pond could be used to stock some old sack of cow or other type of manure.
- It should be considered that higher fish production/growth rates will result from supplementary feeding of fish.

Figure 30. Fishing Pond in Ward 10

These types of pond have been already implied in Ward 10, as show in Figure 30. The owner of this pond reported that he has spent 85 USD to finalize the structure and that he used basic tools to dig it. He is now using the pond to grow fishes and to supply water for his own farm. According to the farmer's statements, the average deep is 117.5 cm (60-175 cm) and to refill it, he relies also on piped water from the common water distribution system or a diesel pump. Another example is a pond built in Samaringa School used as a student's project.

The construction of the pond requires basic technical skills and knowledge to proper maintain and use the system. Moreover, it would require a small initial investment and time to dig the pond itself. The last strongly depends on how many people are involved in the construction.

As mentioned before, a plastic foil could improve the performance of the pond as water storage. The area to cover, assuming the pond as a parallelepiped 10x10x2 m, would be 180 m^2 and the price associated around 80 USD (Angwa Branch, n.d.). To maximize water usage from the pond a drip irrigation system would lead to an extra initial cost around 1.2 USD/m^2 (Shang Wong Borehole, 2016).

It is important considering the aspects related to diseases proliferation. Zimbabwe, and especially Honde Valley, is considered a Malaria risk region and therefore a stagnant water pond could lead to a proliferation of mosquito population, vector of this and other diseases. The fish farming activity should effectively solve this problem due the fact tilapias are omnivore and therefore would control mosquito population. The price to start the fish breeding would be around 70 USD (Classifieds Zimbabwe, 2017). In Table 10 there is a summary of the above-mentioned cost.

Table 10: Summary of cost to install a RWH pond

Item	Cost (USD)
Plastic Foil	80
Drip Irrigation System (20m^2)	24
Tilapia Fish	70
Total	174

4.2.2 Rooftop Collectors

This RWH system should be provided with the following basic components:

- A catchment area to gather the rainfall, typically the rooftop of the building;
- A conveyance system to move the water from the catchment area to the storage area, hence a system of downspout and pipe;
- A storage system to collect the rainwater, therefore a tank;
- A distribution system: the water can be supplied into the already existing distribution system or used directly where collected.

The amount of water has been calculated with the following formula: $S = A\ x\ R\ x\ Cr$. S is the water supplied in litre, A is the catchment area in m^2, R is the rainfall in mm or l/m^2 and Cr a run-off coefficient that considers the losses in the system (WaterAid, 2013).

To avoid the proliferation of algae and to keep the temperature at safer temperature condition, it is important to place the tank in a suitable shadow place (Sustainable Sanitation and Water Management, n.d.).

It is important to treat and filter the water during the collection and to keep maintaining the system in the proper condition. A longer period without precipitation will likely lead to an accumulation of impurities, such as leaves, animal excrements, dusts etc., on the catchment area of the RWH system. To improve the quality of the water in a simple and effective way it is important to prevent the "first-flush", the first water that flows on the rooftop after a long period without precipitation, entering the tank (Doyle & Shanahan, 2012).

Figure 31. RTRWH at school in Misora, India. (Left: whole system with screen, first-flush separator and collection tank. Centre: screen. Right: first-flush separator.) Source: WAFLER (2010)

To implement such a system, it is required to install a T-junction in the system as shown in Figure 31 and a smaller collecting system or a valve to periodically remove the first-flush collected.

Implementing big water tanks fed with rainwater harvested from rooftop collector systems would improve the water supply situation and independence especially in public spaces, such as Samaringa Primary and Secondary School, Business Centres and Clinics, due their bigger catchment areas.

In Table 11 is reported a summary of the costs related to a rooftop collector system implemented on a building with a catchment area of about 100 m^2.

Table 11: Rooftop collector cost summary

Item	Cost (unit)	Quantity	Tot Cost
Gutter 25 mm (m)	$2.75	20	$55.00
PVC Conduits 25 mm (m)	$2.75	1	$2.75
T-junction	$0.50	1	$0.50
Water Tank (200 l)	$75.00	1	$75.00
			$133.25

4.2.3 Irrigation

Most farmers in Ward 10 irrigate their fields by simply pouring water on them with a water hose. This solution is clearly not optimal, in terms of water consumption but also in terms of quality of the result. Appropriate knowledge and technique in this field is necessary in order to maintain a proper moisture level of the ground; several solutions can be proposed, from the digging of the irrigation canals to the introduction of sprinklers and dripping hoses.

Canals are the most widespread and reliable system; they are easy to plan and to dig, durable in time and allow a good distribution of the water (FAO, 2003). The only obstacle might be the conditions of the ground itself. Especially during dry season, the ground is very hard thus there might be a need to apply a more sophisticated and technically advanced device such as: diggers and excavators. Unfortunately, the conditions of the roads are very bad in Honde Valley, so the arrival of such vehicles might be inhibited. The best solution is to start working on this canals system when the ground is softer – directly after or during rainy season.

In parallel with that solution, it is possible to use sprinkler or drip irrigation. Since sprinklers need bigger water pressure, usually created by electric pumps, they cannot be implemented everywhere in the Honde Valley area at the moment, but only when conditions are suitable. Currently used gravity system, however, in some areas is sufficient to guarantee that such system can work. In drip irrigation, rain water stored in the tanks is used to irrigate crops by being placed in a special bucket which is installed around 1 meter above the ground. Long hoses are connected to the bucket and distributed around the field. Gravity provides enough pressure to force the water through these hoses. Thanks to the small holes in the hose water can be channelled directly to the plants. 100-200 plants can be grown using just one drip bucket system.

4.3 Clay filters

Due to the almost non-existing water distribution system in Honde Valley, a large scale purification of water does not seem feasible in the short and medium term, especially because of the poor economic resources available. Small scale water purification is therefore the best option to implement, for its characteristics of being efficient although simple and inexpensive, and in particular because it also offers concrete chances to business opportunities.

The most interesting of all the considered solutions is Colloidal Silver Impregnated Ceramic Water Filters (CWF). These are porous clay vases capable of filtering up to 2 or 3 litres of water per hour, depurating it from bacteria including E-Coli and vibrio-cholera, as well as giardia, streptococcus, total coliforms and cryptosporidium (Potters Without Borders, 2016)(Centers for Disease Control and Prevention, 2012). The only maintenance and care they require is regular cleaning with a mild bleach solution and a soft brush. An example of a simple clay filter is presented in Figure 32.

The lifespan of a clay filter is around 3 years maximum, since after that time, the E. coli removal could not be sufficient (The Ceramics Manufacturing Working Group, 2011).

Figure 32: Colloidal silver impregnated clay filter (Potters for Peace, 2016)

An interesting business opportunity consists in the establishment of a clay workshop: a basic infrastructure, equipped with all the necessary devices, is able to produce up to 100 filters per day at full productive capacity, without necessarily requiring electricity or running water, even if their presence would be preferable. A clay workshop can provide multiple benefits:

- Employment of local people;
- Professional training for youths;
- Spread of a simple but valuable technology.

The handcrafting skills of Ward 10 inhabitants do not present any obstacle to the requirements work with a kiln and a mechanical facility laboratory. Therefore, establishing a production facility and providing the required knowledge and technological tools for pottery production does not represent a difficult challenge

The costs to develop the workshop vary significantly because of the vast inconsistency of conditions in the field. The investment costs for a general location have been estimated in 30,000 USD by Potters for Peace, considering the cost for on-field training provided by a specialised team. The main equipment needed for the production is the kiln, a simple structure that can be manufactured by local builders, possibly upgrading existing facilities.

Potters for Peace can be a potential partner, they are available to work in Sub-Saharan countries including Zimbabwe. In Figure 33the construction of such a kiln can be seen.

Figure 33: Kilns for clay objects manufacturing (Potters for Peace, 2016)

When the production starts, a filter can be sold at a price around 25 USD (Potters Without Borders, 2016) . After a brief training, between 4 and 10 people could start working in the kiln; if the activity is successful this number can be expanded. The clay workshop is interesting also because part of the production capacity can be used to manufacture other products, like Clay Stoves and Pot in Pot refrigerators. All these products are intended to be used at household level, or maybe shared between maximum 2 households. Taking into consideration the number of families of Ward 10, the potential market is very promising, and the prices found on the references and listed in Table 12 are likely affordable for the population.

Table 12: Possible products of Clay Workshop with related prices

Initial investment [USD] (Potters for Peace, 2016)	Clay Filter price [USD/u] (Potters Without Borders, 2016)	Clay Stove price [USD/u] (Benscha & Petersa, 2015)	Big Pot in Pot Refrigerator price [USD/u] (Rolex Awards for Enterprise, 2017)	Number of Households
12 000 – 30 000	25	3.81	4	1310

4.4 SWOT Analysis

Table 13 presents graphically the internal and external, positive and negative factors influencing the whole set of proposals regarding the improvement of water system.

Table 13: SWOT Analysis of water project proposal

Strengths	**Weaknesses**
• Economically sustainable with payment system • Holistic approach • Careful planning of every aspect • Simplicity of solutions proposed • Possibility to re-use existing tanks	• Many assumptions • Need to introduce a payment system before visible improvements are possible
Opportunities	**Threats**
• IT technologies could improve the payment system • Possible partnerships with ZINWA and company to manage water system • Possibility to create more jobs by enlarging business model • Cross-financing with other parts of the project	• Lack of interest from external funders • Lack of participation • Success of project very dependent on public opinion • Lack of proper maintenance

In conclusion, even though the implementation of the aforementioned proposals is delicate and subject to several challenges, the present situation provides many interesting opportunities which can prove extremely helpful for the success of the planned intervention.

5 Sustainable and Clean Energy Access

According to Amos Kapenzi, Power Engineer employed at NRE (Nyangani Renewable Energy) and guide of the team to the hydropower plant, the average price at which ZETDC is buying electricity from NRE is 0.14 USD/kWh. This value will be considered in some further calculations of the business potential in energy sector.

5.1 Battery Charging Station

Different possibilities are available to provide electricity access to rural areas. Solar home systems (SHSs) are stand-alone PV systems that are built to fulfil the basic electricity needs of a household. The typical cost of the system ranges between 170 USD for 12 Wp and 2000 USD for 150 Wp. Since the initial investment cost is often subsidized and in the Honde Valley the grid connection costs 95 USD for the first 16 meters, this option is not feasible in the area because it is preferable to fund directly the payment of the grid connection (Energypedia, 2016). A more economically viable solution is the introduction of Battery Charging Stations (BCSs).

When the grid is not available, BCSs are usually powered with solar PV systems, like small solar carts, spread over the territory of the village. They are usually installed in strategic positions in the village or they are portable in order to increase the adaptability and the flexibility of the system (Subhes, Cook, Kishore, & Palit, 2013). An example of BCS is presented in Figure 34.

Figure 34: Sunblazer II Battery Charging Station, an example of the main structure (IEEE, 2017)

In electrified communities, BCSs can be connected directly to the grid and used to charge portable batteries, that can be carried home and used to power a home lighting kit (Figure 35) and small devices, like mobile phones (Energypedia, 2016). The idea is to solve the problem of access to electricity and in particular of access to lighting sharing the initial investment cost of the existing connections to the grid to create BCSs.

Figure 35: IEEE SV version of the Home lighting kit (IEEE, 2017)

A reference example is the SunBlazer II, a BCS of IEEE Smart Village[5] (refer Table 14).

Table 14: SunBlazer II Specifications

Power installed of the charging station	1.5 kW
Energy Input	PV panels, backup input from small wind turbines or diesel generators
Battery slots	80, estimated to be enough for 500 people
Time to fully charge the batteries	3 to 4 days
Kit lights	Two rooms enlighted, able to operate auxiliary 12V DC loads
Battery pack	18h charge providing light for several days

The proposal for Ward 10 is to create an Energy Cooperative of investors in charging stations spread all over the territory to invest, operate and maintain the installed equipment, and to collect the revenues from customers (refer Table 15).

[5] IEEE Smart Village is an organization that "stimulates social enterprise by providing renewable electrical systems, start-up training and ongoing support to help poor, energy-deprived communities globally build toward sustainable prosperity"
More information:
http://ieee-smart-village.org/about/
http://ieee-smart-village.org/programs/sunblazer/
Explanation video: https://www.youtube.com/watch?v=H2VpQIitkao

Table 15: Proposal for a suitable BCS for Ward 10

Investment Cost	Charging station, charge controller system, batteries, 20 home lighting kits, grid connection, cables, wires
Operation and Maintenance	Electricity cost, technician labor and maintenance
Revenues	Collected by the responsible of the charging station. Optional: automatic payment system based on smartphone payment system

The number of battery slots will be a trade-off between the proximity of the BCS to the houses and the economic viability of the connection sharing. In fact, from one hand, the more battery slots there are, the less BCSs are needed and the more households are dependent on a single station. Some houses are kilometres far from Samaringa centre, isolated on the mountains, and their access to the service will be strongly dependent on the availability of a station nearby. On the other hand, the more people are sharing one single connection, the cheaper the final price for the customer will be. A detailed cost analysis will be needed before the design of the stations.

The final result must be a system with the following attributes:

- Easy to operate
- With low need for infrastructures
- Reliable
- Efficient, with led light bulbs
- Affordable: final price for the customer should be lower to the price of candles and kerosene, even though the higher quality perception can be an important driver in the choice if this condition is not fulfilled

The charging stations will be open for some hours in the morning and in the evening: during this period, an operator will be present to open the box of the battery slots, to verify the status of the equipment and to collect the revenues from the customers.

5.1.1 Business Model

Some different business models can be applied to the BCSs. As mentioned before, a community based Energy Cooperative can be established to manage every aspect of the business. In the area (Hauna growth point or Mutare) there is availability of electric technicians and equipment. The cooperative will take care of a series of steps (refer Figure 36).

Figure 36: BSC Business model steps

Each station will be analysed and proposed to the cooperative by one responsible member. His role will be to make a preliminary study of the marketing potential of his customers, for example asking them if they are interested, showing them the device and how it works. If the cooperative will consider the proposed area profitable, with many potential customers, the BCS will be realized. The responsible member will collect revenues, operate and maintain the station, opening the box for example 2 hours in the morning and 2 hours in the evening to allow people to take and bring back batteries. The revenues of all the stations should finally be collected and equally distributed among the members of the cooperative: this will avoid internal competition and possible arguments of members for the selection of the most profitable areas, and at the same time will reduce the individual risk. If a station will not be considered profitable, prices can be negotiated with customers, or eventually the station can be moved somewhere else. The first place where it could be convenient to build a charging station is in Masere Business Centre: it can be considered as a test to get familiar with the technology and to investigate the interest of people in this solution.

Financing is possible through micro credit, donations or individual capital. The maintenance service could also be delegated on private service provider which operates on a fee-for-service basis (Energypedia, 2016). However, the most beneficial option for the community is to hire or train local technicians and to buy local equipment, if the quality criteria are fulfilled. Users of the system could be offered different payment solution e.g. a renting fee for a charged battery, a monthly fee or a charge fee on the basis of their typical usage of the batteries.

Another possible solution is a franchise-type business model, where the equipment is supplied by an external actor (it can be an NGO or an association, like IEEE Smart Villages or Nyangani Renewable Energy) and it is leased to village operators. In this case the system is monitored by personnel trained directly by the supplier of the equipment itself. An example of this solution is the solar battery charging stations offered by Sunlabob. The company operates the purchase and the installation of the BCSs and offers them for rent to the community. The lamps are bought by the company itself on behalf of the villagers and later given to the community. The company trains two main characters, the village technicians who are in charge of the operation of the BCSs and of teaching the villagers how the lamps work, and the energy committees who are in charge of controlling the energy needs of the village (Sunlabob, 2007).

5.1.2 Cost analysis

Here is presented an example of cost analysis of the battery charging station.

The aim of the analysis is to evaluate the minimum number of batteries that makes the investment viable, that means NPV=0. Some constraints and additional assumptions are considered to simplify the problem:

- Revenues should be equal to the average cost of traditional lighting systems to be competitive. Cost of kerosene-based lighting can be estimated using different sources. In this calculation, it is assumed to be around 0.26 USD/day (Tracy, Alstonet, Jacobson, & Mills, 2010) so if the average monthly cost is considered, it is 7.91 USD/month;

- Minimum profit for each operator: 150 USD/month[6], considering 6 hours of work per day: 4 of operation, 2 of maintenance and other tasks;
- All the batteries are always taken by customers;
- The kit should be able to light 2 rooms for around four hours per day;
- The maintenance costs are assumed equal to a broken battery and lighting kit per month;
- The interest rate is assumed 10%, from micro credit capital;
- Charging efficiency η_c= 90%
- Lifespan of the BCS will be considered 15 years

In particular, the equipment costs are taken from a website of E-shopping similar to Amazon, selling products available in Zimbabwe ("Zimbabwe Classifieds.co.zw," n.d.)

The investment cost consists in:

- Battery charging station
- Home lighting kit
- Batteries

The investment cost of the charging box needs further investigation. It was not possible to find any data of existing solutions, and in general the technical sizing is needed before the cost evaluation. For this calculation, a reasonable value of 500 USD will be considered.

The chosen home lighting kit (refer Table 16) is composed of two led bulbs[7], one wire of 10 m[8], a lamp holder[9] and a connector for the battery. The cost of the connector and of the other possible components is assumed to be 2 USD.

Table 16: Home lighting kit costs estimation

Number of bulbs	Power [W/u]	Daily equivalent hours of utilization [h]	Daily consumption [Wh]	Cost [USD/bulb]	10 m wire [USD]	2 lamp holders [USD]	Other equipment [USD]	Kit cost [USD/u]
2	5	4	40	1.5	4	1	2	10

The reference battery is the DVpro 7 Ah 12 V Solar Battery, sold by Bhola Hardware Mutare[10]. In the Table 17, the main characteristics are presented.

[6] Assumed with the values proposed by Chikuhwa, in chapter 0
[7] http://www.classifieds.co.zw/en/advert-led-3w-light-bulb-1211369
[8] http://www.classifieds.co.zw/en/advert-ripcord-1213721
[9] http://www.classifieds.co.zw/en/advert-pvc-lamp-holder-1226775
[10] http://www.classifieds.co.zw/en/advert-dvpro-7ah-12v-solar-battery-1243730

Table 17: Example of an adequate size battery

Capacity [Ah]	Voltage [V]	Capacity [Wh]	Lifetime [y]	Cost [USD/u]
7	12	84	5	9

The battery capacity, considering the consumption, is enough for a couple of days, so on average 182.5 recharges per year are estimated. The lifetime of the battery is dependent on the number of cycles of charge/discharge. The maximum number of cycles that a lead battery can sustain is 1000 (Power Tech Systems, n.d.) , so in the analysed case if the charging/discharging cycle occurs on average every 2 days, it is approximately 2000 days: 5 years of lifetime will be considered for the calculation, so every 5 years the investment cost of new batteries will be charged. The maintenance costs will be assumed equal to the cost of a full kit and battery per month. The excel calculation sheet is available in Appendix 4: Battery charging station excel sheet: the optimization to set NPV value to zero has been performed with goal seek function.

The total investment cost can be expressed as:

$$I_{tot}[USD] = N\left(C_{battery} + C_{kit}\right) + C_{grid} + C_{BCS} \tag{2}$$

Where N is the number of kits and batteries (a first attempt value of 50 has been considered), $C_{battery}$ and C_{kit} are respectively the cost of one battery and of one lighting kit, C_{grid} is the cost related to the connection to the grid and C_{BCS} is the cost of the battery charging station main box.

The yearly cost of operation and maintenance is:

$$C_{O\&M}\,[USD/y] = S_o + n_y \cdot c_{el} \cdot N \cdot \left(\frac{E_b}{1000 \cdot \eta_c}\right) + 12 \cdot \left(C_{battery} + C_{kit}\right) \tag{3}$$

Where S_o is the yearly salary of the operator, n_y is the number of recharges of each battery per year, c_{el} is the cost of electricity per kWh, E_b is the capacity of one battery expressed in Wh, η_c is the charging efficiency.

Revenues are calculated every year as:

$$R_{tot}[USD/y] = c_k \cdot 12 \cdot N \tag{4}$$

Where c_k is the average kerosene expenditure for lighting purpose of a household, estimated before.

For the year 1, the profit can be calculated as:

$$P_{tot}[USD/y] = R_{tot} - (I_{tot} + C_{O\&M}) \tag{5}$$

For years 5 and 10, the profit should take into account the investment in new batteries:

$$P_{tot}[USD/y] = R_{tot} - (N \cdot C_{battery} + C_{O\&M}) \tag{6}$$

For years 2 to 4, 6 to 9 and 11 to 15 the profit takes into account only the operation and maintenance cost

$$P_{tot}[USD/y] = R_{tot} - C_{O\&M} \tag{7}$$

Once determined the cash flows for the different years, it is possible to apply the NPV formula, and to set the result to zero by changing the number of batteries N to find the minimum value that makes the investment profitable:

$$NPV = \sum_{i=1}^{15} \frac{P_{tot,i}}{(1+r)^i} = 0 \tag{8}$$

The final result shows that approximately 24 batteries are sufficient for one single station, a reasonable number to spread a large number of stations all over the territory. Increasing the number of batteries to 30 per station, the new NPV obtained is 4514.44 USD.

The obtained result strongly depends on the cost of traditional lighting: the cheaper it is, the higher should be the number of batteries per station. IEEE Smart Village, as mentioned before, is using 80 batteries for its Sunblazer II: taking this value for the proposed analysis, the BCS will be profitable if the cost of traditional lighting is equal or higher than 2.62 USD/month.

On the contrary, the NPV is not particularly dependent on the strong assumption made on the charging station price. As it is possible to see in Figure 37, sizing the station for 30 batteries, the NPV remains positive up to a battery charging station price of more than 5400 USD.

Charging station price [USD]	500	1000	2000	4000	5465.88
NPV [USD]	4514.44	4059.89	3150.8	1332.62	0

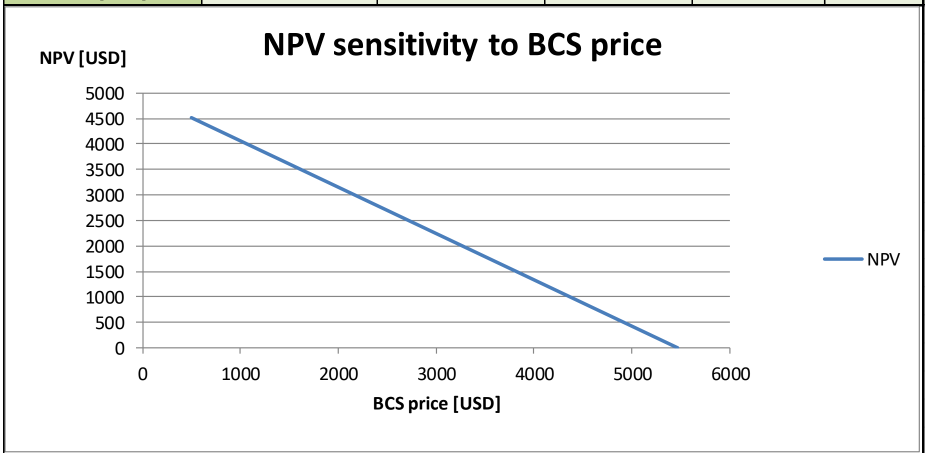

Figure 37: NPV sensitivity on the BCS price

In this calculation, the disposal cost is not considered: no adequate references and information have been found on how much this cost can be. However, when dealing with the final investment assessment, this cost must be considered, because it can be significantly high and change all the values obtained in the simplified model presented.

5.1.3 Risk and SWOT analysis

In Table 18, a SWOT analysis of BCS is performed. The advantages mentioned are summarized, and also some challenges are presented.

Table 18: SWOT analysis of BCS

Strengths	Weaknesses
• Cheaper than kerosene and candles • Clean technology (no indoor pollution) • Innovative • Better quality lighting • Local skills adequate to operate and maintain the facilities • Materials locally available	• Need for new infrastructures • Need for external partnerships • Pollution of expired batteries • Cost of the charging station
Opportunities	**Threats**
• Business opportunity for locals • Easy business model • Peer opinions • Replicable for its modularity • EcoCash payment system	• Unwillingness to switch to new technologies • Vandalism • Bad return conditions of equipment • Huge electricity price variations • Opposition of sellers of kerosene and candles

Before implementing the system, it is necessary to evaluate what is the average expenditure per family for traditional lighting. Changing people's habits can be very challenging, especially in realities where a certain technology has been used for decades. In this situation, one of the main problems can be the refusal to accept the innovations introduced in the community and, consequently, to tackle this danger specific strategies should be applied such as creation of awareness of the benefits and direct involvement of the population in the process. Moreover, workers related to fuel-lighting may express their opposition to switch to the LED-lighting business stating that they would lose their unique source of income if they decide to start an economic activity in an uncertain field that is not completely established on the market (Mills, 2016).

Another risk is related to the return condition of the equipment, that means ensuring that customers will take care of the batteries and of the lighting kits. To partially solve this problem, a caution can be asked to the customers. In particular, the most fragile components are light bulbs, and their cost is 3 USD per kit: this value can be asked to the users of the service and given back if the equipment is returned in proper conditions. Moreover, all the users should sign a register of utilization: the operator of the station can directly take care of the register while distributing the batteries and collecting the daily revenues.

From the environmental point of view, it is clear that the impact of the technology is high: lead acid batteries are very toxic and corrosive. Since the number of batteries involved is very large, the disposal, as mentioned above, must be done carefully and accounted in the costs from the very beginning. The solution with lead acid battery is just an example, some other solutions can be investigated in parallel in the further development of the project.

5.2 Peer-to-peer electricity

Peer-to-peer (P2P) is a term coined in informatics and represents a network in which the computers (the peers) are connected with each other via Internet, and can share files directly between them without the need of a central server (TechTerms, 2017). This concept can also be applied in economy when two individuals interact for the purchase or the sale of a good without the intermediation of a third party, leading to lower transaction costs and lower prices (Investopedia, 2017).

In Honde Valley, this system is informally used by locals in need for recharging some appliances: they usually contact their friends (their peers) with an electricity grid connection and ask them if they can exploit it to recharge their devices, for example a mobile phone or some lights, in exchange of a small monetary compensation[11]. The problem of this method is that, since it is based on friendship and personal initiative, is not available to the major part of the community.

The proposal is to formally organise the system through mobile messaging and EcoCash, a popular Zimbabwean mobile payment system, via fixed tariff. As a result, the villagers will be aware of the location and of the availability of charging points, the household participating in the project, and, therefore, will be able to benefit of it.

A further improvement would be the implementation of electricity meters to measure the exact electricity consumed during the charging. However, the interesting aspect of the peer-to-peer electricity is the facility of implementation, consisting only in arranging information and making it accessible to the largest number of people possible. Consequently, metering the consumption can be considered a medium-term improvement, or as a private investment to allow the utilization of more energy intensive devices, pumps for instance.

The process is explained in Figure 38, the two involved parts are represented through abbreviations. The villager who wants to charge an appliance is A whereas a villager with an electricity socket available is B. The information on the connections available of the people who joined the project can be shared with some posters spread in strategic locations, like Masere Business Centre. Furthermore, a recognition signal can be established and installed on each house participating, like a small flag or a sticker on the door, to facilitate the individuation.

[11] Information obtained questioning locals during the field trip of March/April 2017.

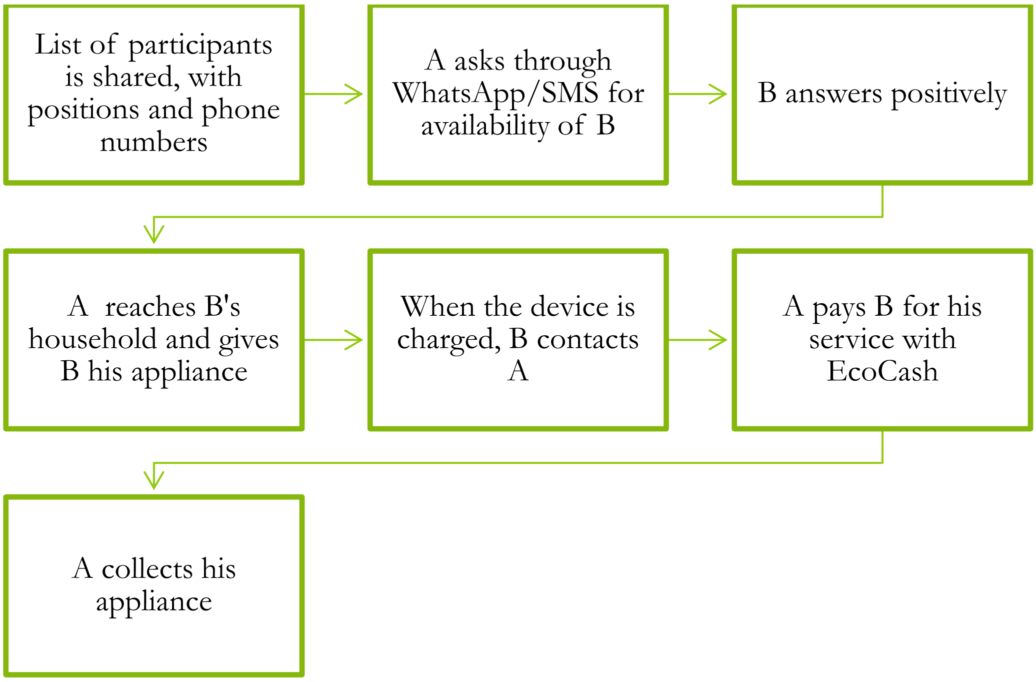

Figure 38: Operation of P2P electricity sharing system

The devices required are mainly already owned by the population. A list of the necessary tools for both part is shown in Table 19.

Table 19: Cost analysis of P2P electricity sharing (classified.co.zw, 2017a, 2017b; EcoCash, 2017)

Description	Cost for person A	Cost for person B	Unit
Mobile phone[12]	50	50	USD/person
EcoCash account[13]	0	0	USD/person
Grid connection	-	95	USD/person
Multiple socket[14]	-	10	USD/person
Other (cables, wires, etc.)	-	10	USD/person
Total	50	165	USD/person

[12] Average price of low-cost (below 100 USD) mobile phones from http://www.classifieds.co.zw.
[13] Transaction below 1 USD are free and no monthly fee.
[14] Average price of multiple sockets from http://www.classifieds.co.zw

The tariffs for charging different appliances can be seen in Table 20.

Table 20: Tariffs of P2P electricity sharing

Description	**Tariff**[15]	**Unit**
Mobile phone	0.19	USD/charge
Small battery (6 hours of charge)	1	USD/charge
Big battery (24 hours of charge)	2	USD/charge

The system would offer great advantages to the population for the reasons listed as follows:

1. better organisation: in this situation the system is organised and the villagers can instantaneously control if a "charging station" is available or if their device is charged;

- use of available infrastructure: a villager who has a grid-connected household is likely to be already in possess of a mobile phone so the sole investments are the purchase of a multiple socket and other equipment for a total expense of 20 USD;
- lower prices: the villagers are negotiating without the intervention of a third party so in the long-run the tariff will be lower compared to a charging station offered by an external business.

In conclusion, the implementation of this option is immediately feasible because it does not require a huge initial capital investment and the infrastructure required are easily found on the local market. A summary of the advantages and risks of the solution is summarized in Table 21.

Table 21: Peer-to-peer SWOT analysis

Strengths	**Weaknesses**
• Immediate and easy • Improvement of what already exists • Cheap, no need for huge investments • Flexible • Increases electricity access for small devices	• Strongly dependent on the position of the house • Partially based on trust
Opportunities	**Threats**
• Accelerate the installation of new grid connections • Community cooperation • All the equipment available locally	• Bad communication of the members • Problems in determining the tariffs

[15] Tariffs for battery are applied in a charging station in Hauna. Information obtained questioning locals during the field trip of March/April 2017.

5.3 Photovoltaic assembling

In the current situation, solar PV modules used in Africa are mainly imported, thus local business opportunities are not exploited and new PV modules are available at a high price (Moner-Girona, Ghanadan, Jacobson, & Kammen, 2006), while second hand panels can be found for cheap in every market.

Local photovoltaic assembling offers several opportunities listed as follows:

- cost decrease since transportation and logistics costs are reduced (Kurz, 2014);
- creation of new markets;
- creation of jobs;
- products matched to local market requirements.

The main applications of local low-cost modules are small home energy systems where low energy demanding appliances, such as LED lighting, radio, and mobile phones, are utilized.

Local manufacture centres are already available in Zimbabwe, for example in the municipality of Rusape, where shops are currently selling PV modules locally constructed using PV cells imported from Germany[16] (refer Figure 39).

Figure 39: Solar PV modules assembled in Rusape, Zimbabwe. Photographer: Lorenzo Sani

This same idea can be applied in Honde Valley with possible creation of job opportunities.

Solar PV cells are imported from abroad since their shipping is cheaper than complete modules while other materials necessary for the manufacturing, such as wiring and supports, are purchased in the local market. The solar PV modules is then assembled in a local manufacture plant. After this phase, the PV are rented on the local market; the renting helps avoiding problems since the manufacturer is still the owner of the PV modules and is, therefore, interested in the correct operation of its product because it is its main source of revenue. For this reason, it is also the

[16] Information obtained questioning locals during the field trip of March/April 2017.

provider of the maintenance service. The main passages are explained in Figure 40.

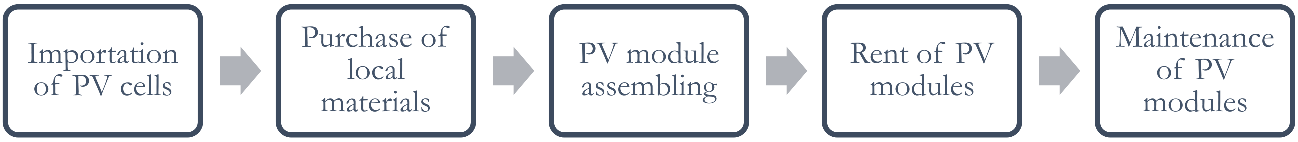

Figure 40: PV assembling steps

According to (IRENA, 2016), the cost for a PV module in Africa in 2015 varies between USD 0.52 and USD 0.72/Wp after a decrease in the price of approximately 80% since 2009.

In the case of local photovoltaic assembling, savings of USD 0.015/Wp can be achieved in logistic and, in addition, a local content price premium of 5-10% can be attainable with favourable governmental policies. On the other hand, costs in the local market for labour, utilities and materials could easily be higher, increasing the price from 5 to 10% per Wp (Kurz, 2014).

A summary of the cost of a PV module can be found in Table 22.

Table 22: PV module cost (IRENA, 2016)(Kurz, 2014)

	Min	Max	Unit
PV cost	0.520	0.720	USD/Wp
Increase costs for module materials, utilities and labour	0.026	0.072	USD/Wp
Saving in logistic	0.015	0.015	USD/Wp
Total	0.531	0.777	USD/Wp

This proposal is an interesting opportunity for the development of the economy of Honde Valley with the creation of job and the use of local content but it is difficult to state the feasibility at the current state of affairs. The main constraint consists in the initial monetary investment required to set up the assembling plant and for importing the cells from abroad. A more-in-depth analysis is necessary for the implementation of this solution.

5.4 Biogas

The key point for the future development of the community on various aspects is the adoption at community level of anaerobic digesters for the production of biogas from organic waste, animal dung and human excreta.

In the last years, biogas plants have widely proven their success in many rural areas, especially in India and Nepal and are progressively spreading all around Africa. Biogas production creates positive outcomes not only for waste management but also for cooking, internal household air quality and sanitation. These are relatively cheap to build in developing countries and can use household waste, human excreta and cattle manure. The produced biogas will provide a clean cooking fuel and lighting during night time; in addition, the by-product is a bio-slurry that offers a high effective fertilizer.

The best advantage in using biogas is the high efficiency that can be obtained when it is burnt; using heaters, the efficiency can be around 80-90% while with stoves is around 50-60%. The common values of efficiency in burning biomass are of 10-15% in a traditional stove and 25-30% in a better-designed stove. So burning biofuel, the efficiency of the combustion is doubled, diminishing consistently the amount of fuel consumed. (Wargert, 2009)(TDBP, 2013).

There are different types of bio-digesters with various shapes, sizes and construction materials. The most common technologies for domestic biogas are: plastic tube digester, plastic tank digester, fixed dome model and floating drum digester. For biogas production at a household scale the solutions are:

- Plastic Tube Digester or Polyethylene Tube Digester (PTD): The main material used for the digester is polyethylene, which is very cheap. On the other hand, polyethylene can be easily damaged. The technology lifespan is therefore potentially short, depending strongly on the care of the user and the occurring of accidents. This technology requires a specific training of the users for the digester because installation and operation are complex and delicate.
- Plastic tank digester: This technology is mainly composed of two pre-built rigid plastic tanks: a first tank where the digestion of organic materials occurs, and a second tank for the storage of the produced biogas. Thus, this technology is easy to install. The tanks are usually not placed underground; thus, they are potentially damageable. This digester is derived from water tank technologies, so a lifespan of 20 years can be expected by analogy with water tanks. However, the number of plastic tanks digesters currently installed is very low.
- Technologies based on the Fixed Dome model: This family of bio-digesters has been widely and successfully used in Asia, the most successful applications were in Nepal where more than 250,000 plants have been installed in 20 years. Fixed dome plants require specialized construction companies for building and maintenance. Employment creation is therefore a side benefit of the dissemination of this type of technology.
- Floating drum digester: It is made of two chambers: the digester pit is located underground, and the generated biogas flows up to a reverse drum (made of steel, also called gas-holder), that is floating over the fermenting slurry, or in a separate water tank. Since the drum can move, the gas pressure inside is constant, and its level aboveground indicates the amount of gas that is available. Such designs have been widely used in the past especially in India, but are considered as obsolete nowadays, compared to fixed

dome models (due to a shorter lifespan and more maintenance requirements) (TDBP, 2013).

However, the best and common used option is the household based fixed dome biogas plants, as shown in Figure 41. This solution is the most common due to its relatively low price, its robustness and the simplicity to operate.

Figure 41: Anaerobic Digester construction (Wilkie, 2015)

The digester is fed from an inlet that leads the biomass to the main chamber where the anaerobic digestion produces the biogas. The gas will remain in the digester until it is used or moved into a storage tank. While more and more gas is being produced, the pressure inside the digester rises forcing the residual slurry to be expelled from the digester into the removal tank. The residue of the digestion is a bio-slurry that mainly consists in a mix of digested matter and water, with a high concentration of mineral substances and nutrients such as nitrogen (N), phosphorous (P), potassium (K) and magnesium (Mg). As a result, bio-slurry is a very good fertilizer that could improve the productivity of the soil (TDBP, 2013).

5.4.1 Community Biogas Digester

The implementation of the Community Biogas Digester is based on the centralized anaerobic digestion (CAD) which is an evolution of the co-digestion, the digestion of a variety of substrates.

This practice offers several advantages. A single but large plant is a feasible solution for community where members are not capable to have their personal AD plant mainly for economic reasons. It improves the digestion performance and the quality of the fertilizer produced as the nutrients are more balanced. Moreover, it increases biogas yields if high methane yield wastes are added. Other advantages of this choice are a better control of substrate and biogas supply (Jingura & Matengaifa, 2007).

The first steps are to build a bio digester is to make sure that enough water is available and to conduct a survey to verify the substrate availability, local materials and willingness of the villagers to adopt the new technology. It is necessary to evaluate and assess different sites and identify the proper one. Typical locations are close to big buildings, for instance schools, concentration of sanitation facilities or farms, because they are usually the sites where the availability of substrates is higher (Otim, Okaka, & Kayima, 2006).

Figure 42: Biogas digester construction (Julius, 2017)

Different solutions are available for the design of the digester. A trade-off between durability and cost is represented by the fixed dome design (refer Figure 42). Its main characteristics are shown in Table 23.

Table 23: Characteristics of the fixed dome design (energypedia.info, 2016)

Factors	Fixed dome
Gas storage	Internal gas storage up to 20 m3
Gas pressure	Between 60 and 120 mbar
Skills of contractor	High; masonry or plumbing
Durability	Very high, (20 years)
Agitation	Self-agitated by biogas pressure
Sizing	6 to 124 m3
Methane emission	High
Installation cost	Medium
Feedstocks used	Cattle dung, domestic sewage, kitchen scraps, grass clippings
Applications	Rural households, small scale farming

The typical livestock in the Honde Valley is composed by cows, sheep, goats and poultry. Due to lack of accurate and validated information regarding the count of livestock in Honde Valley, these values are considered a reasonable assumption, based on the statistics for livestock in Manicaland province (Zimbabwe National Statistics Agency, 2016). According to the Zimbabwe National Statistics Agency, about 98.3% of Manicaland population lives in rural areas and 51.6% are communal farmers. A ratio of Ward 10 population to Manicaland population is used to estimate the livestock in Ward 10. Assuming that the 15% of the communal farmers in the Honde Valley can participate to the community biogas digester project due to their economic situation, distance from the chosen location and other eventualities, the expected daily biogas yield can be seen in Table 24. The biogas production can be used in several ways: it can satisfy the electricity demand of some villagers or economic activities, or provide fuel for cooking. It must be considered that, in order to benefit of the biogas digester, the related activities mentioned should be close to it. However, the purpose of this calculation is to estimate the economic potential of the investment, and it will be assumed that all the biogas will be used to produce electricity, eventually sold to the national grid. The reference price at which electricity is sold to the grid is 0.14 USD/kWh, that according to Amos Kapenzi, guide of the team to the hydropower plant, is the price at which Nyangani Renewable Energy is selling electricity to ZETDC.

Table 24: Daily biogas yield (Jingura & Matengaifa, 2007)*;* (Hemstock & Hall, 1995)*;* (Mukumba, Makaka, Mamphweli, & Misi, 2013a).

Stock	Number of animals	Dry dung output [kg/(head*day)]	Biogas yield [m^3/t]	Manure per animal per day [kg]	Gas yield per day [m3]
Cattle	54	1.8	281	97.2	27.3132
Sheep/Goats	34	0.4	120	13.6	1.632
Poultry	44	0.06	359	2.64	0.94776
Humans	266	0.4	70	106.4	7.448
Total	398	/	/	219.84	37.34096

Considering that the biogas electricity production is 9 kWh/m^3 and the ratio between the biogas yield of plant located in Nyazura Adventist High School in Rusape, Zimbabwe and the estimated of the proposed plant in Ward 10 is used to linearly estimate the volume of the fixed dome digester and the costs of the plant an evaluation of some economic parameters has been conducted (Mukumba et al., 2013a). The results are shown in Table 25 and Table 26.

Table 25: Fixed dome digester volume and estimated monthly electricity production

Description	Value	Unit
Volume of the digester	86	m^3
Electricity production per m^3 of biogas	9	kWh/m^3
Estimated monthly electricity production	10222.0878	kWh/month

Table 26: Overview of the investment

Investment cost			
Description	Quantity	Unit price in USD	Total in USD
50 kg cement	172	7	1204
Bricks	20165	0.019	380.72
6 m gas pipes	8	30	240
4 m PVC pipes	12	35	420
Steel [kg]	413	2	826
Mesh wire [m^2]	62	1	62
Copper tubes	5	30	150
Sand [m^3]	20	19	380
Aggregate [m^3]	8	30	240
Generator	1	1200	1200
Paint [liters]	14	10	140
Heat exchanger	1	600	600
Others	/	/	497.38
Labour	/	/	746.82
Total	/	/	7086.92

The Levelized Cost of Energy (LCOE) and the NPV is estimated considering the following assumptions:

- The annual capacity factor of the plant is 70% lower than the average value of 90% due to the possibilities of failure in order to obtain a conservative prediction (Kater & Adam, 2009).
- The lifetime of the plant is considered to be 15 years.
- The discount rate is assumed as 10%.
- The operational costs include operation and maintenance costs, man power costs and other energy related costs such as the connection of the grid.

The Net Present Cost of the biogas plant is:

$$NPC\ [USD] = \sum_{i=1}^{15} \frac{C_{tot,i}}{(1+r)^i} = 77031.43\ USD \tag{8}$$

Where $C_{tot,i}$ is the total cost related to the year i, including both investments and O&M costs. The estimated monthly electricity production is:

$$E_m \left[\frac{kWhel}{month}\right] = E_V \cdot V_d \cdot \frac{365}{12} = 10222.09\ kWh/month \tag{9}$$

Where E_V is the electricity production per cubic meter of biogas, accounting also the efficiency of the generator, and V_d is the estimated biogas yield of the digester per day.

The LCOE can be calculated as:

$$LCOE\left[\frac{USD}{kWh}\right] = \frac{NPC}{\sum_1^{15} \frac{E_{m,i} \cdot 12 \cdot C_f}{(1+r)^i}} = 0.118\ USD/kWh \tag{10}$$

Where C_f is the capacity factor of the system.
The NPV can now be calculated as:

$$NPV\ [USD] = \sum_{i=1}^{15} \frac{(E_m \cdot 12 \cdot (e_p - LCOE))_i}{(1+r)^i} \tag{11}$$

Where e_p is the market price of electricity paid by ZETDC. The obtained NPV is 14402.59 USD (refer Table 27).

Table 27: LCOE and NPV of the biogas digester

Description	Value	Unit
Investment cost	7086.92	USD
Operational cost	9280.57	USD/y
Capacity factor	0.70	-
Annual energy production	85865.54	kWh/y
Lifetime	15	years
Discount rate	0.10	-
LCOE	0.118	USD/kWh
NPV	14402.59	USD

In other parts of Zimbabwe such as Chishawasha, Harare and Kushinga Agricultural College, biogas digesters were installed but are not operational because of the lack of appropriate knowledge to perform the basic action of operation and maintenance of the system for example non regular feeding of the digester (Mukumba et al., 2013a). This problem needs to be addressed with an appropriate training of operators through explanatory courses on the operation of the digesters and regular updates.

Another hurdle is poor quality of the construction raw materials or equipment. It is necessary to control and verify the quality of the materials before the beginning of the construction as it could lead to youth failures of the system.

Absence of the required substrates is harmful to the operation of the digesters as it forces an off-design operation and in extreme cases the closure of the digester for a certain period.

After the first report, Jacob Chikuhwa started the construction of a digester in his house, and the structure has been completed in the early days of June. The digester is a Fixed Dome model, and the construction time has been more or less one month. The implementation of the proposals is the main driver of the interest of people, and private initiatives like this are a useful for the future implementation on large scale. A picture of the digester is available in Figure 43, while a detailed list of the costs is available in Appendix 7: Biogas costs.

Figure 43: Fixed Dome biogas digester, built by Jacob Chikuhwa

5.4.2 Household Biogas Digester

Biogas digester at household's level can be a solution for cooking and fertilizer production. These systems are of a smaller scale compared to the previous and can be fed from organic waste or from human faeces available in blair toilets (Rajendran, Aslanzadeh, & Taherzadeh, 2012).

A company which is currently implementing these units (refer Figure 44) is HomeBiogas located in Israel. The characteristics are presented in Table 28 (HomeBiogas, 2017).

Table 28: HomeBiogas household digester characteristics (HomeBiogas, 2017)

Description	**Characteristic**
Input	Up to 6 l of food waste Up to 15 l of animal manure
Output	600 L of purified biogas (65% CH_4 and 35% CO_2) Refined all-natural fertilizer
Required average ambient temperature	17° C
Dimensions	127 x 165 x 100 cm
Weight (empty)	35 kg
Cost	1090 USD + 140 USD for shipping and handling

Figure 44: HomeBiogas household digester (HomeBiogas, 2017)

Household biogas digester are a great opportunity to supply energy access and alternative cooking fuels but the high capital investment cost is still an obstacle that needs to be overcame. As a result, further research on this topic, especially on funding partners, is necessary to understand the viability of this proposal in Honde Valley.

5.4.3 SWOT Analysis

In Table 29, a SWOT analysis of the biogas proposal is performed. The advantages mentioned are summarized, and also some challenges are presented.

Table 29: SWOT analysis of Biogas

Strengths • Built with local materials and workforce • Fertilizer is a great by-product • Useful for cooking and electricity	**Weaknesses** • Need for new infrastructures • Need for external partnerships • Cost of the materials
Opportunities • Business opportunity for locals • Easy business model • Replicable for its modularity	**Threats** • Unwillingness to switch to new technologies • Difficulty to create a community • Lack of maintenance

6 Clay workshop

The solution proposed in this chapter consists of the implementation of a workshop to manufacture clay products, in particular colloidal silver impregnated ceramic clay filters (see chapter 4.3) and improved cooking stoves (see chapter 3.3.2). The manufacturing facility will provide multiple benefits to the community, in terms of products, employment and cash flows, by establishing a commerce with neighbouring areas.

6.1 Location selection

The identification of the facility location plays an important role throughout all its useful lifetime. The workshop should be as near as possible to the paved road, but still accessible to the workers living in the villages around Samaringa, that are further away from the main road. Ideally, it should have access to electricity, and to water which might not necessarily be purified. In this report three suitable locations are proposed (Figure 45)

Figure 45: Satellite view of possible locations for clay laboratory (Google, 2017)

a) Near the schools in Samarainga: this presents the possibility to access water both from derivations of existing rivers such as Turumhu, and from existing or new boreholes. Moreover, it has the advantage of being easily accessible to workers and to school students, in case activities, collaborations, and trainings are organised. Nevertheless, the distance from the paved road can represent a considerable obstacle for the import and export of materials.

b) Masere business centre: this location is neared to the paved road and easily accessible to the workers. A warehouse and several suppliers are present nearby, and the establishment of the workshop could bring other commercial activities to the business centre. Nevertheless, the access to water is not as immediate as in Samaringa.

c) Near the bridge on Honde river: this location is in proximity of a useful source of water, and approximately a few hundred metres from the paved road, which simplifies the transport of materials. On the other hand, the distance from the villages might represent an obstacle to the workers, and access to electricity should be verified.

6.2 Process of production for clay filters

The production of colloidal silver impregnated ceramic clay filters does not differ much from that of a common clay vase, as showed in Figure 46. The clay needed for their production must present a good plasticity, and have the ability to maintain its shape when still wet and pressed out of the mold.

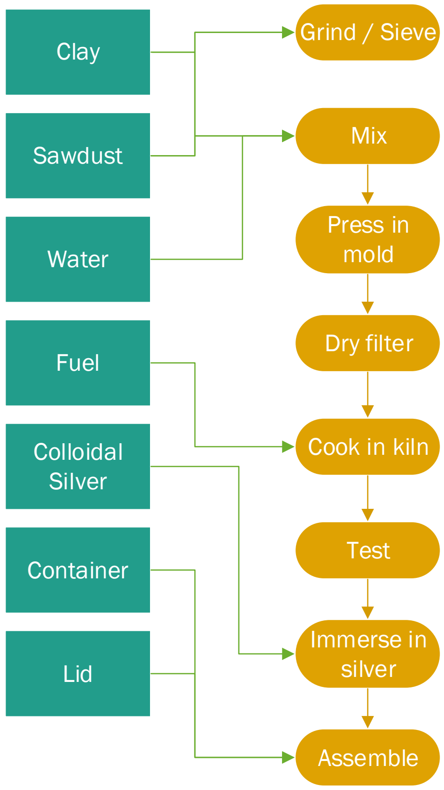

Figure 46: Flow scheme of ceramic filter production

The sifted clay must be mixed with thin sawdust, which will burn during the cooking in the kiln at about 890 °C (Potters Water Action Group, 2013), leaving small pores in the finished product.

Both before and after being fired in the oven, the filter must stay in a shadowed place, possibly in open air, in order to dry (before firing) or to cool (after firing). Direct sun exposure should be avoided in order to prevent the formation of cracks. The time in which the filters should rest is a factor that must be considered in the layout of the workshop, in order to have enough storage space for the filters.

Testing the filters is fundamental in order to ensure their proper working. The mass flow should be sufficient for the use as a filter, but should not exceed about 2-3 l/hour (Potters Water Action Group, 2013).

If a filter passes the mass flow test, it can be dried again and treated with the active substance, colloidal silver. Such material is the most difficult and expensive to find; nevertheless, only small quantities are required (about 500 USD of colloidal silver can be used for up to 20000 filters)(Potters Water Action Group, 2013). After a final drying, the filter can be assembled into the plastic bucket which will contain the water that has been filtered. The container can be bought or crafted according to many designs. In collaboration with Potters for Peace, the department of Industrial Design of the University of Johannesburg proposed an interesting design based on the existing Potpaz home water treatment device for use within rural households of the Vhembe region of South Africa (Adrianzen, 2013) (Bolton, 2009). More detailed information about the required materials is presented in Appendix 15.3.

6.3 Process of production for Improved Cooking Stoves (ICS)

As mentioned in paragraph 3.3.2, it has been demonstrated that the usage of Improved Cooking Stoves instead of open fire stoves can lead to a significant reduction on the impact on the environment (indoor air pollution, GHG emissions) and on human health (respiratory diseases such as pneumonia or Chronic Obstructive Pulmonary Disease (COPD)) (Alternative Energy Promotion Center, 2008).

A small manufacturing facility can have a production on the order of magnitude of 500 stoves per month (Houck & Tiegs, 2001), with a production cost between 1.91€ and 3.30€ per stove (van der Gaast, 2006). More sophisticated designs, with also a metal casing, can cost up to 12.00€ (GIZ - HERA (Poverty-oriented basic energy services), 2011).

The steps of fabrication and materials needed have many similarities with those of the clay filters, except that the clay does not need any sawdust fillers. The metal casing can be crafted from a foil of mild steel, which must be shaped (by hand or with electrical devices) in order to contain the clay vase which is perforated at the bottom. The metal case supports the clay liner, allowing to ventilate the fire through an aperture on the side which can be closed with an hinged panel, as showed in Figure 47.

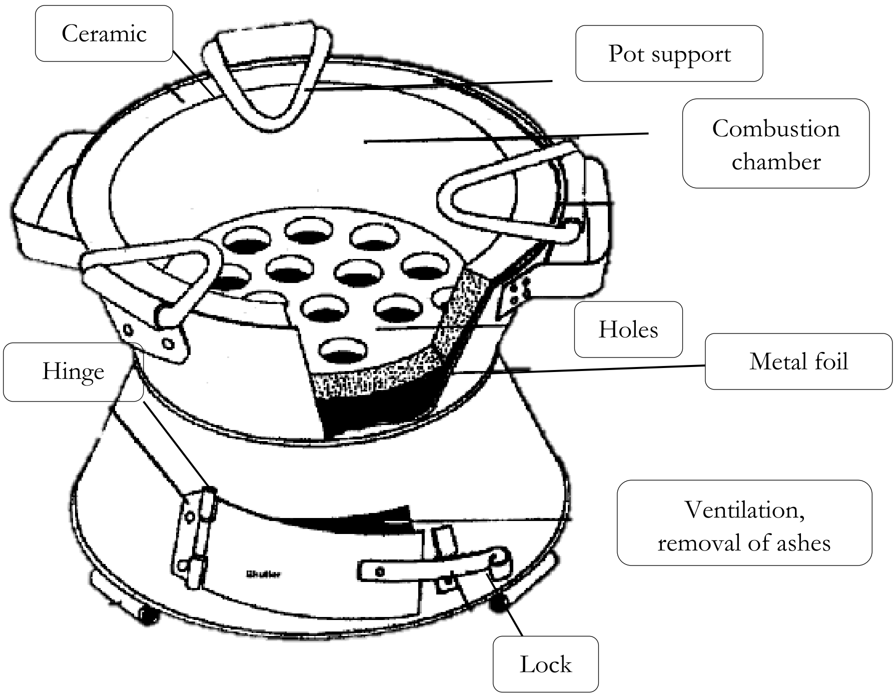

Figure 47: Scheme for *Jambar* Improved Clay Stove (PERACOD, 2011)

6.4 Laboratory layout

In Figure 48 is illustrated a proposed layout for the clay workshop. The facility is divided into two main areas, a main one which will be indoors, for the processing of materials and components, and a second one for storage which can be outdoors, sheltered from the sun. The most convenient position for the kiln is between such two areas, in order to minimise the distances for moving the filters during the different steps of their construction.

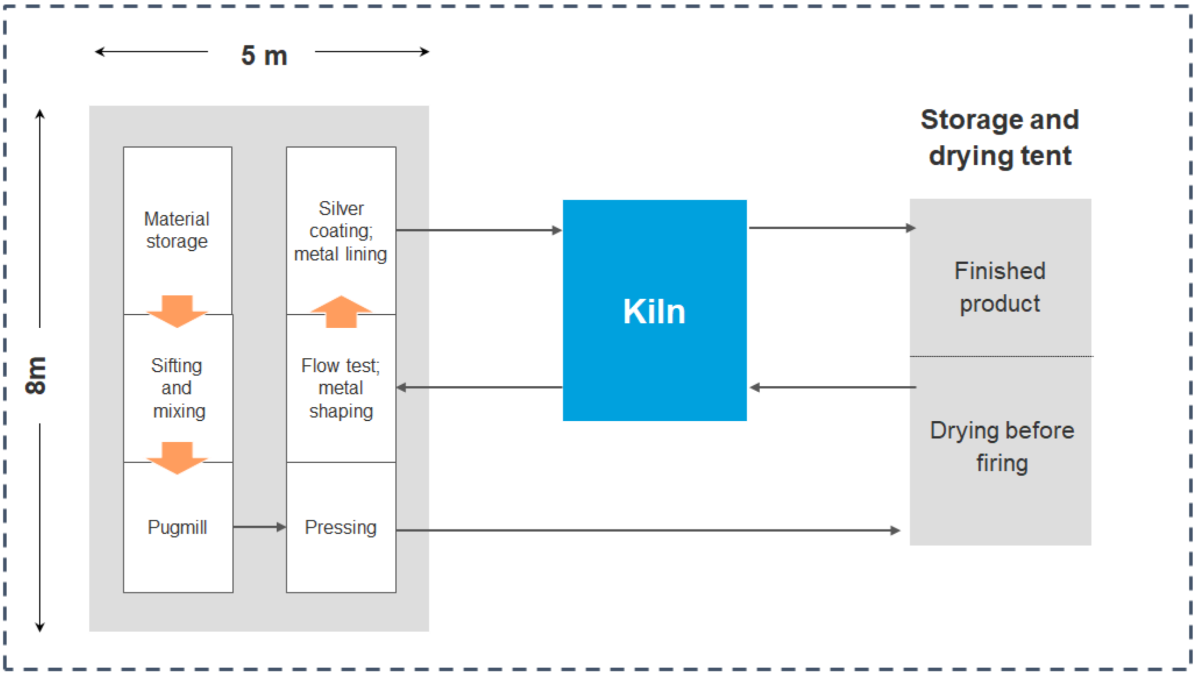

Figure 48: Laboratory layout

6.5 Feasibility analysis

Figure 49 illustrates the cost range for the filters and the stoves already mentioned in the previous paragraphs. According to the survey which has been conducted during the second trip in Honde Valley, 60% of the inhabitants are interested in the filters and 81% in the stoves. When asked how much is the maximum price they would pay for the two products, they expressed a much higher interest than expected, translating in an average willingness to pay of 30.89$ for the filters and 65.49$ for the stoves.

Such prices allow to perform an approximate analysis of the conditions necessary for the economic success of the clay factory. An example can be seen in Figure 50, where the red plane represents the break-even points, while the blue plane represents all the possible operative points of the clay workshop, assuming the parameters shown in Table 30. It is possible to observe that the break-even point is reached with reasonable amounts of products sold every month, of the order of magnitude of around 50 units per type of product, thus demonstrating the feasibility of this project proposal.

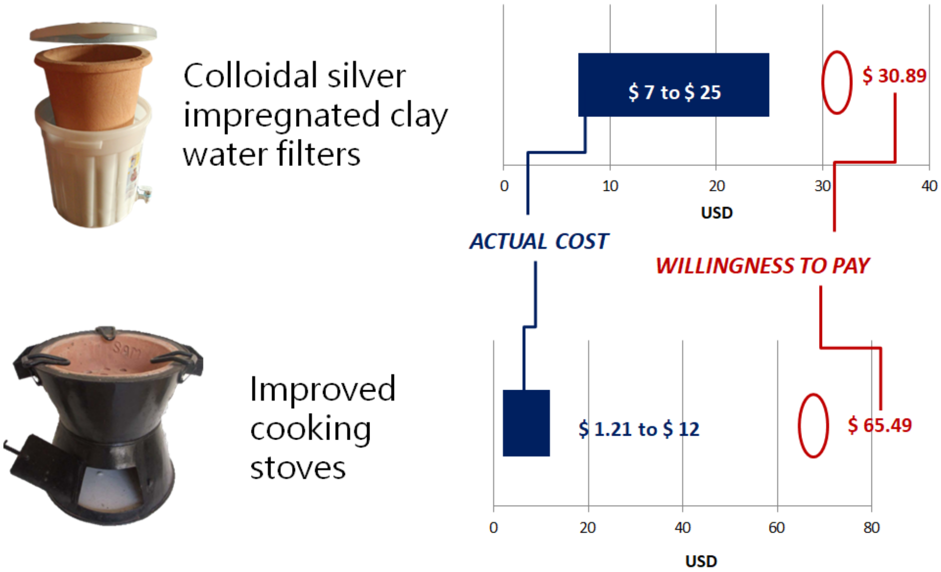

Figure 49: Estimated costs and willingness to pay for products of the clay workshop

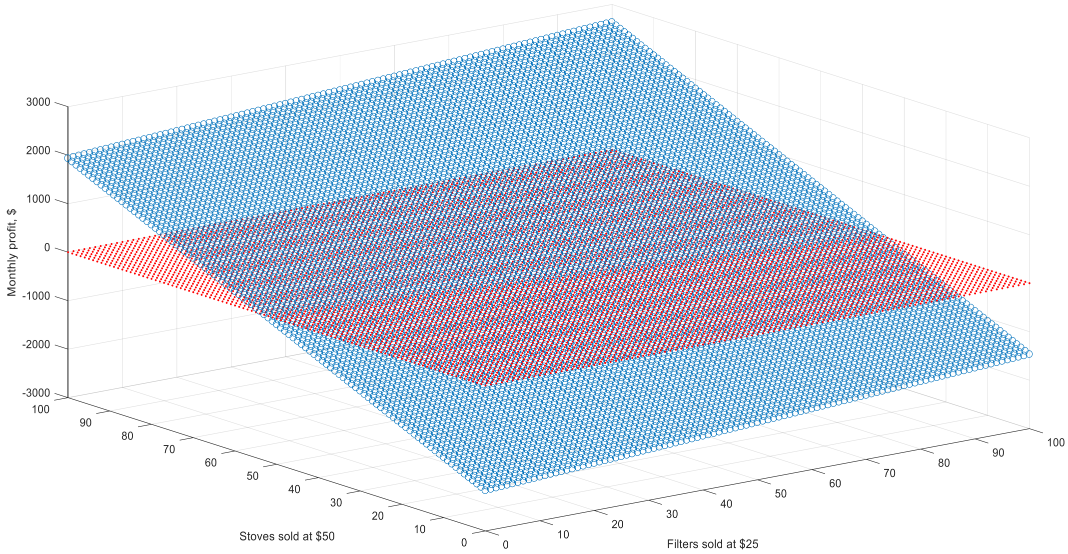

Figure 50: Economic profit of clay workshop as a function of sales

Table 30: Assumptions for economic study of clay factory

Lifetime	20 years
Interest rate	3%
Investment cost	30000 USD
Filter production cost	18 USD
Stove production cost	9 USD
Filter retail price	25 USD
Stove retail price	50 USD
Number of workers	8
Monthly salary	250 USD

7 Agriculture

In Honde Valley, farmers are owners of small lands where they grow crop mainly for self-subsistence and income. The work is mainly manual as tractors are not common. The sale of the products is done by the individuals in the Business Centres, or house by house. Prices are usually arranged by bargaining.

The proposal of a farmers' cooperative in Samaringa village can open the community to several new opportunities, which would be otherwise not exploitable. In particular, the initial capital required to initiate improvements or acquire a new technology is not affordable for the single villager. Thanks to a sharing economy and to economies of scale, many activities can be done in a cheaper way and new ideas can be introduced. Moreover, the whole agricultural system that exists today can improve thanks to this institution: the cooperative would provide its members with tools and advice that will enable each farmer to increase his yield from the cultivation and the selling profit while mitigating risks involved in farming. For example, a study of smallholder farmers' income found that the mean income for those who have market linkages is relatively higher by 41.05 USD than those without it. Measured as possession of a telephone by the household head, the rationale behind this finding is that households who have efficient means of communications are better linked to the market and had higher per capita incomes than those who are constrained by information asymmetry. (Tavonga Mazorodze, 2015)

7.1 Participation to the cooperative

The single farmers living in Ward 10 can participate in the cooperative supplying goods that are exceeding their own needs, e.g. vegetables and cattle, but also materials, tools and heavy equipment. They can participate with direct workforce, to improve the infrastructures, to manage the goods of the cooperative or in the administration. Finally, it is also possible to participate with funds: a small annual subscription fee could be introduced after the first start-up period, and eventually raised according to common investment projects.

Subscription process needs to include a contract between the subscriber and the cooperative, where duties and benefits are clear and transparent: a statement of the individual contribution, an agreement on ownership of goods and revenues share. The main decisions of the cooperative must be taken in a council of the participants.

7.2 Activities of the cooperative

The main organizational activities done by the cooperative are:

- Production of goods from the shared land and cattle;
- Retailer for the members of the cooperative, with convenient prices;
- Retailer in bigger markets, Honde Valley or even export;
- Renting cooperative equipment (tractors, vehicles, agricultural tools);
- Consultancy and technical help for members to improve production, knowledge sharing;
- Quality control of the products;
- Building and improvement of the infrastructures from the revenues of sales and fees;
- Provision training for employers;

In the following some interesting economic activities are listed that can be economically viable for the cooperative. These should be taken into consideration in the future.

- Fish breeding in pond;
- Cooperative biogas plant;
- Beekeeping;
- Greenhouse;
- Organic waste collection
- Solar dryer for food products, like dried mangos;
- Packing of products;
- Energy crops;

7.2.1 Expenses

The following assumes that the number of communal farmers in Ward 10 is proportional to that of Manicaland. This assumption is based on the statistics offered by the Zimbabwe National Statistics Agency which finds that in Manicaland 51.6 percent of the population works in communal farming, which is the most dominant farming method in Honde Valley. As such the following expenses and revenues are assuming 1171 communal farmers in Ward 10, and with 3 people per household approximately 590 farms. Table 31 details the total sum of costs inquired by communal farmers in Honde Valley.

Table 31: Annual cost of agriculture in Ward 10 (Zimbabwe National Statistics Agency, 2016)

Ward 10 communal farming - annual cost related to agriculture*		**USD/year**
Infrastructure	Buildings:	
	Housing	32,427
	Tobacco barns and curing tunnels	1,153
	Livestock related	2,870
	Crop related	653
	Stores and workshops	174
	Irrigation work	1,470
	Fencing	931
	Establishment costs for plantations and orchards	546
	Land improvement and conservation	849
	Roads, grids, bridges, drifts, airstrips	93
Livestock O&M	Purchased stock feed	4,746
	Homemade feed	1
	Home grown fodder	12
	Veterinary Services	746
	Dipping levy	1,140
	Vaccines	1,563
	Detergent and disinfection	143
	Other	3
Equipment	Transport	4,693
	Tractor drawn	1,299
	Other plants, machinery and equipment	44
Total expenses		55,557
***All values represent the total sum for all communal farmers in Ward**		

7.2.2 Income

The Cooperative would combine profits from a diverse portfolio, including beehives (Table 32) and various crops (Table 33).

Table 32: Beekeeping Nyahari Producers Association (Honde Valley); (Mudefi, 2014; Nel, Illgner, Wilkins, & Robertson, 2000)

Members	**34**
Time (months)	3
Beehives owned by a member	74
Input cost per beehive (USD)	48
Produce brut per beehive (kg)	15
Produce net per beehive (kg)	12
Sales product (500gr bottle)	24
Price per item (USD)	3
Income per beehive (USD)	72
Total member net profit (USD)	5,328
Total profit of Cooperative (USD)	181,152

Table 33: General crop income

Farmer profit (USD/crop season)	**3,500-5,000**
Irrigators (USD/crop season)	4,000-7,000
Total cooperative net profit*	6,495,236
*Assuming (1) average crop seasonal income with an irrigation system installed (2) 2 crop season per year (3) an average of 5500 USD/crop (4) 590 irrigating farms	

As can be seen in Table 33 that irrigation allows higher degree of crop diversification that cannot be achieved by rain based agriculture. This allows an increased yield and profit in terms of a longer crop period as well as a higher revenue during each crop season. A study in Gweru, Zimbabwe, found that loans respectively credits enabled the acquisition of an irrigation system which was easily reimbursed by the farmers (Dube, 2016). Moreover, credits delivered by the company Favco in the Honde Valley reported a 30% return on investment (Machilla, Lyne, & Nuthall, 2015) which highlights that such economic development is financially viable.

Table 34: Net expenses and profits of the cooperative

Basic Net Profit Evaluation	USD/Annual
Investment	55,557
Income:	
Beekeeping*	181,152
Irrigated crop	6,495,236
Net income of member (USD/month)	311
*** Assuming 4 annual beehive cycles and 64 beekeepers**	

The estimation of profit seen in Table 34 estimation demonstrates the potential economic growth that can be attained by applying simple improvements in technologies and skills training in the agricultural field in Honde Valley.

Since the farmers would probably consume a higher than average water quantity, they will benefit from the harmonization of the water system the most and therefore could dedicate a certain percent of the annual income to the operation, maintenance and upgrading of the water scheme. As agriculture is already a primary source of income in Honde Valley, the cooperation of the population is highly likely and should meet low hesitation or resistance.

8 Waste management

In the following paragraphs, the proposal that the group developed on the theme of waste management is presented, the focus of the proposal is to integrate gradually also some of the other topics that are treated within this report. The topics that will be touched in addition to waste management are improved cooking methods, energy access, improved sanitation and agriculture. The proposal consists on gradually introducing waste management practices in both the primary and the high school, starting from separate waste collection, and having in the final development a school kitchen equipped with a biogas digester.

The main scope of this proposal is to educate the population on the intrinsic value of any kind of waste, and to create the environment for a successful implementation of a large-scale waste management system. The acceptance of the community must be achieved, with the incentive of the production of a fuel that would be cheaper and healthier than the alternatives, so the community can use it and see the benefits (Nair & Jayakumar, 2008).

8.1 School Waste Management Education and Workshop

The school has been identified as the first location where proper waste management practices should be implemented. The school is a location where a large concentration of people produces a significant amount of waste annually. Above all, the most important achievement of implementing this system will be providing young generations with the knowledge and habits required to face radically the waste management issue. As a matter of fact, the success of a waste management system is totally based on the participation of every single citizen and, to obtain this participation, a behavioural change is required.

At the moment, in some courses delivered to high school students, the theme of waste management is treated and it is mostly focused on the disposal of biodegradable remains, mostly to produce compost; at a certain extent, also the theme of bio-digesters is touched. Even though the education part is partly provided, all around the school any separate waste collection bin can be found, but only a few old iron barrels where all the waste is collected. All the collected waste is then incinerated. It is easily understood how this situation creates a paradox that makes the waste management education appear inconsistent to the students.

Therefore, the first step consists in spreading around the school some bins for the separate collection of paper, plastic, glass and undifferentiated waste. Students will be encouraged to use them by teachers and by some engaging events. For example, the primary school could organize some clean-up events where one class is brought to a polluted area to clean it up, and retrain it for new purposes. In high school, focus should be put on the dangers related to improper waste management practices and on the opportunities, that could rise from recycling and reuse. Regarding the hazards, themes like environment degradation, water sources pollution and health issues related to breathing the fumes generated while plastic material is burned should be covered. Regarding the importance of recycling and reuse different examples could be provided, including the production of biogas from biodegradable materials. A kind of a challenge could be proposed to students where the proposers of the best ideas to reuse or recycle some waste items could be rewarded.

The school facilities also host a women empowerment group which helps housewives develop trade skills. These women currently focus on sewing uniforms for the children school and other household items. They could get involved in small scale manufacturing workshops, which could include artistic recycling, LEDsafari solar light assembly or PV soldering. These products could then be both a business opportunity for the women as well as a tool to raise awareness of the value of waste management in the community.

8.2 LEDsafari workshop

In this framework could be included the proposal of a workshop with LEDsafari, where students will be able to build their own lamps while reusing some scrap materials (e.g. plastic or glass bottles).

LEDsafari is a social start-up based in Lausanne, Switzerland that aims to assimilate clean energy, sustainable innovation education through a unique science experience, and design training centred on creating a solar LED lamp. Its funder, Govinda Upadhyay, is an Innoenergy alumnus who in 2015 won the EIT Change Award and was a finalist in the Forbes Under 30 Change the World Competition. LEDsafari offers kits to assemble LED lamp which is a low cost MIY (Make-it-yourself) solar lamp that uses a small solar panel (0.5 W) to convert energy from the sun, store it in a battery and use it to power a LED bulb. LEDsafari is not only selling lamps to people in need, but it is also selling a kit to teach them how to make the lamp. The company's focus is children in secondary schools, especially in the 12-16 age group, and in the next two years they plan to reach 1 million students.

Additionally, LEDsafari offers a wide range of different programs: entrepreneurship programs, education programs, social campaigns and recreational workshop. All these services got the result to increase the effectiveness of the start-up. For example, the entrepreneurship programs is designed to create local entrepreneurs in power deficient parts of developing countries with engineering and entrepreneurial knowledge, offering training and business creation support (LEDsafari, 2017a);(EIT, 2015).

For children, the experience with the lamp can be considered a school experiment where they are building their own lamp using their skills and creativity.

The kit is composed by the following components (see Figure 51) which children are supposed to assemble on their own together with reused or local material (plastic or glass bottles or wood) to build their own lamp:

- resistance (20 ohms, 0.25 W) ~ 2 g
- diode (IN4007) ~ 2 g
- li-ion battery (1000mAh) ~ 20 g
- Epoxy solar PV (0.5 W, 5 volt) ~ 15 g
- SPDT switch small ~ 2 g
- 0.5 W white LED ~ 2 g

To assemble the kit components, it is required a 25 W soldering iron.

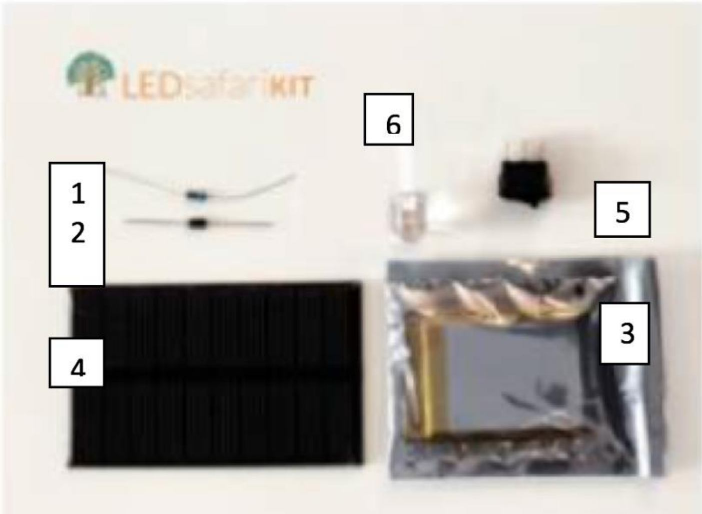

Figure 51: LEDsafari lamp components (LEDsafari, 2017)

The workshop will have multiple positive effects on student's education. Firstly, during the construction of the lamps pupils will learn some basics of electronics, and will build their first electric circuits. Secondly, recycled materials will be used during the construction of the structure of the lamp. Finally, in the best-case scenario, students will be able to keep the lamp they built with them, and use it as a clean lighting design instead of being dependant on dangerous and polluting lighting sources, (i.e. paraffin candles or bonfires) which are still very common in Honde Valley.

LEDsafari offers a special program for NGOs and schools which is composed by an online "training of the trainer" where the trainer, in this case on teacher, though a multi-lingual online platform with high quality animations and graphics is educated on how the lamp is built and the physical principles that stands behind it. In this way, the certified trainer will be able to guide students on the building of the lamp, and to teach them the theory of how it works in an effective way (LEDsafari, 2017a).

The price of the training is of 60 CHF (62,3 USD) and the price for lamp is of 10 CHF (10,4 USD) each for deliveries of more than 20 units (LEDsafari, 2017a). These data, compared with the data provided by Jacob Chikuhwa about the candles expenses per family, are extremely interesting and show how the payback time per family for the purchase of the lamp could be of about two months. According to Dr. Chikuhwa, on average 18 candles per month are consumed per household and this translate into 4,5 USD per month (3 packets of 1,5 USD of 6 candles each). Therefore, it is evident how the LEDsafari lamp could be extremely convenient also from the economic point of view.

8.2.1 LCA study on LEDsafari proposal

A group of students[17] (including Niccolò Primo and Lorenzo Sani) in the framework of the course "Sustainable Energy and Environment" held at UPC by Professor César Valderrama, produced a Life Cycle Assessment (LCA) regarding the "Comparison between conventional lighting methods and solar lamps in Honde Valley, Zimbabwe". This study investigated the

[17] The group of students is composed by: Denitsa Kuzeva, Federica Tomasini, Lorenzo Sani, Niccolò Primo, Olga Gerasimenko and Samir Ahmed.

environmental and social impact of providing light for a household located in Honde Valley during a period of five years (the expected lifetime of the lamp). The solar lamp that has been considered in this study is LEDsafari lamp and the selected location is Samaringa high school.

The LCA focused on evaluating the global warming potential and other environmental indicators that shows the overall impact of the two alternatives. In Table 35 the three most important environmental indicators that have been analysed are presented; the results have been obtained through GaBi, a software dedicated to LCA analysis and inventories. To compare the same functional units the solar lamp has been compared with the number of candles needed to provide the same service for five years (1080 candles).

Table 35 Main results of the LCA analysis

Indicator	LEDsafari lamp	Candles
Global Warming Potential [kgCO2 eq]	0,873	458,0
Human toxicity potential [kg DCB eq]	0,34	93,8
Acidification potential [kg S02 eq]	0,07	3,26

The results obtained clearly show the extreme positive environmental impact obtainable with the adoption of the LED lamp instead of using paraffin candles. These values provide a more than safe confirm of the environmental sustainability of the proposed solution.

In addition, the added value of the LCA study has been providing LEDsafari with a methodology to perform an analysis of the social impact that the solar lamp could have on the local community. Three main areas of focus have been considered in this part: education, health and economic and entrepreneurship. This analysis expects to quantify the impact that the adoption of the lamp could have regarding these three fundamental social areas. Even though the results of the social impact are still not available it is expected that the company in the future will use these guidelines to perform its own analysis which will allow them to furtherly assess the positive impact of their product.

8.3 School bio-digester

A long-term project, which would follow or be conducted in parallel to an education about waste management, would be the implementation of a biogas digester at the school, which would bring an improvement to sanitation system, currently composed of blair toilets (refer Figure 52), and the creation of a canteen service in the school.

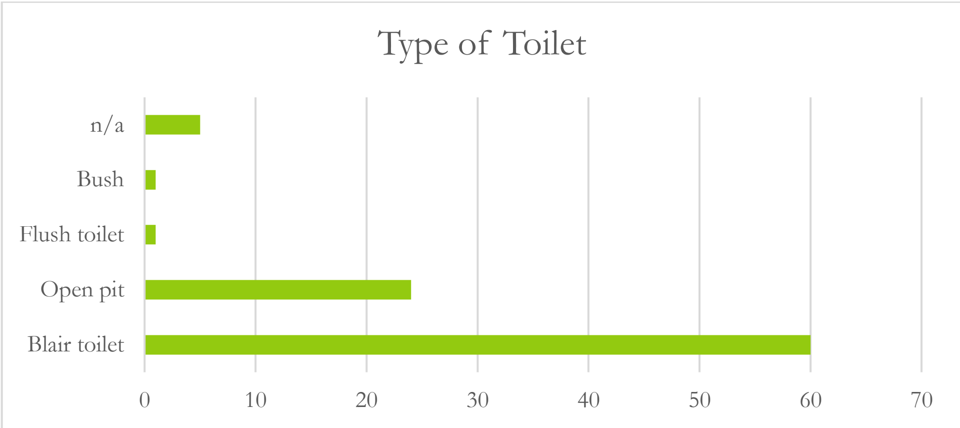

Figure 52: Type of toilet in Ward 10

The two topics are strongly interconnected and are related to the waste management system. In fact, the whole plan is based in the construction of a bio-digester that collecting biodegradable waste human excreta will produce biogas, to be used in the kitchen of the school as a clean cooking fuel.

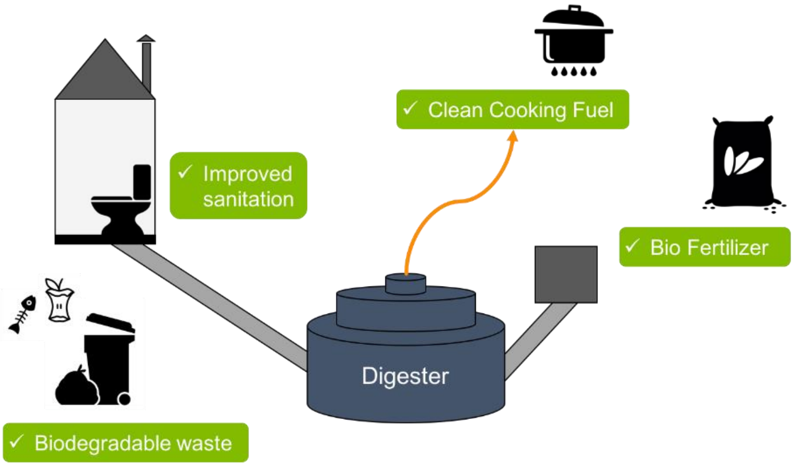

Figure 53: Schema of digester, adapted by Lorenzo Sani

In Figure 53 it is possible to see a schematic explanation of the bio-digester is supposed to work. The substrate is composed by biodegradable waste and human excreta; the biodegradable waste is coming from segregate waste collection in school, from animal dung or food harvesting waste and potentially could come from cattle dung. The toilet system of the school will be connected through piping with the bio-digester, providing a continuous flow of substrate. The use of human excreta can be ambiguous and potentially dangerous, this theme is treated in following section (see paragraph 8.3.1). The produced biogas, usually composed by methane (50-75%) and carbon dioxide (30-50%) (Renewable World, 2016), can offer to the kitchen of the canteen service a big share of the total amount of cooking fuel required in form of a clean cooking fuel, so that it is not endangering the health of the workers. Depending upon the design and operating conditions, the efficiency of biogas cook stoves in developing countries may range from 20% to 56% compared to the 5-15% efficiency of open fire or mud cooking stoves (Surendra, Takara, Jasinski, & Khanal, 2013). A similar project in Uganda, the Kasiisi school biogas digester, has shown that the biogas produced could cover approximately 80% of their fuel needs (The Kasiisi Project, 2017).

Finally, the bio-slurry resulting from the digestion process can directly be used as a liquid fertilizer, or can be dried to become a solid organic fertilizer becoming a perfect substitute for chemical fertilizers, due to its high content of Nitrogen, Phosphorus and Potassium (Surendra et al., 2013)(L.T.C. Bonten, K.B. Zwart, 2014). Anaerobic digestion significantly improves the fertilizing value of livestock manure and other compost by mineralizing organically bound nutrients like nitrogen. In addition, due to its physical properties, the digestate can penetrate the soil faster, subsequently reducing nitrogen losses in the form of ammonia. Agricultural reuse of the digestate from low-cost tubular digesters in rural Andean communities observed a 27.5% increase in potato yields and 8.8% higher forage yields when digestate from a tubular system, fed with pig manure, was applied to the land and compared with unfertilized control conditions. Interestingly, anaerobic digestion has been reported to inactivate weed seeds, bacteria, viruses, fungi, and parasites present in the influent feedstock (Surendra et al., 2013).

One interesting application of bio-slurry is when it is adopted in aquaculture for fish pond fertilization. This kind of adoption has been proven to be particularly interesting for fish ponds whit fish that feed on phytoplankton such as Tilapia and carp cultures (L.T.C. Bonten, K.B. Zwart, 2014). Bio-slurry seems to be a promising replacement for chemical fish pond fertilizers (de Groot & Bogdanski, 2013). The fish pond application could be particularly interesting for Samaringa High, since they have implemented a productive fish pond project where the bio-slurry fertilizer could of great use. Eventually the remaining bio-slurry could be dried and sold at the local market as organic fertiliser.

8.3.1 Food Safety Risk

There are some health issues related to the use of bio-slurry produced from the digestion of human excreta, mostly related to pathogens bacteria (bacteria and viruses) and presence of heavy metals. According to a study published in 2013 by the FAO, if bio-slurry is appropriately treated it reduces the risk of contaminating crops with harmful pathogens as opposed to undigested farmyard manure. However, if not properly treated there is the risk to transmit pathogens to vegetables, animals and agricultural workers (de Groot & Bogdanski, 2013). The addition of human excreta as feed stock might give additional risks for bio-slurry, although literature does not provide a definitive conclusion on that.

The resulting digestate may contain pathogenic micro-organisms (e.g. Salmonella, Listeria, Escherichia coli, Campylobacter, Mycobacteria, Clostridia, and Yersinia) depending on the nature of the feedstock. Although anaerobic digestion can decrease the concentration of harmful pathogens, the by-product is not completely free of pathogens; especially when the substrate is digested under mesophilic temperatures (35 – 40 °C) and at a short retention time. For example it was found that three weeks at mesophilic temperature was enough to destroy hookworms and other pathogens responsible for the diseases like typhoid, cholera, dysentery, and schistosomiasis, but was not enough for the complete destruction of pathogens such as helminth eggs, tapeworm, roundworm, E. coli, and Enterococci (Surendra et al., 2013).

Thus the importance of retention time and digestion temperature become central, increasing the temperature range, thermophilic conditions (50 – 65 °C), this problem is avoided and the digested results sanitized. However, maintaining these conditions of temperature could be a difficulty in the colder seasons requiring the need of an additional treatment. The suggested treatment in this case is composting the slurry with other raw organic matter for a period longer than 40 days; in this way all the pathogens are eliminated and a solid high yielding fertilizer is obtained (Surendra et al., 2013).

The EU standard where animal by-products are present in the feedstock is pasteurisation at 70°C for 1 hour or with thermophilic digestion, with a guaranteed retention of 5 hours at 53°C (Lukehurst, Frost, & Seadi, 2010). Regarding viruses, many common viruses are killed during mesophilic and thermophilic digestion. In summary, anaerobic digestion (particularly thermophilic) can offer a useful means of reducing numbers of pathogens that could otherwise lower the productivity of livestock farms or present a risk to human health (Lukehurst et al., 2010).

Regarding heavy metals, according to the report from FAO, there is no indication that bio-slurry contains more heavy metals than undigested manure. However, there is the risk of heavy metal accumulation in the bio-digester, this problem could be avoided by proper maintenance (de Groot & Bogdanski, 2013).

8.3.2 Impact of the proposal

A cost analysis for a bio digester project is already performed in paragraph 5.4.1 with positive results. In the case of the school proposal the numbers will be similar with the exception that there will not be the need to purchase an electricity generator to convert the biogas in electricity but it will be necessary to build a kitchen and employ someone in charge of cooking for the students.

The investment required for the kitchen should be investigated in order to validate the cost analysis, however it is not expected to be high and to decrease the profitability of the investment.

The result of the application of such a system will obtain results both in the environmental, economic and social areas. Regarding environmental aspects, the improved toilets will reduce environmental pollution by human sewage and the bio-slurry, after proper treatment, will provide a good fertilizer which could increase the yield of the crops and decrease the risk of soil erosion. Additionally, using biogas as a clean cooking fuel will reduce wood or charcoal consumption thus reducing the risk of deforestation.

The economic sustainability is granted by the continuous production of the fertilizer that could be sold on the market and by the very low costs of maintenance of the system. In addition, the canteen service could provide extra revenues to the school depending on the kind of business model that will be implemented (e.g. subsidies or charging a small amount to the student's families for the additional service). Since Ward 10 economy mostly relies on agriculture, an additional value to the digester would be a revenue gained by selling the by-product of the digester as a fertilizer. As such this project would benefit both the school and the local farmers.

Finally, the most important impact of this project is expected to be in the social area, in fact various topics will be addressed by this proposal such as health aspects, raising awareness on dangers by indoor pollution, providing job opportunities for some students, improving the service offered by the school and so on. The most important is probably the fact that involving students in all the steps of the construction of the digester, from the design to the maintenance, will give the opportunity to learn skills that could provide them a future job opportunity becoming biogas technicians. Additionally, the canteen service could offer some other job position to young unemployed locals. The Kasiisi project has particularly shown how providing a meal every day to students improves their interest and their willingness in going to school increasing the overall participation rate. Finally, it has been reported that such projects have attracted many visitors from neighbouring communities, who sought to evaluate the replicability and implementation for their own community (The Kasiisi Project, 2017). The School could host workshop for a certain fee and teach how to conduct such projects.

8.3.3 Similar projects:

Medium and small biogas digesters have been proven to be an extremely interesting resource for clean cooking fuel for rural areas in sub-Saharan Africa. Various no profit organization are promoting their diffusion in small communities and schools. In the context of this project, the most interesting effort is carried out by SNV (Netherlands Development Organisation) which with the National Domestic Biogas Programme in Zimbabwe is successfully developing a market-driven domestic biogas sector with over 150 biogas digesters having been constructed so far. SNV already obtained some important results employing more than 80 workers and improving the life of 1385 rural households. In addition, new appliances are currently been tested in the market, such as refrigerators, heaters and cookers that operate with biogas (SNV, 2016).

As mentioned above, in the Kasiisi project (Uganda) a similar biogas digester has been built Figure 54 , the school constructed a digester that generate approximately 80% of their fuel needs, providing an alternative to wood.

Figure 54: The Kasiisi School Biogas Digester (The Kasiisi Project, 2017)

The construction was done by the students and local agents; human waste mixed with urine would be the prime feedstock for the digester. Other organic materials such as food waste and grass clippings and agricultural waste can also be used. As long as it is maintained properly the system is estimated to last 30 years. Other similar projects can be used as a reference for the viability of this project such as 3 school bio-digesters projects developed in Kenya by WASTE (WASTE, 2015a) (Hojnacki, Li, Kim, Markgraf, & Pierson, 2011).

Finally, a study published in 2013 from South African and Zimbabwean scientists assessed the biogas potential at Nyazura Adventist High School in Rusape (Zimbabwe) a co-educational school with a total enrolment of 700 boarders. The study also considered the production of electricity to cover the energy needs especially in case of load shedding periods. The results suggested that the proposed project was feasible, and it was concluded that the school can produce enough biogas from its feedstocks to support a feasible project (Mukumba, Makaka, Mamphweli, & Misi, 2013b). This project has got many similarities with the proposal for Samaringa High School, especially the location (only 130 km of distance) and the size of the school (700 students). Thus, it is interesting analysing the economic data produced by this study, the total investment required was of 9,957 USD and the payback time was estimated around 2 years (Mukumba et al., 2013b).

8.3.4 Potential partners

For the design, construction and maintenance of the biogas digester a deep knowledge in the field is required in order to complete successfully all the phases. For this reason it is strongly suggested to look for a partnership with an organization which is already holding a good experience in biogas engineering. The following potential partners have been identified:

- Netherlands Development Organisation (SNV) which already built some similar projects I Zimbabwe,
- Hivos after developing biogas programmes all over the world in 2015 launched a biogas project in Zimbabwe where 184 digesters were constructed and 74 masons trained. The Zimbabwe programme aims to establish a vibrant biogas sector, which will benefit more than 67,000 households, in five years (Hivos, 2015).
- Waste has got experience in waste management and specifically biogas digesters with projects in Malawi, Zambia and India (WASTE, 2015b).

8.4 Recycling

AS previously mentioned, there seems to be no waste collection system in Ward-10 and no authority capable of managing waste in Honde Valley. Figure 55 depicts some of the waste and waste collection attempt that were observed during the field trips in Honde Valley.

Figure 55: Waste collection bins in Honde Valley

During the field trip, it was notice that the "Aberfoyle Lodge" tea plantation closed compound does segregate waste into categories – plastic, metal, glass, and compost. They do so in order to meet obtain certificates of international environmental standards, namely UTZ from Denmark and the Rainforest Alliance which are related to the manufacturing industry. Thus, metal is collected and sold to an external agency while and compost is used to fertilize the plantation. However, the plastic is incinerated and glass bottles are buried in pits within the company closed compound.

The benefits of investing in recycling infrastructure and processes have been found to provide regional economic stimulus from new collection and processing jobs and increasing the local market manufacturing business. The following steps are considered a general framework for developing a regional rural recycling program.

- Determine the current level of recycling and to identify the types and quantities of recyclable materials in the regional waste stream. The potential recyclables should be evaluated by estimating the specific total weight compared to the total weight of the waste stream.
- Establish a committee that includes members from the private and public sectors, non-profit organizations and the general public who have recycling experience. This committee will evaluate various aspects of the recycling market as well as policies that could be developed to facilitate this industry.
- Assess the availability and level of demand in in order to determine which materials will be recycled. Identify local processors, manufacturers and other recycling entities that could be potential partners/customers. The Environmental Management Agency (EMA) of Zimbabwe has an extensive list of recycling companies (see APPENDIX) that could be contacted to evaluate which facility would be the most effective buyer for the waste collected in Honde Valley. Since rural areas may not have local manufacturers that accept recyclables it is important to explore potential buyers on a national and international scale. Depending on the material and quantity a large industry might be interested in purchasing the raw waste collected.

It is recommended to consider Coop business model since a group in consensus has both more product to offer as well as a stronger marketing power. This strategy helps them to achieve higher market value, to obtain better transportation rates and to increase the types of materials accepted by the manufacturer. For example, some end-users will provide free transportation to their factory if a region can supply consistent quantities.

Cooperative marketing requires centralized management. The cooperative's daily administration can be undertaken by staff from a "lead" city or county, a solid waste authority or a non-profit organization. State or federal grants typically provide funds for establishing market coops. Membership fees, technical assistance consulting charges and revenue from the sale of recyclables also are used to fund cooperatives (Siniard Stinnett, 1996).

As can be seen in Figure 56 , the questionnaire revealed that most of the respondents were not interested in paying for waste disposal. However, the majority is willing to work in a job related to waste. This factor is important since it was not known if members of the community would be willing to implicate themselves in jobs that relate to waste management.

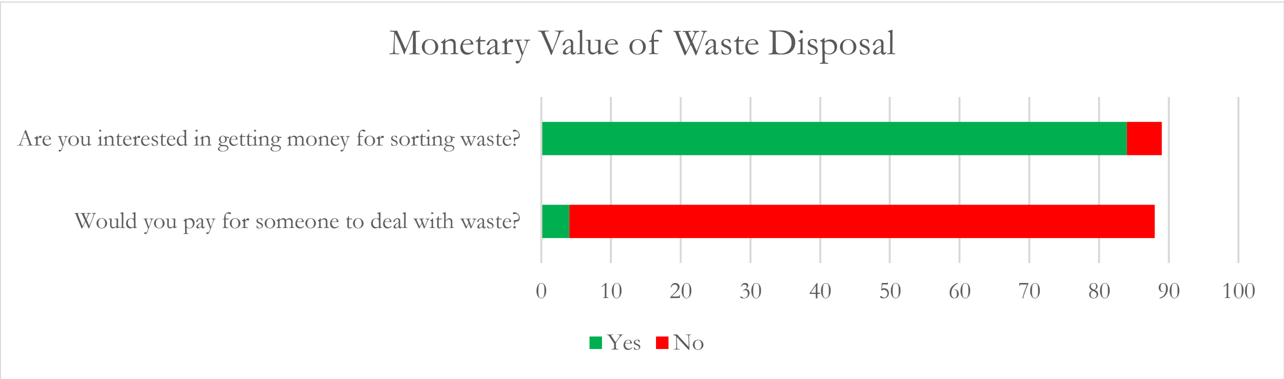

Figure 56: Questionnaire results for waste management monetary value

8.5 SWOT Analysis for Waste Management

The following Table 36 describes some of the key advantages and discrepancies that need to be addresses in order to effectively implement the waste management proposals

Table 36: SWOT analysis for waste management

<table>
<tr>
<td>Strength
Resources (waste) readily available and cheap.
Interest of many local residents to work in this field.
Novelty - not many competitors in this area.
Multitude of potential income source -local authority can pay for waste management services, recycling companies can pay for the raw waste material.
Local farming can buy the bio-slurry fertilizer.
Producing fuel locally for self-sustaining purposes which can reduce cost of purchasing fuel.
The students already receive basic waste management education.
Many residents separate organic waste for personal compost.</td>
<td>Weakness
The condition of the roads make transportation in small vehicles is difficult.
Local inhabitants do not have waste collection and separation habits.
No waste collection facilities on the premises.
Unexperienced work force – will have to provide training.
No known current waste management network operating in the region.
Need of initial capital investment for bio-digester</td>
</tr>
<tr>
<td>Opportunity
Employment/income creation.
Building a recycling facility that can process the raw material into a finished product (plastic fences, boxes, etc) to increase the monetary value of the sold product.
Increase working skills of some local residents.
Partnerships on the National level with agencies such as EMA can increase the visibility and reputation of Honde Valley.
Remediating to some health hazard consequences related to local waste accumulation and incineration.</td>
<td>Threat
Lack of participation from the local residents that do not see the immediate benefits of waste collection.
Mistrust in the Cooperative business model.
No clear standards for waste management.
No authority to regulate waste management in higher regional levels.
Bio hazard if human excrement not properly treated when producing a fertilizer.
Improper maintenance and use of the bio digester</td>
</tr>
</table>

9 Transport and infrastructure

In this chapter, the description of transport and infrastructure proposal is presented followed by a cost analysis of the works required for the selected roads.

9.1 Do-nou technology for roads improvement

The improvement of the rural roads in Ward 10 could draw benefits to the whole community, reducing the time needed to reach Hauna market, making the access to Samaringa clinic easier and generally upgrading the travel conditions of the inhabitants of Ward 10.

Typically, the upgrade of roads is an activity that requires a high initial investment but ensures little to no revenues. Therefore, the challenge for an African country, where public money is often limited and the government is occasionally present in rural areas, is to find a way that does not use considerable resources in terms of money and equipment required. In addition to this, an ideal solution has to comprehend the initiative of the community. This can only be done through simple technologies and locally available material.

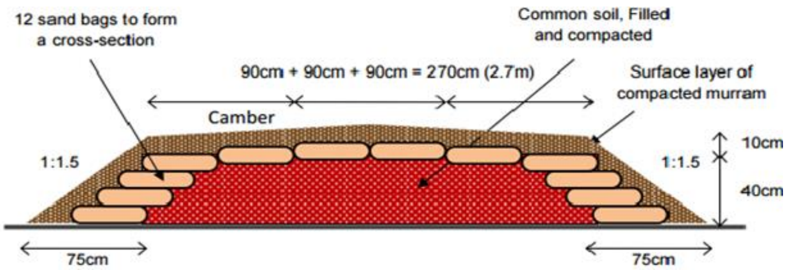

Figure 57: Cross Section of a Road Improved with "do-nou". (Agency & With, 2014)

A method, that has already been tested and applied in African rural communities, exploits do-nou, the Japanese term to indicate soil bags[18] and its scheme can be seen in Figure 57.

Do-nou, soil wrapped in bags, has the property of having a high comprehensive strength and, therefore, it can be used to reinforce the base course of the road. Road improvement made with this technology does not require any compaction equipment and can be easily taught to community members, that can actively participate in the works. Moreover, roads improved with do-nou bags have proven to prevent deformation of the road and to be able to bear the typical traffic loads of rural African communities. The bags used for the described technology usually contain crops, fertilizer, sugar, flour and are commonly made of polypropylene or some other similar synthetic strong fibres. Sisal bags are also a great solution for this technology. These types of bags are easily found in rural areas and are typically very cheap. Furthermore, they have been submitted to tests for do-nou applications in laboratory, where their tensile strength has been measured, and placing and driving test have been conducted showing that do-nou effectively reduces the compression of the base course subjected to the traffic load (Agency & With, 2014).

Once the target road or road section is identified, all the mud, if present, must be removed before starting the excavation of the area. The next step is the filling of do-nou bags with soil or sand. After closing the bags tightly, they are laid down on the road course with a specific disposition layout, that can be observed in Figure 58. A coating layer of soil is then placed on the layer(s) of

[18] A video description of the technology is available at: https://www.youtube.com/watch?v=AqTrkM8PAgI

bags in order to protect do-nou from deformation and to provide a smooth passage for combis and bicycles. The compaction of the coating layer of soil can be done manually or by using the traffic load of the passing vehicles.
Moreover, the cross-section of the target road can be designed so that water would flow on the sides of the road to avoid the formation of grooves on the pavement, as it can be seen in Figure 57.

As it can be expected from an activity of roads improvement, the implementation of do-nou is not a fast process. The already existent applications in Kenya showed that the daily productivity with a team of 20 people is of 30 meters. Limitations on the technology are represented by steep sections of the road. While do-nou improvement has been confirmed to be effective for roads flat terrain or gentle slope, the technology is not applicable to steep sections, where the cover layer has been found to be rapidly washed out by rain water, exposing the bags to damages (Fukubayashi & Kimura, 2014).

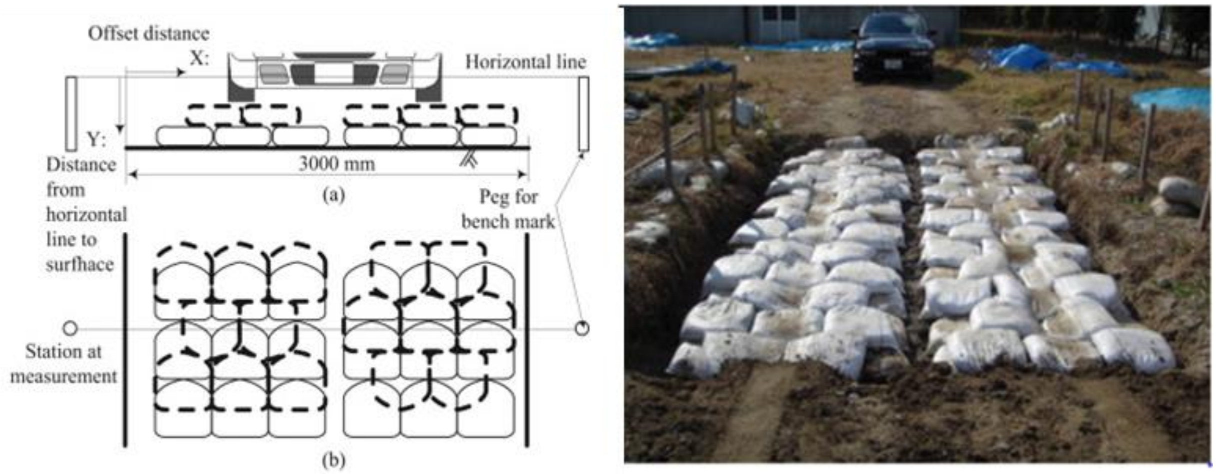

Figure 58: Front section (a), plain section (b) and a picture of the disposition of "do-nou" during the driving tests. (Agency & With, 2014)

In Ward 10, several roads could benefit from the upgrade of the conditions that do-nou can provide. During the field trip of December 2016, four important paths were noticed as key transport routes: the road that brings to Samaringa Clinic, the road that leads to the paved street towards Hauna market, the path that reaches the water source and the road to access the valley. These roads are of primary importance and have some portions that could be improved with the do-nou methodology.

9.1.1 Samaringa clinic access road from Masere

The main activity of Samaringa Clinic is the delivery childbirth. Although, since the access road is in very poor conditions, pregnant women have to be hospitalized when the date of delivery approaches. A detailed satellite view is available in Figure 59.

Figure 59: Satellite view of the Samaringa Clinic Access Road. (OpenStreetMaps, 2017)

This is due to the inability to reach the clinic on the birth day created by the poor road condition. Therefore, the improvement of the access road, paired with a combi bus transport service could change the situation. Unfortunately, some portions of this road present a slope and, thus, a more accurate feasibility study is necessary to assess the suitability of the improvement for the different street portions. Nevertheless, the access to the clinic seemed a sensible issue to the interviewed local people, that complained about the difficulties that they have to face in the transport of the patients from the village to the clinic and from the clinic to more efficient hospitals. Thus, it would be important to assess the feasibility of do-nou on this road.

To guarantee the access to the clinic, the road between Masere Business centre and the end of the access road is considered. The distance between the two points is 2.7 km and it crosses a river, so a bridge is present. A satellite view of the road is presented in Figure 60.

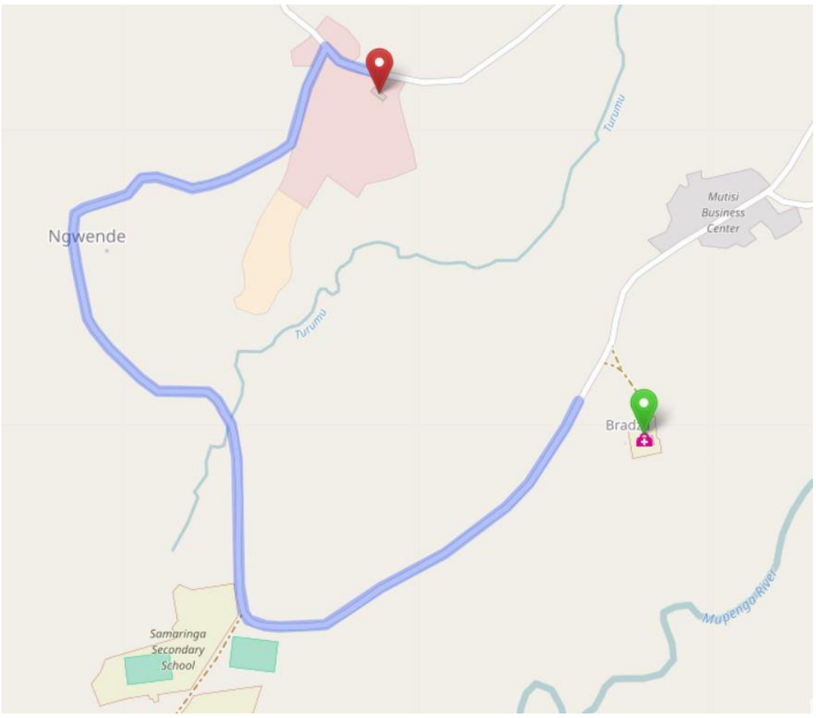

Figure 60: Road between Masere Business Centre and Honde Clinic. (OpenStreetMaps, 2017)

9.1.2 Road to Hauna Market from Masere

Hauna has almost reached the dimension of a town and the market area offers better facilities compared to other business centres, such as transportation services with combi buses to other major cities, a supermarket with more and better products availability compared to the local small shops and several stands that sell fruits, vegetables and other goods as it is visible in Figure 61.

Figure 61: Hauna Market stands. Photographer: Marco Occhinero

The road to Hauna Market Area is paved in the final section. However, in order to access this, combis have to cover an unpaved section of road, closer to the village that can be seen in Figure 63. The length of the unpaved part, that links Masere Business Centre and the tar road for Hauna is 8.4 km, and a satellite view is available in Figure 62.

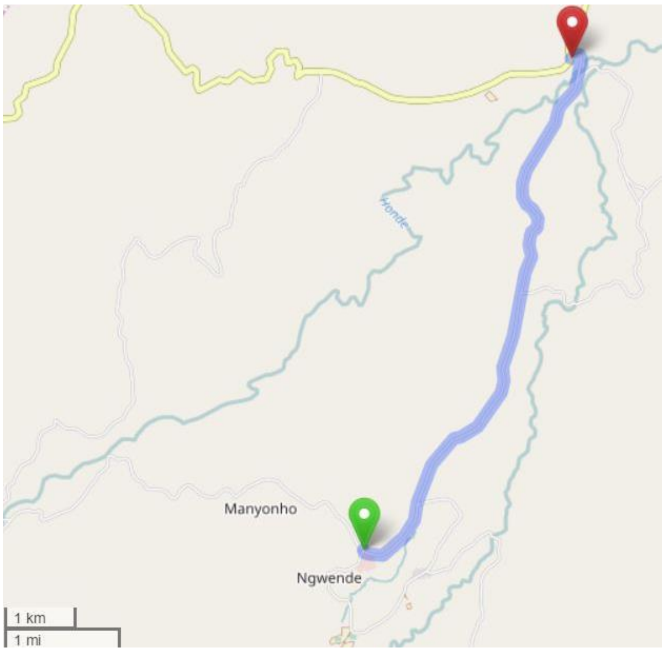

Figure 62: map view of the unpaved road from Masere to Hauna. (OpenStreetMaps, 2017)

Figure 63: Unpaved road for Hauna Market. Photographer: Marco Occhinero

The improvement of the unpaved section of the road could reduce travel time, especially during the rainy season, and allow combis to increase the number of roundtrips. This would create the opportunity to increase both the mobility opportunities of the inhabitants of the village and the business of combi drivers.

During the Honde Valley trip the whole team has noted that combi buses often carry more people than the maximum capacity allowed, resulting in a situation of poor security conditions and comfort inconvenience, other than an overly degradation of the condition of the combis.

If the possible number of back and forth trips will be increased by an upgrade of the road conditions, it is possible that the passenger would be more equally divided between the trips, resulting in a fair number of passengers for each trip.

9.1.3 Road to the water source and to the big water tank

Ward 10 water supply currently entirely depends on a single water source. The water source is located on a higher level with respect to most households, within a mountainous area, so that it flows naturally down in the valley. The water is canalized into a pipe by the means of a small dam. The location of the intake of the pipe can currently be reached by motorized means of transport only until a certain point of the uphill road. After this point, the road becomes a footpath and it is only accessible by walking as it can be seen in Figure 64.

Figure 64: Foot path that leads to the water intake. Photographer: Marco Occhinero

The water intake has to be freed of the sediments brought by the water flow up to three times a week during the rainy season, and the troublesome access way creates difficulties in this operation, making this process long and hard. Additionally, some of the access footpath sections are steep and are not suitable to be proposed for an improvement with do-nou. Moreover, another problem regarding the water source and its proximity is the importance that this location has from a spiritual point of view for the community. The whole area is kept under the surveillance of a woman that has a role of spiritual guidance for the community and grant access to the source during the visits. Since this problem falls in the range of social studies, the group still has not found any specific way to solve it or by-pass it, but it has to be taken into account for every operation that has to take place close to the water source.

Nonetheless, the upgrade of the water intake and his maintenance would be facilitated by an improvement of the access road. Further studies should be made on what percentage of the footpath could be improved, taking also into account the time and the human resources required. This feasibility studies should highlight whether it would be convenient to apply this specific solution to the water intake access footpath. However, it should be considered that the access for motorized vehicles to the water intake point would make its development and further maintenance easier. Therefore, the best approach consists of starting with simple improvement as, for example, an enlargement of the narrower parts of the footpath (refer Figure 65), so that it would at least be accessible during the dry season, when the roads are not muddy and slippery.

Figure 65: One of the narrow portions of the water intake access foot path. Photographer: Marco Occhinero

In the short term, if the path for the water source cannot be realized without complication, it would be significant to pave at least the road towards the big water tank. In fact, the big water tank also needs continuative maintenance and surveillance, being fundamental in the security of water supply of the village, in particular during the dry season. The big water tank is located on the way to the path for the water source, so it can be considered a first investment, to be extended if the economic and technical feasibility will be proven. The distance between Samaringa Secondary School and the main water tank is 1.6 km, and a satellite view is available in Figure 66.

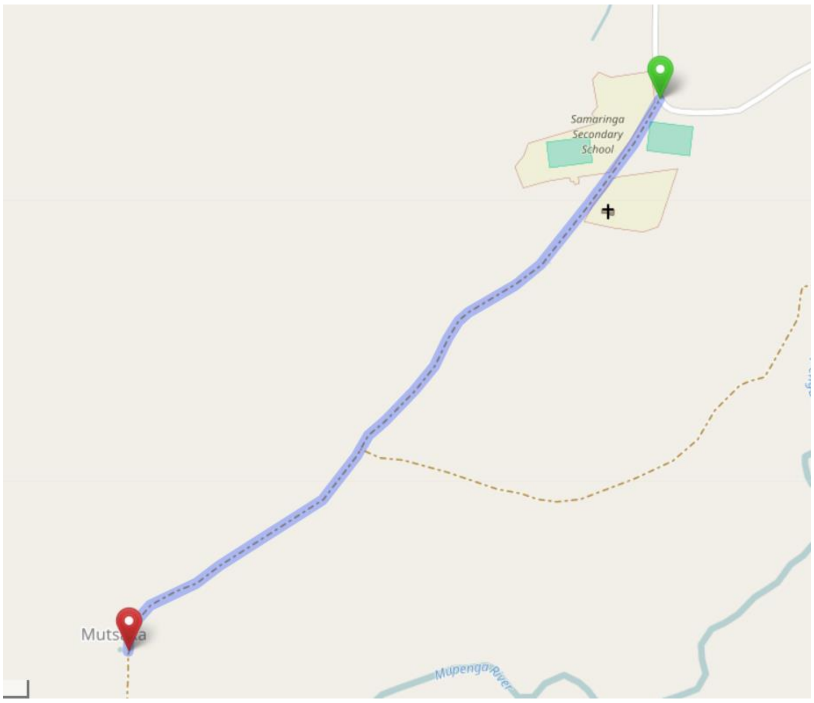

Figure 66: Road to reach the main water tank from Samaringa Secondary School. (OpenStreetMaps, 2017)

9.1.4 Road to access Honde Valley

There are several accesses to Honde Valley: from Mutare it is possible to reach directly Hauna using a tar road, but in order to access directly Ward 10 from Harare, the fastest way is an unpaved road. The conditions of this road are not extremely bad, but probably they are dependent on the season and are variable in time, so it is recommendable to intervene in order to guarantee a fast and safe access, coming directly from the capital of the country. The priority of this intervention is probably lower, since there is already the existing access from Mutare: however, several smaller villages of the area can benefit from the implementation of this road, that has the potential to facilitate transports to a huge portion of Ward 10 population.

The length of the unpaved part is 27 km, in Figure 67 a satellite view is presented.

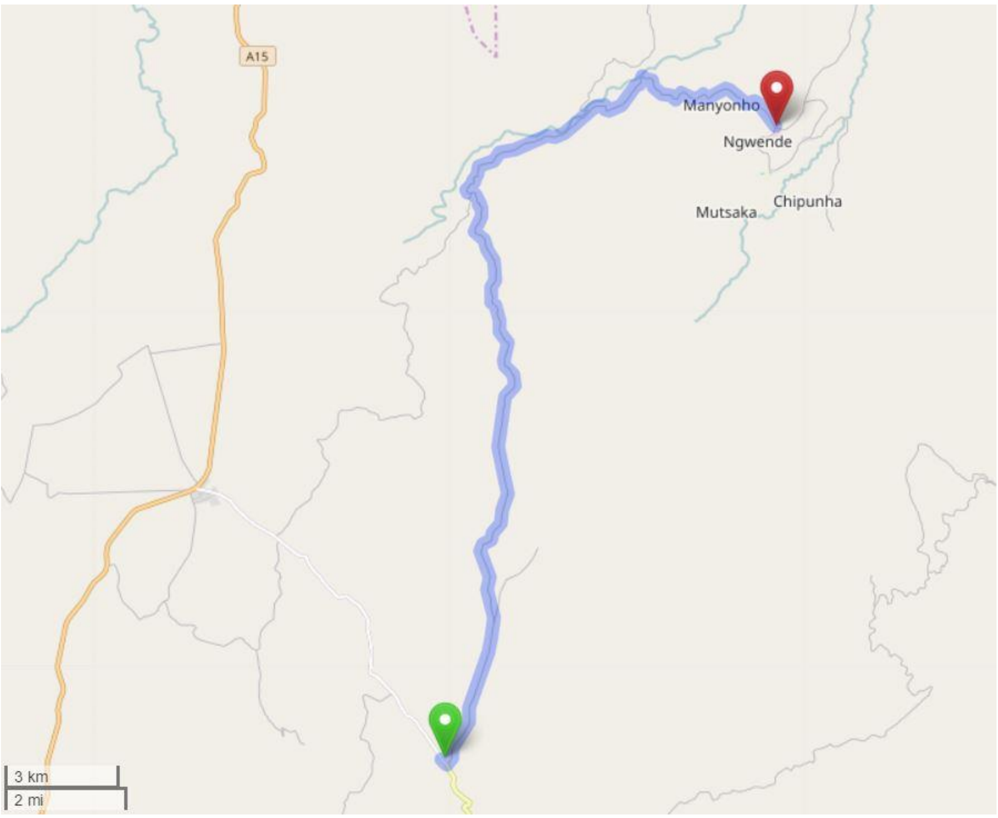

Figure 67: Road to access the valley, passing through several small villages of Ward 10. (OpenStreetMaps, 2017)

9.1.5 Involvement of the Community

An indirect benefit brought by the implementation of the do-nou technology is the high involvement of the community in the improvement works. The methodology is based on teaching the community members skills that should be actively used to participate in the improvement and maintenance of their roads. This strategy has been already proven to empower people in communities in Sub-Saharan Africa. The statistics of the positive responds can be seen in Figure 68 (Fukubayashi & Kimura, 2014).

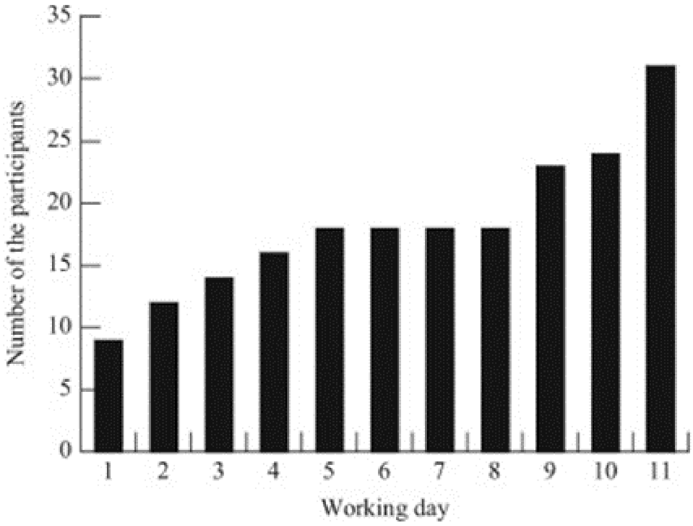

Figure 68: Trend of the number of participants during demonstration in Kenya. (Fukubayashi & Kimura 2014)

Prior to the start of working, demonstration sessions of step-by-step operations have to be organized in the community, in order not only to teach the community members how to work on their own, but also to demonstrate the validity of the solution and the benefits brought.

In fact, in previous applications it has been noted by the groups of people proposing do-nou improvements that the communities would be sceptical at first, not believing that the upgrade would be effective enough or that it would not be effective at all. Typically, after an initial period of scarce participation, the interest of the community members in do-nou implementation would start to grow and more people would want to be involved in the works.

9.1.6 Cost Analysis

In order to assess the cost in USD/m of the do-nou improvements, some preliminary assumptions have to be made. The major part of the whole expenditure is related to the bags, while other minor costs are to be faced in the collection of additional materials like shovels, pick axes, laces to close the bags and containers to collect soil before filling the bags. Other than this strictly necessary pieces of equipment, tap meters and spirit levels can be employed if available to improve the quality of the work.

The bags can be found in online stores in stocks of 1000, but they can typically be found locally in markets and also can be recycled after being used for their original purpose of containers. The cost of the bags in the online shops is between 0.38 USD/bag and 0.93 USD/bag, depending on the size. The local price is not precisely known, but taking into account the fact that recycling of old bags is not only possible but advisable, it has been chosen to consider an average price of 0.50 USD/bag, but there is probably potential to acquire the bags at a minor price. While bags are found typically in different sizes, instructions for the placement of the bags recommend to fill them up until a fixed height of about 50 cm and close with a lace. Therefore, 50 cm in the road direction will be the considered length of each bag laid down on the course of the road.

Regarding the number of bags that is needed to fill the entire width of the road, this figure change depending on the actual width of the main course and on the width of each bag. Consequently, an average of six bags per single lane has been considered for this analysis.

Hence a first estimation of the cost of the required bags per meter of improved road can be done:

$$6\frac{bags}{row} * 2\frac{rows}{m} * 0{,}50\frac{\$}{bag} = 6\frac{\$}{m}$$

The cost of the additional equipment is a single-time expense and in Europe would account for about 300 USD for a set of 5 shovels (30 USD/each), 5 pickaxes (24 USD/each) and 2 spirit levels (15 USD/each), that would allow at least 10 people to work simultaneously on a road. These prices are to consider as an estimation on European prices, but the figures can probably be decreased by acquiring the equipment locally. However, given the lack of proper data on the local prices, the European ones have been taken as reference. Therefore, 300 USD can be taken into account as fixed costs for a 10-people team.

Since the advancement speed of the process calculated from previous application of this technology is of about 30 meters of road every day with a team of 20 people, the costs to be sustained for the upgrade of 100 m of road in about 3 days would be of 600 USD for the purchase of bags plus other 600 USD for the purchase of the working equipment, that can be reused for future applications, for a total of 1200 USD.

This estimation is to be considered as a worst-case scenario and therefore, with the help of local associations like FDC, there could be the potential for a sensible reduction of the costs (e.g. recycling of old equipment or working with a “bring your own tool” policy).
In Table 37, the summary of the proposed roads is presented according to the priority of implementation.

Table 37: Summary of the proposed road improvements, with projection of costs and time needed for the implementation

Road	Distance [km]	Cost [USD]	Estimated time (20 people team)
Samaringa Clinic – Masere	2.7	16,200	81 days
Hauna – Masere	8.4	50,400	252 days
Masere – big water tank	1.6	9,600	48 days
Road to access Honde Valley	27	162,000	810 days

In conclusion, it is believed that the implementation of do-nou technology in Honde Valley could bring several benefits and bring profit the community. The poor condition of the roads is widely considered as a key issue of rural development by various ONGs that have worked in sub-Saharan Africa. The community involvement created by this solution is also directed towards the escape from the social immobility situation in which the community is trapped as a result of the extreme poverty.

10 Honde Valley Energy Centre

10.1 Objectives

There are few primary and high secondary schools but still a lot can be done to promote and encourage people towards education. Making people pay for certain services which they utilize can be challenging, but it can be achieved through education and community mobilization. This current situation illustrates that a huge margin of improvement is available in Honde Valley Ward 10 and the warehouse could help provide ways to ameliorate this current situation.

The goal is to utilize the unutilized building in a useful way which would be beneficial for the rural community. The people whose monthly incomes are not high enough to take the electricity connection from the national grid, can still have access to affordable and accessible basic lighting and electricity services through this model, where all the services are housed in one centre proximate to the community.

Another goal is to develop a sense of community in the people, by providing ways to interact with each other. The promotion of education and the enhancement of the employment opportunities are also the auxiliary objectives.

10.2 Offered Services

The key of the community building is the provision of services which the people are willing to use. Services of focus are tools, applications, devices or needs which cannot be satisfied by the majority of people individually. Moreover, the energy centre will focus on services which empower the community itself, e.g. a venue for events, or a shared television room, where people can watch television together. The importance of providing shared facilities in a community can be deduced from the historical development of parish halls in villages, where the common building was not only used to encourage a dialogue in between the community members, moreover facilities, like rooms and kitchen were used for different events and occasions. This concept as a basis has the potential to be implemented successfully in Ward 10.

The concept is already described in literature and can be easily adapted for the situation. Muchunku et al. shows some elementary services and their successful incorporation in a community building, or "Energy Centre" (Muchunku, Charles; Ulsrud, Kirsten; Winther, Tanja; Palit, 2014). Figure 69 shows the different offered services: TV room, battery charging station, lantern rental and a public office. These ideas have been implemented and complemented with further possible services which could be requested by inhabitants of Ward 10.

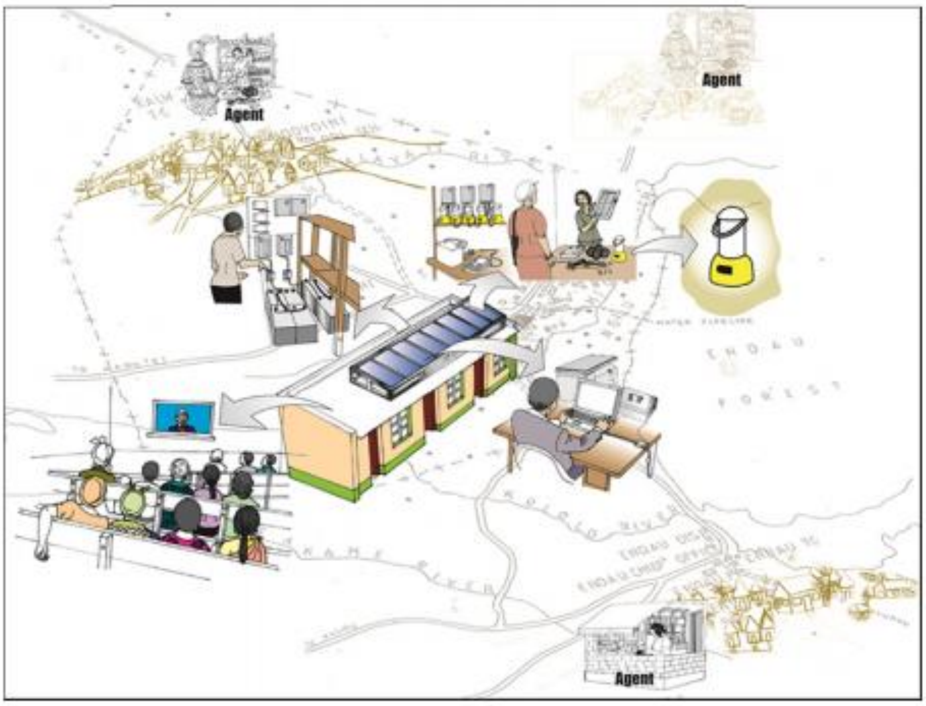

Figure 69: Building design of the Energy Centre (Muchunku, Charles; Ulsrud, Kirsten; Winther, Tanja; Palit, 2014)

Battery Charging Station/Lantern Rental

The Energy Centre implements a model of the Battery Charging Station, which is described in 5.1. The geographical central position and availability of electrical grid connection at the warehouse offer a suitable condition for the provided service, which requires a physical place for storage and charging of the batteries. Moreover, an organisation is pre-requisite to take care of the issue in conjunction with the expenses.

IT and Internet access

Providing computers with cheap internet access is crucial for lifelong learning, together with encouraging free education. At the moment, the only public computer access is in the primary school and its usage is restricted for school students. The proposed service is aiming to extend the offer in the Honde Valley, by implementing the proven concept of internet cafe and providing two computers with internet access, complementing the typing and printing facility.

Common room/Television

The TV room is the place where TV and video shows would be screened, with the aim to develop a sense of community within the people by watching the TV together. Given that, the cost of this service is kept considerably low. The room is also envisioned to hold meetings, workshops and trainings for awareness, and experience sharing with the rural community.

Sanitation

In dialogue with the already existing community building committee, sanitation has to be identified as a service urgently required. The current water situation is not sufficient in order to provide farmers the possibility to wash their hands after they have used fertilizers. This service is usually implemented in other central places and was directly asked by the committee. Therefore, the possibility to provide clean water access has been identified as an appealing future service. Initially, the service is planned to be restricted to a sink and a small shower. Appropriate charges will be collected for the use of water, since it is a scarce source. The aim is to implement the charge with the use of other services.

It is standing to reason to install a water tank in order to guarantee a steady and independent supply of water at the energy centre. Moreover, during the rainy season the water tank can be filled utilizing the roof of the warehouse. Respective methods of rainwater harvesting have been described earlier in this document.

Electricity Access

The main barrier in the Honde Valley for proper electricity access is the fact that a grid connection costs at least $95. For many people, especially those without a regular income, this expense is too big. However, the access to electricity is still a very important issue and consequently will be provided in the Honde Valley Energy Centre. The fee for using the electricity will be in the same margin as from the public grid with an own meter. The possibility to implement a fee in a general Energy Centre membership can be considered.

An attractive possibility to lower the overall cost of electricity, would be the implementation of Solar Photovoltaic on the rooftop of the warehouse. Thus, the hours of electricity consumption can be produced through PV. The main intention would be to use the electricity ad-hoc, thereby the possibility to sell the electricity to the grid is not considered.

Tool sharing

The concept of sharing economy has become very popular lately and in case of Honde Valley, it can be an attractive way to empower the community behaviour. However, the concept is only successful if the community is ready to share with each other. Therefore, this service needs to be implemented carefully, because the community reaction and acceptance needs to be evaluated. Tools of focus are devices which are mainly needed temporarily, e.g. construction tools, drill, saw, screwdriver etc. Once the service is accepted and widely used, further investments can be valued asking for feedback of the local people. It is important to ask which tool they might need and how often they are planning to use it. The results need to be saved and published publicly, so the paying members can see if the investment was justified or not. Otherwise, there is the risk that tools are purchased which are barely used.

Workshop/Mechanical Store

The workshop is a public room, where people can come and work with the existing tools. It will complement the offer of tool sharing, by providing work benches and stationary tools. The workshop is supposed to provide all necessary tools to build or repair. In future, it can be considered to extend the workshop to a mechanical store, where metal work can be performed.

10.3 Warehouse transformation

Currently, the warehouse only has one big hall. It has been proposed that, after transformation of the warehouse, the energy centre would have separate rooms to offer separate activities and services. The number of rooms would be 7, and the proposed layout of the building is shown in Figure 70.

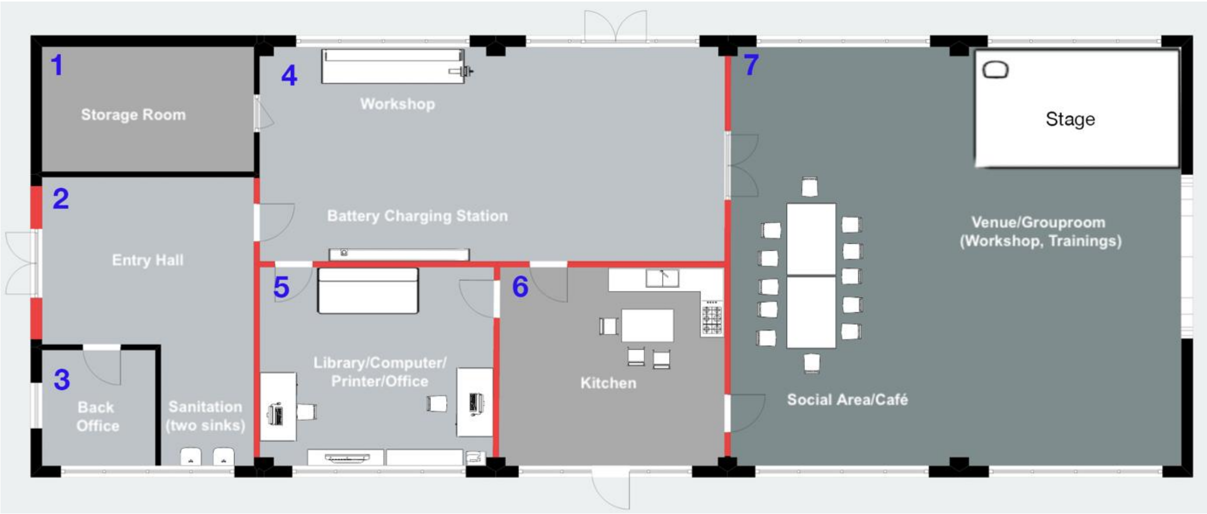

Figure 70: Proposed retrofit of the existing warehouse in Ward 10

The existing structure has been analysed based on photos, made on both trips and satellite imagery. A detailed plan of the existing warehouse was the result and aided for a detailed distribution. The walls marked black in the floor plan are already existing. This includes the outer walls, the windows, the storage room and the back office. The red marked walls need to be constructed for the division of the main hall. The proposed distribution aims for a minimal effort to increase the usable rooms. It is imperative that all doors should have the possibility to lock and escape the building in case of emergency, e.g. a fire. The entrance gate on the left needs to be converted in to a conventional door. The room allocation and list of required things is provided in Table 38.

Table 38: Room allocation in the Honde Valley Energy Centre.

	Room	Usage	Requirements
1	**Storage Room**	This room will be mainly used for shared tools and materials which can be used for workshops.	Lighting in the room, lockable door
2	**Entry Hall**	The entrance to the building will provide a whiteboard with announcements, e.g. job offers or things to sell. A sink gives the possibility to wash their hands.	Whiteboard, sink, water access
3	**Back Office**	This will be used for the administration of the Energy Centre. Respective documents can be stored here. People also can give their devices to charge. The devices are supervised by the administrator, working in the office. This person will also take care about the correct allocation.	File cabinet, desktop, chair, outlet, power strips
4	**Working space**	A work bench with tools gives the possibility to work or craft something. The room is mainly used to store and charge the battery for the battery charging service. The room can serve to store heavier tools or devices, which don't fit in the storage room.	Workbench (table), rack, tools, outlets
5	**Library**	The IT room and Internet Point - where typing and printing service would be provided through two desktops equipped with computers. Additionally, book shelves will provide some literature.	Outlets, internet access (router), two desktops, two computers, book shelves, books, printer,
6	**Kitchen**	A simple kitchen unit with the basic equipment for cooking and dining. An electric kettle can provide hot water for coffee or tea.	Water access, sink, electric stove plates, shelves, pots, silverware, plates, table, chairs, electric kettle
7	**Venue**	The venue can be used for all kind of events. Ideally, it will provide a small sound system (speaker and microphone) and a small stage, which can be made from wood. Moreover, tables and chairs for a decent amount of people will be provided.	Outlets, speaker, microphones, tables, chairs.

10.4 Organisation

The existing community building committee will be no longer adequate to implement a financial acting company. New structures need to be established ensuring a transparent administration, financial control of funds and payed fees, and guaranteed employment.

The proposed organisational structure, which is shown in Figure 71, derived from already applied structures in non-profit organisations consisting of a board and a supervisory board. All fee-paying members and customers of the Honde Valley Energy Centre are electing members for the supervisory board. Ideally, these are people who represent the needs of the members and act in their interest. The supervisory board may consist of up to 10 members. These members elect once a year the board, which consists of at least one manager, one treasurer and one maintainer. If negative development occurs, the supervisory board is able to intervene. Aim of this organisational structure is to generate transparency and control for the fee-paying members to ensure an optimized usage of funds. Investment can only be done with the agreement of the supervisory board.

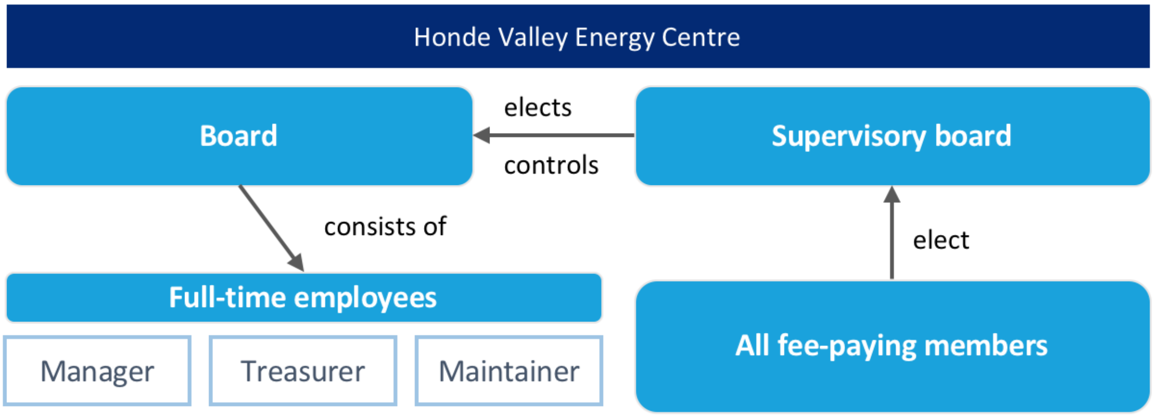

Figure 71: Proposal of an organisational structure for the Honde Valley Energy Centre

10.5 Cost Analysis

In the following the costs and the involving assumptions for the individual services have been discussed. Further details have been provided in Appendix 15.1.

10.5.1 Battery Charging Station/Lantern Rental

Within the cost analysis of the Energy Centre only the lantern rental service has been considered, since this was the approach chosen by Muchunku et al. (Muchunku, Charles; Ulsrud, Kirsten; Winther, Tanja; Palit, 2014). In this document, another very prospering and cost-competitive proposal of the BCS has been identified which can be implemented in the Energy Centre as well (see chapter 5.1).

10.5.2 Mobile Phone Charging

Mobile phones charging price would be set at the rate of $0.19 per charge. For the people who could not afford to pay for taking the expensive electricity connection from the grid, this could still be a viable option to charge their mobiles. This service is incorporated in the energy centre by keeping in mind that most of the people could have mobile phones, even if not in possession of the electricity connection at their homes. Therefore, it has been projected that a major portion of earning of energy centre would come from this service. Usually, the cost of charging a phone is under a dollar per year. However, it has been identified that this service will cross-finance other services.

10.5.3 IT services and Internet point

The IT room has few computers and laptops along with a printer. The following IT services would be available at the energy centre:

- Typing of the important documents of the energy centre to make a record of the sales and buying which would help in future to improve the services provided.
- Printing of official documents.
- An Internet access point would be placed in the same room and would be a good source of earning for the energy centre. The cost \$0.20 per hour has been set for using the internet.

10.5.4 Multipurpose Room for general hire and TV/ Video shows

Table 39 shows initial rates proposed for hiring the multipurpose room.

Table 39: Initial rates for hiring the multipurpose room

Duration	Hire with electricity use	Hire with no electricity use	Educational purpose
Half day hire (5hours before 6pm)	\$ 4	\$ 2	\$ 1.5
Full day hire (9am-7pm)	\$ 8	\$ 4	
Evening hire (6-9pm)	\$ 4	-	

The energy centre would screen TV/ video shows, with the following initial prices: Prices for watching shows available in Table 40.

Table 40: Prices for watching shows

Shows	Prices
Afternoon shows/ news	\$ 0.045 per person
Evening shows/ news (@9:30pm)	\$ 0.045 per person
Evening movie (7-9pm)	\$ 0.18 per person

It has been decided that the movies would be screened on weekends as per the demand of the people. These prices have been kept low to encourage more people towards this activity. Given the very low price of a single use, packages of multiple uses (e.g. a carnet of 10 uses) could be set up.

10.5.5 Yearly Revenue generation and Expenditures

The Table 41 demonstrates the yearly cash flow along with the rates set for each service. The major portion of earning has been anticipated to be received from mobile charging and multipurpose room. The detailed explanation of calculations and assumptions can be seen in Appendix 1: Cost Analysis of the Warehouse.

Table 41: Yearly Revenue generation

	Income sources	Cash flow per year	Cost charged for each service
1	From Lantern charging and renting	$ 1,734	$ 0.19 for 2 consecutive nights
2	From Mobile charging	$ 6,935	$ 0.19 per mobile charge
3	From Multipurpose room	$ 6,699	$ 2-8 depending upon the time of hiring with and without electricity
4	From IT service (printing and typing)	$ 270	$ 0.27 per page
5	From internet service	$ 3,650	$ 0.20 per hour
	Total yearly cash flow	**$ 19,288**	-

Table 42 demonstrates the yearly expenditures at the energy centre. However, the detailed calculations have been shown in Appendix 1: Cost Analysis of the Warehouse.

Table 42: Yearly expenditures at the Energy Centre

	Expenses		Cost expenditures per year
1	Salaries		$ 12,000
2	Consumables	Printing Paper, A4 rim	$ 120
		DSTV subscription	$ 384
3	Internet service		$ 1,416
4	Electricity bill		$ 2,400
5	Maintenance fund		$2,000
	Total yearly expenditures		**$ 18,320**

These projected results clearly illustrate that the energy centre could be sustainably run along with marginal profits in the initial years, which would increase with the passage of time.

10.5.6 Capital costs

Since the building is already erected, the initial investment of constructing the energy centre building from scratch has beenavoided. However, certain modifications in the building are still required. The initial investment needed to renovate the building is broken down in Table 43. The explanation of the cost calculations and assumptions have been shown in Appendix 15.1.

Table 43: Breakdown of capital cost of the energy centre building

	Item	**Cost**
1	Business Permit/ Company Registration	$ 145
2	Renovation & construction cost (including painting, making wooden shelves and labour cost)	$ 1,785
3	Furniture and fitting (includes chair, table, couches, fans, LED lams, LED tube lights)	$ 9,620
4	Appliances (laptop, computer, printer, TV, lantern)	$ 4,110
5	Start-up stationary and equipment (Stapler, pens, marker, stamp, glue, clipboard, ruler, calculator, file folders)	$ 410
6	Other additional cost (including construction, making wooden shelves, installation, transportation etc.)	$ 1,000
	Total costs	**$ 17,070**

10.6 Implementation

The main barrier in this project is overcoming the investment which has to be done in order to retrofit the warehouse and purchase the necessary equipment. The calculations made in this chapter proof the financial feasibility of the project. However, an investment of around $ 17,000 must be made to get to an operating state, which can generate revenue and pay employees.

The expected outcomes are, aside from local revenue generation and employment, a strong community empowerment, which make this project very appealing for funds by social sustainable development organisations, such as World Vision. Another funding possibility would be social crowdfunding through platforms such as startsomegood.com or crowdfundingsocial.com. Crowdfunding is the practice of funding a project or venture by raising monetary contributions from many people. Normally, people donate to a promising product and through this they get it as one of the first. However, crowdfunding always comes with the risk, that the project which was presented can fail. Ergo, the more trustworthy the presentation is the more money is funded by the crowd. Social crowdfunding platforms work in a similar way. Instead of promising new products, social projects are presented. There is no physical return for the donator, only the assurance that the money is used in its best way to create positive social change. The reason why social crowdfunding is working quite successfully is that the donator has more control on how the money he is spending is used. Consequently, the more transparent the social project is presented, the better the chances to get funded.

10.7 SWOT Analysis for Honde Valley Energy Centre

In this chapter, the emerging strengths, weaknesses, opportunities and threats coming together with the implementation of the Honde Valley Energy Centre are assessed in a SWOT analysis (see Table 44).

Table 44: SWOT Analysis for the Honde Valley Energy Centre

<table>
<tr><td><u>Strength</u>
• Sense of community development
• Build a "Good Village" that would be self-sustainable
• Education promotion
• Saving Money
• Safety
• Local population benefit</td><td><u>Weakness</u>
• Low acceptance rate
• Wrong Services
• Organisational abuse of power</td></tr>
<tr><td><u>Opportunities</u>
• Potential of expanding the business
• Increment in employment opportunities
• Increment in literacy rate and modern education
• Prosperous Nation</td><td><u>Threats</u>
• Legal barriers
• Lack of transparency
• Vandalism
• Theft</td></tr>
</table>

Strengths

Sense of community development - In the Multipurpose room, when the people will come and sit together for watching TV and video shows, a sense of community would be developed, which is one of the main pillars of our project. Additionally, the people would become customers only once they have paid a marginal membership fee for the Energy Centre. The centre would be run and managed by the community members, therefore it could become a Community Headquarter.

Build a "Good Village Model" that would be self-sustainable – After the initial investment, the Village could self-sufficiently and sustainably run this Energy centre without any external aid or assistance.

Education promotion – The lanterns could be used for studying, which in turn would promote education. Moreover, the training sessions for computer skills would be provided in the multipurpose room for education as well.

Saving Money – Mobile charging would allow people to contact their relatives and friends in both urban and rural areas. The added value of this pilot project would be that the people who cannot afford electricity connection to the grid, can avail the same affordable and accessible services within the Energy centre.

Safety - Street lights would be necessary for the safety of the individuals living in Honde Valley, for ease of travelling during night time and for security of the homes. Since, in Honde Valley, our group members observed that there are no street lights available; therefore, the lantern lights can be used effectively for this purpose.

Weaknesses

A possible low acceptance rate could threaten the success of the financial sustainability of the energy centre. In case the prices are set too high people are not able to use and pay for the services. In another case, the offered services are not satisfying the needs. Therefore, an open dialogue with the community has to be maintained. Organisational abuse of power needs to be prevented: it cannot be that the Honde Valley Energy Centre is not acting and working for the benefit of the whole local community. In case individual take over the control over decisions for their own benefit, the supervisory board should be still able to divest the connected positions for this person.

Opportunities

Currently, there are less opportunities for the rural inhabitants, especially the vulnerable youth, to have employment chances. With the Honde Valley Energy Centre, employment rate will surely improve, because the plan is to appoint the inhabitants as the staff members responsible for the organization and activities of Energy centre. In the long run, the Energy centre could also expand its business of lantern and mobile charging to other nearby villages or cities by hiring local agents (another prospect of job creation for the community).

With the inclusion of computers in energy centre and special seminars/ workshops that will be organized frequently, there is a possibility of improvement in the education of the rural community. This trend could be further enhanced in the long run and will result in the educated village citizens and Zimbabwe overall. The provision of computer awareness will not only allow youth to acquire modern knowledge, but will also provide them information about the current happenings in the world. This will broaden their mindset, together with the future goal of achieving and aiming something substantial in their life. All of the above-mentioned facts, will lead towards the prosperity of nation.

Threats

External influences threatening the success of the Honde Valley Energy Centre are legal barriers, which not have been identified sufficiently in order to offer the services. The organisation needs to be a proper registered company, declaring their incomes and expenses. This is also of importance to justify certain investments in front of the community. Another possible threat might be a lack of safety or vandalism which can harm the success of the Energy Centre. The building needs to be properly saved at all time. Also, the possibility of theft needs to mitigated at all time.

10.8 Conclusion

For the long-term strategy, the services provided at the Energy Centre could be changed with the passage of time and the change of the needs of the people. Since efforts have continuously been made in Africa to increase the electrification rate, it has been anticipated that in future Honde Valley could also be equipped with electricity in the majority of the households. Keeping this fact in mind, the Energy centre would be flexible to incorporate additional new services to increase revenue generation.

11 Ecotourism

Tourism has a significant role in the global economy as it represents almost 30% of the world's exports of services. Consequently, around 450 billion USD reach developing countries. Along with the impact on economic growth and sustainable development, tourism is one of the sectors which provides jobs and opportunities for entrepreneurship. However, tourism can also cause environmental pollution, seasonal unemployment, loss of cultural values and exploitation of labour. It is crucial to identify these negative consequences and eliminate them.

Furthermore, according to the World Tourism Organisation (UNWTO), a specialised agency of the United Nations, sustainable development of tourism has the potential to alleviate poverty, hunger, gender inequality and environmental degradation. To ensure, that tourism helps to achieve the UN Millennium Development Goals (MDGs), the principle of ecotourism can be applied. Ecotourism is now defined as *"responsible travel to natural areas that conserves the environment, sustains the well-being of the local people, and involves interpretation and education"* (The International Ecotourism Society, 2015).

The "*eco*" in ecotourism stands for increased ecological awareness and respect, which results in more sustainable travel and conservation of nature. But Ecotourism is not only about diminishing the environmental impact, it is also generating financial benefits for local people and private industry without any kind of labour exploitation, sharing mutually cultural values and therefore providing a positive experience for both visitor and host (The International Ecotourism Society, 2015; World Tourism Organization, 2016).

11.1 Community Based Ecotourism (CBET)

One degree higher than ecotourism is the concept of Community Based Ecotourism (CBET). It is defined as an ecotourism venture, which is mainly owned and controlled by the local community. The benefits are obvious; the returns are mainly reinvested into the community. It also recognizes the need to promote both the quality of life of people and the conservation of resources. The success of the community-based approach strongly depends on the consent between the community members. In this study a way to establish CBET is evaluated, since it has a way bigger potential of empowerment for the community, than any other form of tourism (Scheyvens, 1999).

11.2 The potential Market of Ecotourism

When analysing the potential of ecotourism in the case of Ward 10, a closer look on ecotourism in general has to be made, in order to understand the potential of growth of this sector. The idea of ecotourism is existing already since a long time and its market is constantly growing since almost 30 years (Plovitz, Jorgenson, & Boley, 2016). In the beginning, ecotourism was mainly considered as a form of "Alternative Tourism" which is competing with the group of "mass tourism" (refer Figure 72). But with constant growth of the market, people involved in tourism are noticing the potential financial value in attracting sustainable tourists. This explains why in the beginning the market segmentation assessed eco-tourists based upon only their psychographic and demographic information. Later, the financial analysis gained more weight and the potential expenditures of sustainable tourists was given priority. Considering this, it was found, that the average ecotourist is spending more money, while having a lower environmental impact. This might appear as attractive business case, but considering that the number of eco-tourists is much smaller than for example in the sector of "mass tourism", ecotourism is not cost-competitive. The sustainability-profitability trade-off limits the potential of ecotourism. (Plovitz et al., 2016; Weaver, 1999)

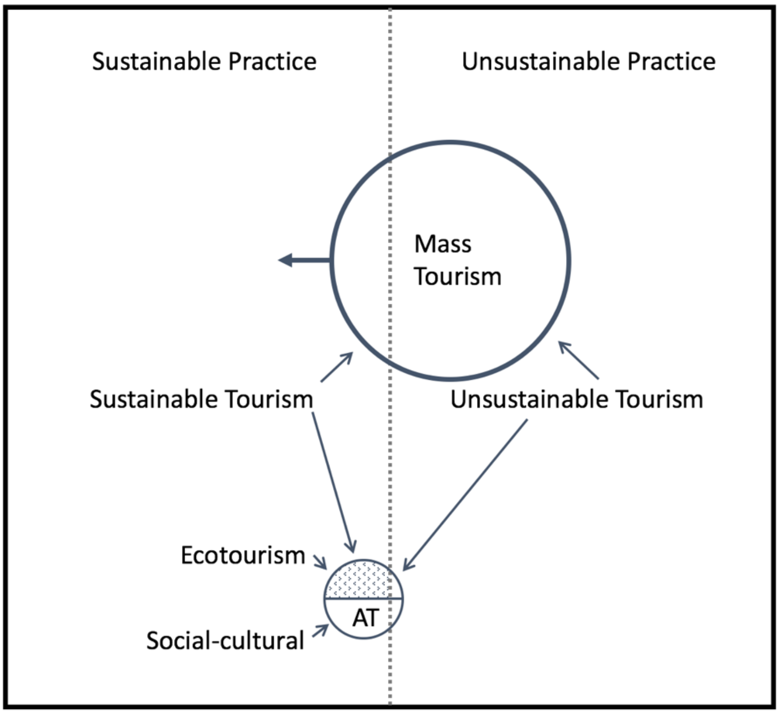

Figure 72: Relationship between Mass-, Alternative, Eco and Socio-cultural tourism (Weaver, 1999)

However, ecotourism can be considered as an attractive business case, especially within regions and destinations, which do not offer any opportunities for mass tourism. It is perfectly suitable for small communities e.g. in the case of this survey Ward 10, because in this scale it brings comparable high expenditures connected with low environmental impact.

11.3 Description

Tourism is a business opportunity that has got high potential to bring benefits to the communities, since Honde Valley has many touristic attractions including pure natural landscapes, unique wildlife and traditional culture that make this area competitive with other famous African destinations. In addition, the partial isolation of these communities from the globalized world gives an added value to the potential that tourism could have there.

This resource has not been exploited yet, mainly due to the lack of adequate facilities and structures that could host some tourists, such as: lightning, proper sanitation, transportation etc.

As for the social aspect, during the field trip of the group, it was observed that many locals were meeting Occidental people for the first time in their lives. Therefore, this report is not focused on traditional tourism but on the new trends that are increasingly spreading in the market.

The proposal is for a social tourism model based on a collaboration with the famous platform Airbnb. The advantages of this partnership are numerous and could bring to a successful implementation of tourism in Zimbabwe. A model based on social tourism has been selected because it offers the possibility to match what Honde Valley offers with the characteristics considered by people interested in this kind of experiences. Secondly, the collaboration with

Airbnb will increase the visibility of the offer, minimizing the costs for advertisement that otherwise will be unsustainable.

Airbnb is a popular world-wide operating online platform, that enables people to lease short-term lodging including holidays rentals, apartments, homestays and hostels. Airbnb is based on the principles of collaborative consumptions and sharing economy, in fact the company does not own any lodging but connects hosts with guests. The main advantages for guests is that they can find a cheap accommodation outside of the traditional tourism channels. On the other hand, hosts have got the opportunity to easily rent their flat or a part of it for a few days.

Airbnb has been selected especially because of the product that has recently launched (beginning of November 2016) that matches perfectly with what Honde Valley could offer. This new offer is called "experiences" and is composed by a collection of travel experiences that increase the value of a normal trip proposing activities that allow users to enjoy unique local travel experiences. The tours and experiences offered on the platform are all hosted by locals and are focused on discovering the location from the point of view of the locals instead of proposing classical tourism attractions. A special focus has been set on the experiences with social impact. An example of what Honde Valley could propose is the "Agent of Change" 2-days experience which is a Nairobi (Kenya) based holiday by a local NGO, empowering women. (Airbnb, 2017)

One experience offered in Honde Valley could be a multi-day experience that shows the local culture, the natural attractions and the Zimbabwean traditions. The main advantage of this approach is that it will allow to start tourism in this area without big investments and without having to wait until the local services are comparable to the ones of developed countries. The visitor interested in this kind of trip is prone to sacrifice some of their everyday comforts for enjoying the opportunity to deeply experience the local community and this is the added value that would turn this proposal successful.

In order to minimize the emerging costs and to provide a better experience to the travellers, the community should be actively involved in the organization of the whole system. Nevertheless, the community impact of this proposal will not be limited to the creation of job positions and incomes for a small group of people but will bring other significant benefits to the whole community. In fact, the cost of the trip will include a fixed share of the total cost that will be collected for social causes. Consequently, the revenues will be divided between the people directly involved with tourists, and FDC could use such revenues to fund the solutions proposed in this project. Figure 73 offers a description of the costs breakdown, highlighting the revenue system that will be applied (detailed calculations can be found in the following section).

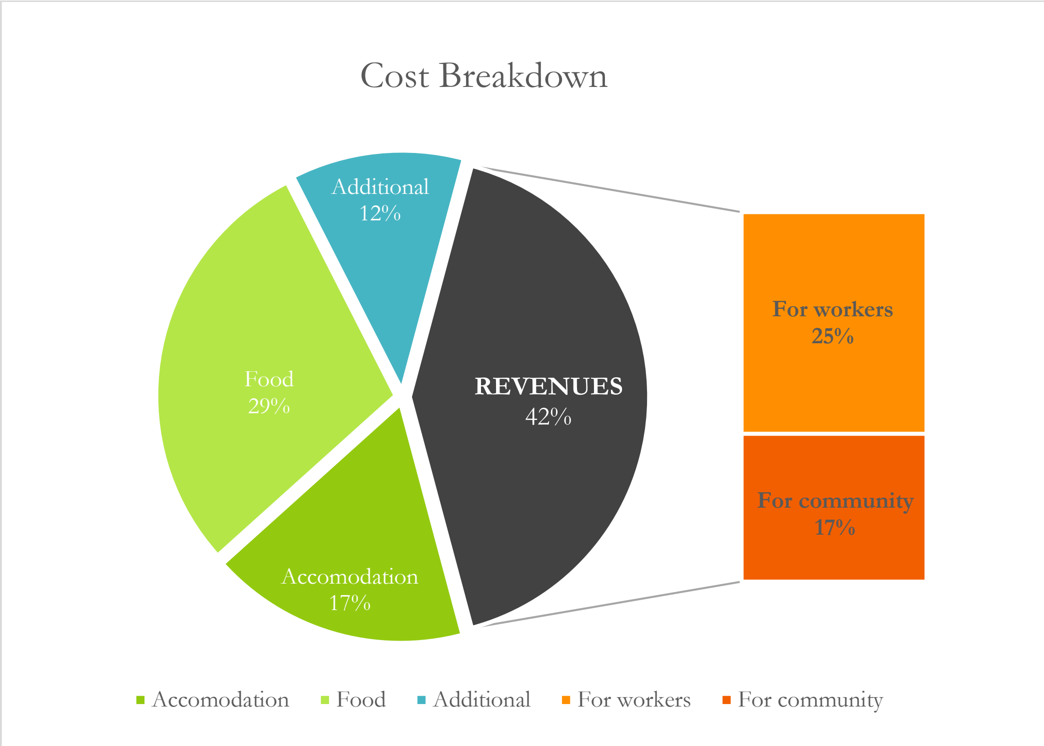

Figure 73: Trip cost breakdown

The division of revenues will offer an additional added value to the Honde experience, providing to tourists the opportunity to actually help the local community.

Another successful implementation of ecotourism is the one proposed by TAO Philippines Explorers Wanted. This social enterprise, which is based in the Philippines is including island communities as partners. Their goal is to empower the situation of the local communities of islanders bringing tourists that could experience island life hosted by local families. Currently, TAO is a community of over 200 islanders that welcome travellers from all over the world. (TAO Philippines, 2017)

11.4 Practical description

One of the accommodations which may be devoted to host tourists could be the Chikuhwa Residence, where the group stayed during the stay in Honde Valley. This building could provide housing for groups of maximum six people. The building is currently under rehabilitation and there is already a plan to make it suitable for possible visitors. Nevertheless, the focus of the experience will be to have local families hosting tourists in their houses during their stay. This will increase the value of the experience because travellers could share the local tradition and culture living side by side with the locals.

The trip will include visits to Mutarazi falls, Vumba mountains and tea estates. The Nyanga National Park is suitable for hikes offers a vast animal life, unique birds variety of species such as the Anchieta's tchagra, and eventually historical cultural sites. (Nyanga National Park, 2016). It could also include workshops about local colture such as cooking, farming, and so forth (Figure 74).

Figure 74: Traditional cooking lesson (Photo by Sofia Gonçalves)

It is very important that travellers are aware what they will face and will be prone to adapt to a rural lifestyle without many of the comforts of modern life. Therefore, it will be explicitly stated on the website that this journey is not suitable for everyone. Also, there will be risks involved and every experience will differ from the other. However, even though these issues will dissuade some people, the travellers who decide to participate will be more positive and enthusiasts towards what they will face and will not be bothered if something does not completely fulfil their expectations.

11.5 Economic analysis

According to the expenditures of the field trip in Zimbabwe it has been possible to estimate the possible cost of this travel experience. A seven-day trip as been considered for the calculations. The results are presented in the following table.

Table 45: Trip price analysis

Price analysis per person	
Accommodation [USD/day]	15
Food [USD/day]	25
Additional [USD/day] *	10
Total [USD/person]	350
Trip basic price [USD/person]	500
Final trip price [USD /person]	600
Revenues for workers USD /person]	150
Revenues for community [USD /person]**	100
* Additional costs include the expenses for transportation and the material required for the activities. ** The additional price for the community has been estimated according to the results of the survey.	

In Table 45 are excluded extra expenses that will be responsibility of the travellers such as flight transfer and transfer to Honde Valley, because these costs are normally not offered on a fixed estimated price and highly depend on the location of departure.

To understand the feasibility of the proposal and the possible revenues, different scenarios have been assessed, which are varying the expected number of tourists per month and the average size of the groups. The results obtained and shown in Table 46 are profitable, but it needs to be said that this is still a first approach to ecotourism and the resources required have been estimated to be very small.

Table 46: Tourism scenarios

Scenarios	A	B	C	D	E	F
Average size of the groups	2	2	2	4	4	4
Number of group per month	1	2	3	1	2	3
Number of people per year	24	48	72	48	96	144
Revenues per year (USD)						
For workers	3600	7200	10800	7200	14400	21600
For community	2400	4800	7200	4800	9600	14400

The scenarios implemented are ranging from very conservative (A) to very optimistic assumptions (F). Consequently, the revenues streams are very different; however, in case A the incomes could provide an interesting economic source.

In the most promising scenario (case F), the revenues from ecotourism can offer a salary to up to five employees, considering an average wage of 350 $ per month.

Moreover, this first structure could be easily expanded just by increasing the number of people from the community involved in the project. In fact, the idea that local families host people in their houses to share their experiences and traditions might be a considerable next step.

11.6 Questionnaire Results on Ecotourism

During the second study trip the overall interest towards ecotourism in the Honde Valley was assessed (see Chapter 2.2 and Appendix 15.2). The first question assessed the acceptance of tourism in general within the community. It is interesting to see, that the majority of people (87.01%) thinks, that tourism is beneficial for the community (refer to Figure 75). However, it needs to be said this question is methodologically problematic because of the biased way of asking it. Nevertheless, it can be said that the community is generally open-minded towards tourism in the area.

In the second question, possible job opportunities and willingness to contribute in any form within tourism was evaluated (refer Figure 76). The three-given options host, cook and guide were almost equally of interest. The role of a driver was only proposed once. This might be due to the fact, that cars are expensive and not so common to possess as an individual in the Honde Valley. It needs to be pointed out, that due to the lack of employment people are likely interested to work in one of the mentioned position, even though they believe ecotourism will not be beneficial for their community.

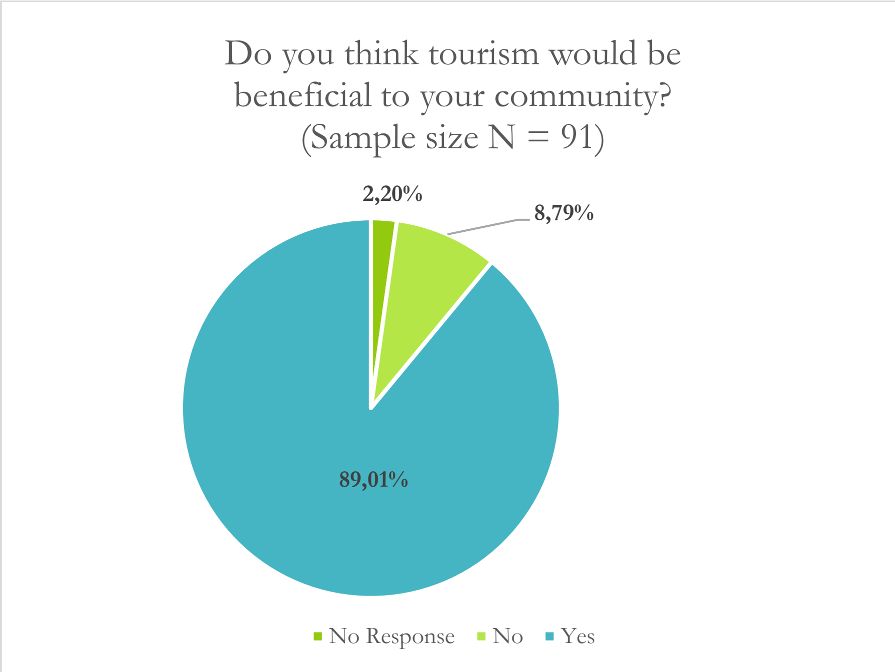

Figure 75: First question on possible ecotourism activity in the Honde Valley

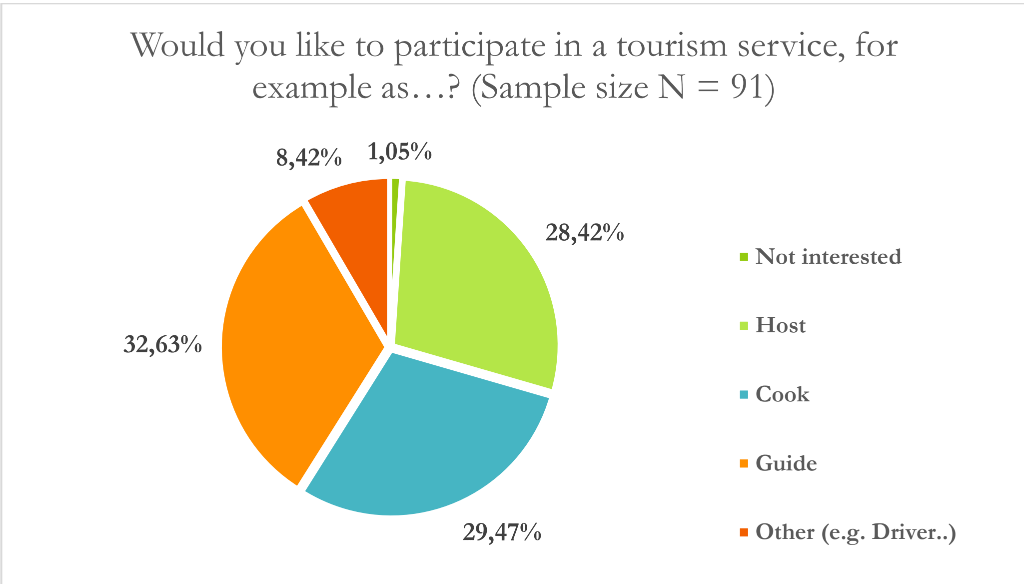

Figure 76: Second question on possible ecotourism activity and possible job opportunity in the Honde Valley

11.7 Customer Survey

To understand the actual interest of people toward the experience proposed, the group created a survey (Appendix 15.5). The survey reached 144 people all over the world and the results have been very positive. In detail, the interest of people in this kind of trip Sub-Saharan Africa is very high, registering an average value of 4 (where 1= no interest and 5= high interest) as presented in Figure 77.

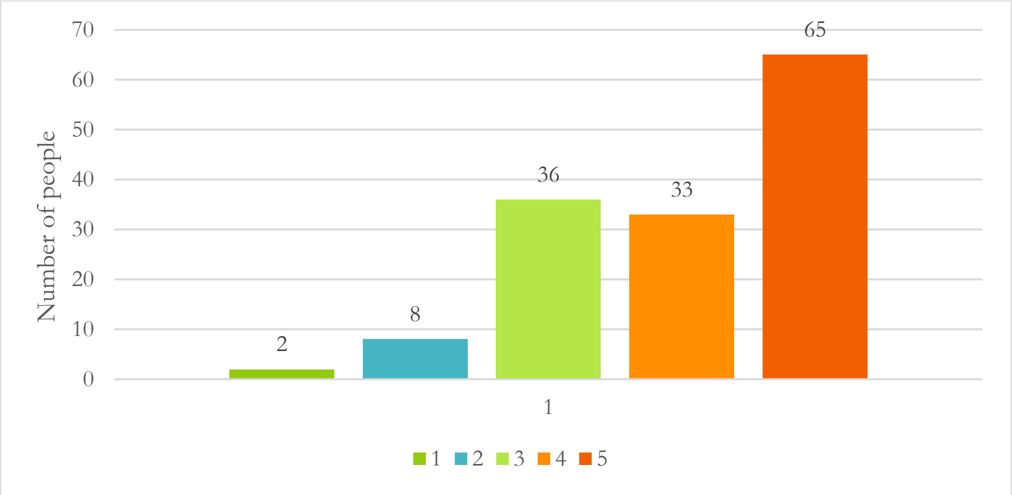

Figure 77: Survey, interest toward a trip in Zimbabwe (1= no interest 5=high interest)

Additionally, 97% of the voters accepted that they would agree to sacrifice their comfort in order to live a more authentic experience

Finally, the most interesting result is the one regarding the question if people would accept to pay some extra fees on the overall cost of the trip. The results presented in Figure 78 show that 49% of the voters would accept to pay 100 USD more which stands for 20% of the total cost of the trip.

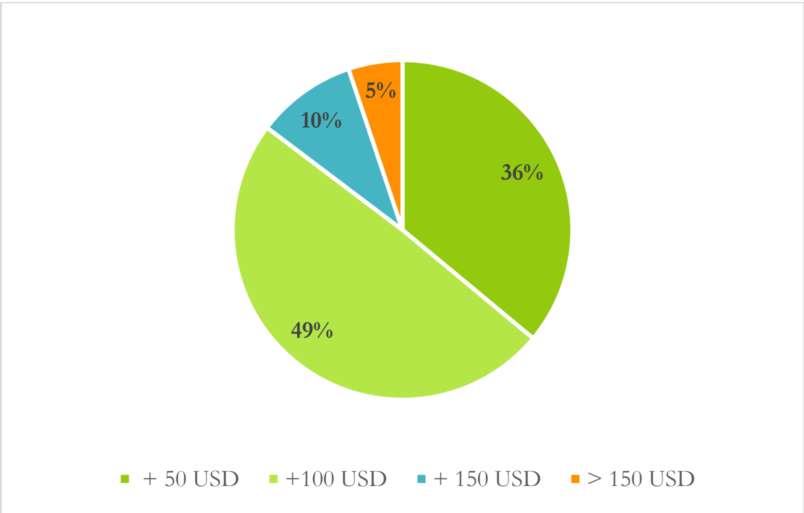

Figure 78: Consumer surplus towards ecotourism

In conclusion, even though this survey cannot provide a completely reliable source, the results have shown that it would be possible to launch ecotourism in Honde Valley, because people revealed considerable interest in this kind of adventures.

11.8 CBET Management

Similarly, to the Honde Valley Energy Centre (Chapter 10), there is a need to establish an organisational structure that will be responsible for making decisions regarding ecotourism activities. In fact, since the tourist flows are expected to bring a big impact on the whole community, there is the risk that the benefits will not be equally distributed. For this reason, the creation of a decision-making entity is strongly recommended. The structure that the organization could adopt is like the one adopted in the energy centre (see chapter 10.4) where the all the stakeholders involved in ecotourism (i.e. potential hosts, guides, cooks) will be able to elect a supervisory board that, subsequently, will elect the members of the board.

Aside from financial and organizational issues, the board will be responsible of managing the extra funds collected by ecotourism and decide how to reinvest them in a beneficial and sustainable manner. Considering the importance of the board's decisions, the necessity of an independent organism that controls the board and represents the interests of the community is crucial. Additionally, the board employees will be responsible for maintaining the contact with organizations like Airbnb or travel agencies that could be interested in sending tourists to Honde Valley.

In the beginning, it needs to be decided who could become a potential host and how the tourists will be distributed and managed within the community. Regarding how to manage the flows of tourists it is suggested that the bigger groups could be hosted in the Chikuhwa residence while smaller groups (2-3 people) could be hosted in local houses sharing the home with the hosting family.

A couple of conditions need to be fulfilled by the host and their house to satisfy the basic needs of ecotourists. Minimum services should be provided to the guests to grant the safety of their experience and to allow them to live an enjoyable experience. The specific requirements could be set working together with some Airbnb workers and some travel agents to assure that their requirements are satisfied.

Regarding the revenue system, the board will be responsible of ensuring that the revenues are fairly distributed among the workers to grant that the economic impact of ecotourism is not a benefit just for a few people. Additionally, the board will be responsible of managing the extra revenues collected that are supposed to be used for investing in projects that could benefit the whole community. Thus, the board should gather periodically to decide where to invest the extra revenues collected for the community development, this economic flow could allow the community to finance by itself some of the project that are proposed in this document.

11.9 SWOT and Risk Analysis for Ecotourism

The strengths, weaknesses, opportunities and threats caused by community based-ecotourism can be summarised in Table 47. Moreover, a detailed assessment distinguished in four layers; economic, psychological, social and political aims to supplement the SWOT-analysis in this delicate topic. Thus, the isolated analysis allows to design actions which need to be taken to diminish risk and empower the opportunities.

Table 47: SWOT Analysis for ecotourism

Strength	**Weakness**
• Already existing tourism (small) infrastructure. • The residents strongly support the need of ecotourism in this region. • Area provides interesting sights for ecotourists	• Lack of coordination among local people. • Low involvement of local people in tourism.
Opportunities	**Threats**
• High interest of local people in ecotourism • Job opportunities motivates people • High willingness to share culture	• Potential negative environmental impacts • Lack of proper management causing negative impact community • Tourists' dissatisfaction after visiting this place.

Economic layer

Ecotourism brings sustainable economic benefits to the whole community, if everyone is either directly or indirectly involved with the tourists. The cash earned through tourism is shared/spent within the community. This cash can help to pay the maintenance of water systems and power grids or improved permanent housing material.

On the other hand, there is the risks that mainly a few individual benefits directly from financial profits. Others may be excluded from this development due to the lack in capital or appropriate skills. The result could be an economic gap between individuals, families, ethnic or socio-economic groups. (Scheyvens, 1999)

Psychological layer

Incoming tourists, which show interest in the people and culture of the community, enhance self-esteem. The increasing confidence can empower individuals to seek out further education or training. Educational advantages and resulting access to employment may also lead to an increase of status for women and youths.

When members of the community do not benefit in any way or only a little bit economically from the development, their attitude towards tourism will be negative and this is can threaten the success of a sustainable ecotourism development. (Scheyvens, 1999)

Social Layer

The successful ecotourism venture empowers the individual development and educational status and consequently this enhances the social cohesion of the community, assuming individuals reinvest part of their income in local community development purposes.

A major risk connected with tourism is that outside values will influence the local community ans will be accompanied by the loss respect for traditional culture. Moreover, the economic gap, mentioned before, can result in a social gap. Subgroups with the community are competing with each other and rivalry or jealousy are present. (Scheyvens, 1999)

Political Layer

Assuming a properly implemented community-based-ecotourism, the agencies searching for community consent when deciding about the prospects of different issues should invite multiple interest groups to share their concerns and raise questions. This provides members of the community the sense of being part of a decision-making-body and empowers a democratic way of reaching consent.

In the contrary scenario, the agency acts as an autocratic self-interested leadership, which doesn't involve the community as a whole. Exploiting of labour and nature are the consequences and as a result, no ecotourism can be achieved within this structure. (Scheyvens, 1999)

11.10 Conclusion & Benefits

Community based Ecotourism can be considered as a promising long-term contributor to a sustainable community development. It creates yield which can be, in an ideal case, completely reinvested in the community. Moreover, it diversifies the income possibilities by creating new jobs like hosts, cooks or guides, and increases the local demand for goods and crafts.

In the case of Ward 10 the prospect of ecotourism strongly depends on the national political situation which directly influences the touristic popularity of Zimbabwe. In the past 5 years a slight decrease in visitors was recognized. Regardless of this trend, CBET can be established. Especially, in the starting phase a small number of tourists is needed in order to create positive empowerments in the psychological and social layer.

Finally, it needs to be said, that CBET is not necessarily economically more appealing than, for example, agriculture or farming. However, it diversifies the job market and brings a strong psychological empowerment into the community, which shouldn't be underestimated. Moreover, ecotourism reduces the environmental impact since the harvesting of environment through farming is compensated other wisely. Instead, the new approach proposed could help promote ecological responsibility, environmentally conscious habits and self-sustainability within the community of Ward 10.

12 Roadmap, timeframe and financial aspects

As mentioned before, the project is meant to be developed in the future years, improved and to be complemented by new proposals. The report presented several proposals that can be classified in different levels of priorities, according to the objective. In fact, even though the goals of the project are interconnected, the proposals can be prioritized according to:

- The preferences and of the FDC;
- Major needs perceived by the community;
- Needs perceived by the team;
- Technical and financial feasibility;
- Short term benefits;
- Long term sustainability and benefits;
- Job creation
- Etcetera.

12.1 Roadmap

The roadmap to implement the project is dependent on the priorities that will be defined by FDC with the cooperation of the community and the suggestions of the report. Also, the availability of partners ready to be active in the project is a key aspect: getting started with each proposal requires knowledge and training of the locals, technical support and the participation of the community. The social acceptance and the interest of people will be the main driver to the success and the endurance of the proposals in the long run.

12.2 Financial possibilities

FDC is supported at the moment by the Immanuel Church of Stockholm, and by private donations. Several other possibilities are available according to the specific proposal.

- ZINWA, Zimbabwe National Water Authority, will directly be involved in funding the improvement of the water system. FDC is in constant contact with it, and with the help of the report, the major problems of the water system can be identified and tackled. ZINWA can also be directly involved in the improvement of the infrastructures, supplying equipment and manpower.
- Sida, Swedish International Development Agency, is a government agency working for the Swedish parliament. Their main goal is to reduce poverty in the world. Sida gives the possibility to apply for funding to associations, like local civil society organisation, active in developing countries. Sida is already active in Zimbabwe, and FDC is considering it as a potential partner that will likely join the project.

The visibility of the project and of the activities of the associations like FDC is fundamental when it is necessary to apply for funds. The website developed during this project is one of the tools that can be considered helpful in this sense.

12.3 Financial and economic summary of the proposals

Summarizing the proposals, many prospering opportunities have been identified supporting different goals within this project. Not only the creation of employment opportunities was in focus of this project, but also ways in order to improve the quality of life, empower the community and develop the infrastructure. The purpose of the following Table 48 is to give a summary of the expected financial requirements, and expected outcomes of the proposals provided by this report, and how they can be measured. It needs to be said that some proposals don't provide a very detailed financial assessment, due to their nature. Consequently, they do not allow a reliable economic analysis. Moreover, the investment cost needs to be understood for the respective scenario described. In focus are the expected goals the individual projects try to aim for. Concluding it can be said that all proposals are providing a beneficial contribution to the Honde Valley, and seem to be promising from a social, environmental and economic point of view. Nevertheless, the investment is a major barrier.

Each proposal is either considered to be self-sustainable, or it relies on foreign direct investment. In the first case, the initial investment is comparably low and can be done without external partners, e.g. with microcredits. Bigger projects, as for example the battery charging station depend on a larger investment and can therefore only be established with external contribution and support.

Table 48: Financial and economic summary of the proposals

Proposal	Estimated Investment cost	Type of investment	Goals	Priority (Time horizon)	Measures
Water management team		Self financing	• Ensuring reliable and steady water supply; • Job Opportunities;	High (3 years)	• Confirmation through new survey; • Satisfaction of water supply
Rainwater harvesting		Foreign Direct Investments	• Mitigating the demand of other sources; • Establishing secure water supply for irrigation;	Medium (5 years)	• Amount of rooftops retrofitted for rainwater harvesting
Roads Improvement with do-nou	156,000 $	Self- financing	• Improvement of infrastructure and access to health services; • Better maintenance of the water system	High (5 years)	• Kilometres of paved road
Clay workshop	30,000 $	Foreign Direct Investments	• Job employment; • Water purification; • Skills training; • Cooking stoves for clean cooking	Middle (5 years)	• Filters and stoves sold, • Return of investment,
Battery Charging Stations	1040 $	Foreign Direct Investments	• Clean lighting access; • Job opportunities; • Improved access to education; • Ecological sustainability	Medium (3-4 years)	• Amount of subscriptions; • Acceptance by the community, return of investment
Peer-to-peer electricity	165 $/person	Self- financing	• Access to electricity; • Revenues for privates; • Individual cooperation for community development	Medium (1 year)	• Number of households involved; • Number of people using the service
Photovoltaic assembly		Foreign Direct Investments	• Access to electricity; • Technical skills development; • Job opportunities	Low (5-7 years)	• Number of participants; • jobs created

Biogas digester	1,000 $	Foreign Direct Investments	• Clean cooking fuel; • Reduction of greenhouse gas emissions; • Improved waste management; • Employment opportunities	High (3 years)	• Cubic meters of methane produced; mass of fertilizer produced; • Amount of cattle providing sewage for the digester
Farmers' cooperative		Self-financing	• Shared economy; • Improved development; • Implementation of new products; • Community strength on the market; • International fair trade	High (less than 2 year)	• Number of farmers cooperating; • Number of tools purchased; • Number of sold products through cooperative.
School waste management (LEDsafari)		Self-financing/ Foreign direct investment	• Education towards a better sustainability; • Technical skills; • Knowledge spread within the community; • Understanding of renewable energy importance	High (1 year)	• Segregation of waste; • Amount of waste sold to external companies • Students involves in LEDsafari workshop
Honde Valley Energy Centre	17,070 $	Foreign direct investment	• Shared economy; • Empowerment of the economy; • Access to shared services; • Revenue generation; • Employment opportunities	Medium (5 years)	• Number of members • People employed • Revenue generated
Community based Ecotourism	6,500 $	Self-financing	• Accommodation for 6 tourists • Community empowerment;	Medium (5-7 years)	• Number of tourists • People involved/ Jobs generated • Revenue generated

13 Conclusions

13.1 Lessons learned from the project

This project is quite different and unique, in terms of assessing and prioritizing a wide range challenges of the local community, that the group members had never experienced before. The group had a broad picture of the Honde Valley problems to deal with. One of the main obstacles since the start of project was the lack of information about the context, and the actual situation of the community. During the initial phase, it was challenging for the team to decide the main topics to be followed due to lack of available information. This hurdle was overcome by following a methodology of gathering general data and information prior to the trip followed by more specific approach after the trip.

During the trip, one of the most important lessons learned was how to deal with people from different cultures. Since this is a community based project, it was crucial to understand different mind-sets and grasp the point of view of the local population. In fact, an important factor that influenced the following work was to understand which problems the population think is important and which are completely not foreseen as a problem.

The field trip allowed the team to assess all the initial ideas and their relevance to the local community, thereby having to abandon some notion and evolve with new ideas, constantly re-evaluating their applicability in the socio-economic, political and geographical condition specific to Ward 10.

Another noticeable lesson learned is the expectation management skill. The possibility to interact directly with local leaders of the community has been a great opportunity to discuss about the project topics, what the report can provide and what are the limits expected from a Project Of the Year, in terms of time and efforts.

Dealing with a customer means understanding what the expected outcome of the project is. A high-quality work is important, but also the marketing aspect which is important to prioritize the customer's preferences.

Some other lessons learned from the project are:

- Learned to work as a team with an open, honest and respectful communication and make fair group decisions that are supported by everyone's opinion.
- Prioritizing the most important tasks and dividing the workload in work packages for each member.
- The team has used procedures for diagnosing and analysing each other's work in a time efficient way.
- Communication via skype is not always easy, but it is the only way to perform this kind of projects with participants from all over Europe.

13.2 Project costs

The most significant costs related to the project were in relation to the two field trips conducted in December and April. The flight tickets, food and accommodation fees can be seen in Table 49 and Table 50.

Table 49: Expenses related to the 1st trip

Activity	Details	Cost in SEK	Cost in EUR	Institute taking the responsibility of the cost
1	Visa and travel clearances to Zimbabwe for study/research (2000 + 500x7)	5500,00	576,29	InnoEnergy
2	Travel Insurance for all travellers (1500x7)	10500,00	1100,19	InnoEnergy
3	Vaccination (6 people)	12000,00	1257,36	InnoEnergy
4	Air Tickets (7 people)	56000,00	5867,68	InnoEnergy
5	Transport from Harare Airport to City			Fortune Development Centre
6	Accommodation is Harare 5th December and dinner (Dinner in USD)	1459,06	152,88	InnoEnergy
7	Transport from Harare to Samaringa (6th December)			Fortune Development Centre
8	Accommodation in Samaringa from 6th to 10th December (four nights for the visiting group)	4924,32	515,97	Fortune Development Centre
9	Food for the period 6th to 10th December (for the visiting group)	9119,58	955,55	Fortune Development Centre
10	Local transport in Samaringa for data collections/local area visits and interviews			Fortune Development Centre
11	Transport from Samaringa to Harare on 10th December	446,84	46,82	InnoEnergy
12	Accommodation on 10th December in Harare and dinner	1459,06	152,88	InnoEnergy
13	Transport from Harare city to airport	455,91	47,77	InnoEnergy
	TOTAL	**101864,76**	**10673,39**	

Table 50: Expenses related to the 2nd trip

Activity	Details	Cost in SEK	Cost in EUR	Institute taking the responsibility of the cost
1	Visa and travel clearances to Zimbabwe for study/research	5296	545,38	InnoEnergy
2	Travel Insurance for all travellers (1500x6)	9000	926,82	InnoEnergy
3	Vaccination (6 people)	12000,00	1257,36	InnoEnergy
4	Air Tickets (6 people)	56000,00	5867,68	InnoEnergy
5	Transport from Harare Airport to City	663,36	68,31	InnoEnergy
6	Accommodation is Harare (30 March)	3078,01	316,97	InnoEnergy
7	Dinner in Harare (30 March)			Fortune Development Centre
8	Transport from Harare to Samaringa (31 March)			Fortune Development Centre
9	Accommodation in Nyanga Rhodes Hotel (31 March and 1 April)	4924,32	515,97	InnoEnergy
10	Accommodation in Samaringa (2-3-4 April)			Fortune Development Centre
11	Food for the period in Samaringa (2-3-4 April)	7075,89	728,68	Fortune Development Centre
12	Local transport in Samaringa for data collections/local area visits and interviews	7783,48	801,54	InnoEnergy
13	Transport from Hauna to Harare (3 and 5 April)	446,84	46,82	InnoEnergy
14	Accommodation in Harare (3 and 5 April)	3078,01	316,97	InnoEnergy
15	Transport from Harare to airport			Fortune Development Centre
	TOTAL	**110628**	**11392**	

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15 Appendices

15.1 Appendix 1: Cost Analysis of the Warehouse

Calculations for Capital Cost[19]

This is the cost required to register the company in Zimbabwe prior to starting a business. Moreover, the time frame required to accomplish this task is 6 working days (Zimbabwe Investment Authority (ZIA), 2017).

The building is abandoned; therefore it needs renovation and retrofitting. To that aim, wall paint of the entire building is required both from the inside and outside to make it ready for the energy centre operation. With the rough dimensions of the building[20] (5×30 meters), it has been calculated that 30 litres of paint would be required (B&Q, 2017). A wall paint having a cost of 11$ per litre has been selected (Webdev (Pvt) Ltd., 2016).

$$Paint\ cost = \frac{\$\ 11}{litre} \times 30\ litres\ paint = \$\ 330$$

For construction and painting of walls, labour would be needed. It has been considered that 3 labours would be enough to complete this task in 10 days. The average cost of labour has been considered as 15 $ per day (Ledriz, 2016).

$$Labour\ cost\ required\ for\ wall\ paint = 3\ labours \times 10\text{days} \times \frac{\$15}{day, labour} = \$\ 450$$

Although the warehouse already contains some furniture. However, with new alterations, it has been planned to add 100 chairs, 50 tables and 2 couches in the building. As described earlier, the warehouse would be transformed in 7 rooms. Therefore, 20 lights (approx. 3 lights per room) and 16 fans have been considered for the energy centre. For emergency situation, it has been decided to add 10 LED lamps in the building as well. The cost for all the furniture has been taken as

$$Cost\ of\ furniture = \$\ 9{,}620.$$

50 lanterns have been estimated to initially put in the energy centre for renting. This number has been kept small initially with the aim to observe the people behaviour for this service. Two televisions have been considered for watching TV and video shows in multipurpose room. Three desktop computers have been decided to place one on the counter for retaining the data of buying and selling, and other two for internet point service. Two laptops have been considered to make the rural children and adults aware of the modern technology usage and function. Further, it would also help during workshop and training sessions as well. One printer has been considered to provide the service of typing and printing out the official documents. The cost for all the appliances that would be installed in the Energy centre have been taken from (Webdev (Pvt) Ltd., 2016).

$$Cost\ of\ appliances\ installed = \$\ 3{,}760$$

[19] These calculations are roughly done based on online available data. However, more accurate data can be obtained locally for finding out the accurate initial investments and capital costs.

[20] This dimension has been provided by the group members who visited the Honde Valley in Dec 2016.

Start-up stationary has also been considered for the start of the energy centre with the aim to store data of the buying and selling in the folder files manually. Stationary items include stapler, pens, markers, stamp, glue, clipboard, ruler, calculator and folders. The cost for all the stationary items have been taken from (Webdev (Pvt) Ltd., 2016).

Other additional cost for construction of the building; making wooden shelves for placing the folders, files and lanterns; installation of electricity sockets, lights, fans etc; and transportation cost of bringing the materials of construction has been considered to be $ 1,000.

Calculations for Yearly revenue generated

It has been considered that the lanterns would be rented for 2 consecutive nights at the cost of $0.19[21]. 50 lanterns have been decided to place initially at the energy centre. For calculating the cost generated from lantern renting service, it has been projected that all the 50 lanterns would be rented every day. The Honde Valley has a total household of 1050[22]. Therefore, a very conservative assumption has been made that out of 1050 households, only 50 households would rent 50 lanterns (which is feasible and possible).

$$Income\ from\ lantern\ renting = \frac{\$0.19}{2\ days, lantern} \times 50\ \text{lanterns} \times \frac{365\ \text{days}}{year} = \frac{\$1{,}734}{year}$$

For mobile charging, the cost of one charge has been set as $0.19[21]. Majority of the people in Honde Valley possess mobile phones but not every household has an electricity connection at their homes[23]. Since total inhabitants of Honde Valley are 3,400[22]. Therefore, a very conservative assumption has been made that out of 3,400 people, only 100 people would come for charging their phones per day.

$$Income\ from\ mobile\ charging\ = \frac{\$0.19}{phone\ charge} \times 100 \frac{phone\ charge}{day} \times \frac{365\ \text{days}}{year} = \frac{\$6{,}935}{year}$$

In multipurpose room, TV shows and videos would be screened.

For evening movie, it has been decided that it would be screened at a specific time from 7-9pm. For the earning from this service, a conservative assumption has been made that 45 weeks out of 52 weeks of the year, 100 people would come for at least 4 days a week keeping in mind that the people don´t have much activities in Honde Valley. The time has been specified so that it would not overlap with the evening shows/news time which would start at 9:30pm.

$$Income\ from\ evening\ movie = \frac{\$0.18}{person} \times \frac{45\ weeks}{year} \times \frac{4\ \text{days}}{week} \times \frac{100\ people}{day} = \frac{\$3{,}240}{year}$$

21 In Ikisaya village of Kenya, the similar project of energy centre model had already been successfully implemented [1]. Therefore, for the sake of feasibility report, the same cost has been selected by the group as a reference.

22 According to the latest survey carried by FDC.

23 This information has been collected by the group members from the inhabitants of the people during their trip to Honde Valley in Dec 2016.

For evening shows/news, the rates have been kept very low i.e. $0.045 per show in order to attract more people. Since people are interested to watch evening news/shows every day, therefore it has been considered that 200 people would come for this service at least 5days a week for 45 weeks out of 52 weeks of the year.

$$Income\ from\ evening\ shows = \frac{\$0.045}{person} \times \frac{45\ weeks}{year} \times \frac{5\ \text{days}}{week} \times \frac{200\ people}{day} = \frac{\$2{,}025}{year}$$

For afternoon shows/news, a conservative assumption has been made that 100 people would come for 75 days per year.

$$Income\ from\ afternoon\ shows = \frac{\$0.045}{person} \times \frac{75\ \text{days}}{year} \times \frac{100\ people}{day} = \frac{\$338}{year}$$

For general hiring of the multipurpose room, only 50 days per year have been considered for the conservative assumption. Full day hire means that the room would be booked for 10 hours (9am – 7pm). There would be two options: full day hire with or without electricity. The time has been specified so that it would not overlap with evening shows and movies.

$$Income\ from\ full\ day\ hire\ (with\ electricity) = \frac{\$8}{day} \times \frac{50\ \text{days}}{year} = \frac{\$400}{year}$$

For full day hire without electricity;

$$Income\ from\ full\ day\ hire\ (without\ electricity) = \frac{\$4}{day} \times \frac{50\ \text{days}}{year} = \frac{\$200}{year}$$

For half day hire means that the room would be available for any 5 hours before 6pm in order to prevent overlapping of time with other activities of multipurpose room. Again, there would be two options; half day hire with or without electricity.

$$Income\ from\ half\ day\ hire\ (with\ electricity) = \frac{\$4}{day} \times \frac{50\ \text{days}}{year} = \frac{\$200}{year}$$

For half day hire without electricity;

$$Income\ from\ half\ day\ hire\ (without\ electricity) = \frac{\$2}{day} \times \frac{50\ \text{days}}{year} = \frac{\$100}{year}$$

For evening hire, the time has been specified as 6-9pm. The cost has been kept marginally high at $4 because this would be the peak hours to sacrifice for other evening shows services. 45 weeks have already been assumed to be used for evening shows and movies service. Therefore, for the evening hire, only 7 weeks of the year have been considered to be hired.

$$Income\ from\ evening\ hire = \frac{\$4}{day} \times \frac{7\ \text{weeks}}{year} \times \frac{7\ \text{days}}{week} = \frac{\$196}{year}$$

For printing and typing of documents, $0.27 per page[21] has been considered which is quite reasonable. Since, in the Honde Valley, there are no printing and typing service available right now. Therefore, people usually go to main city for this purpose after spending sufficient amount of money. People usually require printing of certificates for schools and other official purposes[23]. Hence, a conservative assumption has been made that only 1,000 pages would be printed and typed per year.

$$Income\ from\ IT\ service = \frac{\$0.27}{page} \times 1000 \frac{pages}{year} = \frac{\$270}{year}$$

Internet has not currently been available in Honde Valley[23]. Therefore, it would be an attractive service for the inhabitants. A conservative assumption has been made that only 10 people out of 1050 inhabitants would utilize this service for just 5 hours per day. The cost of $0.20 per hour has been selected.

$$Income\ from\ Internet\ point = \frac{\$0.20}{hour} \times \frac{5\ hours}{day} \times \frac{10\ people}{day} \times \frac{365\ days}{year} = \frac{\$3{,}650}{year}$$

Calculations for Yearly expenditures

It has been decided that 5 people would be hired for different positions at the energy centre. One would look at the lantern charging service, second for mobile charging service, one for maintaining the record of buying and selling of the energy centre for future improvements, one for IT service and internet point, and one for multipurpose room. The salary of the personnel has been set as $200 per month.

$$Expenditure\ of\ salary = \frac{\$200}{person, month} \times 5 \text{ persons} \times \frac{12\ months}{year} = \frac{\$12{,}000}{year}$$

In consumables, it has been decided that 1 rim of A4 paper would be utilized per month for printing and typing services, and the cost of one rim paper has been taken as $10 per rim (Webdev (Pvt) Ltd., 2016).

$$Expenditure\ of\ A4\ papers = \frac{\$10}{rim\ of\ A4\ pages} \times \frac{12\ months}{year} = \frac{\$120}{year}$$

In the multipurpose room, TV shows would be screened. Therefore, DSTV subscription would be paid per month having a cost of $32 for compact package (Gambanga, 2015).

$$Expenditure\ of\ DSTV\ subscription = \frac{\$32}{month} \times \frac{12\ months}{year} = \frac{\$384}{year}$$

It has been planned that the satellite internet service would be installed with the aid of TelOne Company which deals with the affordable telecommunication services in Zimbabwe (Telone, 2016).

$$Expenditure\ of\ Internet\ bill = \frac{\$118}{month} \times \frac{12\ months}{year} = \frac{\$1{,}416}{year}$$

It has been assumed that $200 would be paid per month for electricity bills.

Maintenance fund would be required if computers, lanterns, laptop would damage. A fund of $2,000 has been reserved for these services per year.

15.2 Appendix 2: Questionnaire for Honde Valley

Is here presented the questionnaire delivered to the local population with its original layout.

A. GENERAL			
Village:		Gender and Age:	
Education:		Occupation (if applicable, employer):	
Vehicles:		Monthly income:	
		Source of income:	

B. WATER					
1. Is your water supply sufficient to your needs?	☐ 1- **not** sufficient	☐ 2	☐ 3	☐ 4	☐ 5 – **very** sufficient
2. Source of drinking water:	☐ Own well	☐ Other's well	☐ Common tap		☐ Pipe connection
	☐ Others:				
3. How far away from your home is the drinking source? (in meters)					
4. Do you clean the water? If yes, how?					
5. What would be a reasonable price per month for you for clean water at a distribution point near you?					USD per month
6. When you treat water, how much time does the process take (to make the water potable)?					
7. Would you consider buying a filter to clean the water, which would save time and heating fuel?					
8. What price you would pay for buying it?					USD

C. COOKING				
9. Which cooking fuel do you currently use?				
☐ Gas	☐ Kerosene	☐ Electricity	☐ Firewood	☐ Other:
10. How much do you spend on cooking fuel per month?				USD per month
11. What distance you have to cross in order to obtain the needed cooking fuel and how much time does it take you per week?			Distance ... km	Time ... hrs/week
12. What type of stoves are you using and how many pots do you use simultaneously?				
13. Would you consider buying an improved cooking stove, which can provide better fuel efficiency, less smoke and greater safety?				
14. What price you would pay for buying it?				**USD**

15. What type of method do you use to store your food? (for example fridge, salt)

D. ELECTRICITY					
16. Are you satisfied with the electricity you have?	☐ 1 – not satisfied	☐ 2	☐ 3	☐ 4	☐ 5 – very satisfied

17. What electrical devices, do you have in your home?									
	Phones	Refriger a-tor	Fans	Radios	Tele-vision	Lights	Air Condit-ioning (AC)	Cooker/S tove	Others: ______
Quantity									
Usage (hrs / day)									

E. WASTE		
18. How do you dispose of waste or trash?		
19. If disposed in dumpsters, are there sufficient containers in the area and are there any negative effects? (for example animals, smells, mosquito breeding, etc.)		
20. Would you pay for someone to deal with waste?	☐ Yes	☐ No
21. Are you interested in getting money for sorting waste?	☐ Yes	☐ No

F. SANITATION					
22. How satisfied are you with the type and the number of toilet facilities in your village?	☐ 1- not satisfied	☐ 2	☐ 3	☐ 4	☐ 5 – very satisfied
23. What type of toilet facility do you use?					

G. AGRICULTURE		
24. Do you grow your own vegetables and seeds?	☐ Yes	☐ No
25. If yes, what kind of vegetables and crops are you planting?		
26. How much area do you have in order to grow crops or vegetables?		m^2

H. TOURISM				
26. Do you think tourism would be beneficial to your community?			☐ Yes	☐ No
27. Would you like to participate in a tourism service, for example as...?				
☐ No, I'm not interested	☐ Host	☐ Cook	☐ Guide	☐ Other:__________

Thank you for participating in this survey! ☺

15.3 Appendix 3: Clay Workshop details

In this appendix, some details regarding the clay craft shop costs and fabrication are presented, based on data found on Potters for Peace website. In Table 51 some costs are listed.

Table 51: Cost estimation of a ceramic filter factory (Potters for Peace, 2016)

Item	Specification	Quantity	Price	Comments
Ceramic Filter Construction				
Clay	high plasticity	as needed		
Burnout material	fine sawdust or rice husk, uniform if possible	as needed		
Press	Manual or Electric, at least one manual recommended if power failures common	1 or 2, depending on desired production	Electric ≈ $2000 Manual ≈ $1200 plus shipping	Press and mold set including shipping to nearest port are currently free, with cost of PfP consultancy.
Molds	Aluminum	1 set	$850 plus shipping	
Press Plates	Round, flat plates to fit bottom of female mold - make sure to make them sturdy, as thin plates will cause uneven filter base, and lead to cracking during drying	100		
***Mixer**	Motorized, dough mixer preferred	1	$1500 - $3000	
***Hammer mill or grain grinder**	2-3 hp electric motor, interchangeable sieves	1	$1000 - $2000	
Sieves	#30 mesh	2 1x0.5m hand-held or 1 vibrating table		
Large Scale (Balance)	25 - 50 kg capacity	1		
Hydraulic Jacks	20 ton (standard truck jacks)	3		

Buckets	Must be able to suspend filter, usually 5 gallon/ 20L	20		
Tarps	Large enough to spread raw material for drying	2 or 3		
Wheel Barrows	sturdy	2		
Storage Sacks	Woven plastic recommended	75 -150		
Serial Number Stamp	large enough for easy identification	1		
Graduated Flask	1-2 liter, plastic	2		
Plastic Bags	can replace with coconut or palm oil if using electric press	2 per filter, sometimes reusable		
Car Wax	wax press-molds to ease separation after pressing	as needed		
Rubber Mallet	used to encourage separation of press-molds when wax isn't sufficient	1		
Production Log	In addition to matching serial numbers with flow rates, keep track of press, fire, and silver application dates for all filters.	1		
Safety Equipment	goggles, gloves, facemasks (for dust)	enough for each employee		
Turn Table	optional	1 or 2		
Pug Mill	optional	1		
Silver Application				
Silver	Colloidal Silver	1 kg to start	≈ $1500 - depends on current market price of silver	

	OR Silver Nitrate ($AgNO_3$)	1kg to start	a little less expensive but also less effective than colloidal silver	
Small Scale (Balance)	Digital, 0.001g accuracy	1		
Paint Brushes	Broad, for application of silver	1		
Plastic Container	Light-proof, for storage of stock silver solution, 2L	1		
Filter Firing				
Kiln	Mani Kiln ≈ 1700 bricks, (400 at 5x10x20cm for roof, 1300 at 7.5x12.5x25 cm for fireboxes, chimney, and walls, and 15 at 5x35x35cm for table) angle irons, steel rods, metal wood supports	1 or 2	≈ $1200 each	
Digital Pyrometer / Thermocouples	Two-terminal	1 pyrometer, 2 t-couples	≈ $200	
Pyrometric Cones	010, 012, 014	200 each		
Kiln Fuel	wood, sawdust, agricultural waste or recycled oil	as needed		
Axe	only if chopping own wood for fuel	1		
Pencils	Mark flow-rate on lip of each filter - #2 or darker	as needed		
Fire Log	record firing data	1		
Filter Finishing				

Filter Receptacles	Plastic and Ceramic, with lid, no handles - mouth should fit filter, minimum 5 gallon, silk screening if possible	1 per filter		
Faucets	sturdy, plastic or metal	1 per filter		
Packaging Material	Cardboard boxes, 2-ply, corrugated	1 per filter to be shipped		
Instructional Stickers / Silk screening	Translate to local language(s)	1 per filter		
Brush - optional	Laundry brush for filter cleaning, to rejuvenate flow rate			
Infrastructure				
Factory Site	Covered Building, minimum 50m x 50m	1		
Shelving	Sufficient for drying and storage of at least 1000 filters, open for air circulation, 8-10cm taller than height of filter mold			
Soaking Tanks	drainage system with capacity for 50 filters, if possible			
Kiln Shelter	Build after kiln construction, basic, all-metal construction if possible	1		
Other				
Skilled Potters	Access to clay and equipment, skills for making mini-filters, ceramic filter receptacles, and for finishing of filter after pressing	At least 2		

Marketing and Promotional Materials	Brochures, radio and TV adverts, signs, newspaper ads, coloring books, mini-filters, live demonstrations etc.	the more marketing, the more sales		
Occasional Laboratory testing	Reliable microbiological testing to ensure quality filter performance	Frequent testing initially to ensure quality product, occasional testing once production is consistent		
Broom	Care should be taken in sweeping of floor as inhalation of silica dust is dangerous for the respiratory system. Water should be used in cleaning in order to minimize dust.	as needed		

15.4 Appendix 4: Battery charging station excel sheet

Is here presented (Table 52) the excel sheet with which the optimization of the number of batteries per charging station has been performed.

Table 52: Battery Charging Station NPV calculation

Investment cost [USD]				
Charging station	Batteries	Home lighting kits	Grid connection	tot
500	210.4848908	233.8721009	95	1039.356992

Operation and maintenance [USD/y]			
operator	Electricity	maintenance	tot
1800	39.83621451	228	2067.836215

N. of batteries	23.38721009
N of recharges per year	182.5
Cost of electricity [USD/kWh]	0.1
Efficiency of charge	90%
Monthly operator income [USD/month]	150
kerosene average cost [USD/month]	7.91
interest rate	10%

Battery				
capacity [Ah]	voltage [V]	Capacity [Wh]	Lifetime [y]	cost [USD/u]
7	12	84	5	9

Lighting kit								
number of bulbs	power [W/u]	daily equivalent hours of utilization [h]	daily consumption [Wh]	cost [usd/bulb]	cost of 10 m wire [USD]	cost of lamp holders [USD]	other equipment [USD]	Kit cost [USD]
2	5	4	40	1.5	4	1	2	10

year	costs	revenues	profits
1	3107.19321	2219.914	-887.279
2	2067.83621	2219.914	152.0778
3	2067.83621	2219.914	152.0778
4	2067.83621	2219.914	152.0778
5	2278.32111	2219.914	-58.4071
6	2067.83621	2219.914	152.0778
7	2067.83621	2219.914	152.0778
8	2067.83621	2219.914	152.0778
9	2067.83621	2219.914	152.0778
10	2278.32111	2219.914	-58.4071
11	2067.83621	2219.914	152.0778
12	2067.83621	2219.914	152.0778
13	2067.83621	2219.914	152.0778
14	2067.83621	2219.914	152.0778
15	2067.83621	2219.914	152.0778
NPV	€ 0.00		

15.5 Appendix 5: Social Tourism Survey

The survey reached 144 people from all over the world and of different age ranges. The questions asked are the following:

- Would you like to have a trip to experience the rural community of Zimbabwe? (give a number between 1 and 5, 1= not interested – 5= very interested)
- Would you travel with your family?
- Would you be interested in a trip that will give you the chance to experience the traditions and habits of the local community?
- Would you be willing to sacrifice a bit of your comfort zone for experiencing rural community?
- The price of the whole experience including the accommodation and all the proposed activities will be around 500 USD. Are you still willing to come?
- Would you consider paying more if you knew that that extra money will be used to improve the life conditions of the local community?
- If yes, how much would you pay more?

Results:

Age	18-29	30-39	40-49	50+
Number of people	122	7	6	18

Origin	Europe	Asia	North America	South America	Africa	Oceania
Number	111	20	5	4	3	1

Interest	1	2	3	4	5
Number	2	8	26	33	65

Question number	Yes	No	Maybe
2	79 (55%)	65 (45%)	
3	137 (95%)	7 (5%)	
4	139 (97%)	5 (3%)	
5	88 (61%)	3 (2%)	53 (37%)
6	131 (94%)	9 (6%)	

Extra cost	50 USD	100 USD	150 USD	>150 USD
Number	49	67	13	7

The complete survey can be found at the following link: https://docs.google.com/forms/d/e/1FAIpQLSdoRXxEiMSPWq_Cq-6zUA2LcvSNGGG7M1KjbeL4i-d1MuzmdQ/alreadyresponded

15.6 Appendix 6: Mechanic workshop

One of the interesting proposals for the transportation and mobility part is the construction of a motor mechanic workshop. This proposal has been considered valuable and feasible by the team, but it has been included in the appendix because it requires more time and insight to be properly designed. The idea comes originary from Fortune Development Centre, with the objective to employ and train mainly school leavers and unemployed youths.
The valley has few service stations, and in particular none of them is present in Ward 10. The closest one is located in Hauna, and it is in poor conditions of maintenance. During the two trips, the team relied on a service station in Juliasdale, 50 km far from Masere Business Centre.

In Honde Valley, mechanical skills are common, and people are used to repair engines, pumps, cars for a much longer time than the expected lifetime of these machines. In the big urban areas, finding spare parts is relatively easy, but in rural areas there are few or no sellers.

The proposal of building a mechanic workshop and a related service station is considered key in the area, since it can provide a professional service, closer to the population, generating revenues for the community. Moreover, it would improve the management of waste, that can otherwise harm the environment (oil, lubricants, metals). A detailed project of the service area and workshop must include:

- Sustainable energy supply system, fully or partially independent from the grid. Installing pv panels on the rooftop is the easiest and cheapest solution;
- Adequate waste management of parts and fluids: if released in the environment, lubricants, fuels, motor oil are toxic and can pollute land and water;

The idea of FDC is to build a carpentry factory and a two-storey administrative block include a service station. The selected location should be close to Masere Business Centre, a central position for the area.

15.7 Appendix 7: Biogas costs

DATE	ITEM	COST ($)
	LABOUR	
2 May, 2017	Trenching (7 days)	70.00
	Building	140.00
3 June, 2017	Trenching Outlet (3 days)	30.00
6 June, 2017	Trenching Inlet	20.00
7 June, 2017	Building	15.00
	MATERIALS	
16 May: 2017	Rock harvesting	45.00
	Concrete	30.00
22 May: 2017	Cement Bricks (350st)	39.00
22 May: 2017	Transport	36.00
23 May: 2017	Cement Bricks (350st)	39.00
28 May: 2017	Cement Bricks (350st)	39.00
28 May: 2017	Transport	34.00
6 May, 2017	Cement (2 bagas)	23.80
8 May: 2017	Cement 2 bags)	23.80
16 May: 2017	Cement (4 bags)	47.60
18 May: 2017	Cement (4 Bags)	47.60
18 May: 2017	Cement (2 bags)	23.80
23 May:2017	Cement (1 bags)	11.90
26 May: 2017	Cement (1 bag)	12.00
28 May: 2017	Cement (2 bags)	24.50
29 May: 2017	Cement (1 bag)	11.90
2 June, 2017	Cement (2 bags)	23.80
8 June, 2017	Cement (2 bags)	23.80
4 May, 2017	Sand	2.00
18 May: 2017	PVC Pipe (3m)	7.50
29 May: 2017	PVC Pipe (3m)	7.50
2 June, 2017	PVC Pipe (6m)	15.00
24 May: 2017	Deformed Bars 2 x 6m x 12mm	11.00
24 May: 2017	Tying Wire Plain 1kg	3.00
24 May: 2017	Wire Netting Mesh 20m	50.00
5 June, 2017	Gas-out let horse	15.00
		922.50

Figure 79: Costs of biogas digestor in the Chikuhwa residence

15.8 Appendix 8: Water Monthly Costs

Table 53: Calcution on monthly water cost per cluster and household

Ward 10 Water Information				Tank [2]			Chlorine[2]			Maintenance				Water Team		Sum	
Village[1]	**Population**	**N° of Houses**	**Water Consumption l/day/village**	**N° tanks per position**	**Price for those tanks $**	**Monthly Cost $/month**	**Amount kg/day**	**Price /month**	**Price/ year**	**Investment (roof etc) $**	**Monthly cost of investment $/month**	**Repairs (10%) $**	**Monthly cost of repairs $/month**	**Number of Employees**	**Total cost of workers**	**Total monthly cost $/month**	**Cost per hh $/hh**
CLUSTER 1	1544	502	92640	10	11000	92,09	0,50	100,76	1209,1	1000	8,37	1100	9,21	5	1500	1710,4	3,41
CLUSTER 2	649	217	38940	4	4400	36,84	0,20	40,30	483,6	400	3,35	440	3,68	2	600	684,2	3,15
CLUSTER 3	594	177	35640	4	4400	36,84	0,20	40,30	483,65	400	3,35	440	3,68	2	600	684,2	3,87
CLUSTER 4	646	414	38760	4	4400	36,84	0,20	40,30	483,6	400	3,35	440	3,68	2	600	684,2	1,65
WARD 10	**3433**	**1310**	**205980**	**22**	**24200**	**203**	**1**	**222**	**2660**	**2200**	**18**	**2420**	**20**	**11**	**3300**	**3762,9**	**3,02**

The villages of each cluster are described in the folowing page

The costs were calculated with the assumptions demonstrated in table53 (following page)

Table 54: Population and number of households in each village

Village	Population	Number of Houses	Water Consumption 1/day/village
Matingo	840	191	50400
Chipunha	155	77	9300
Nyakabinga	305	57	18300
Saruwaka-Gowa	244	177	14640
CLUSTER 1	1544	502	92640
Samaringa	151	54	9060
Mutsaka	154	54	9240
Baradza	165	51	9900
Hambira	179	58	10740
CLUSTER 2	649	217	38940
Ngwende	321	88	19260
Mutetwa	273	89	16380
CLUSTER 3	594	177	35640
Manyonho	294	189	17640
Nyabadza	145	106	8700
Mutsamba	207	119	12420
CLUSTER 4	646	414	38760
WARD 10	3433	1310	205980

Table 55: Assumption made for calculated costs

Tanks	
Water consumption according to WHO l/person/day	60
Plastic Tank Volume l	10000
Tank Price $ (Information acquired during trip)	1100
Tank Lifetime (years)	12
Interest rate	0,03
CRF	0,100
Chlorine tablets	
Chlorine average amount mg/l	5
Clorine Price $/kg (Classifieds.co.zw, 2017)	6,625
Employee Income	
Hour fee ($/hour)	1,25
Hours per day (h)	8
Montly fee ($)	300

15.9 Appendix 9: Recycling Companies in Zimbabwe

Company	Contact Person	Contact details	Plastic	Paper	Glass	Metal /Cans	Other materials/Comments	Tonnage/ mnth
Conductus Investment	Masiliner Sakambuya Ngoni Kangara	04-748358/9 0772357825 0772269731 0774512114 Unit 6 Monde Building, 2 Shepperton Rd/ Boshoff Drive, Graniteside, Harare Email: conductus@zol.co.zw kangara@econetmobile.co.zw	Black sheeting and polythene bags; Buy LDPE only				Involved in the whole plastic production line- They make finished products; plastic ware	10
Eden Recycling	Nonku Jijita	0774660550 20 Lauchlan Avenue, Haig Park, Mabelreign, Harare Email: nonku.edenrecycling@gmail.com				Collect Cans for artefacts		1
Greendale Waste Collection and Recycling Centre (E. Africa)	Mukundi Mutasa Sandra Gobvu	04-492148/55 0774803770 0772965112 0772683906- teresa	Collect for free	Collect for free	Collect for free	Collect cans and supply recycling companies		10
Recycle Today	Dickson Makombera	713 Davies Rd, Prospect Industries Waterfalls, Harare Email: dicksonmakombera@recyclezim.com Website: www.recyclezim.com 0773600121		Buy Cardboard and any type of paper	Buy	Collect can and export		5
Plastic Profile	Reuben Kambasha	04-66710/770951/749155-6 0772219002 6 Coben Place, Cnr Bristol/ Dumfries	Buy plastic and Pellets from SA and local CBOs to make end					5

Company	Contact Person	Contact details	Plastic	Paper	Glass	Metal /Cans	Other materials/Comments	Tonnage/ mnth
		Roads, Workington, Harare Email: info@plaspropipes.com Website: www.plaspropipes.com	products such as pipes, black shitting					
Collect-a-can	Mike Abrahams David Takudzana	0772331919, 0775436779 Sherwood Golf Course, Mabelreign, Hre 23 Masonic Homes, Burton Rd, Belvedere, Hre Mikeabraham042@gmail.com				Collect, compact and exporting cans		4
M&M Boston	Innocent Chasvinura	0773411415 16220 Unit M, Seke, Chitungwiza Email: murewaboston@gmail.com	Buy Plastic- All Types and recycling to produce raw material					3
Mapepa Handmade Papers for Africa	Walter Ruprecht	04-669151 0772490200 891 Willow Road, New Ardbennie Harare Email: marketing@mapepa.co.zw Website: www.africanhandmadepapers.com		Collect Paper				1
Mega Pak P/L	Guide Ndawana	0273-2935-8 0772125666 211 Chihombe Road, Ruwa Email: gndawana@megaind.co.zw Website: www.megaind.co.zw	Recycling of plastic					10
National Waste Collections	Albert	Mutsadyanga 04-770097-138 0713139112 111 Kelvin Road South,		Buy Paper				1200 tonnes per month

Company	Contact Person	Contact details	Plastic	Paper	Glass	Metal /Cans	Other materials/Comments	Tonnage/ mnth
		Graniteside, Harare Email: jchinowaita@artcorp.co.zw Website: www.artcorp.co.zw						
Saltrama	Mr. O. Machikiti	obert@saltrama.co.zw 0774 638 578	Plastic recycling					
PET Recycling Company of Zimbabwe, (PETRECO Zim)	Tawanda Masuku	04- 620231-6 ext 361; 0772102646 tmasuka@petreco.co.zw / tawanda.masuka@yahoo.com 41 Dover Rd, Adebenie	Buy PET					60 tonnes /month
Plastix Incorporated	Kumbirayi Rubaba	0772605589 72 Lytton Road, Workington, Harare P. O. Box 10888, Harare Email: mwazara@plastixinc.net krubaba@plastixinc.net	Buy plastic and Pellets					
Marytime	Mary Wazara	Mary Wazara 0778 484 447 therecyclinglady130@gmail.com	Polythene bags from LDPE					
Polywaste Plastics	Maxwell Taremedzwa Dumba Tadiwa Muratu sheofficer@polywaste.co.zw 0712 387 659 04- 331537	04-771357 0774946850 Corner Lytton and Paisley Roads, Workington, Harare Email: operationsmanager@polywaste.co.zw Website: www.polywaste.co.zw	Recycling plastics into plastic bags & bin liners for sale, black shitting				20tons per month of waste recycled	
Man Pac	Mr Chikwaiti	0773 303 645	Black shitting, recycling plastics into				1.5tons of waste processed daily	

Company	Contact Person	Contact details	Plastic	Paper	Glass	Metal /Cans	Other materials/Comments	Tonnage/ mnth
			flexible packaging					
Roplast		0772 236 079	Manufacturing plastic packaging- virgin material				1.5tons of waste processed daily	
Global Plastics			Buy plastic, and pellets					
Itachi Plastics	Mr Kulupanga	04-661309/660327	Buy virgin waste from Akol and sell packaging to cosmetics companies				5tons per month processed	
Afdis	Mr H. Nduna	hullecn@afdis.co.zw 0772 767 263 04-303862			Buy Glass Bottles			
VESAPAK Health and Safety	Mr. Mugiyo	mugiyo@versapak.co.zw 0733 419 683	Produce Kaylite from virgin material					
Chloride Zimbabwe	Mr Muchuchuti	0772 572 206/0712 605 971/ 04 669710; 621479, 621482/5)	Battery crap and plastic material from batteries and sell to plastic manufacturers				Batteries crap 400tons/month Plastic 60tons per month	
Madze Plastics	Joe	Chikwana, Chitungwiza 0772 990181	Plastic Recycling					
ONP Plastics		Gate 2 Mashonaland Holdings Complex; Cnr Kelvin Rd/Cripps Rd, Granitesite	Manufacture of food packaging from virgin material					
Tisunungureiwo	Edna Tsarwe	Granitesite	Buy Plastic for resale					
Waverly Plastics	Aaron Vico	Glen Eagles	Recycling of					365

Company	Contact Person	Contact details	Plastic	Paper	Glass	Metal /Cans	Other materials/Comments	Tonnage/ mnth
		0772161510	HDPE: irrigation pipes and packaging containers; polypipe, 5l and 20l recycled containers, buckets					tonnes per month(4 380t/yr)
Wessecsol	Mrs Chimatira	5 Coldrac Road Msasa 0771923625	Irrigation Pipes					
Cobert Plastics		0733405406 0772233127 Ruwa	Household plastic ware from HDPE					
Reclaim Plastics		Ruwa	Black sheeting from LDPE					
Zim Earthworm farms	Dr. E. Whingwiri	Chitungwiza					Composting and Vermiculture (worm farming)	
Graceb Steel	Ruwa					Buy scrap metal and make steel rodes		
PJ Metals	Ruwa					Scrap metal buying		
Stidol Investments	Mbare					Buy scrap metal and make steel rodes		
Thermoplastics	E. Nyaruwa	0773819943	Making of Blacksheeting from LDPE					
Lym Plastic Manufacturing	Dawit Abdi	0772 206 816	Plastic Recycling					
Vorivet	Liu Jun	0772414730	Plastic					

Company	Contact Person	Contact details	Plastic	Paper	Glass	Metal /Cans	Other materials/Comments	Tonnage/ mnth
Investments			recycling					
Stawes investment	K. Lunga	0734289450	Plastic recycling					
Shapecon Market	C.T. Zimowa	0773210319	Plastic recycling					
NATIONAL METAL FOUNDERS AND ENGINEERS	T. TARUBUDA	0772 747 926				Scrap metal collection and recycling		
POCAVE INVESTMENTS	E. NYIKA	0773 016 359				Scrap metal collection and recycling		
PADDOCK GEARS AND ENGINEERING	O. MAJERA	0773 239 742				Scrap metal collection and recycling		
TOPPINGSHAN METALS	D. DZUMBUNU	0773 598 541				Scrap metal collection and recycling		
AGRIQUIP ENGINEERING PVT LTD	AJARA A	0772 356 960				Scrap metal collection and recycling		
GOOSEFILED RESOURCES PVT LTD	BANGIRA B	0772 554 477				Scrap metal collection and recycling		
RAVEDGE MARKETING ENTERPRISE	GILVAS MAWUNGIRA	0774 130 130				Scrap metal collection and recycling		
Ecoplastic		0776905611				Collect		

Company	Contact Person	Contact details	Plastic	Paper	Glass	Metal /Cans	Other materials/Comments	Tonnage/ mnth
						LDPE		
Vesapak	Mr. Mugiyo	mugiyo@versapak.co.zw 0733 419 683				Produce and collect kaylite		
Madze Plastic recycling-	Joe	Joe 0772 990 181 0773 536 249 Chikwanha, Chitungwiza				Make plastic pellets		

Running Recycling Companies

Recycling Company	Waste Stream	Contacts
Recycle Today	Cardboard, bottles, PET, can, tetrapack- longlife milk, bond paper	Mr D. Makombera; 0773600121 0772615207- Brian
Petreco Zim	PET (1)	Mr Masuka; 04- 620231-6 ext 361; 0772102646
National Waste Collection	Paper and cudboard	Albert 04-770097-138 0772865536
Plastics Incoporated	LDPE (4)	Kumbirayi Rubaba 0772605589
Marytime	LDPE (4)	Mary Wazara 0772399453
Polywaste Plastics	LDPE (4)	Maxwell Taremedzwa Dumba 04-771357 0774946850

Waverley Plastics	LDPE (4)	Glen Eagles 0772161510
Wessecsol	LDPE, HDPE	Mrs Chimatira 5 Coldrac Road Msasa 0771923625
Cobert	HDPE (2)	0733405406 0772233127 Ruwa
Thermoplastics	LDPE (4)	0773819943
Tapvice	HDPE (2)- mahewu, cascade, harpic, sta soft,	Mr Mlambo/ Mpandawana 0771799675
Shingi	LDPE (4)	
Spencer	PVC- 3 (electric pipes, bank cards)	
Acts Plastic	LDPE (4)	Muzenda 0773869343
Tisunungureiwo	PET, HDPE, PP	Edna Tsarwe
Conductus	LDPE	Masiliner Sakambuya Ngoni Kangara 04-748358/9 0772357825 0772269731 0774512114
Mr Guo	PP, HDPE	0772 415 120
Webster	PP, HDPE	Chitungwiza