Installation of a solar pump, water tower and SODIS demo

Oyugis – Kenya

June – August 2016

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PROJECT OUTLINE

THE PROJECT LOCATION

Imbeke Trust
P.O.Box 193
OYUGIS – 40222
Kenya

Latitude[1] : **0°29'43.66"Z**
Longitude : **34°43'16.86"O**

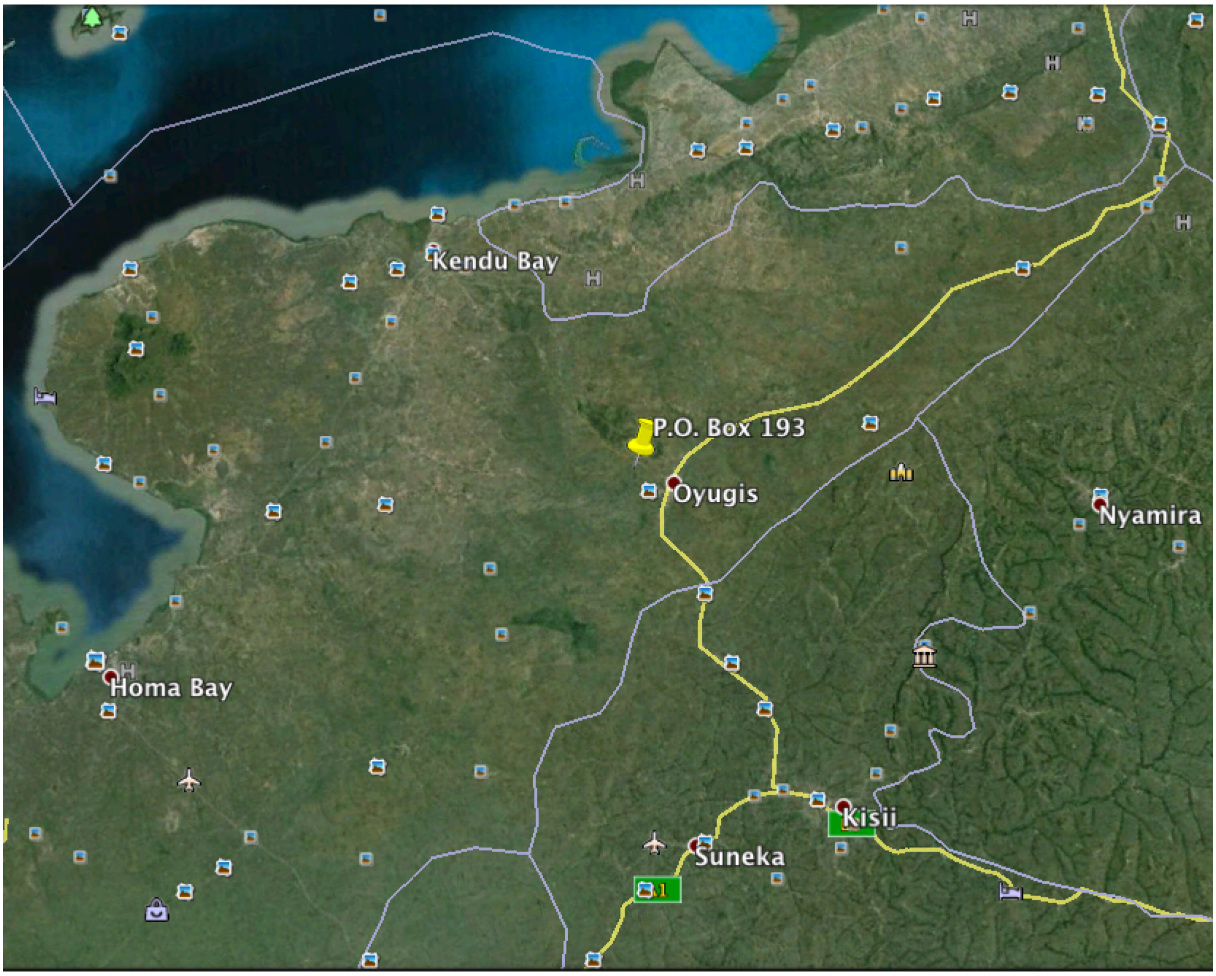

Figure 1: Project Location

[1] These coordinates are given by Google Earth.

THE PROJECT INDEX CARD

Project title:	Installation of a solar pump, water tower and SODIS demo
Location:	Oyugis
Province:	Homa Bay
Country:	Kenya

THE PROJECT PARTNERS

Partner in Belgium:		**Partner in the south:**	
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PROJECT STUDENTS & RESPONSIBLE

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COMPANIES

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Company: Email: Telephone number:	Go Solar Systems Ltd. sales@gosolarltd.com +254 020 552216
Company: Email: Telephone number: Adres:	Chujio Ceramics chujioceramics@gmail.com 254-722-393816 P.O. Box 990-00217 Limuru, Kenya

EXPERTS

Name:	Erick Ndeda (Kenyan) Person who has already done welding for Imani in the past. He can be contacted through Sophie, our local partner.
Name: Email:	Sam Van Dyck sam.vandyck.92@gmail.com
Name: Email:	Mr. Albert albertogoma@yahoo.com He provided us with the capacity test for the well. He is situated in Kisumu.

Other used experts are family or school related persons.

TABLE OF CONTENT

ABOUT KENYA

HISTORICAL BACKGROUND[1]

A part of Southeast Africa, the territory of what is now Kenya has seen human habitation since the beginning of the Lower Paleolithic. The Bantu expansion from a West African center of dispersal reached the area by the 1st millennium AD. With the borders of the modern state at the crossroads of the Bantu, Nilo-Saharan and Afro-Asiatic ethno-linguistic areas of Africa, Kenya is a truly multi-ethnic state.

European and Arab presence in Mombasa dates to the Early Modern period, but European exploration of the interior began only in the 19th century. The British Empire established the East Africa Protectorate in 1895, from 1920 known as the Kenya Colony.

The independent Republic of Kenya was formed in 1964. It was ruled as a de facto one-party state by the Kenya African National Union (KANU), an alliance led by Jomo Kenyatta during 1964 to 1978. Kenyatta was succeeded by Daniel arap Moi, who ruled until 2002. Moi attempted to transform the de facto one-party status of Kenya into a de jure status during the 1980s, but with the end of the Cold War, the practices of political repression and torture which had been "overlooked" by the Western powers as necessary evils in the effort to contain communism were no longer tolerated.

Moi came under pressure, notably by US ambassador Smith Hempstone, to restore a multi-party system, which he did by 1991. Moi won elections in 1992 and 1997, which were overshadowed by political killings on both sides. During the 1990s, evidence of Moi's involvement in human rights abuses and corruption (Goldenberg scandal) was uncovered. He was constitutionally barred from running in the 2002 election, which was won by Mwai Kibaki. Widely reported electoral fraud on Kibaki's side in the 2007 elections resulted in the 2007–2008 Kenyan crisis. After that Kibaki was succeeded by Uhuru Kenyatta.

DEMOGRAPHY[2,3]

Population (2014): 45,010,056

Age Structure	
0-14 years	42.1%
15-24 years	18.7%
24-54 years	32.8%
55-64 years	3.7%
65 years and over	2.8%

Population by province (2009)	
Kenya (country total)	38,610,097
Nairobi (capital city)	3,138,369
Central	4,383,743
Coast	3,325,307
Eastern	5,668,123
North Eastern	2,310,757
Nyanza[2]	5,442,711
Rift Valley	10,006,805
Western	4,334,282

[2] Nyanza is recently renamed to Homa Bay

Figure 2: Map of the provinces of Kenya and capital cities

Ethnic Groups

Kenya has a very diverse population that includes most major ethnic, racial and linguistic groups found in Africa. The majority of the country's population belongs to various Bantu sub-groups, with a significant number of Nilotes.

CIA World Factbook gives the ethnic composition as follows (out of a total population of 38.6 million): Kikuyu 6,622,576 = 17%, Luhya 5,338,666 = 14%, Kalenjin 4,967,328 = 13%, Luo 4,044,440 = 11%, Kamba 3,893,157 = 10%, Kenyan Somali 2,385,572 = 6%, Kisii 2,205,669 = 6%, Mijikenda 1,960,574 = 5%, Meru 1,658,108 = 4%, Other African 13%, non-African 1%.

Religion

Christian 82.5% (Protestant 47.7%, Roman Catholic 23.5% and other Christian 11.9%), Muslim 11.2%, no religion 2.4%, African Traditional Religion 1.7%, Bahá'í Faith about 1%, Buddhism 0.3%, other 2%.

GENERAL INFORMATION[4,5]

Although Kenya is a multilingual country (up to 68 different languages), the official working *languages* are Swahili and English.

Area: 581,309 km^2 (of which 2.3% water)

Currency: Kenyan Shilling (KES), 1 USD = 101,5 KES, 1 EUR : 113,8 KES

National alarm number: (+254) 112 or 999/911

Motto: "Harambee" (Swahili, "Let us all pull together")
Anthem: Ee Mungu Nguvu Yetu (Swahili, "O God of all creation")

Time zone: EAT (UTC+3)

Neighbouring countries: Uganda, South-Sudan, Ethiopia, Somalia and Tanzania

Traffic: Left-handed

Electricity: 220-240V à 50Hz (if available and working)

Figure 3: Kenyan plug and socket

ABOUT THE PROJECT

THE GOAL

The Imbeke training centre was only recently constructed by the people of Imani, as work has only started in 2014. Therefore the basic utilities needed to support the working of the centre like electricity and water are not yet fully completed. Since there recently has been made a connection to the electric grid (end of 2015) our main focus will be oriented to the water supply. However one goal during our stay will be to evaluate the possibilities to become (partially) independent of this very unreliable grid (the grid is offline at least 20 per cent of the time).

Right now, the staff and students in the centre have access to a well and two tanks of rainwater. These however have their limitations, as (despite the natural gradient of the terrain) they are unable to deliver sufficient water pressure to service the recently completed sanitary building. Also the lack of water during the dry season is a problem (as the supply is limited to the manually operated well). As a large part of the lessons given in the centre are about farming techniques there is also water needed for irrigation to be able to continue the lessons during the dry season. Therefore the main goal of our project is to construct a all year round operational water supply, capable of delivering the required pressure and flow anywhere on the terrain. The effect for the local population is also double. Because of our project, water for sanitary will be available and therefor hygiene will be improved and the spreading of diseases will be contained. The water for irrigation has an educational goal and will indirectly increase local food production and hopefully also serve as an example installation for the use of irrigation techniques.

The lack of clean potable water is another problem the students and staff, and by extension the entire local population faces on a daily basis. In the present situation they drink water directly from the well or even rainwater, despite the availability of chloral tablets. An important goal of our project will be to tackle this danger to public health by starting a demonstration project and a small awareness campaign about the dangers of drinking contaminated water and demonstrate a cheap 'Do it yourself' technique to decontaminate water based on solar radiation (Sodis technique). This last goal is an important factor in fighting waterborne diseases and will hopefully make a contribution to increase public health both in the centre and the nearby village(s).

To conclude, the project is part of the main goal to upgrade the standard of living of local (and often poor) people in and around the Imbeke training centre. The project will intend to do so by:

- Making the people aware of the importance of clean potable water and thereby indirectly trying to decrease the amount of waterborne diseases.
- Improving the hygiene by making sure water is available in the sanitary block.
- Helping to improve the education of the local people by making water disposable for irrigation. Indirectly helping to increase the harvests as a result of better irrigation techniques.

PLANNING

Literature study:

In the first semester, we started out by writing a thorough study about water filtration. This focused on our social assignment, which is providing clean potable water for the local community. We listed out all possible initiatives and putted in a lot of thought in the pro's and contra's of every technique. It rapidly became clear that most of the existing methods are not effective in their purpose and the effective ones were too expensive. So we decided to focus on a very simple technique that every household can do for himself, based on the SODIS principle. This implies that we will have to work on a cultural aspect of the community, because the technique requires input of the people themselves.

Design:

The design of the main assignment, this is the PV installation, started out at the beginning of February. In the beginning we had a lot of difficulties according to decisions, which had to be made. This is why the communication with our partner was not always that smooth in the beginning. We had to review a lot of things along the way.

Logistics:

For the supply of the needed goods, we can count a lot on the gained experience by Imani vzw. The water tank and the elements of the concrete tower (resources like sand, granulates,..) will already be available in Oyugis at the time we arrive. These resources will be protected since the domain is protected by a guard and our local partner Sophie is present on the domain on a daily basis. So our hope is to not have any logistics problems according to the construction of our tower and the water tank itself. We will buy the pump and the solar panels directly from the suppliers in Nairobi. We will do this the moment we arrive in Kenya and will take them with us on our way to the project site. For the little components such as tools and wiring, we count on the nearby cities and we are able to get them ourselves if needed.

CULTURAL AND SOCIAL ASPECT

Going on a development project to a third world country is often not as easy as it seems.

Together with Imani vzw, we are trying to develop a community inside Oyugis where mostly women and children will be able to get education about agricultural techniques and health care. During the years, every building that has been built has had an impact on the community. Of course a physical impact, but while the community is growing year after year and with every new building, the social impact is getting bigger and bigger. This is why a lot of cultural and social aspects have to be taken into account.

The first and maybe biggest problem that will occur is the language barrier. In theory, English is one of the national languages of Kenya, but compared with Western countries, that does not mean everyone can speak English. Only a minority, mostly people with an education, can speak at least a little bit English, while the majority can only speak KiSwahili or local dialects. In the regions around Oyugis (Eastern part of Lake Victoria), this local dialect is probably Dholuo or other smaller dialects.

To handle this problem, our local partner Sophie will help us by being our interpreter when we work with the local people. If it's possible, we will even try to find a pupil of a school nearby to help us interpret so that it will be a win-win situation. This because the pupil can improve his/her English while we will be able to communicate with everyone else. In worst case, when there is no interpreter present, the use of a dictionary (if available) or gesticulation is inevitable.

Another problem that might occur is the difference in religion or habits combined with this religion. While Oyugis is mostly inhabited with Luo people, the main religion is Christianity. This means that in general there will not directly by a problem with religion but we have to make sure we adapt to their more local Christian traditions. It also is possible that there still is a more traditional African religion. To be sure, it is important to ask our partner what the main habits are and how to copy them.

A social case that certainly has to be taken into account is the gender inequality. The Imbeke centre is in hands of a community of women, but when local men get to know that Western people are coming, women are being pushed aside because men think they aren't strong enough to build something. This can be a problem because it is important to involve women when it comes to building a water supply, because it mostly is the duty of women to go to rivers or wells to supply their families with water.

It therefor is important to make good arrangements with the women of the centre and men in the area, because when we will be gone, the men will lose interest in the project but the women will still need to know how to fix problems of the well when they occur. To make these arrangements, it is important to communicate beforehand with Sophie, to see how the relationship between men and women is in the centre and how we can implement our project. Luckily, Imani told us that the foundation, and other parts of the previous buildings, were made by the women themselves, so we hope that we can extend this experience to the building of our water tower.

This previous case leads to another important one. We Western students are going to Kenya with the best will and to give 100 per cent of ourselves to help as much as possible. But not everyone will see it that way. Every human being has a way of proudness and self-respect and it therefor is possible that some people will see us as intruders or that they are not willing to accept our form of help (which obviously is understandable) because it sometimes is hard to admit that it isn't within their reach to develop such a project all by themselves. A good communication and well-made agreements before we start are therefor one of the most important things of our project.

Another social (and cultural) problem that has to be taken into account is the water cleaning part of our project. We are trying to implement a way to make potable water, but we have to question ourselves if the local people are willing to use this. Imani told us that there are already chloral tablets available, but people don't use them because they don't find it necessary. This because they aren't use to do so (cultural history), they think they will lose too much time and because no major illnesses already occurred due to the fact of waterborn diseases. This leads us to find a way to clean water that is easy to implement, easy to maintain and doesn't need a lot of work and time to use. The explanation of which process we will use, is explained later on in this report.

The fact that Annelies, a social-oriented student is joining us to Oyugis, will (hopefully) give a boost to the social part of the project. She will use some of her experience about the WUC's (Water Using Committees) to help and guide the women's community in the Imbeke centre. This is necessary because the sudden availability of almost 10.000 litres water extra a day will have a big social impact on the centre.

To conclude, it is needless to say that a good communication is obligatory. Good rules and arrangements have to be made before we start building our project. It therefor is recommended to spend a day (or more) to communicate with the locals and to get to know each other more. What are their expectations, are they happy that we are trying to help, learning about their interests beside the project,... are all questions we need to know the answer to. To let the work go fluently, it is important to have a good interaction with everyone involved, because you will have to spend almost 8 weeks by each other's sides.

TECHNICAL SPECIFICATIONS

After consulting with the local partner (Imani Belgium vzw), we have decided to place a tank of 10.000 litres, this to provide enough storage capacity to buffer immediate needs while the pump can operate more slowly and at a constant rate. This tank supplements two 5000 litre tanks for rainwater collection that are already present in the centre. However during dry season when the need for our installation is at its highest there is almost no rainfall, so these tanks often stand dry. Because of the fact that the new tank will supply the two already existing tanks, there will be made no difference between ground water and rainwater. Both 'types' of water are expected not to be drinkable. This is where our social part of the project will help, to build a SODIS-demo so that they can clean the available water.

To make sure the sanitary block can be used no matter the water level in the tank it is important that the bottom of the tank is placed at a higher elevation then the showerheads, this will guaranty according to the principle of communicating barrels that water will be available at any water level. As the sanitary building lies about 80cm lower than the current well, the natural slope is insufficient which necessitates the construction of a tower on which the tank can be placed. To insure a minimum of pressure in every access point of the distribution network it is advisable to increase the height of the tower further than the minimal height necessary to supply water to the showerheads, the height of the tower will therefore be increased to about 3 meter.

Both above mentioned specifications will in turn determine the specifications of the pump, the only missing information (started from a given depth of the well and dimensions of the tower including tank) is information about the daily consumption of water, as a average human uses about 40 liters a day. Tis is an estimation of the UN and World Health Organisation (WHO) so that the most essential needs can be made. This will be further illustrated in the technical design. For now it is sufficient to say that we will aim to deliver the full capacity of the tank in approximately a day.

The installed power of photovoltaic cells (or other renewable energy source) is of course linked to the choice of pump. Again a more detailed explanation will be given further on, but a simple estimation can already be made to form a specification for the solar array:

$$P = Q * g * h * \rho$$

Using:

- the density of water ρ = 1000 kg/m³
- g = 9.81 m/s²
- Q = 10m³/day => 2m³/hour (5 solar hours)
- H = 6 (tower) +7.62 (25 feet) (well)= 13.62m

This enables us to estimate the required power supplied to the pump to be about 74 watt, this is of course a huge underestimate of the actual required power, because of the efficiency of the pump etc, this will be further explained later but as an indication we can assume about 200 watts of installed power.

TECHNICAL CONCEPTS

For the sake of clarity we will maintain the same subdivision in independent subsystems as in the previous paragraph, this being the tower, the pump and the solar array. The water storage tank (where meanly the size could be subjected to a comparison) is not mentioned because of the explicit wish of the partner organisation to work with a 10.000 litres tank. Although the tank has a capacity of 10.000 litres, it is unlikely that the tank will be full when in use. Because of the fact that there is a high demand of water (for drinking, irrigation and sanitary), the water inside the tank will not stand still for a long time. The reason why the thank has to be 10.000 litres, is for expanding in the future when possible.

The tower

As the shape of the tower is further discussed in the technical design chapter, the focus of this comparison is about the materials in which the tower could be constructed. A brick tower without any reinforcement was ruled out because of the very questionable quality of local bricks and the inconsistency in shape. The partner however has always expressed the request for a (brick) walled structure to safely store electric components and a main valve to completely shut down the water supply to the rest of the terrain. As this wall will have to be constructed anyhow it is again not considered as a concept but rather as an extra with all the concepts. This leaves three possible main construction materials for the tower: wood, steel and concrete.

- Steel, like both other materials, has no problem carrying the mechanical load. However large steel beams are rather expensive and there is no welding equipment available in the centre, which means this would have to be rented or a local welder would have to be employed. Also the long term sustainability (corrosion) is questionable, although this is easily countered with simple solutions like paint. The advantages of a fast construction time do not outweigh these disadvantages and also both Humasol and the local partner expressed a rather negative opinion (problems with welding: safety, quality and electricity availability and the availability of quality steel in Kenya or neighbouring countries) to use steel as construction material.

- Wood, is an easy workable and cheap alternative for both the columns as the roof itself, according to the local partner it is however very difficult to find quality beams of appropriate size in the region. Both the local partner and Humasol were also concerned about the long term survivability of a wooden construction because of the maintenance which is required as wood can display rot after a period of time when not properly treated.

- Concrete, as the most used construction material in the region has the advantage that the local partner already has experience with this type of construction, as well as good contacts with suppliers. This combined with the durability and long life time compensate for the longer construction time. This option was eventually selected for the final design.

Material	Pro's	Contra's	Conclusion
Steel	• Fast • Strong • Height easily increasable	• Quality steel is Expensive • Equipment and labour cost • Corrosion (or extra cost for paint)	A good alternative, but not further considered mainly because of the higher skill level required
Wood	• Cheap • Strong • Height easily increasable • Easy to work with • Environmentally friendly	• Rot • Possibly not easy to acquire	Not recommended by Humasol and therefore not further investigated
Concrete	• Favoured by Humasol and the local partner • Best long term solution	• Longer construction time	As the option favoured by all partners, selected for the final design.

Table 1: Summary and comparison of the different concepts

Remark: As both partners were from the start fond of a concrete structure there never has been made a full budget for each option, price information in the above comparison is therefore mostly based on estimates and thus not 100 per cent representative. For example a steel construction with a larger number of smaller profiles could be equally cheap as a wooden construction, etc....

Pump

The final selection of a specific pump will be further elaborated in the technical design section, but to keep this section as focused as possible to the selected design, below is given a short comparison between the different types of pumps in the market.

- Surface pumps have the advantage to be easily accessible because the only component to be placed inside the well is a hose. They are also cheaper in general. These pumps are however made for lift rather high flows with a smaller head. All surface pumps are limited to a theoretical maximum of 10m head in front of the pump (otherwise the suction pressure would become too low, which causes cavitation). This is perhaps not a problem for the current well (of about 7.6 meters depth) but will become an unsolvable problem if the partner switches to a borehole (which will mean an enormous improvement). Therefore these pumps do not meet the requirements and are not further considered.
- Submersible pumps can be further divided depending on their working principle as there exist piston pumps, helical rotor pumps and centrifugal pumps. Of these the first principle is often not implemented in the more powerful pumps (head > 10m, necessary in this project), although exceptions exist. Of the other two the helix rotor (comparable with a Archimedes screw) is preferable for this project, as it has fewer (small) parts (serviceable) and can cope a lot better with sand, which would block the impeller of a centrifugal pump. This advantage outweighs the higher price with ease.

Power supply

As there is no water current with a sufficient drop present close to the desired location of the pump, the choice is limited to either a wind turbine or a solar array. However as solar panel are directly available in Kisii and Kisumu and solar panels are often more reliable (less moving parts, wind gusts and rapidly changing winds at low altitude, etc) and as this option is favoured by both the local partner as Humasol itself, we eventually opted for a solar array of 1 or 2 panels. The reason why this option is favoured by Humasol, is because the cost of a wind turbine is less than a solar installation.

It is worth mentioning that a theoretically more environmental friendly, durable and efficient solution can be found when the axle of a (vertical) wind turbine is directly mechanically coupled to the shaft of the pump itself. By completely eliminating all electric components, the number of components is reduced drastically. This option is not further explored for various reasons:

- As there aren't many of these systems on the market it could be necessary to construct one by hand, resulting in problems to find replacement parts. This is further complicated due to the limited time available to design, construct, test and improve a prototype of such an installation which normally would take more than 2 years of research.
- This solution is not expandable if in a later fase the solar array is expanded to provide electricity for other applications.

LITERATURE STUDY

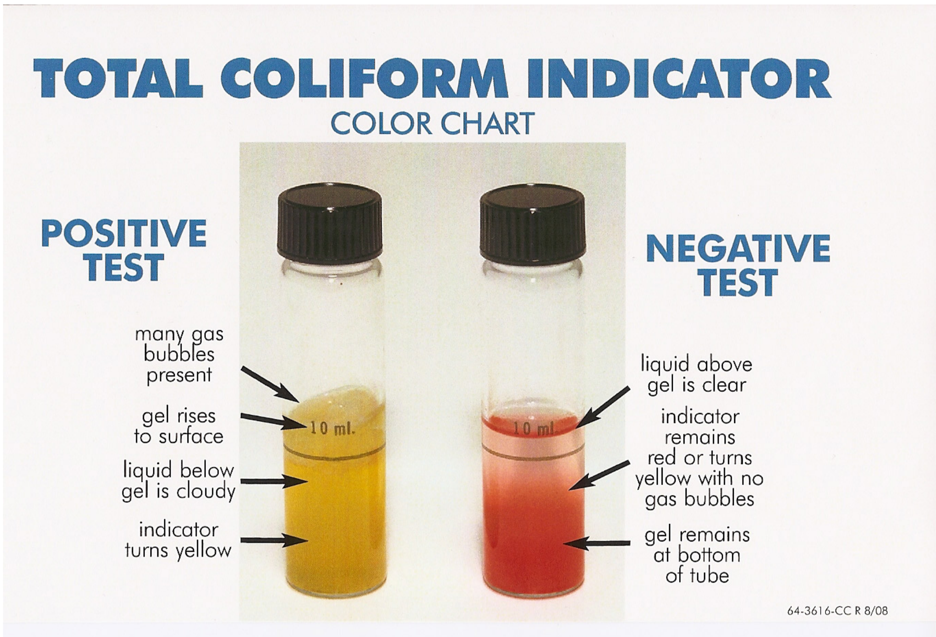
In the context of the installation of a PV installation and water tower in Kenia, the possibilities are being examined for the filtration of the water being pumped. In the following text we will speak in short about all the existing technologies and why we did or did not chose to use them.

Situation

In Oyugis, there is no clean potable water available. The local community relies on the use of rainwater, but sometimes this is contaminated, with waterborne diseases as a result. The local population is now provided by chlorine tablets to clean their water, but the major problem is cultural history. From generation to generation, the community is used to drink the water that is provided to them by nature. So at the moment they drink rainwater (which is not that bad) or water from the well (which can be contaminated if it stands still for too long). We think that with creating awareness around the topic, we can encourage them to use the SODIS system. It is simple in implementation and technique, which we will set out in a further paragraph.

Bacteria tests

The biggest danger with drinking non-filtered water lies in high bacteria levels. The most common bacteria are the **E.Coli** bacteria and **legionella**. Coliform is a bacteria that is naturally present in our intestines, so also in our feces. The presence of the coliform bacteria in water indicates that the water is possibly contaminated with other bacteria, such as legionella. So our number one concern is testing on E.Coli. This can be done by a simple test kit, priced at 30,45 euro per kit.[13]



Figures 4&5: Coliform Test Kit

The test is conducted as in the picture above. We plan to buy 2 test kits so we can do 10 tests. We think that this will supply us with enough information to conclude the drinkability of the filtered water.

Test results

To be sure that the available water is chemically safe, we ordered a series of tests on the quality of the rainwater, water from the well and also from the river. Attached are the results.

River water

WATER RESOURCES MANAGEMENT AUTHORITY	
TITLE: Water Sample Analytical Certificate -Physical Chemical Results	**REF. NO:** F/9/1/3
	ISSUE NO: 04
DEPARTMENT: Technical	**REV. NO:** 03
ISSUED BY: DTCM	**DATE OF ISSUE:** 15th April, 2013
AUTHORIZED BY: TCM	**PAGE:** 1 of 2

SERIAL NO…………3……………………Sample No……**899/15**…………………………

Name of customer…**Imbete centre**……..Address…**Box 193 Oyugis** ……………………

Purpose of sampling…. **Assessment**……County…..**Homabay** …………………………

Date Sampled…**14/03/2016**…………….Date Received…**15/03/2016**………………………

Source………………..**River** ………………….Date compiled……**21/03/2016**……………

PARAMETERS	UNIT	RESULTS	WHO STANDARDS	KEBS(KS 459-1:2007) STANDARDS
pH	pH Scale	**6.71**	6.5-8.5	6.5-8.5
Turbidity	N.T.U.	**11.3**	Max 5	Max 5
Conductivity (25^{0}C)	µS/cm	**246**	Max 2500	-
Calcium	mg/l	**45**	Max 100	Max 150
Magnesium	mg/l	**8**	Max 100	Max 100
Total Hardness	mgCaCO$_3$/l	**112**	Max 500	Max 300
Total Alkalinity	mgCaCO$_3$/l	**180**	Max 500	-
Chloride	mg/l	**14**	Max 250	Max 250
Fluoride	mg/l	**0.17**	Max 1.5	Max 1.5
Nitrate	mgN/l	**0.4**	Max 10	Max 10
Nitrite	mgN/l	**0.003**	Max 0.1	Max 0.003
Total Disolved Solids	mg/l	**123**	Max 1500	Max 1000
Others				

Name of analyst…**Florence Okoth**…………Signature………**21/03/2016**……………………

Figure 6: River water test results

We can clearly see that all the tested parameters lie in the safe region indicated by the WHO. Only the turbidity of the rainwater is way to high, but this is not a concern to us, while we will not use water from the river.

Rainwater

WATER RESOURCES MANAGEMENT AUTHORITY	
TITLE: Water Sample Analytical Certificate -Physical Chemical Results	**REF. NO:** F/9/1/3 **ISSUE NO:** 04
DEPARTMENT: Technical	**REV. NO:** 03
ISSUED BY: DTCM	**DATE OF ISSUE:** 15th April, 2013
AUTHORIZED BY: TCM	**PAGE:** 1 of 2

SERIAL NO…………**1**……………………Sample No……**897/15**………………………

Name of customer….**Imbete centre**…….Address…**Box 193 Oyugis** …………………..

Purpose of sampling….**Assessment** ……County….. **Homabay**…………………………..

Date Sampled…**14/03/2016**………………Date Received…**15/03/2016**…………………

Source………**Rain water**…………………Date compiled…**21/03/2016**…………………

PARAMETERS	UNIT	RESULTS	WHO STANDARDS	KEBS(KS 459-1:2007) STANDARDS
pH	pH Scale	**6.51**	6.5-8.5	6.5-8.5
Turbidity	N.T.U.	**0.98**	Max 5	Max 5
Conductivity (25^0 C)	µS/cm	**22**	Max 2500	-
Calcium	mg/l	**0**	Max 100	Max 150
Magnesium	mg/l	**0**	Max 100	Max 100
Total Hardness	mg$CaCO_3$/l	**0**	Max 500	Max 300
Total Alkalinity	mg$CaCO_3$/l	**4**	Max 500	-
Chloride	mg/l	**8**	Max 250	Max 250
Fluoride	mg/l	**0**	Max 1.5	Max 1.5
Nitrate	mgN/l	**0**	Max 10	Max 10
Nitrite	mgN/l	**0.001**	Max 0.1	Max 0.003
Total Disolved Solids	mg/l	**11**	Max 1500	Max 1000
Others				

Name of analyst…**Florence Okoth**…………Signature……**21/03/2016**………………………

Figure 7: Rainwater test results

Rainwater is their number one supply of drinking water. We can see that all the parameters are conform the recommended values by the WHO. Despite the water is rather on the poor side concerning mineralization, it is chemically safe to drink. So this water is ideal to filter bacteria and protozoa to make it fully potable.

Water from the well

	WATER RESOURCES MANAGEMENT AUTHORITY	
	TITLE: Water Sample Analytical Certificate -Physical Chemical Results	**REF. NO:** F/9/1/3 **ISSUE NO:** 04
	DEPARTMENT: Technical	**REV. NO:** 03
	ISSUED BY: DTCM	**DATE OF ISSUE:** 15th April, 2013
	AUTHORIZED BY: TCM	**PAGE:** 1 of 2

SERIAL NO............**2**........................Sample No......**898/15**..........................

Name of customer....**Imbeke center**.......Address...**Box 193 oyugis** ....

Purpose of sampling...**Assessment**. ......County**....Homabay**...................................

Date Sampled......**14/03/2016**...........Date Received....**15/03/2016**..........................

Source.........**Shallow well**...........Date compiled...**21/03/2016**..............................

PARAMETERS	UNIT	RESULTS	WHO STANDARDS	KEBS(KS 459-1:2007) STANDARDS
pH	pH Scale	**6.88**	6.5-8.5	6.5-8.5
Turbidity	N.T.U.	**1.25**	Max 5	Max 5
Conductivity (25^0 C)	µS/cm	**381**	Max 2500	-
Calcium	mg/l	**48**	Max 100	Max 150
Magnesium	mg/l	**10.7**	Max 100	Max 100
Total Hardness	$mgCaCO_3/l$	**164**	Max 500	Max 300
Total Alkalinity	$mgCaCO_3/l$	**252**	Max 500	-
Chloride	mg/l	**10**	Max 250	Max 250
Fluoride	mg/l	**1.6**	Max 1.5	Max 1.5
Nitrate	mgN/l	**0.1**	Max 10	Max 10
Nitrite	mgN/l	**0.002**	Max 0.1	Max 0.003
Total Disolved Solids	mg/l	**191**	Max 1500	Max 1000
Others				

Name of analyst...**Florence Okoth**...........Signature.........**21/03/2016**.......................

Figure 8: Water from well test results

The water from the well is also chemically clear to drink. We only see a slight problem with fluoride, but the exceeded value is so small, that they concluded the water to be chemically safe to drink. In following letter, the latter is proven.

	WATER RESOURCES MANAGEMENT AUTHORITY	
	TITLE: Water Sample Analytical Certificate -Physical Chemical Results	**REF. NO:** F/9/1/3 **ISSUE NO:** 04
	DEPARTMENT: Technical	**REV. NO:** 03
	ISSUED BY: DTCM	**DATE OF ISSUE:** 15th April, 2013
	AUTHORIZED BY: TCM	**PAGE:** 2 of 2

Comments by head of laboratory …**All the tested parameters are within the required limits except for Fluoride which is slightly above the recommended limits. However, the water is chemically safe for drinking.**

Name……**Florence Okoth** ……………………………………………………………………..

Signature………………………………………Date……**21/03/2016**……………………………

Issued by: ……………………………………………………………

(Deputy Technical Coordination Manager)

Approved by:……………………………………………………

(Technical Coordination Manager)

Figure 9: Water test conclusions

We only conducted chemical analysis on the different water sources. We also need bacterial analysis to be sure that the water is safe to drink. The reason we haven't conducted such an experiment yet is because we want to know the difference between filtered and non-filtered water. So we will test the water again on bacteria while we are on site before and after filtration, so we can sketch an image of the efficiency of the used techniques.

Filtration techniques

Reverse Osmosis

Reverse osmosis uses a semi-permeable membrane to filter the bigger parts out of the water. In the first place this concerns salts, but it can also be applied to many other molecules, ions and even bacteria. However there are important differences with the other, more conventional filtration techniques. A big part of the stream stays at the polluted side of the membrane. This prevents the filtered parts to build up a layer and to clog the membrane. However this is an asset of reverse osmosis, on the other side for every litre of clean water, we need several of contaminated ones, which stay unused.

To realise reverse osmosis, we pressurize the incoming water. When streaming along the membrane, a part of the water will go through, to minimize the energy (principle of osmosis). Because only H_2O-molecules are able to go through, the water gets filtered. So because of this technique, the efficiency of this process relies on the applied pressure and the initial concentration of the solution.

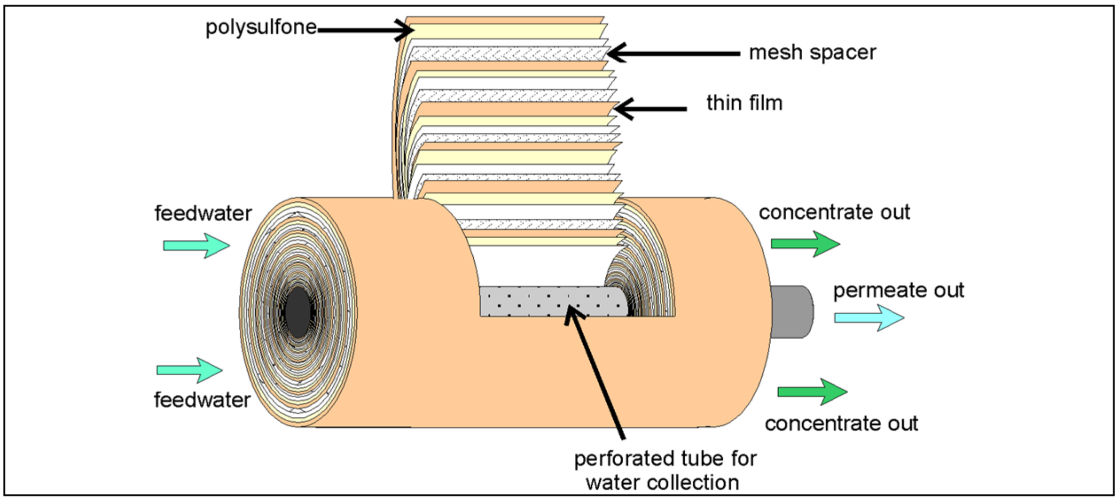


Figure 10: Reverse osmosis

The big advantage of this technique is that it is very effective to clean salt water. The disadvantages are that other contaminations, such as bacteria and viruses cannot be filtered out with this technique. The pre-filters have to be replaced on a regulatory basis, which will be a problem. It is a very water consuming technique with a very low efficiency of around 30%.

We can conclude that reverse osmosis is not the right technique for our project. We don't have salty water in the surroundings and the technique is not sufficient enough according to bacteria filtration.

Ceramic filter

Ceramic filters are effective when it comes to filtration of bacteria and protozoa. The working principle is as simple as can be. You put water at one side of the filter and the filter blocks everything that is bigger than it's pores. A good ceramic filter has pores from 2 to 5 micrometre. This is small enough to filter bacteria and protozoa, but too big to filter out viruses.

Potters for peace is a worldwide organisation in developing countries that helps the local community to produce ceramic filters. There is a little factory nearby Oyugis and one in Nairobi that is connected with this organisation. The price of a filter lies between 20 and 60 euros. This is a rather low minimal cost if you know that the filters have a very long life span.

This technique is not to be favoured because the described flow rate is rather low. However this technique has proven it's efficiency according to diminish the bacteria levels. We had already contact with a Potters For Peace supplier in Nairobi who can provide us with ceramic filters for 20 euro each. We are going to buy 2 filters to introduce them in the community. We will test the efficiency and if it is a success, it can be expanded with more filters.

Aeration

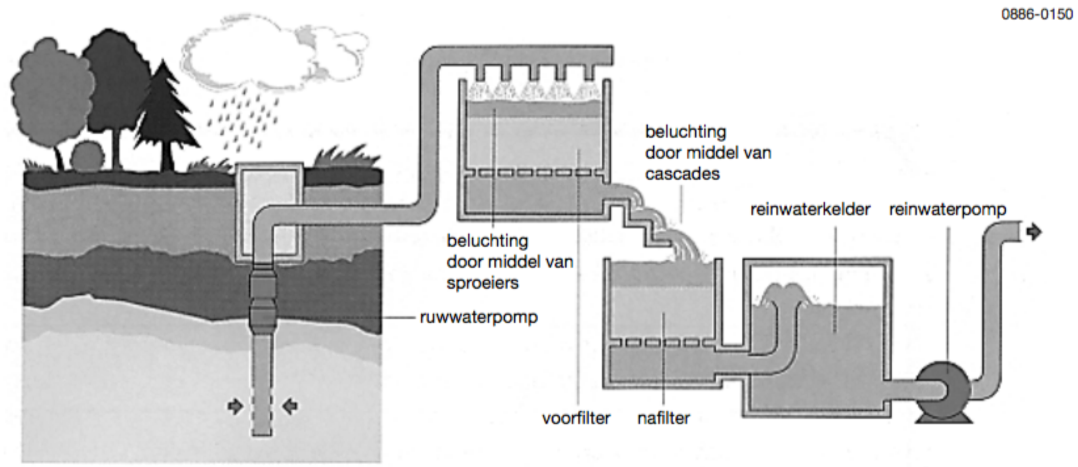


Figure 11: Aeration

The working principle is easily described on the figure above. Ground water is being pumped up and being transferred to sprayers that spray the water into the underlying filter. The reason to do so is that the oxygen level increases. Next the water goes through a filter, which can be a ceramic filter, or a sand filter. Then using a system of cascades, the aeration takes place once again to further increase the oxygen level of the water. This causes the concentration of certain acids and of CO_2 to decrease.

The implementation of this process is rather simple, but the initial cost is high.

We did not choose for this system, because we think it is too fragile. It doesn't take a lot for the sprayers to get obstructed, or a pipe can easily gets blocked. Another disadvantage is the fact that it has to be open-air because otherwise, the amount of oxygen can't increase. Making an open-air solution takes the risk that wild animals can pollute the water by their feces or caring bacteria to it.

UV-c filtration

UV-c filtration is the most efficient filtration technique of all. This method relies on UV radiation, which filters almost all contaminations out of the water. It is very handy because the filters are compact and are so easy to move.

There are a couple of reasons why we didn't choose this technique. First of all, the initial cost is very high. We could buy one or more filters for the community with our project budget but when the filters break, there will be no money left to replace them. Also, this is a western solution to a southern problem. It is not our incentive to hand over an already made solution to their problem, but we are more likely to work on a solution together.

SODIS

After eliminating every other filtration technique, we decided to go with Solar Water Disinfection. We made this decision with a lot of aspects bared in mind. First of all the most important aspect of the decision making process was the cultural aspect. We are very well aware of the problem with tradition. We can gain a lot of information by the fact that they have a method available, but are not using it. With that in mind, we wanted a simple technique, which requires little effort but is effective and low budget. In the further explanation it will become clear that SODIS meets all of these requirements.

Working Principle:

The technique relies on the influence of incoming sunlight. Sunlight contains different components which all have a positive influence on the drinkability of water. In fact, SODIS combines two already existing techniques described previously in this study.

- UV-radiation: Comparable with the other elaborated section on UV-filters, natural UVA-light (350-450 nm) of the sun works on the water and kills bacteria. UVA-light interferes after all directly with the metabolism of the bacteria and destroys in that way the cell structures.
- Heating: Boiling water is a well-known technique to clean water. Despite the cooking point is normally not reached with SODIS, a long term exposure to sunlight causes the temperature to rise high enough the kill an important fraction of the present bacteria. Because of the fact that the boiling point is not reached, the water doesn't become sterilized. However the remaining concentration still lies a lot lower than the WHO prescribed acceptable upper limit. The only thing needed to be taken into account is the fact that the time between filtration and consuming can't be very high, otherwise the bacteria get the possibility to regain their initial condition and get contaminated once again.
- Synergy between the two: The effectiveness of SODIS relies in a great way on the mutual fortifying effect of the both technologies on each other. A higher water temperature strengthens the disinfecting effect of the UV-radiation. This latter process will run to three times faster with a water temperature of 50°C.

Of course SODIS only filters out natural biological sources of contamination. Heavy metals or poisonous chemicals are not affected by this technique.

Realisation:

To build a working installation, very little attributes are necessary. It suffices to expose water during a long period of time directly to the sunlight in a transparent container. In practical use, this transparent container is mostly a well-cleaned PET bottle. The time of exposure is dependent on the temperature. With a water temperature of 30°C, an exposure time to full sunlight with an intensity of 500 W/m^2 of five hours suffices. Normally, the rule of 6 hours is utilised in plain sunlight to be sure. When the sky is semi covered in clouds, the bottles need to be exposed for two full days. Further we can optimize the technique to lay the bottles on a waved sheet of metal. This sheet heats up which will increase the water temperature even more and it reflects the UV-radiation.

It is also very important that the water is directly consumed out of the bottles that were used to clean the water. Otherwise there will always be a chance of recontamination.

Figure 12: the SODIS-principle

Advantages:

Most of the advantages of SODIS rely on the ease of use and cost efficiency:

- Very low cost. PET bottles are in fact a waste product, so they are very cheap to come by. Also a metal sheet is not that hard to find, nor expensive.
- However little education is needed to ensure the correct implementation of the system, the required technical knowledge is very limited. Combined with the previous point, this means that the technique is very easy to implement, use and even to spread out.
- If wanted by the population, this technique can be automatized very easily, using a pipe system with water flowing through it at a very low speed. This has the very big advantage that the danger of misuse will disappear almost completely.

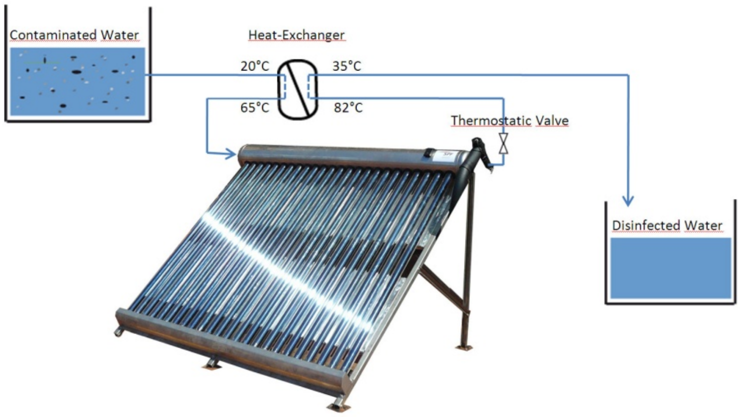


Figure 13: SODIS cleaning with metal sheet

Disadvantages:

The main disadvantages of SODIS are due to the incorrect use of the system. We only can conclude from this that we have to spend a lot of time and effort in the learning process. We need to make sure that every aspect and its importance is understood by it's full extend.

Another big disadvantage is the limited volume that can be filtered with one bottle. In fact this is easily to solve, just by simply using more bottles.

Conclusion:

Despite the little disadvantages, SODIS is a technique that is very easy to implement, teach and use. We think that this is the technique that requires the least effort and cultural change. We are very well aware of the difficulties that come with the transmission of this filtration technique, but we will put a lot of effort in this when we are on site. The SODIS-principle is also an accepted cleaning technique by the WHO.

For making sure the SODIS-demo will work, we will build one the first week we arrive. We will send a sample of before and after the cleaning to a lab and will see what the results are. These results are expected to be available after max. 2 weeks (similar tests have already been made on the ground- and rainwater and the results were available after 1 week). For a quick indication, we will bring small water tests to give a first result. If the water is found not clean enough, we will advise to keep using the chloral tablets which are already available but often not used.

As a second filtration technique we will buy 2 ceramic filters in Nairobi, which we will take with us to Oyugis. We will display the two techniques to the community and give elaborate explanation about the working principle and more important on the maintenance of the filters. We will also control the efficiency of this filter with a test, so we can compare the two. The most important thing though is to see which technique is liked most by the community and if they will effectively use it.

Depending on the success of the techniques explained above and the availability of time, another possible technique to demonstrate is a slow sand filter. As all materials needed for the construction of such a filter are present or easily accessible close to the centre and also cheap no further planning is needed for this technique (tests on the quality can be done as explained above).

Like the previous paragraphs about the technical specifications and concept, the same division is used in this paragraph into the different sub-systems of the installation, namely the tower, the pump and the solar array.

Tower

As explained in a paragraph above, the final design was made around a masonry water tower, with a brick wall to be able to safely store the pump controller and a main valve inside. This brick wall is not included in the calculations because of the very irregular shape and quality of the bricks. This wall however will be constructed first and remain as a permanent mold for the concrete columns that will carry the weight of the platform (and tank) above. The main dimensions of the tower can be found on the figure below.

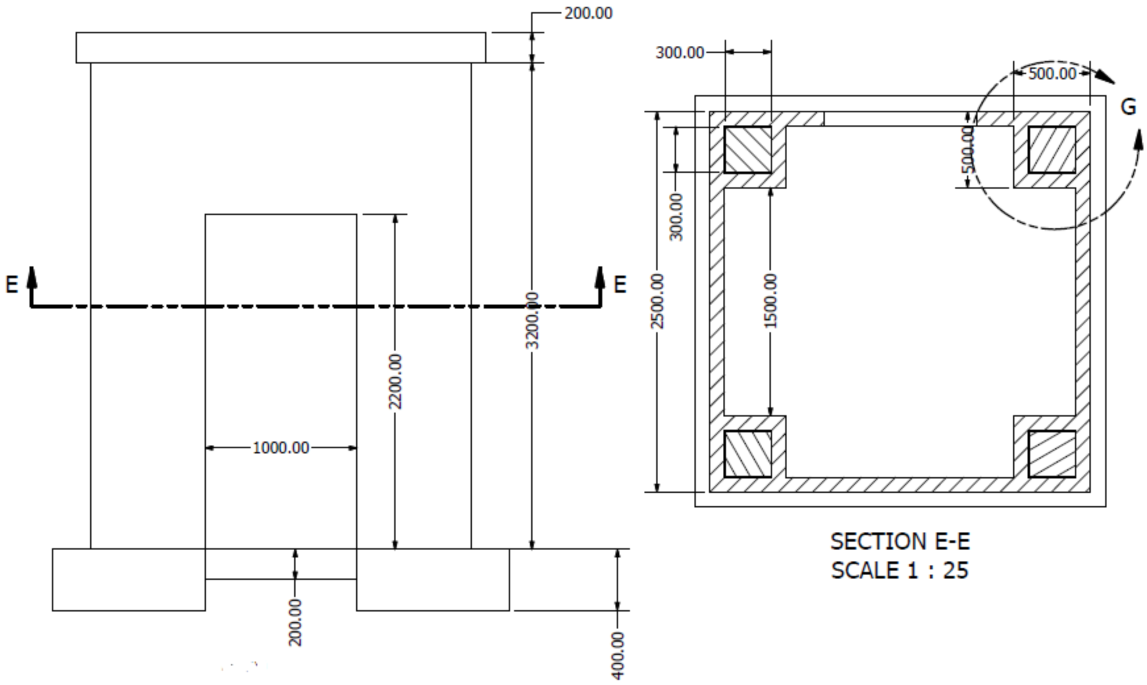


Figure 14: Main dimensions of the water tower

These dimensions form a compromise between the mechanical preferable case of supporting the load (weight of the tank) as centered as possible, and the wish of the local partner to have a maximum of useful space inside the building, which requires the load to be supported eccentrically. If the tank would be placed entirely between the walls/columns the bending moment in the platform supporting the tank would become very high, but with the benefit of a large space inside the building. Therefore a compromise with the local partner was made to limit the span of the platform to 2 meters. This way the columns are placed inside the perimeter of the tank (which measures about 2.4 meters in diameter). The right side of the above figure shows the concrete columns (30cm x30cm) inside the brick wall. The wider sections at the bottom of the left figure are part of the foundation, on which more detail is provided later.

The platform:

Of the main concrete components, the platform on top is most heavily loaded in bending, therefore it is necessary to calculate the required amount of rebar required to ensure the strength of the construction. For this purpose we will first consider a 2 dimensional cross section of this load. As the platform is not supported at two complete sides (only in the corners) extra rebar will have to be placed along the sides of the square to divert the load further to the corners (second calculation)

A 2D representation can be made as follows:

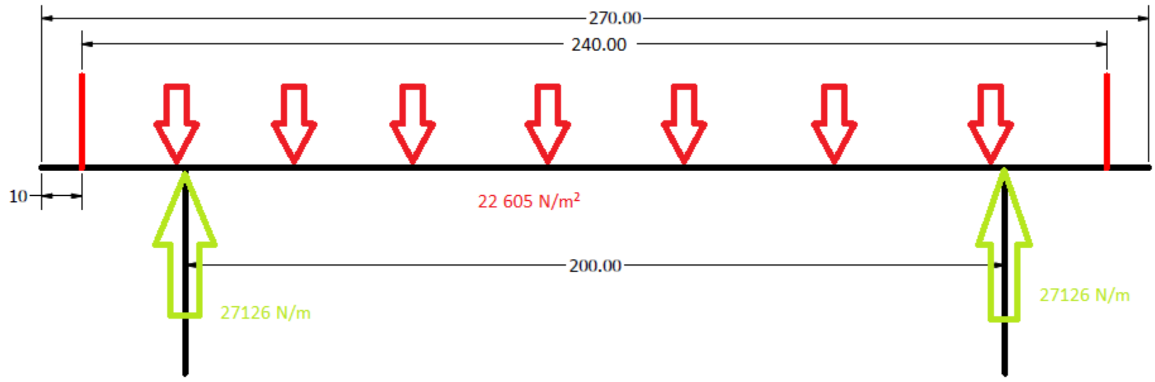


Figure 15: 2D cross section of the load on the platform

To keep the calculations readable and clear we will adopt some typical assumptions used in civil engineering. We will consider the columns to be narrow and assume them to be a simple support instead of clamped. This way the construction is no longer hyper static. It is worthless that both assumptions correspondent to a worse case than the real design. The first one increases the span (with half of the width of a column at both sides), the second one increases the bending moment in the centre of the platform as there is no counter moment at the top of the columns. The magnitude of the forces was calculated per meter depth (in the page) as follows:

$$Load = \frac{10{,}000N}{\pi * 1.2m^2} + \rho_{beton} * 0.2m$$

This way we find the load per meter depth and per meter width (hence /m²). The first part is the weight of the water, divided by the surface of the tank, the second the weight of the concrete itself. With a typical density of concrete of about 2,500kg/m³ this gives a load of 22,605 N/m². When multiplied by the width on which the load is active, and divided by two (as there are two supports) the balancing force delivered by the supports is easily found as:

$$F_{support} = \frac{22{,}605N}{m^2} * \frac{2.4m}{2} = 27{,}126N/m$$

This is of course a force per meter depth (hence /m). The weight of the tank and the part of the platform outside of the tank perimeter are neglected, but these are small compared to the rest of the load, and therefore easily covered by the safety margins (see below).

From this load case, the values for shear force can be found:

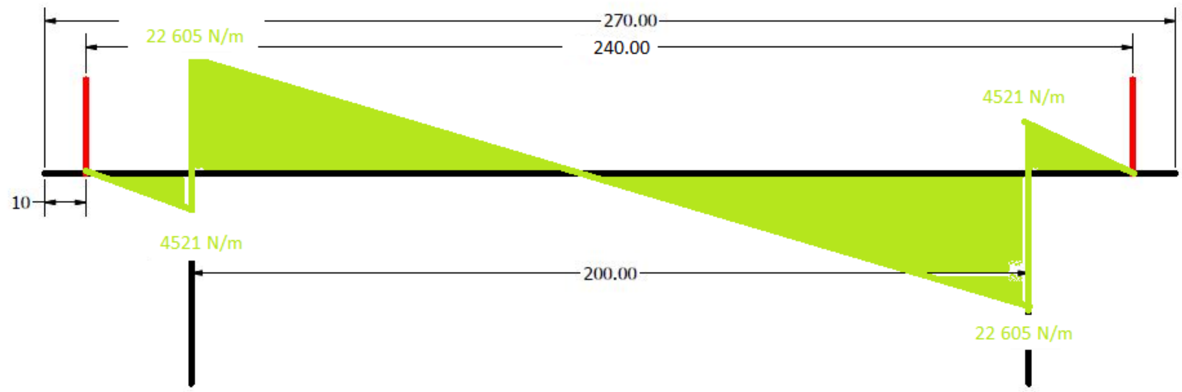


Figure 16: Shear force values of the platform

The values of the magnitude of the forces can be easily found by multiplying the length of each segment with the load. By integrating this (as it are triangles this is simply the width of each triangle times half the force at the end) the bending moment can be found:

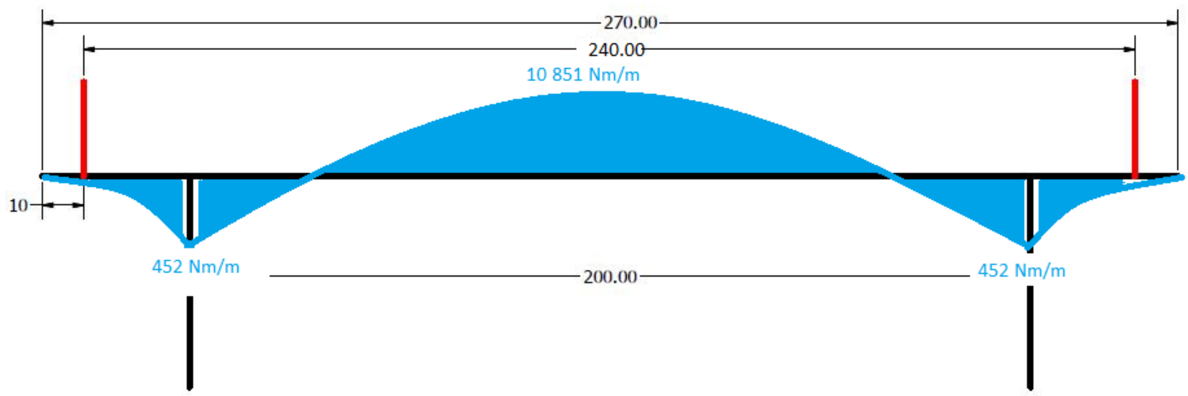


Figure 17: Bending moment values of the platform

With the maximum value for the bending moment (10,851 Nm/m) the required amount of rebar can be calculated. As concrete has very weak properties in tension, we assume that all tensile strengths are absorbed by the steel. A typical value for the yield strength of the low quality steels available in Kenya is 235MPa. The required second moment of area can now be calculated.

$$\sigma = M * \frac{y}{I}$$

In this formula M is the calculated bending moment, σ the acceptable yield strength, y as show in the figure below and I the required second moment of area. This leads to (using y = 80mm):

$$\mathrm{I} = \mathrm{a}^2 * \mathrm{A}_{\mathrm{steel}} = 3{,}693{,}958 \ \mathrm{mm}^4$$

As the maximal distance between the rebar and the centerline of the platform is limited (to keep the steel properly covered by the concrete we have to maintain a minimum 3 centimeters thick layer of concrete at the edge. With a known the total surface area (still per meter depth) can be found:

$$A_{steel} = 674.57 \text{ mm}^2$$

With the available steel bars of 12mm diameter or 113 mm² surface area (which we will be using) this can be translated to a minimum of 6 bars per meter.

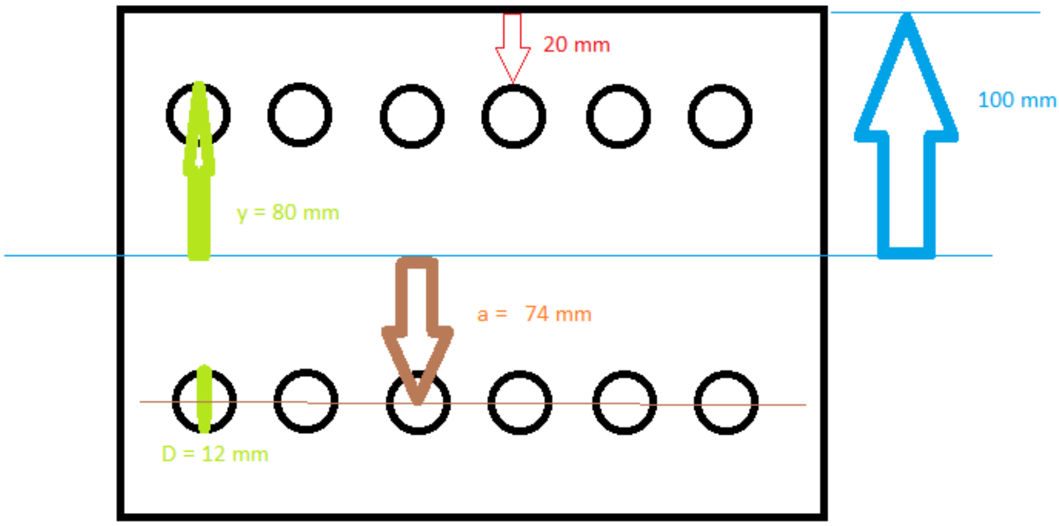


Figure 18: Cross section of the used pillars

<u>Ring beam:</u>

To expand from the to the 2D cross section to the real situation we have to take in account that there are only supports in the four corners (the walls are again considered as an extra safety, but are not taken into account in the primary strength calculations). To this end we can consider one of the four beams that make up the ring beam and add the support forces from the 2D case as a load. This would result in an identical situation as described above with the load scaled from 22,605N/m² to 27,126N/m. The second /m is not taken into account because we no longer consider a situation per meter depth but for a beam with a fixed width. This results in a moment of 13,021,000 Nmm, which would require about 7.2 steel rods of 12 mm diameter spread out over the 30cm width. This approach has the disadvantage that it doesn’t take into account the non-uniform loading caused by the tank (as most of the weight of the tank rests in the center), this means that the part of the load located outside of the main span (which has a negative contribution to the bending moment in reality is not or less present. An alternative approach could be to place one fourth of the total load in the center of each of the beams of the ring beam.

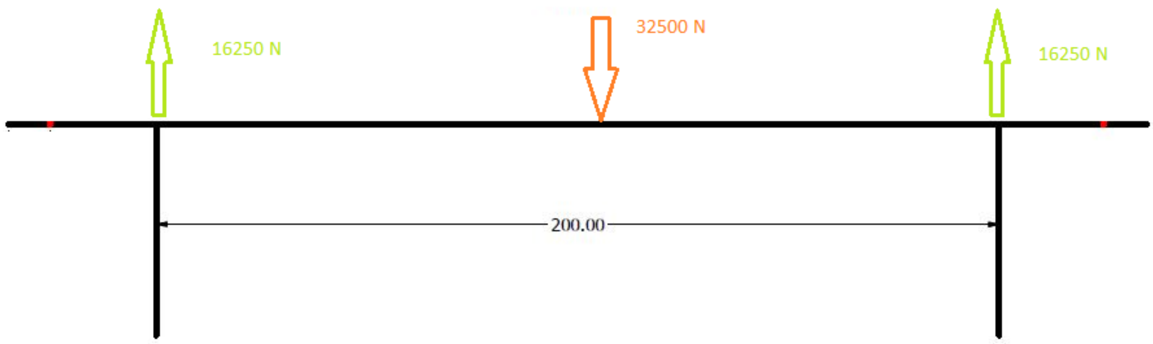


Figure 19: Simplification of the loads on each side of the tower

As the span is 2 meters the maximum moment for this case can be estimated by multiplying the column loads with half the span resulting in 16,250,000Nmm. This load would require about 9 bars of 12 mm diameter spread over the width of the beam. This number, however, is rather big to fit within 30cm of width as there isn't much space in between the bars to ensure a proper attachment to the concrete.

It actually is not necessary to place such a high number of steel rebar rods in these beams, as they are in reality fully supported by the brick wall and the load by no means is fully centered in the center of the beam. Therefore a smaller of about 5-6 rods will be sufficient.

As the real tower is a 3D structure there will be rebar in two directions instead of one (as shown in the top view below). This means that in reality only half of the weight will have to be carried by the rebar as considered until now (except in the last paragraph with the central load in the 4 ring beams). For safety reasons it is however common practice to work with a safety margin of multiplying with a factor of 1.5 or higher, as we cannot be sure of the quality of the steel, etc. This safety margin of two is kept despite the extra safety from the brick wall.

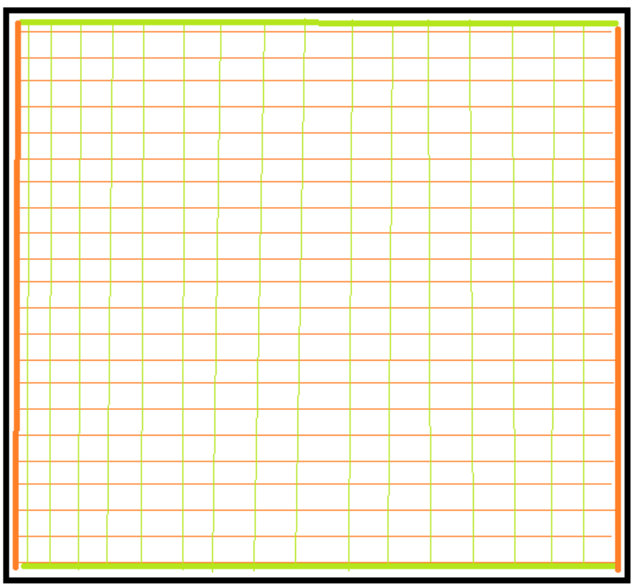


Figure 20: reinforced concrete construction of the platform

As the platform rests on 4 relatively narrow supports it is worthwhile to check the construction for the danger of the columns "pressing" trough the concrete. For this purpose we will first only consider the concrete itself. With the formula of Jourawki

$$\tau = \frac{F * S}{b * I} = \frac{32500 * (4 * 300) * 100 * 50)}{(4 * 300) * (200^3 * 4 * 300)/12} = 0.203\ MPa$$

Using:
F = (100000 (tank)+30000(concrete))/4 the load on 1 column
S =(static moment)
B = the width of the column (folded out, see figure)
I = b*h³/12 the second moment of area

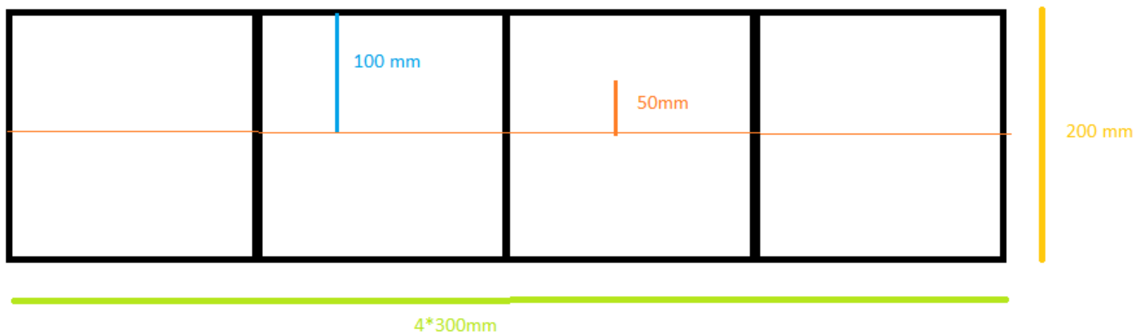


Figure 21: Dimensions of the platform

As this value is below the acceptable values for concrete, the danger of the columns pressing trough, especially with additional strength of the steel, is non-existent. There is therefore no need to add extra reinforcement of any kind. Also here it is worth mentioning that the brick wall will also carry the weight of the platform giving even more strength.

The columns:

As the columns are loaded in axial pressure, the concrete itself is more than capable of carrying the load, eliminating the need of further reinforcement. However we will add structural rebar as this common practice in construction works as an extra safety and counter possible local pulling forces due to unforeseen eccentricities.

The maximum load one column can carry can be easily found using simple axial pressure:

$$\sigma = \frac{N}{A}$$

With maximal pressure of 5 MPa typical for concrete we find a maximal acceptable load of 450,000 N or 45 tons, which is already 3 times higher than the weight of both the platform and the tank. We can also check the columns for buckling, according to the Euler formulas

$$Nmax = \pi^2 * E * \frac{I}{L_{knik}^2}$$

Using a E-modulus of 20.000 typical for low strength concrete and a buckling length of 3,200mm (the full height of the tower a maximum load of over 13,000,000 N can be found. Even with the commonly used safety factor of 4 to take into account not perfectly centred loads, this still means a maximal acceptable load of over 3,250,000 N or 325 tons.

Foundation:

As the weight of the tower rests mostly on the four columns, it is sufficient to place the foundation mainly under these pillars. To this aim we will build concrete column bases under each column. The lack of a full foundation plate is also beneficial for connecting underground lines or piping. To start the construction of the walls from a flat and straight surface we will also place a wall foundation underneath them. The walls are however not heavily loaded and therefore these foundations don't have to be as deep. The entire foundation is displayed in bottom view below. As visible in the figure with the main dimensions above the depth of the wall foundation can be limited to about 20 centimetres.

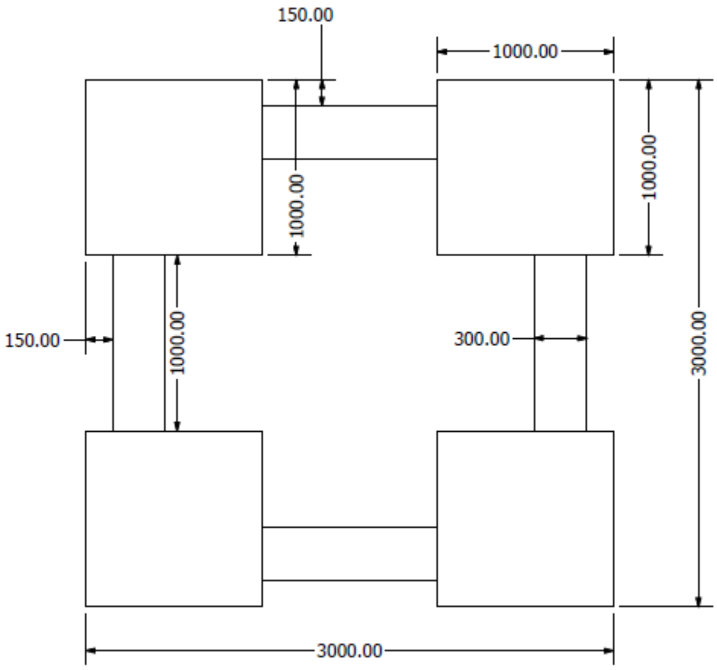


Figure 22: Dimensions of the foundation

Based on the limited data available about the soil (mainly Murram) and the experience of the people of Imani, we estimate that a surface area of about 1 m² per column will be sufficient to distribute the weight of the structure over the ground, without the danger of the building sinking away or tilting. To guaranty that the load of the column is distributed evenly over the surface area of foundation we can use as a commonly used rule of thumb that the load spreads with a 45° angle. As the foundation is about 35 centimetres wider than the column this means a minimum depth of 35cm. To add a safety margin we will opt for a 40cm thick foundation.

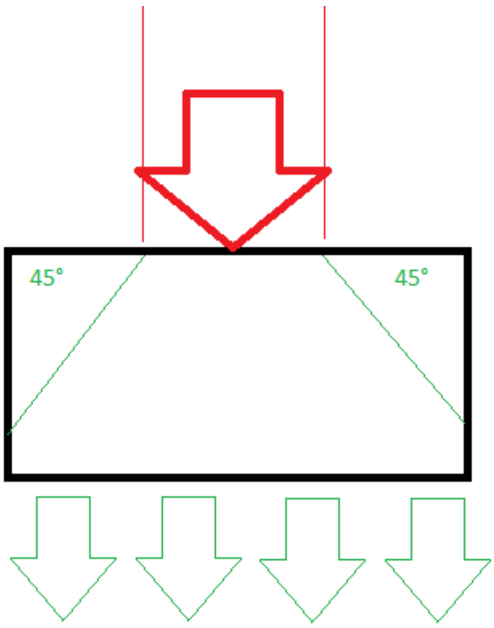


Figure 23: Division of load on the foundation

Very similarly to the platform, this foundation is also loaded in bending, with a potential risk of the column pressing trough. However as this slab of concrete is much thicker and shorter the occurring tensions are considerably lower. Similar calculations as in the above case for the platform show a shear tension of 0.16MPa (as a result of the pressing force), this is well within the limits of the concrete itself. The maximum occurring moment is about 4,375,000 Nmm (or about 2.5 times lower than in the platform). As the thicker slab has a much larger second moment of area ($h^3*b/12$) the maximal tensile strength is only about 0.164 MPa when only considering the concrete, although this is perhaps acceptable, it is advisable to add rebar to the foundation (this is common practice for all structures) especially in case of not uniform load, etc. Therefore another rebar mesh will be added to the concrete for extra added strength.

<u>Concrete composition</u>

Strength class: C25/30
Consistence class: S3 “Semi fluid”
Maximum diameter granulates: 20 mm

} $(W/C)_{max}$ = 0,55
C_{min} = 300 kg/m^3

1) Buist formula

   $f_{cmcub150}$ = 0,9 * N + 25/(W/C)-45 → W/C = 0, 517 < max → OK

2) Compressive strength

   f_{cm} = 25 + 8 = 33 N/mm^2
   $f_{cm,cub150}$ = 33/0,79 = 41,77 N/mm^2

3) N dependent of type cement

CEM I 32,5 R → 18 N/mm^2

4) Water

S3 ~ diameter 22 mm → 185 kg/m^3
C = W/(W/C) = 185/0,517 = 357,83 kg > min → OK

5) Volume granulates

V_y = 1 – 360/3150 – 185 /1000 = 0,7 m^3
We use 1/3 sand an 2/3 of ballast

So we can conclude from this calculations, that we will use a composition of 70% granulates, from which 1/3 consisting out of sand and 2/3 of ballast. We will use around 360 kg cement per cubic concrete and 185 kg water.

We will use this composition if we can measure the quantities exactly on site. If this is not possible, we will use the rule of thumb: 1 part water, 1 part cement, 2 parts sand, 3 parts gravel. These are volume quantities and are not so different than the calculated percentages.

Implementation of the tower

Figure 24: Placement of the tower

The exact place of the tower has to be as close as can be to the well to minimize losses in electrical wiring and hydraulic losses in the water pipes, but not too close so that the foundation of the tower will not slide towards the well. The tower will be placed on the other side of the well, as shown on figure 24.

The pump

Sizing:

As explained in the chapter about technical specification, it is almost impossible to exactly quantify the daily need in water. However several assumptions can easily be made:

- Up to 20 people in the centre require up to 40 litres a day (including sanitary). This is an overestimate as not all students live in the centre, they can however take water home for family members, etc. This results in a basic need of 2 m^3/day.
- In the dry season the water will be distributed to the people of the village and the local partner expects that even inhabitants of other villages in the region will also drop by for water. If 100 people each take home 40 litres this means another 4m^3/day.
- Irrigation is dependent of the type of crop, the area of farmland etc, and is therefore very hard to estimate, but extra water will be needed for this application. However the water of the well is not intended for a full irrigation installation. This would not be a durable solution as there is surface water (a small river) close to fields, which could be easily accessed with a small surface pump with a higher flow capacity or even a channel collecting water upstream. In this project we will only foresee a tap at which water can be collected to manually water some plants. Therefore the flow demands are rather small (<1 or 2 m^3 /day)
- The local partner is planning to place a borehole in a later phase, using the same pump therefore a little growth margin is taken into account. The reason why this borehole is planned for in the future is because the existing well is sufficient for the current demand of water. Beside this, the boring of a new hole was not in the reach of our budget
- The local partner has explicitly asked for a 10,000 litre tank, as they noticed that the two 5,000 litre tanks now in place are insufficient. As the pump and tank are designed to work together they have to be matched to each other. As water that stands still for too long has to be avoided, it is (as most needs are on a daily basis) logical as an aim to pump the full capacity of the tank in 1 or 2 days.

All of this taken together suggests a pumping capacity somewhere between 5 and 10m^3/day. The pump described here is therefore designed to meet these needs. It is however very important to take into account that the well is only capable to deliver a certain amount of water. Therefore we did a capacity test on the well. This is measured by a proper borehole company and the results meet our needs. In the attachments in the deadline folder you can find a document from the test itself. It is the original document, given to us by the driller. We can conclude from it that it is safe to install a pump that delivers 1m^3/u, also according to expert Albert.

The pump preliminary selected to deliver the ‘high’ flow is a Lorentz PS 200 HR-07, as sold by Cat.co.ke in Nairobi (full datasheet is included in attachment, as well as a link to the salesman in Nairobi.) This pump was selected (in consultation with Sam Van Dyck form Humasol) because of several advantages:

- The controller and all electronics are placed at the surface, facilitating service and limiting the number of components inside the pump.
- As a Helical rotor pump it is less sensitive to sand and other polluting substances and (as there are less moving parts) easily repairable, which justifies the higher cost.
- The controller is specifically designed to operate directly with solar panels, eliminating the need for a dedicated controller for the solar array. The solar panels can be connected directly to the pump.
- The pump has a max rpm setting which allows to limit the flow from the pump in case the well cannot deliver the desired flow. In a later phase (when the borehole is placed) , the same pump can still be used.

The selected pump can deliver a flow of 8.3m³/day, as can be found in the table below (for an input voltage 36 to 48V, which matches our solar array), found in the data-sheet supplied by Lorentz.

irradiation 6.0 kWh/m²/day, tilted surface

vertical lift		pump type	peak flow rate	flow rate for PV array power peak [m³/day]			wire size
[m]	[ft]		[l/min]	150Wp	200Wp	250Wp	[mm²]
5	16	HR-04	12.0	6.3	6.6	7.3	2.5
		HR-07	19.5	8.5	9.5	10.5	
		HR-14	36.0	11.0	15.0	18.0	
10	33	HR-04	11.8	6.0	6.5	7.0	2.5
		HR-07	19.0	8.0	9.0	10.0	
		HR-14	34.0	9.0	13.0	16.0	
15	50	HR-04	11.5	5.5	6.0	6.8	2.5
		HR-07	18.5	7.0	8.3	9.5	
		HR-14	33.0	8.0	11.0	14.0	
		HR-04	11.5	5.5	[illegible]	[illegible]	

Figure 25: Lorentz PS 200 HR-07 specifications

The average solar irradiation for Oyugis, Kenya was determined using surface meteorology data from NASA (also included in attachment), to be around 6.3 kWh/m²/day (peaking in the dry season when the pump is most needed). As the look up table above is based on 6.0 Kwh/m²/day we add a little safety to our design. The vertical lift (height of the tower and depth of the well combined is about 13.6 meters with flow losses added the total dynamic head is about 15m (in a worst case scenario) . Combined with the desired output of 10m³ meter a day, we can find in the table 200Wp (or slightly higher) as a target value. The 2.5mm² wire size in the last column is a minimum to keep losses (voltage drop) limited to 4 per cent. To minimise loses it is better to work with 4 or even 6mm² cables but it is more expensive. (The connection to the pump is a 10 to 15 meter four core cable). As solar energy is free (and a reduction of the losses will not be sufficient to downsize the entire installation) it is logical to work with a 2.5mm² cable. The Hr-14 Pump listed next in the tables above is available for the same price ($1,526) and is capable of delivering a higher flow. However this type of pump is limited to 20 meters dynamic head and therefore not very interesting taking into account that in the near future a potentially deeper borehole can be placed.

The table shown above is based on a nominal voltage of 36 to 48V, which is a rather high value for a single panel (typical values are around 12V). To run the pump a minimum voltage of 24V is required, therefore at least two panels will be placed in series. However the efficiency of the pump increases with increasing Voltage. Taking this into account it is necessary to take into account that the actual flow will be lower than 8.3m³ as the pump cannot function with the same efficiency. This can be solved by adding a third 12V panel. However 66.666 Watt panels do not exist and it is not advisable to place panels with a different power rating in series (as this causes problems with the Mppt). This means that the installed power will most likely be higher, further increasing the flow. If (based on the test) the flow becomes more than the well can sustainably deliver the pump will be connected to only 2 panels.

Pump Attachments

The full installation has several other components next to the panel, controller and pump. These are displayed in the figure below:

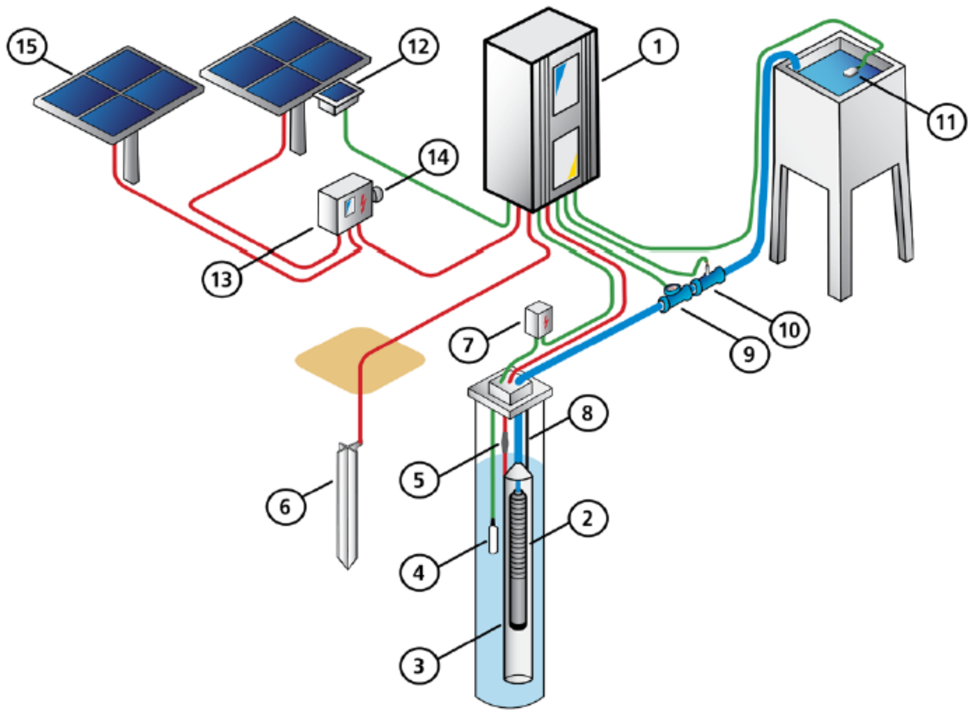


Figure 26: Entire installation

However not all components shown above are absolutely necessary. Numbers 1-2 represent the actual pump and controller and are therefore obviously necessary. Number 3 is a stilling tube to reduce the amount of sand entering the pump, as a helical rotor pump is less sensitive to sand this is not necessary. Number 4 represents the probe well (which protect the pump from dry running) and will be connected by two (0.75mm²-1mm²) cable to the controller. Number 5 is a slice kit to make a waterproof connection, which will also be necessary (like the sensor, this is also available in the store in Nairobi). Number 6 is the ground pin, which should also be placed of course to ground the controller and panels (pump is grounded true the controller). Components 7, 13 and 14 are surge protectors and lightning detectors with a PV-disconnect. As these are expensive component they will be replaced by Varistors (Who will be supplied by Sam Van Dyck from Humasol), there will also be fuses (circuit-breakers) added at these locations in the scheme to protect against peak currents. Number 8 is a strong waterproof nylon cord carrying the pump. Numbers 9 and 10 are optional pressure and flow sensors for data collection, in our current design they are not included (as they are rather expensive: +-150 euros), we are however still consulting the local partner if they think this would be useful. Number 11 is a float switch that can be used to detect a full tank. This component (+- 30 euro) can be an alternative to an overflow directly connected to the irrigation system. Number 12 is a sun switch that could be used to switch of the installation depending on the amount of solar radiation. This sensor is however not foreseen on the smaller Lorentz pump, like the one we are using.

The wiring schematic is shown more in detail in the figure below. If a sensor is not used it can be bridged, as shown in the figure for the float switch (number 11) between terminals 3 and 4.

Installing the pump

The pump will be held in place using strong nylon robes (at a fixed position above the bottom of the put, this has the advantage that the pump remains upright and cannot collide with the sides of the well (compared to a floating pump). The exact number of cords, weights, etc will be determined on side.

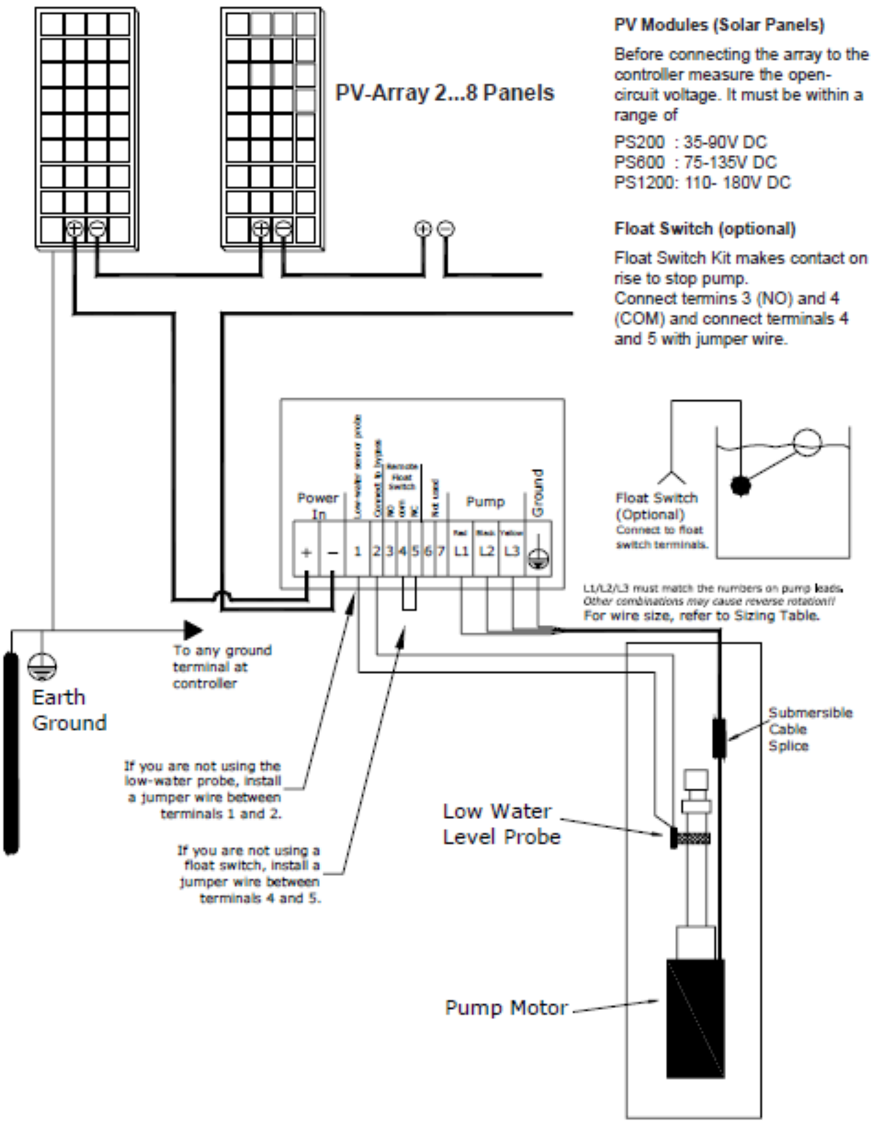


Figure 27: Wiring scheme of the pump

Electrical part of the installation

The solar panels

To calculate the amount of power and voltage needed for the installation, good knowledge of the used pump and solar panels is mandatory.

Out of the catalogue of the pump, following data is given:

- Amount of power: 200 W
- Operating voltage: 35-90 V

Using this data, the amount of solar panels can be found. The data of the panels, given by the same manufacturer as the pump, is as follows:

- Max. power output: 100 W
- Nominal voltage: 12 V
- Mppt voltage: 17-18 V
- Max. open-clamp voltage: 21-22 V

If we look at the amount of power needed for the pump, two solar panels are sufficient. But an important part is the operating voltage of the pump. If we use the Mppt voltage as reference, we can see that at least 2 panels are required. But because this voltage is really close to the minimal operating voltage, we opt to use three solar panels. In this case, every 'sort' of voltage (nominal, mppt, max open-clamp) is safely between the range of 35 and 90V. This will lead to a max of 300W power available.

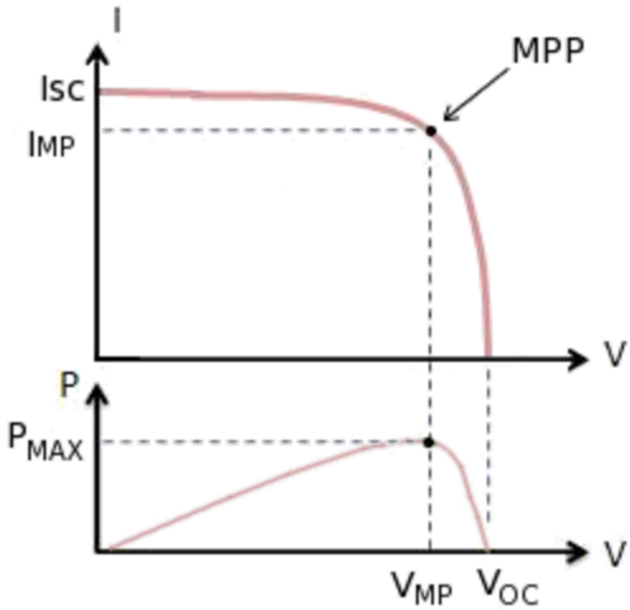


Figure 28: I/P-U characteristic PV-cell

On the given I-U characteristic, a lot of values can be explained.

- In the MPP (Max Power Point), the voltage is 17-18V and P is 100W.
- When the panel doesn't deliver any current, the voltage is 21-22V. (V_{OC} = open-circuit or open-clamp voltage)
- The nominal voltage of 12V is not given on the characteristic because this is only needed when the solar panel is connected to a battery but in our project, this is not the case.

The conclusion out of this characteristic is that 200W has to be delivered by three panels. If we assume that the panels are equal, this means that each panel has to give about 67W.

67W equals 67% of the max power output by the panel, so the amount of current is therefor a third lower than at the max power output. The operating voltage will therefor rise. Saying that the MPP voltage is 17,5V and the open-clamp voltage is 21,5V, we can assume that the operating voltage (used for feeding the pump) will be around 19V. The total amount of voltage, delivered by the solar array therefor is 57V.

DC-cable

Knowing which cable to use, the amount of current needed for the pump needs to be calculated.

If the operating voltage is 57V and the amount of power needed is 200W, the amount of current is:

$$I = \frac{P}{V} = \frac{200W}{57V} = 3{,}51A$$

We opt to use an XVB-cable with ground (3Gxx, with xx the diameter of the cable). The data of this type of cable is given in following figure

XVB 0,6/1 kV (NBN IEC 502 NAD)

TABEL 11 B

doorsnede (mm²)	2 x 1,5	2 x 2,5	2 x 4	2 x 6	2 x 10	2 x 16	2 x 25	2 x 35	3 x 1,5 of 4 x 1,5	3 x 2,5 of 4 x 2,5	3 x 4 of 4 x 4	3 x 6 of 4 x 6	3 x 10 of 4 x 10	3 x 16 of 4 x 16
buitendiameter ongeveer (mm)	9,0	10,0	11,0	12,0	13,5	16,0	20,0	23,0	9,5 of 10,5	10,5 of 11,5	11,5 of 12,5	12,5 of 13,5	14,0 of 15,5	17,5 of 19,0
gewicht ongeveer (kg/km)	120	150	200	250	360	560	840	1170	140 of 160	180 of 210	235 of 285	310 of 375	450 of 560	710 of 890
mat. van de geleiders							KOPER							
Rdc bij 20 °C (Ω/km)	12,1	7,41	4,61	3,08	1,83	1,15	0,727	0,524	12,1	7,41	4,61	3,08	1,83	1,15
Rac bij 90 °C (Ω/km)	15,5	9,49	5,90	3,94	2,34	1,47	0,931	0,671	15,5	9,49	5,90	3,94	2,34	1,47
L (mH/km)	0,323	0,309	0,285	0,271	0,255	0,241	0,242	0,234	0,356	0,332	0,308	0,294	0,278	0,264
spanningsverlies cos φ = 0,8 (V/A/km)	21,6	13,2	8,26	5,60	3,32	2,09	1,35	1,01	21,6	13,2	8,26	5,60	3,32	2,09
Icc gedurende 1 sec (kA)	0,215	0,358	0,572	0,858	1,43	2,29	3,58	5,01	0,215	0,358	0,572	0,858	1,43	2,29
I luchtleiding (A)	26	36	49	63	86	115	149	185	23	32	42	54	75	100

Figure 29: Data of an XVB-cable

When we look at the amount of current able to go through each thickness of cable, it is clear that even the smallest cable of 3G1,5 may be used. However, we decided to use a 3G2,5 cable. This because the resistance of the cable is lower (so less energy loss) and it is possible to connect other users to the cable if they plan to expand in the future. The reason why we don't go to a 3G4 or even bigger cable, is because it becomes too expensive and because the maximum of 32A for a 3G2,5 cable equals 5 solar panels working at their maximum power point. Placing more than 5 solar panels above the water tank is impossible, so the need of a bigger cable is out of question.

Protection against the sun

Due to the fact that we use a solar array, the cable connecting the array to the pump has to be protected against the sun. This is also a reason why we use a XVB-cable, because this type of cable has a PVC housing, the cable automatically is protected against the sun.

To give some sort of extra protection, we will place the cable in the shadow of the panels and through the roof of the tower, so that the cable will almost not be exposed to UV-light or bad weather conditions. To connect the control box (see later) inside the tower to the pump itself, we will place the cable underground.

Calculation of the losses

To calculate the losses in the cable, an estimation of the length has to be made.

- For the height of the tower, the height of the tank and the solar panels, 5m of cable is provided.
- The length from the control box to the pump inside the well is estimated to be 12m.

This gives a total length of 17m, which will be rounded up to 20m.

In the data is given that a 3G2,5 XVB-cable has a resistance of 7,41 Ohm/km. The total resistance of the cable therefor is:

$$Z_{cable} = 7{,}41 * 0{,}020 = 0{,}1482\ \Omega$$

The voltage drop over the cable is:

$$\Delta V = 0{,}1482\ \Omega * 3{,}51\ A = 0{,}52\ V$$

The power loss, connected with this voltage drop is:

$$P = 0{,}52\ V * 3{,}51\ A = 1{,}82\ W$$

This power loss is this low that it is negligible and won't be taken into account in further calculations.

Electrical protection

Short-circuit protection

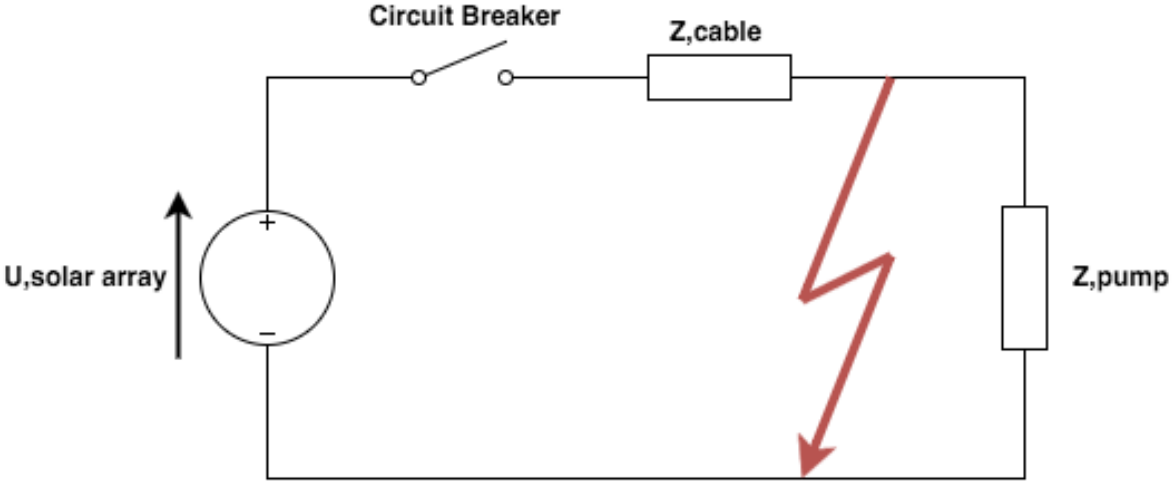


Figure 30: short-circuit in the pump

When there is a short-circuit in the pump, the only resistance is the one of the cable.

If we first consider the moment directly after the short-circuit, the short-circuit current can be calculated:

$$I_{cc} = \frac{U_{solar\ array}}{Z_{cable}} = \frac{57\ V}{0{,}1482\ \Omega} = 384{,}62\ A$$

This current seems very high and dangerous, but if we look at the I-U characteristic of the solar panel (figure 28), we can see that a high current through the panel means a serious drop in voltage. Therefor, the I_{cc} will start to drop and thus the solar panel sort of protects itself against a short-circuit.

Another explanation can be given too. If we calculate a short-circuit current, we assume that the source is infinitely strong but that's not the case, because the total power of the solar array only is 300W. When there is a short-circuit, the only voltage 'needed' is the voltage drop over the cable (0,52 V). If we have another look at the P-U characteristic, we can see that the amount of power delivered at 0,52 V almost is 0%.

Because of this, a overcurrent protection will not be placed.

Personal protection

If there is a problem in the isolation of the housing of the pump or in the solar array, it can be dangerous for a person if there is direct contact. For international standards, it is obligated to protect the installation if the voltage is higher than $50V_{DC}$. It therefor is necessary in our installation to do so.

To make sure the voltage at direct contact is lower than $50V_{DC}$, a grounding rod will be installed. In this way, the grounding rod will work as some kind of 'voltage divider', which will cut the voltage at direct contact at least in half (so maximal $30V_{DC}$).

The grounding rod will be connected to the solar frame with a grounding wire. This wire has to be coated in green-yellow. The pump will be connected to the solar frame through the grounding cable, inside the 3G2,5 XVB.

Although the grounding rod can be placed very far from the installation (it is OK as long as the grounding resistance stays under 30 Ohm), it is advised to place this grounding rod not that far, because otherwise the resistance of the grounding cable will become too high and the safety will drop.

If you want no risk at all, a residual-current circuit breaker (Dutch: een verliesstroomschakelaar) can be placed. A problem is that most of these circuit breakers only work on AC currents so there is a risk we won't find one for DC currents in Kenya. This will make the project not durable if the circuit breaker gets broken. Beside that, a DC residual-current circuit breaker is a high cost and because it isn't obligatory for the safety, this part will not be installed.

Surge protection

The best way to protect against surges such as lightning strikes is to place a rod on top of the roof of the tower. Problem is that this has to be installed very properly because otherwise it can be a risk to set the whole tower on fire. Because we cannot guarantee that it will be installed correctly, another solution will be used.

There exist surge protectors whom can be placed in the circuit. These protectors are very fragile for sudden voltage increases. The only problem is that they get broken after every lighting strike. Luckily, such a protector is a very low cost so we will already provide an amount of protectors for replacement (of course we will learn the local people how to replace it as well).

Switch and control box

To conclude, the protection of the installation will consists out of a grounding rod and wire and a surge protector. It is advised (if it is possible) to place the surge protector on a spot where it is easy to replace. Because we will build walls around the tower, we are going to build a control box inside. This control box will consist out of the surge protector and a switch. This switch will only serve to disconnect the solar array from the pump when the people of the centre will find it necessary.

List of working tools

· Electrical tape (3G2,5 XVB)
· Multimeter
· Screwdrivers and screws
· Wire strippers
· WAGO Connectors
· Folding ruler
· Hammer and pins
· Wiring nuts
· Pocket knife
· Climbing harness
· Rope
· Helmet
· Electrical resistant gloves
· Security glasses

Water distribution

The water will be distributed to the sanitary bloc and the irrigation fields by a network of pipes. There will also be made a connection to the existing 5,000 litre tanks. For this network we will use buried PVC or PE pipes and cast iron pipes for the short ends above the ground as PVC and PE will become brittle and weak when exposed to direct sunlight during longer periods. Another possibility is the use of open (brick) channels (with use of the gradient of the terrain). The total required length is estimated as part of the budget (including the number of turns and valves, etc). The pipe running to the pump will be a flexible (HD)PE tube, as a rigid one would break because of the oscillations of the pump itself.

Estimate lengths of piping.

A general overview of the buildings at the Imbeke training centre is given in the figure below. In this figure the position of the water tower, next to the existing shallow well is marked as well. The location of all the training fields isn't known exactly but they are all in the general area marked by the green circle in the left side of the figure.

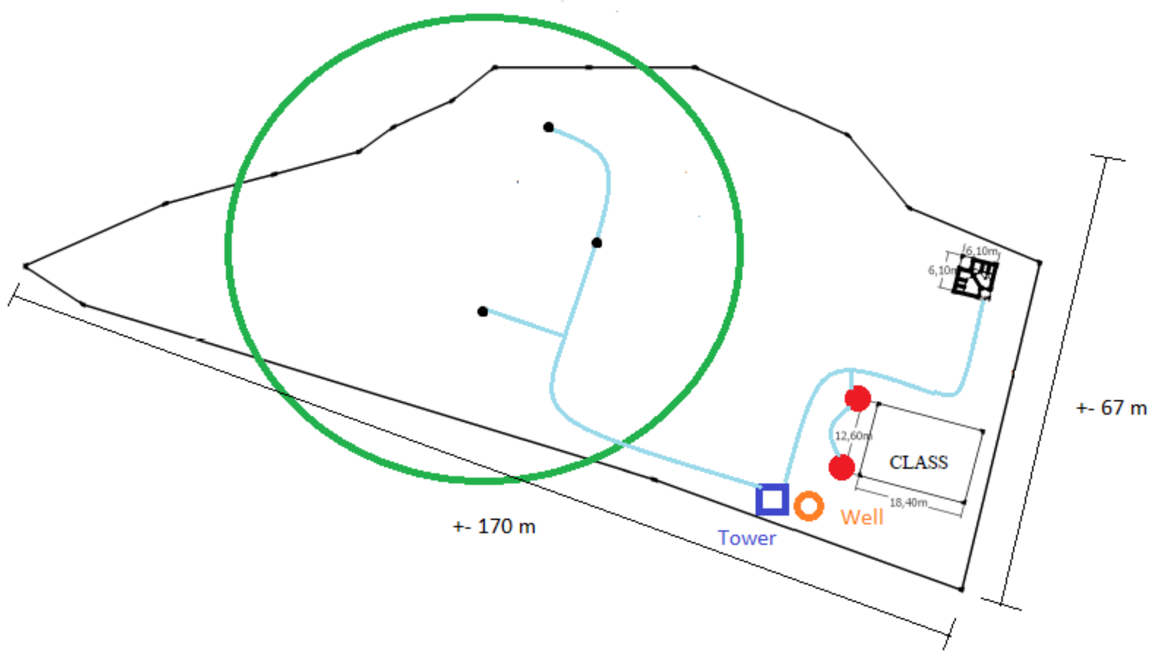


Figure 31: General overview Imbeke centre

Also included in the figure is a general idea of the water distribution network that will be constructed. Of this one part is already determined quite well, being the connection with the sanitary blok in the upper right corner of the terrain. We estimate the length of the pipe in this area to be around 60 to 70 meters as the length of the pipe parallel to the main building (class), which is about 20 meters (as the building itself measures 18.4m), is compensated by the distance won because neither the tower or the sanitary block are at the outmost edge of the domain. Also the connection with both 5000l rainwater tanks is indicated. This connection is made so that during the dry season water can be leveled from the main tank into these tanks, doubling the capacity of the system. However as the rainwater tanks are at ground level, they cannot give the same pressure as the main tank, and the water can therefore no longer be used as drinking water. When not needed, or when the lower tanks are full, this connection can be closed manually by turning a valve.

The left part of the figure is less determined as the exact number and location of the water taps will be decided on side in consultation with the people who will be actually using them, as they will have a better image on what can be useful for them. These way they can co-design their own installation, making it more user friendly and in the meantime let them improve their installation, making it a little more theirs. To make an estimate for the calculation of the flow losses, we can however already conclude that the length of these section will be slightly larger (roughly between 80 and 120m) , the number of taps will be around 3.

In the figure below a close up Is shown from the area containing the well and the tower, here a different possible configuration to connect the rainwater tanks is shown, this time using 2 valves. The final selection will be done on side based on practical considerations.

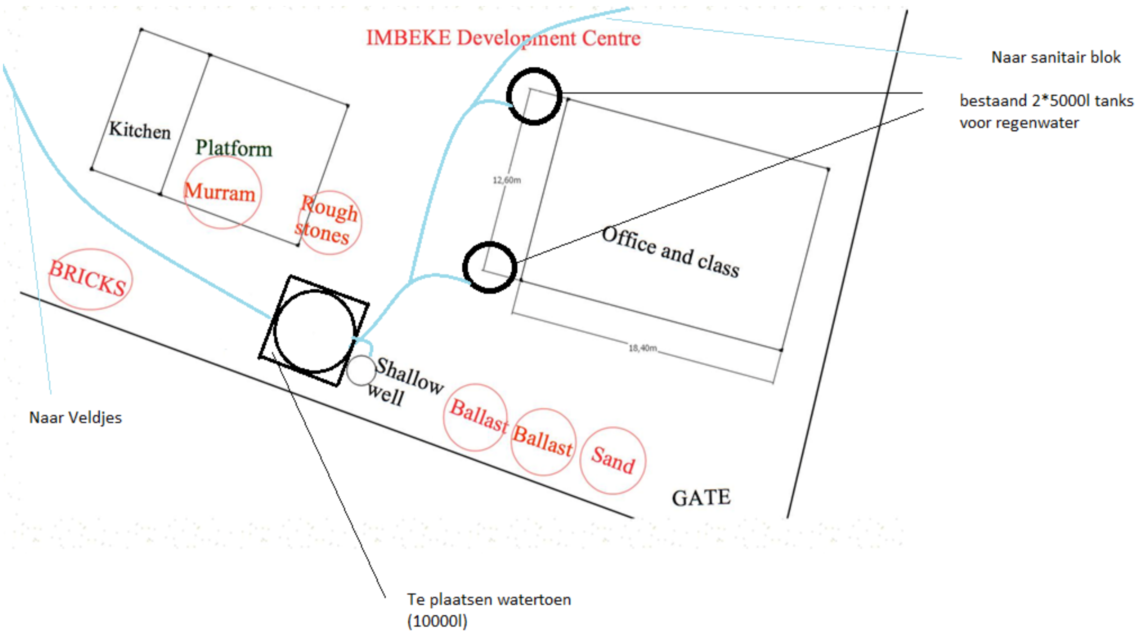


Figure 32: Close-up from the well and tower

Flow losses

As the diameter of the pipes used will depend on what is available in the area an exact calculation cannot be made, however an estimate can be made. For the vertical pipe the manufacturer of the pump has already provided a look up table expressing the head loss (in meter per 100 meter pipe for several sizes of tubing. As this is expressed in l/min, using as a safety factor an underestimate of 5 solar hours:

$$Q_{l/min} = 10\text{m}^3 * 1000/5/60 = 33.333\text{l/min}$$

Flow Rate Volumenstrom		Pipe Diameter Leitungsdurchmesser											
		½*	¾	1	1 ¼	1 ½	2	2 ½	3	4	5	6	in nominal
[US-Gal./min]	[l/min]	0.66	0.82	1.05	1.38	1.61	2.07	2.47	3.07	4.03	5.05	6.06	in actual
1	3.8	1.0	0.40	0.10	0.02								
2	7.6	3.0	1.2	0.40	0.10	0.05							
3	11	6	2.3	0.7	0.20	0.10							
4	15	10	4.0	1.2	0.32	0.15	0.05						
5	19	16	6	1.8	0.48	0.23	0.07						
6	23	22	8	2.5	0.7	0.32	0.10	0.04					
7	27		11	3.2	0.9	0.43	0.13	0.06					
8	30		13	3.9	1.1	0.5	0.16	0.07					
9	34		16	4.9	1.3	0.6	0.19	0.08					
10	38		19	6	1.6	0.8	0.24	0.10	0.04				

Figure 33: Flow losses in the piping

To calculate the actual loss the values in the table have to be divided by 100 and multiplied by the length of piping between the pump and the exit at the top of the tank. For each 90°turn we add another 2m as a rule of thumb. With 3 turn this adds up to a pipe length of 3*2+13.7 + 5 (margin for horizontal distance) ~ 25 meters. This results in a dynamic head loss of 1.25m for a 1 inch pipe, which is not negligible but still less than the safety added using the look up table of the pump (15 instead of 13.6 m head). For larger pipe sizes the losses become negligible.

This result can also be verified using a more numerical approach. In the calculations below we will verify this result for a 1 inch pipe. For these calculations the flow is converted to a speed.

$$V = \frac{Q}{A} = \frac{33.333\ dm^3/60s}{2.54cm^2 * \pi} = 0.2741m/s$$

The resulting Reynolds number, with the dynamic viscocity of water $\nu = 1.004\mathrm{e}^{-6}\mathrm{m}^2/\mathrm{s}$

$$Re = \frac{V * D}{\upsilon} = \frac{0.6962 * 0.0254m}{1.004e^{-6}} = 6934.4$$

Which correspondents to a turbulent flow. The losses due to the length of the tube can now be found. The friction factor f was determined using iterations using the Colebrook iteration method. For this purpose a typical roughness height of 0.0015mm for PE was applied. The piping length is taken as about 20m as there is also a (small) horizontal distance to cover.

$$\frac{1}{f^{0.5}} = -2.0 * \log\left(\frac{e/D}{3.7} + \frac{2.51}{Re * f^{0.5}}\right) => f = 0.0342$$

$$h_{loss} = \frac{f * L * V^2}{D * 2} = \frac{f * 20 * 0.2741^2}{0.0254 * 2} = 1.0109\ [m]$$

When we add some additional losses due to the bends, using the formulas below with a K of 1.1 (for a straight 90° bend (alternatively one can take an equivalent L/D of about 30 to 40). Again using 3 turns

$$h_{minor\ loss} = 3 * k * \frac{V^2}{2} = 1.1 * \frac{0.2741^2}{2} = 0.1240m$$

The total losses are in this approximation around 1.1348m, very similar to the values found in the look up table, and again well within the margin created when using the look up table. Doing the same calculations with a wider tube, which is preferable if it can be found locally (e.g. 2 inch or about 5 cm diameter), show even lower values for the flow losses. In the latter case the head loss is only about 0.0463m (the flow table indicated approximately 0.19/4 = 0.0475!). These losses are of course rather negligible.

Losses in the distribution pipes can be estimated in a similar way, although not many data are available. It can therefore by useful calculate these losses for a variety of diameters and lengths of piping (always including 3 turns). Based on the demanded flow an acceptable working area can be selected in the figure. The figure below was made using a maximum pressure loss of 0.2 bar (based on the difference in height between the bottom of the tank and the showerheads). However because the showerhead forms an additional obstruction we should add an equivalent of 10 to 20 meters of pipe to the overall length of about 60 meters. As there are 3 showers and a shower uses about 10liters a minute a minimum would be 30l/min. To be sure we will aim at 50l/min.

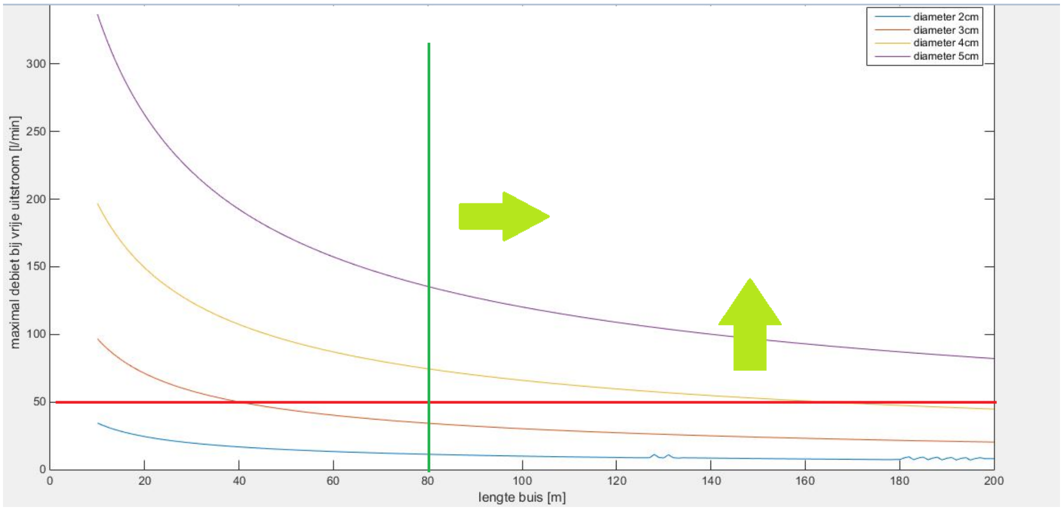


Figure 34: Flow rate as function of pipe length

If we look at the area above 50l/min and a pipe length of over 80 meters, we see that it is preferable to place a 4 or 5 (inner) diameter pipe. Looking at the water distribution to the fields the unknowns increase even more, both in terms of length (depending on exact location and preferred placement of the taps (decided by the people of the centrum) between 50 an 100 meter) and the required flow. However as it only concerns a few taps for manually watering some plants the flows are all in all relatively small. Therefore it is sufficient to take a few basic rules into account. With increasing diameter the losses decrease, but the cost also increases. The final selection for the pipe diameters will be done on site, when more information is available about prices, requirements, lengths and availability. If necessary the matlab-code used to make the above figures will be available on site.

Final note on the influence of the tower height.

The pressure of the water distribution net in Belgium is about 3 to 4 bar, to achieve an equivalent pressure (even without losses) a tower of 30 to 40 meters needs to build (which is not realistic for various reasons, including safety, material use, etc). However this indicates that any extra height is beneficial from a pure flow perspective, as a higher tower also allows for smaller pipes to be used (compensating for the increased losses). Therefore the height of the tower is determined based on the initial design made by the people of imani and practical considerations like lifting the concrete for the platform.

Aim for the future

After our project is finished, we will have built an installation that is able to provide about 8.3m^3 water per day. This installation is powered by two solar panels of a total of 200W. The total capacity for water storage will be upgraded from 10.000 litres to 20.000 litres. The capacity of the tanks will never be exceeded because the aim of Imani is provide the local centre and thus not more than 500 people.

When Imani wants to expand the installation, there are 2 solutions:

- Upgrading the pump to one with a higher capacity (if the well is able to provide this amount of water). The solar panels will be able to provide power for a pump that uses about 150% of the existing pump (74W to 111W).
- Drilling or digging an extra well (drilling preferred). This will need the placement of extra solar panels. They can be placed on the roof of the existing buildings.

PLANNING & STATUS

Before departure	We need to be sure that the components (cement, sand, steel,...) for the construction of the tower are ordered by our partner Imani and that they will be there when we arrive. We don't expect to have any troubles concerning this. We also need to contact Sophie again if the tank has already arrived and if not we need to make clear that this needs to happen straight away.
Week 1	Arrival in Nairobi the 28th of June at 8 am. We will need to get used to the climate at first. We will contact all the suppliers (pump and solar panels) and buy the components we need in Nairobi itself. We plan to stay there 1 night, that should be sufficient to do all the things we need to do in Nairobi. The next day we count a full day of travelling from Nairobi to Oyugis with all our components and luggage using public transport (or taxi if, depending on the local situation). When we arrive in Oyugis we will meet the local community and get to know their wishes and needs. It's also important to spent a great deal observing their working principles so we don't disturb their culture.
Week 2	We will start the construction of the tower. This concerns deciding the most perfect spot (probably next to the well). We think the construction will take up 2 to 3 weeks of work, in association with the local community. Starting to build the SODIS-demo in our spare time or in the evening. Contacting local people to ask opinions about cleaning water.
Week 3	Continue building the tower and building the SODIS-demo.
Week 4	Installing the tank onto the tower and installing the pump system.
Week 5	Installing the electrical system and the safeties. Finishing the water cleaning demo.
Week 6	Installing the pipes from the water tank to the lavatories and to the fields. Also installing the 'irrigation system'.
Week 7	Controlling every element if it works properly. Also checking the electricity grid for possible extents to see if there is potential for a follow up project. Going to local people to demonstrate the SODIS demo.
Week 8	Reserve and looking for potential new projects/local partners in the neighbourhood. (This last aspect is in fact an all-round one). Going to local people to demonstrate the SODIS-demo.
Logistics on site	As explained in a previous section, most of the elements we need will already be available at the project site. We will buy the things that are not transported such as the pump and the solar panels in Nairobi and we take them ourselves to Oyugis. This line of action will result in the least logistics problems as possible. For the provision of PVC and steel pipes, we count on the availability in the region. We will check this as soon as we arrive. If this is not the case, we have still time to order the pipes and connections, because we plan to install them in week 6.

Humasol vzw
Ingenieurshuis, Desguinlei 214, B-2018 Antwerpen - info@humasol.be – http://www.humasol.be
KBC: 733-0558533-37 - IBAN: BE35 7330 5585 3337 EUR - BIC: KREDBEBB
Organization number: 0809.102.140

PROJECT BUDGET

Cost calculation PV installatie Oyugis 2016

Note: In kostencalculatie is rekening gehouden met wisselkoers van 1 KES = 0,01 euro

MATERIAL					COST		
Element	Material	Remarks	Quantity	Unit	/unit	Ksh	Eur (0,01/Ksh)
Sand			6	Ton	1500	9000	90
Ballast 10/30			3	Ton	2000	6000	60
Ballast 20/40			0	Ton	2000	0	0
Cement		bags of 50 kg	43	Bags	800	34400	344
Chalk		bags of 25 kg	10	Bags	500	5000	50
Bricks			1583	/	10	15830	158,3
Steel Y12			372	m	180	66960	669,6
Steel R6 x 9 m		(3 brackets/m)	45	m	150	6750	67,5
PE-foil			6	m2			16,9
Lintel		1600x100x60	1	/		1000	10
Binding wire			5	kg	200	1000	10
Metal Door			1	pcs		20000	200
Plastering							
Inside Walls	sand+cement		27,24	m2			
Outside Walls	sand+cement		32,36	m2			
Timber							
Wood							
Nails							
Oil							
Concrete tower							
Columns	concrete		1,152	m3			
	steel Y12*4m	6 bars, 3,2m height	96	m			
Top plate	concrete		1,458	m3			
	steel Y12x3m	2 mesh layers, 7,29m2, 150/150	216	m			
	Steel Y12x3m	extra steel for reinforcing	36	m			
Foundation trench	concrete		1,2	m3			
	steel Y12x1m	2 mesh layers, 1m2, 150/150	24	m			
	PE-foil		6	m2			
Walls	Bricks	32 bricks/m2	42	m2			
Foundation walls (walls)	Bricks	32 bricks/m2	3,6	m2			
Foundation walls (columns)	Bricks	32 bricks/m2	3,84	m2			
Mortar			49,44	m2			
PV-installation							
Water tank	/	(cost includes transportation)	1	/	118000	118000	1180
Ropes		Manilla 32 mm (2x10m)	20	m	475	9500	95
Pump		PS200 HR-14-3	1	/	134012	134012	1.340,12
Low water probe			1			2100	21
Float switch			1			6600	66
PVC pipe		Under ground water transport	180	m	180	32400	324
Steel pipe		Above ground water transport	20	m	480	9600	96
Connections		Change in direction	20	/		8000	80
PVC to steel joint			5		1000	5000	50
Control valve			5		500	2500	25
Solar Panels		120 Wp x 2 = 240 Wp	3	/	12000	36000	360
Lorentz Stilling Tube		Reducing pump pollution	1			6600	66
Electric wiring		XVB 4mm2 4g	50	m		6500	65
Grounding rot						8500	85
Lorentz splice kit		waterproof connection	1	pcs		1500	15
Aluminium frame		12 x 2,5m	12	pcs	2500	30000	300
Labour							
Installation tank					2000	2000	20
Welding						5000	50
Plastering						9500	95
Water Filtration							
Ceramic Filters			2	pcs	2000	4000	40
Coliform Test Kit		5 test/kit	2	pcs	3025	6050	60,5
Workshops		This cost is a maximum estimate				30000	300
Varia							
Test well capacity						60000	600
Tools						10000	100
Radio						3000	30
Transportation of bricks			1	trip	2500	2500	25
Unforeseen cost						50000	500
						764802	7664,92

Figure 35: Cost calculation

Concrete tower

Concrete Composition:

The volumes of all concrete elements (top plate, columns, foundation trench) are calculated and are to be found in the fourth column. The composition is explained in a previous section. We use 70% (volume%) granulates and 360 kg/m^3 cement. For the granulates we use 1/3 sand and 2/3 ballast 10/30. The prices for each component are based upon the report of previous Imani projects. We think that their prices are the most accurate we will be able to find.

Walls:

For the walls, we used the sizes and price of bricks Imani used in their previous project.

Steel:

We use beams bars of 12 mm diameter. This is sometimes over dimensioned, but we think because of the lesser quality of the steel there, it is safer to work with a slightly thicker bar. For an appropriate reinforcement, we calculated that we would need 372 m of steel bars Y12.

To make brackets for the reinforcements in the columns we will need steel with a diameter of 6. This is to hold the bars in place while pouring the concrete. We will use 3 brackets per meter of reinforcement. Adding this up, we come on a total of 45m of R6 steel.

PE-foil:

We will use a layer of PE foil for our foundation according to the Belgian way of work.

Lintel

This is placed above the metal door.

Binding wire

This is used to bind the reinforcement nets together. This amount is estimated on the report of Imani's last project.

Metal door

To properly secure the inside of the tower where the controller of the pump will be placed, there is need of a heavy metal door with a proper lock. The price of this door, lock and placement is informed to us by Sophie and will be 200 euro.

Mortar

For the mansory wall we will need mortar. We calculated that we will need 1600 bricks and we count on 3cm mansory joint. So this comes to a total of 1,8144 m^3 mortar. (the size of one brick is very variable, but we counted with 18x14x9) Mortar is made of cement, chalk, sand and water. I used following proportions to calculate the volume of every element.

	Cement	Chalk	Sand		Water
Metselen van bakstenen Bijv. bakstenen 6 x 11 x 22 cm voor 7 m² met basterdmortel	25 Kg	25 Kg	250 Kg of 135 L	50 Kg of 34 L	25 L

Figure 36: Composition of mortar

The applied densities are ρ_{cem} = 1250 kg/m^3, ρ_{chalk} = 600 kg/m^3, ρ_{sand} = 1600 kg/m^3. So we calculated everything very carefully and we came to 250 kg cement, 250 kg chalk and 1,7 tons of sand.

Plastering

Because the bricks are not of such a great quality, there is a need to plaster the inside and the outside walls. The elements needed for this are sand and cement. The quantities are calculated on the areas that have to be plastered.

Timber

This post is at the moment empty because probably everything we need will be on site from the previous projects of Imani.

PV Installation

PE Water tank

This is a fixed cost of around €1,030. This also includes transportation to Oyugis. We gathered this information from our local partner Sophie who has already experience in ordering this element. She also told us to fix another 2000 Shilling (= 17,4 euro) for the men we will need to lift the tank on the tower.

Ropes

Will be necessary for lifting the tank up on the tower. We count on the use of 2 ropes of 10 metres each, this should be sufficient. If we use Manilla ropes, we will be sure they won't break.

Pump PS200 HR-14-3

The pump will be bought from a Lorenz supplier in Nairobi (contact information above). The cost of €1,340.12 includes the pump and the controller system.

Low Water Probe

Necessary for the pump to not run while dry. Fixed cost of 21 euro, supplied in Nairobi.

Float switch

Necessary component in the tank to assure the correct working of the pump system. Fixed cost of 66 euro, supplied in Nairobi.

PVC pipes

We will use PVC pipes for underground water transportation. We can't use them above ground, due to unfortunate UV characteristics. This is a rough estimation of 180 metres at the European price of 1.8€/m. The length estimation depends a lot on the distance between the tower and the fields. This is something we can't say for sure, but 180m will be the maximum.

Steel pipes

For above ground water transportation, we will use steel pipes, because they are UV resistant. We don't need a lot of them. The main use will be at the irrigation fields, for the tank itself and at the connection with the already existing pipe grid. We are sure 20m will more than enough.

Connections and PVC to steel joints

These parts are to connect the pipes together.

Side note: All lengths of pipes and numbers of connection units are estimations. We won't order this beforehand, but we use this as a maximum to calculate the 'worst case scenario'. When we are on the project site, we will be able to determine all correct numbers.

Control valve

We will use 2 for irrigation purposes and 2 to be able to shutdown each subsystem.

Solar Panels

We will buy 3 panels of each 100W. For the price we had contact with our supplier in Nairobi. He asks 120€ per panel, so this is a total cost of 360€.

Lorentz stilling tube

This is a component for the pump that prevents sand and dirt to be sucked in the pump. This improves the life span of the pump and the quality of the water considerably.

Electric wiring

We will use XVB 4mm^2 4g cables to connect all the parts. This is the prescribed cable size by the brochure of the pump, provided to us by Lorentz. Taking exact placing of the pump and controller into account, we estimated around 40m of cable is needed.

Grounding rod

To secure the circuit, we need a proper grounding rod. The estimated price is 85€. The cable we will use will also be XVB 2,5 mm^2.

Lorentz Splice kit

To ensure a waterproof connection for the electrical wires inside the well.

Aluminium frame

We will construct an aluminium frame on top of the tower to place the solar panels. Because we are positioned almost exact on the equator, we can lay the panels completely horizontal. This reduces the complexity of the construction. The construction will exist moreover out of 4 beams of aluminium and a top plate to ensure it is strong enough to carry the weight.

It is not easy to calculate the exact cost of this frame because we do not know which type of profiles are to find near Oyugis and what the price is over there. An estimation is made as follows:

- 4 beams of 2,5 m (vertical): 100€
- 4 beams of 2,5m (horizontal, to connect the columns): 100€
- 4 beams of 2,5m (horizontal on top to ensure easy mounting): 100€

Labour

This section includes the cost Sophie expected for the men needed to install the tank. We also counted welding into this section, because we won't be able to do this ourselves. 50 euros is an estimation and an absolute maximum.

There is also a post plastering. This is included because we won't be able to plaster the walls ourselves properly. This 95€ is information provided by Sophie.

Water filtration

Ceramic filters

Next to the SODIS system (which cost is negligible), we are also going to demonstrate ceramic filters to the community and do tests on the potability of the filtered water. Therefore we are going to buy 2 filters for a price of 22€ each.

Coliform test kit

We are going to test the water before and after the filtration techniques. The most important bacteria in water is the coliform bacteria. We found a testkit with 5 tests for a reasonable price of 30,25 euro per kit. We are going to buy 2 kits.

Workshops

This cost is included to cover the costs we maybe will make during workshops. This probably won't be a lot because we will use the ceramic filters and plastic bottles, but it is include to be sure.

Other

This section includes all costs that are unforeseen and variable. For our personal transport from Nairobi to Oyugis we count around 170 euro for the three of us. We arranged personal transport in a van from Nairobi to Oyugis. This price is made on our request by a vehicle company in Nairobi and so is correct. This price is not included in the calculation because this is a personal cost.

We will also need tools to complete our project. A lot of things will already be available there due to the past projects, but we expect some things to be absent. We counted on a cost of 100 euro.

The test of the well capacity will cost around 600 euro. This is a very important test that can't be omitted and will provide us with very useful information concerning pump dimensioning.

Transportation of the bricks is information provided by Imani. This is a small cost of 25 euro.

A radio has to be bought there on advise of Humasol to stay informed on security related topics.

A cost unforeseen is being implemented as a security to the budget.

SAFETY ANALYSIS

INFORMATION OF THE MINISTRY OF FOREIGN AFFAIR ON KENYA[6]

General

Kenya is a popular touristic destination. Tourism in Kenya is possible if you take following advises into account.

Public gatherings and manifestations take place now and then. Every gathering, even if they are announced as peacefully, can lead into riots, more specifically in Mombasa. It is strongly recommended to avoid these gatherings and to follow local news updates.

In the light of on going lawsuits, we consider that the risk of being kidnapped as Belgian should be taken seriously. Extra alertness is obligatory.

Ethnic tensions frequently cause local conflicts and violence in the northern part of Samburu Country, Moyale (Marsabit County), Mandera County, Wajir County, Lamu County and the Tana delta (Tana River County). Please inform you about the local safety beforehand.

In several locations, mostly in the regions around Nairobi and Mombasa, violent and armed robberies are possible. In case of an armed robbery, it is strongly recommended to show no kind of resistance.

Terrorism

In recent history, Kenya has frequently been affected by terrorist attacks. The risk of new terrorist attacks, potentially aimed against Western people stays high. Belgians who travel or live in Kenya are recommended to be extra alert, mostly in Nairobi and Mombasa, on touristic locations and the coast. It is advised to follow the instructions of local security and always be up to date with local news and actuality before and during your travels.

To stay informed about the local news and events in our environment, we will buy a small radio and our local partner, Sophie will inform us in case of serious danger or emergency.

Situation per region[3]

Nairobi

Travelling to the main touristic cities as Nairobi and Mombasa are possible, but busy places like bars in suburbs, bus stations, commercial centers, recreational places, mass demonstrations and sport events should be avoided.

Transportations to nearby slums like Kibera, Mathare, Huruma, Kariobangi, Kawangware and the Somalian quarter Eastleigh are strongly discouraged. Uhuru Park and City Park should be avoided during the night. If you need to visit these places, always be accompanied by a local guide.

The use of public transport (matatus) is discouraged.

Western part

In the counties west of the country and north of the counties Baringo and West Pokot, the necessary caution should be taken in account, even by daylight, because of potential road blockades and banditry.

The environments of Burnt Forest (County Uasin Gishu), Molo (Nakuru County) and Kilgoris (County Narok) must be avoided. It is strongly recommended to be informed about the safety situation before traveling in the Mount Elgon-region (Trans Nzoia and Bungoma Counties).

Criminality

Criminality is high in the big cities. Armed robberies (theft and carjackings) and theft with violence occur very frequently, mostly in Nairobi, Mombasa, Kisumu and the coastline (Kwale, Kilifi, Mtwapa and Changamwe).

Following recommendations should be taken in account:

- Always be alert and always lock your vehicle;
- Do not wear jewelry or valuable objects where they can be seen;
- Never have a lot of money or bank cards with you;
- Be aware of scammers who search with a pretext the aid of travellers;
- Be aware of people who pretend to be police officers. Always ask their legitimation. If you have the sense that the behaviour of a police officer isn't in accordance with the law, always make clear you will inform the embassy about it. You are in no case obligated to allow a police officer in your vehicule for transportation not even to a police office.;
- Never accept food and/or drinks from an unfamiliar person;
- Do not show any resistance in a robbery;
- Never walk alone on the streets by night, neither in the city nor elsewhere, and most of all do not go to the beach, a park or abandoned neighbourhood.

Nature reserves and – parks usually are safe, but it still is advised to travel with experienced travel agencies. It is mandatory to follow the regulations of the parks and their guards.

In the cities and provinces it is suggested not to travel during the night. People who do have to travel by night, better do this in group and with several vehicules. As tourist, never drive by yourself but make use of a driver you know well or someone who is recommended by a reliable firm or hotel.

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[3] only the regions of Nairobi and the Western part of the country are being taken to account because the project only takes place in these regions.

It is encouraged to close windows and lock the vehicule, mainly in traffic jams. Pickpockets aim for mobile phones, watches, necklaces and bags of passengers. Because of the bad conditions of the roads, the chance of being in a serious accident is high. Whoever makes use of these roads have to be very careful. Also, some accidents are caused on purpose to rob the passengers, mostly on the roads in and to Nairobi and Mombasa.

If you are involved in an accident, it is advised to inform the Belgian embassy.

Precautions

Every member of the project is registered on the national site travellersonline.diplomatie.be so that the Federal Public Service of Foreign Affairs ('FOD Buitenlandse Zaken') will be able to track us and keep us informed in case of emergency.

TRANSPORT

Roads

Public transport (matatus) mostly is badly maintained. Travellers need to inform tour operators about the state of transport and roads before travelling. Most of the roads in the country are in a bad condition (e.g. Nairobi – Masai Mara/Kisumu/Turkana). Be careful when using a taxi, always make sure it is a reliable taxi company.

Aviation

Several companies organise domestic flights to the most important cities of the country. The terrorist threat is real, mostly on busy places and airports are part of them. Always be careful and inform systematically before travelling.

The safety measures on Wilson Airport (Nairobi) aren't optimal. This airport is mainly used for domestic flights including charters. When travelling by charter, it is advised to check the reliability of the company and the state of the plane.

CLIMATE AND DISASTERS

Climate

The climatological circumstances strongly vary between regions due to height differences. Coast and Victoria Lake: tropical and humid. Excessive rainfall (T°: 22°C to 30°C).

Heights (Nairobi): Mild climate with cold season (June – September), short rain season (October – December) and long rain season (March – June). In general, the warmest periods are September-October and January-March.

Natural disasters

Kenya is located on an active plate boundary and some earthquakes may occur.

Safety measures

In case of a disaster or emergency, travellers are expected to inform their relatives as soon as possible and to reassure everything is fine. If foreign communication is impossible, travellers can go to the closest Belgian embassy or consulate.

HEALTH AND HYGIENE

Water and food

Drinking tap water is prohibited. It is recommended to drink water from sealed bottles. Avoid food sold by street venders.

Drinking boiled beverages such as coffee and tea is encouraged.

Eating self-pealed fruit and boiled food is encouraged.

Health

Avoid contact with stray dogs.

Never walk bare foot. Not even in water (especially not in stationary water). The use of water shoes is recommended.

Disinfect even the slightest wound/bruise.

Always wear sun protection. Even after a couple of weeks.

Precautions

Every member of the team has a decent travel insurance.

The presence of a decent travel pharmacy is mandatory.[4]

Vaccines

Every member of the team has been vaccinated against:

- Yellow fever
- Tetanus
- Diphtheria
- Pertussis
- Measles
- Poliomyelitis
- Hepatitis A/B
- Typhoid
- Meningococcal Meningitis ACWY
- (Rabies)

Because there is no vaccination against malaria, every member has pills whom they have to take daily. The use of a special mosquito net is advised. Due to the activity of mosquitoes during sunset, wearing long-sleeved clothes when possible is advised.

Diarrhoea: Not always possible to avoid, even when travelling in good conditions. Always wash hands thoroughly and disinfect potable water. When having diarrhoea, always keep hydrated (clean bottled water) and eating salt is encouraged. If the diarrhoea persists or it is getting worse and worse, the use of correct medications from the travel pharmacy is useful. If it still isn't over after a couple of days, visiting a hospital is advised.

[4] The content of the travel pharmacy: see 'General Precautions'

GENERAL PRECAUTIONS

Contacts

Belgian Embassy

Address

Limuru Road Muthaïga
00100 Nairobi
Kenya

Contact

Ambassador Roxane de Bilderling
P.O. Box 30 461
Nairobi@diplobel.fed.be
http://diplomatie.belgium.be/kenya
+254 20 712 20 11
+254 20 712 21 81
+254 708 036 674 (in case land lines do not function)
+254 733 601 230 Emergency number for Belgians

Opening hours

Monday - Thursday: 8.00 am - 4.00 pm
Friday: 8.00 am - 12.00 am

Holidays

Tuesday 5 July (TBC) (Idd)
Thursday 21 July (National Day)

Honorary Consulate Mombasa (Belgian)

P.O. Box 91109 - 80103
Honorary Consul Lou DIERICK
+254 41 447 42 36
+254 736 394 298
consulbel@mombasa.be

Dutch Embassy

Address

Riverside Lane
Off Riverside Drive
00100 Nairobi
Kenya

Contact

Ambassador F. Makken
nai@minbuza.nl
+254 204 28 80 00
+254 727 59 47 27
+254 727 59 47 67
+254 734 15 27 63
+254 734 08 61 02 (available 24/7)

Phone numbers summary

For having the best way of communication, it is advised to buy a Kenyan pre-paid mobile phone or a Kenyan SIM-card to avoid high costs. In general, mobile phone service (Safaricom, Airtel en Orange) is sufficient throughout the whole country. The use of mobile networks (3G and 4G) is said to be available[5] in the cities, but the reliability is not confirmed.

General: 112/999/911

Ambulance[7] (add +254):

- AMREF Flying Doctors: 020-3315454/5
- AAR Emergency Ambulance: 020-271374
- Kenya Red Cross Society: 020-3950000
- Phoenix aviation Ambulance: 020-6005837
- Intensive Care Air Ambulance: 020-6004945
- Emergency Plus Medical: 0700395395
- Avenue Rescue Services: 020-3743858

Police[8,9] (add +254):

- Kenya Police HQ: 2240000/0726 – 035455/020341411
- Anti-terrorist unit: 020-2724406
- Bahati Police Station (Nakuru): 051-52299
- Highway Patrol Unit: 020-8074602
- Nairobi Central Police Station: 020-225685
- Kisii Police Station: (020) 2083174/3556772
- Kisumu Provincial Police HQ: (057) 2023777

Card stop: +32 70 344 344

Belgian embassy: +254 733 601 230 (Emergency number)

Safety and Communication Center: +254 020 604767

Medical assistance

For severe illness or wounds, flying back to Belgium can be advised. If not, some private hospitals in Kenya are relatively good but expensive, the most important are:

Aga Kahn Hospital Nairobi

www.agakhanhospitals.org/nairobi/

Aga Khan Hospital Building
Third Avenue
Limuru Rd.
00100 Nairobi
Kenya

[5] http://opensignal.com/networks/kenya/safaricom-coverage

+254 366 2020 / 22 or 374 00 00 ext. 2020 / 20 22 (*Accident and Emergency Department*)
+254 366 22 70 or 374000 ext.2270 (*Pharmacy*)

Aga Kahn Hospital Kisumu

http://www.agakhanhospitals.org/kisumu/

PO BOX 530
Kisumu
Kenya

+254 57 20005, 43516, 40372, 43530

Nairobi Hospital

https://nairobihospital.org
hosp@nbihosp.org

The Nairobi Hospital,
Argwings Kodhek Rd,
P.O. Box 30026,
G.P.O 00100,
Nairobi, Kenya.

+254 20 2845000, +254 703082000
+254702 200 200 (*Ambulance Contact*)

Flying Doctors

www.flydoc.org

Wilson Airport
P.O. Box 18617 – 00500
Nairobi, Kenya
+254 20 31 54 54/5

+254 20 6992299 / 6992000 / 3315454 / 3315455 / 6002492 (*Emergency contacts*)
+ 254 (0) 733 639 088 / 736 359 362 / 722 314 239 (*Emergency contacts*)
Radio Frequencies: HF: 9116kHz LSB / 5796 kHz LSB (Call Sign: Foundation Control)

Police offices

Kenya Police Headquarters

www.kenyapolice.go.ke

Vigilance House, Harambee Avenue,
PO BOX 30083,
Nairobi, Kenya.

Telephone: (020) 341411/6/8

Nearby hotels

Homa Bay Tourist Hotel Ltd
Homa Bay Town
Off Pier Rd
Homa bay
(+254) 592122044

Acacia Premier Hotel
Achieng Oneko Road
40100 Kisumu

Ufanisi Resort
Kisii Town
Kisii
Kenya

(+254) 0786758074
www.ufanisiresorts.com

Nearby internet cafes

Skynet Interactive
1000 Street
40222 Oyugis

My Promise Cyber Café
Uhuru Plaza
Kisumu Rd, 3269-40200
Kisii
Tel.: 5831335

Wid-wid Communication
Mega Plaza
1st Flr Oginga Odinga St Lake 2325-40100
Kisumu
Tel.: 020 2047133

Reliable transport companies[10]

- Akamba (most reliable, West Kenya)
- Coastline Safaris (expensive but comfortable)
- Easy Coach (security check all passengers, comfortable, West Kenya)
- Eldoret Express (biggest company, West Kenya)
- Kenya Bus Service (governmental company)

Travel Pharmacy

A short list of what the first aid kit will contain is:

- Malaria pills
- Thermometer
- Scissors
- Bandage to bind wounds
- Band aid
- Safety pins
- Tape
- Plastic gloves
- Pincer
- Nail clipper
- Closing pins
- Bandage to stem the blood
- Perdolan against pain
- Immodium for stomach problems
- Aspirin
- Isobetadine
- Disinfect alcohol or hydrogen peroxide (H_2O_2)
- Bactroban, an antibiotic cream
- Sun cream
- Antibiotics
- Anti-sting spray
- Ointment against stings and bites of bugs and insects (with or without cortisone)

Useful smartphone apps (Dutch) [11]

Douane OK
Check what and how much you can export from Kenya.

SOS Op Reis
In case of loss of passport or car troubles.

GGD Op Reis
App used for health precautions.

Tripadvisor – Booking.com
When in need of a hotel, flight or restaurant.

Trip Journal
To keep everyone informed at home (cfr. blog).

Currency App

TripIt
Helps planning and mapping your trip.

Viber – WhatsApp
Free calling to Belgium if internet is accessible.

Risk matrix[12]

A Risk is the amount of harm that can be expected to occur during a given time period due to specific harm event (e.g., an accident). Statistically, the level of risk can be calculated as the product of the probability that harm occurs (e.g., that an accident happens) multiplied by the severity of that harm (i.e., the average amount of harm or more conservatively the maximum credible amount of harm). In practice, the amount of risk is usually categorized into a small number of levels because neither the probability nor harm severity can typically be estimated with accuracy and precision.

	Minor	Serious	Critical	Catastrophic
Certain	1A	2A	3A	4A
Likely	1B	2B	3B	4B
Possible	1C	2C	3C	4C
Unlikely	1D	2D	3D	4D
Rare	1E	2E	3E	4E

Low	Moderate	High	Extreme

Risk assessment

Category	Situation	Consequence	Prevention	Probability
Transport	Robbery	• Loss of money • Loss of valuable papers	• Divide money among the team members • Second wallet with copies of valuable papers • Hide your wallet or wear a belt pouch	2C
	Transport of people	• Accident with injury • Paying a disproportional price • Luggage loss	• Choosing a reliable (recommended) driver • Keep an eye on the road/environment/luggage • Discuss prices in advance and never show wallet at any time	4E *personal injury* 2C *material damage*
	Transport of materials	• Theft/loss of materials • Damage of materials	• Choosing a reliable (recommended) driver • Make use of delivery if possible • Supervise the transport as much as possible • Keep contact details • Check state of materials before paying • Never pay up front	3C

Category	Situation	Consequence	Prevention	Probability
	Theft or damage of materials	• Theft or damage equals financial losses • Waste of time and money on buying and transporting new materials	• Keep components in a safe location (with lock) • Keep components in their packaging • Never leave materials unattended • Fasten components on a frame	3B
On-site	Theft of installed components (includes after we left)	• Theft or damage equals financial losses • Waste of time and money on buying and transporting new materials	• Keep components safely behind locked doors (especially during night) • Install components on an unreachable place (locks, heights, depths,..)	3D
	Diseases and minor injuries (scratches, bruises, stings)	• Diarrhoea • Malaria • Sunstroke • …	• Carry a complete first aid kit / travel pharmacy • Be vaccinated • Drink enough clean water • Cook food thoroughly • Always be careful with food and drinks in general • Always wear sun protection	1B *Minor injuries and diseases* 3C *persistently, ongoing diarrhoea, infections*
Working on-site	Falling from heights	• Damage to property • Fractures • Loosing consciousness • Severe injuries	• Only walk on supported beams • Attach yourself with lifelines • Always clear obstacles from heights when done working • Wear proper	4D

			protection and shoes	
	Dropping tools from heights	• Injuries to people walking by • Damaged tools	• Tool belt, only take necessary tools on heights • Wear helmets	3C
	Using tools and goods	• Hammer on fingers • Cutting wounds • Splinters • Blisters • Brick on toes • …	• Carry a complete first aid kit / travel pharmacy • Wear gloves • Proper clothing • Know what to do in emergency situations • Know the location of nearby hospitals • Know how to disinfect and treat wounds	2B
	Doing installation works	• Welding • Pouring concrete • Lifting heavy weights	• Wear proper protection • Plan thoroughly before executing • Work precisely, never hurry • Always check temperature, dryness, steadiness before continuing	4C
Voltage and weather conditions	Electrocution	• Burning wounds • Heart fibrillation • Tissue damage • Death	• Wear gloves, glasses and proper shoes • Cover solar panels until the very end of the installation • Educate local people • Use multimeters to make measurements • Install proper fuses and other security	4B
	Lightning/other surges	• Fire hazard	• Surge protection	3E

		• Component failure • Indirect personal hazard		
	Excessive rainfall, flooding (mostly during rain season)	• Short-circuit hazard • Pump overload hazard • Ground movement	• Use of the correct sensors and floats • Make sure everything is well isolated and firmly fixed • Place components out of reach of water	3C
	High temperature and extremely sunny days	• Solar panel overload hazard • Cable melting hazard • Fast cable aging (due to UV-light)	• Placing correct sensors and overload protection • Isolating cables and placing them in tubes if possible	2B
	High wind velocities	• Disconnection and falling of the solar panels • Vertical tension on tower and tank	• Make sure solar panels are fixed tightly • Building and foundation have to be dimensioned properly	3D
Animals	Biting on cables	• Short-circuit hazard • Malfunction of installation	• Placing cables out of reach or in tubes	3E

Medical care and first aid kit

This section handles what to do in case of a minor injury (no hospital required).

Scratch wound

Clean the wound

- Wash hands
- Clean the wound twice a day with tepid water and neutral soap or disinfecting liquid (isobetadine) with a sterile compress. Rub the wound clean from the center to the edge, do not dab.

Disinfect the wound

- Dab the wound with isobetadine or hydrogen peroxide. In case of a serious wound one should lay a compress steeped with isobetadine or excessively pour hydrogen peroxide until it stops foaming.

- Dry the wound in open air for about ten minutes.
- Bactroban can be applied as an antibiotic preventive ointment.

Cover the wound

- Cover with a compress or band aid. Keep the wound as dry as possible.
- Clean twice a day as mentioned above until a crust is created. Keep an eye on infections.

In case of an infected wound

- Infected wounds can be recognized by heavy pains, a red wound, swelling and/or pus.
- If the infection is deteriorating, contact a doctor.

Heavily bleeding wound

Bring direct pressure on the wound with fingers.

Raise the bleeding part of the body relatively to other parts.

Use a pressure bandage. Do not pinch the wound.

See a doctor

Sprains and strains

Give the injured body parts rest. If your feet hurt, avoid walking when possible.

Use ice or anything cold to slow down swelling and infections.

Use some kind of support bandage to give extra support.

Apply anti-inflammatory ointment on the sprained joint, take anti-inflammatory tablets (Dafalgan,..) when needed.

Place the body part relatively higher than other parts when sleeping. Place a pillow underneath your knee or ankle.

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