Master’s Thesis Engineering Technology

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Sustainable potable water solution for Ndhole Primary School and surrounding community using groundwater and renewable energy

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The current situation

Figure 1: Local pond in the Ndhole community

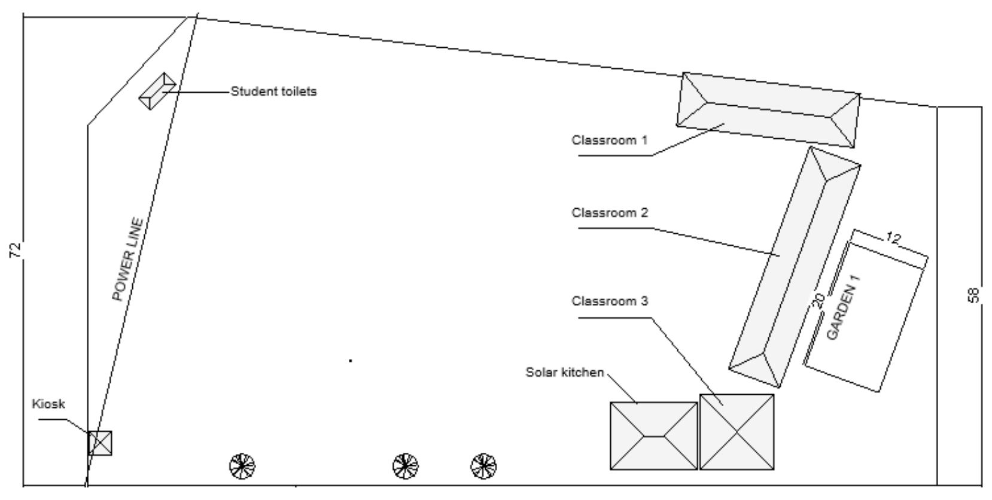
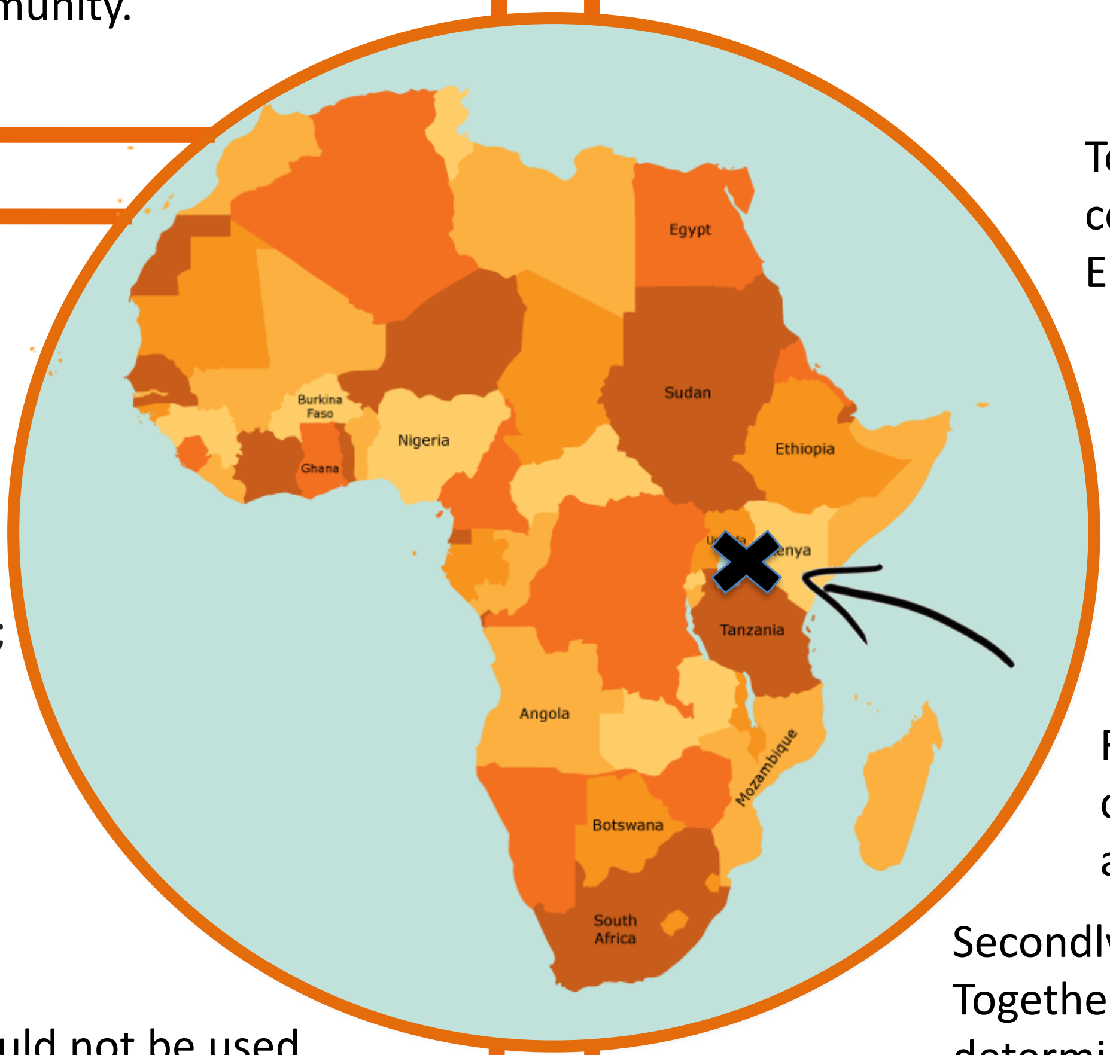


Figure 2: Groundplan of the Ndhole Primary School

Ndhole Primary School, a public institution, in drought-prone western Kenya, Karachuonyo constituency, Homa Bay County, Kenya, is located in the midst of a rural community with 200 students ranging in age from 5 to 14 years old. Villagers in the West Karachuonyo region, continue to face enormous challenges such as **perpetual water scarcity**, neglected or no sanitation, malnutrition, poor nutrition, food insecurity, low school enrolment, early school-leaving due to child labour, violence, teenage pregnancy, abuse, disease and neglect, high infant mortality rates and rudimentary access to energy resources. Climate change, and in particular erratic rainfall patterns, exacerbate many of these challenges.

The students and the surrounding community suffer from a persistent deficit of potable water. This master's thesis aims to provide **a continuous, carbon-neutral, economically viable and maintainable potable water supply** for the students and the surrounding community.



Results and Conclusion

Despite the hydrogeological survey, the water found was insufficient. After a further investigation and several second opinions, a second borehole was drilled. However, here too, the water found was not sufficient for further development of the borehole. The final statement of the hydrologist summarized is:

- the rain is the main source of the recharge for the aquifers in this area, through climate change, the **rain has significantly reduced** for the past years;
- the region has shown to have volcanic activity and therefore is an area with ground movement, which creates **underground voids** that reduce water availability.

Table 1: Results of simulation

Volume storage tank (litres) →

Number of PV panels ↓

	0	800	1600	2400	6400	7200	8000	8800	9600	10400
1	365	365	365	365	365	365	365	365	365	365
2	365	365	365	365	365	365	365	365	365	365
3	365	365	365	365	365	365	365	365	365	365
4	365	365	365	292	265	265	265	265	265	265
5	365	365	326	200	149	149	148	148	147	147
6	365	365	295	134	67	67	64	63	62	61
7	365	359	257	113	34	31	31	29	28	28
8	365	348	206	97	10	9	6	6	6	5
9	364	338	167	88	4	4	1	1	1	0
10	362	330	155	74	4	1	0	0	0	0

Because the Python programme could not be used in practise, a **case study** for an already existing water well is conducted to validate the programme. This simulation gives favourable results, in particular the optimum between the type of pump, the amount of PV panels and the storage tank capacity. Table 1 shows the number of days for which the water demand is not fulfilled over a period of 1 year.

Table 2: Investment simulation expressed in Euros

	0	800	1600	2400	6400	7200	8000	8800	9600	10400
1	224.0	288.8	353.6	418.4	742.4	807.2	872.0	936.8	1001.6	1066.4
2	448.0	512.8	577.6	642.4	966.4	1031.2	1096.0	1160.8	1225.6	1290.4
3	672.0	736.8	801.6	866.4	1190.4	1255.2	1320.0	1384.8	1449.6	1514.4
4	896.0	960.8	1025.6	1090.4	1414.4	1479.2	1544.0	1608.8	1673.6	1738.4
5	1120.0	1184.8	1249.6	1314.4	1638.4	1703.2	1768.0	1832.8	1897.6	1962.4
6	1344.0	1408.8	1473.6	1538.4	1862.4	1927.2	1992.0	2056.8	2121.6	2186.4
7	1568.0	1632.8	1697.6	1762.4	2086.4	2151.2	2216.0	2280.8	2345.6	2410.4
8	1792.0	1856.8	1921.6	1986.4	2310.4	2375.2	2440.0	2504.8	2569.6	2634.4
9	2016.0	2080.8	2145.6	2210.4	2534.4	2599.2	2664.0	2728.8	2793.6	2858.4
10	2240.0	2304.8	2369.6	2434.4	2758.4	2823.2	2888.0	2952.8	3017.6	3082.4

To determine the optimal **solution**, a **combination** is selected where the **water demand** is met, and the **initial investment** is the minimum.
For this purpose, Table 2 is used to look at the investment. The solution with 9 PV panels of 345 kWp and a storage tank of 10400 litres is optimal.

Future works

The project will continue using rain water instead of groundwater. This source is less sustainable, however, it is enough to foresee the children in the Primary school. Moreover, a rain gauge is installed to track the rainfall for the next years. With this data, a rain catchment can be designed to fulfil the water need for the children and the whole community.

Material and methods

After conducting a study, the optimal sustainable solution is to use a solar driven (4), submersible pump (1) that extracts groundwater. The water will flow through an underground pipe network (2) to a water tower (3). Thereafter, the water will be filtrated to the WHO standards and can be collected at the water kiosk (5). Figure 3 shows the final design.

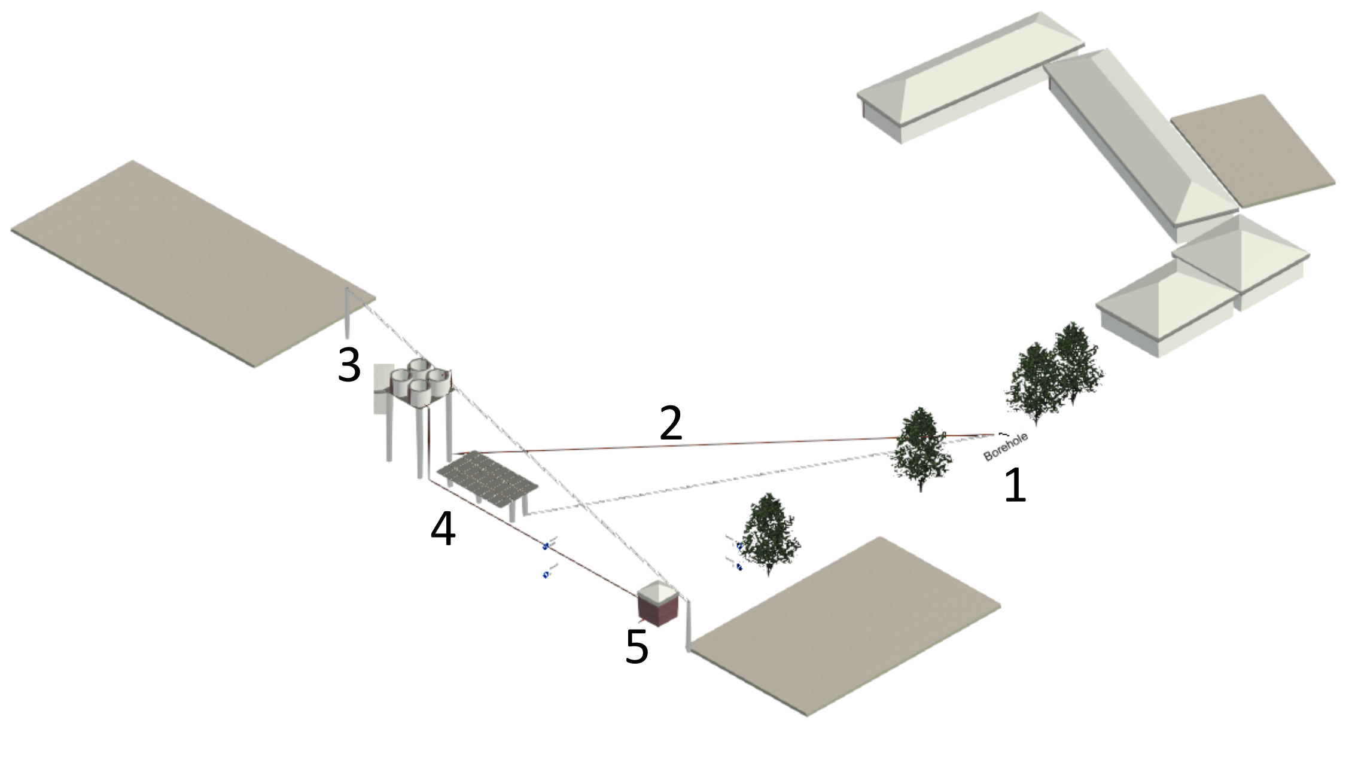


Figure 3: The final design

The Python programme

To optimise the final design, a Python programme is developed. The programme combines **PVlib**, an open source tool for simulating PV systems, and **PVGIS**, a European Union database with solar irradiation data.

Figure 4: PVGIS logo [1]

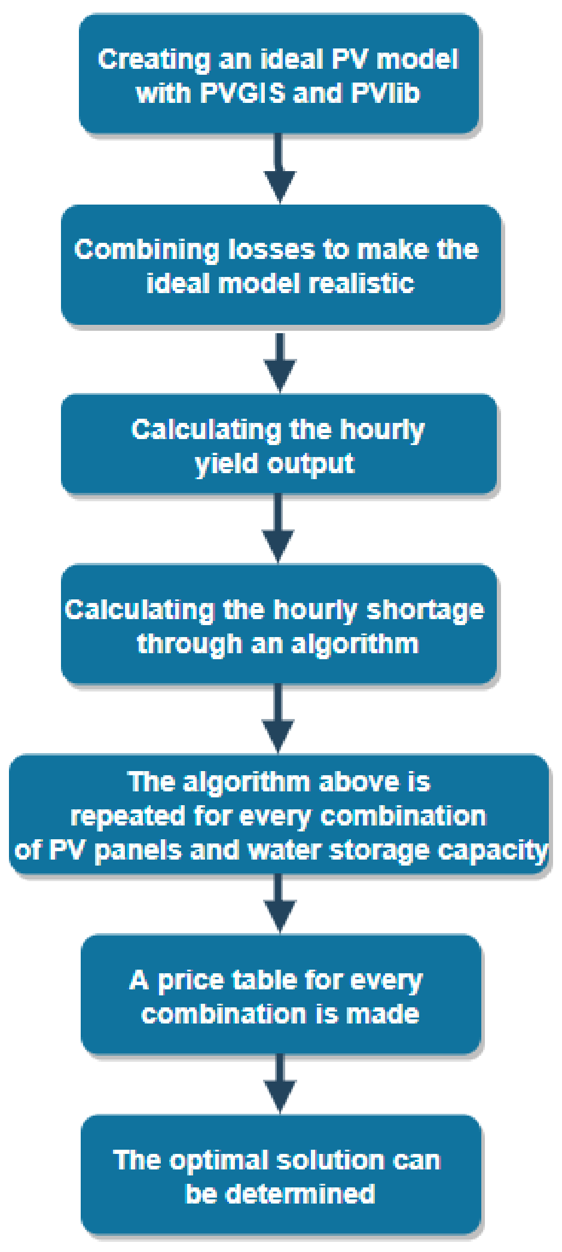
Figure 5: PVlib logo [2]

Figure 6: Python logo [3]

Firstly, the solar data from PVGIS is loaded into the Python programme. This data is then used to build a PV model with PVlib. Furthermore, different losses are taken into account. The **main losses** are due to **dust and cell temperature.**

Secondly, the output of the PV model provides an **hourly power output** for one year. Together with a specific chosen DC submersible pump, the **yield** per hour can be determined.

At last, an **algorithm** is used to determine the exact number of days that there is an insufficient volume of potable water pumped from the well for the community. The number of days is calculated for every combination of a specific number of PV panels and a specific water storage capacity. In the results, a perfect combination can be chosen to fulfil the daily need. Moreover, a price estimation is given for every combination. Figure 7 presents a conceptual flowchart of the working principle of the programme.



Creating an ideal PV model with PVGIS and PVlib

Combining losses to make the ideal model realistic

Calculating the hourly yield output

Calculating the hourly shortage through an algorithm

The algorithm above is repeated for every combination of PV panels and water storage capacity

A price table for every combination is made

The optimal solution can be determined

Figure 7: Flowchart of the Python programme

The hydrogeological survey

The hydrogeological survey is an obligatory document for drilling a borehole. It investigates the groundwater potential in the compound. Moreover, the hydrologist determines the best place for drilling a borehole. Common measuring methods such as vertical electric sounding, and natural electromagnetic field detection are used.

Supervisors / Co-supervisors / Advisors Prof. Dr. Ir. Wim Deferme

[1] “PVGIS.” Accessed: May 16, 2022. [Online]. Available: https://photovoltaic-software.com/pv-softwares-calculators/online-free-photovoltaic-software/pvgis
[2] W. F. Holmgren, C. W. Hansen, and M. A. Mikofski, “PVlib,” The Open Journal, Sep. 2018. doi: 10.21105/JOSS.00884.
[3] “Python.” Accessed: May 16, 2022. [Online]. Available: https://www.python.org/