Dispensary Solar Powered Water System
in
Lukani Village
Tanzania

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Project Period:
July 2014 - October 2014

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2.0 Executive Summary

The purpose of this report is to propose a solar powered water system at the dispensary in the village, Lukani. This report will discuss the current potable water situation in the village, highlight the benefits of adding a water system at the dispensary, and provide the technical details for how to implement a successful system. Lukani is a village of roughly 3,000 people. In 2012, the dispensary began serving roughly 15-18 patients per day. There is one doctor on site, and the dispensary has 13 rooms including a maternity ward and a bathroom with showers and a sink. The piping system is set up in the dispensary, however, there is no running water. Patients have to provide all their own water, including mothers giving birth. In addition, most of the villagers have no close access to clean water as 6 out of the 10 hand pumps are abeyant due to being drilled too shallow or a mechanical issue such as a broken seal. Consequently, for many villagers, the nearby kindergarten, and the dispensary's patients, water is only accessible from open sources. Many of the open water sources tested positive for both E. coli and coliform since the sources are near livestock. Not all villagers are knowledgeable about the importance of clean water; one example is that not all villagers boil their water before cooking.

Saint Paul Partners, with the help of the University of Minnesota, is looking to abate the current situation by implementing a solar powered pump at the dispensary. The 1 horse power pump would be drilled roughly 50 meters east of the dispensary and would be powered by 5 solar panels installed on the dispensary's roof. The water would be pumped to a tower right next to the dispensary and feed into a 2,000 L and 10,000L sim tank. The 2,000 L sim tank would be accessible only to the dispensary and would provide enough water for the patient's needs (about 20L/day per patient). The 10,000 L sim tank would be connected to a spigot accessible to the villagers surrounding the dispensary, but the 10,000 L sim tank would only begin filling once the 2,000 L tank was full, ensuring that the dispensary always has water before the community. We are estimating that the solar powered system would be accessible for daily use for 750 people. In order to involve the villagers, St Paul Partners will work closely with the villagers during the construction process. This will include having villagers provide financial support, an active water committee, and in kind labor. The aggregate amount of the project is estimated to cost: $14,048. Approximately 80 % of the cost will come from donations through St. Paul partners. The remaining costs will be provided by Lukani in the form of in kind labor and money.

3.0 Project Profile

3.1 Project Title

Lukani Dispensary Solar Powered Water System

3.2 Project Type

Construction of a solar-powered submersible water pump system at the Lukani dispensary with compliance from the village water committee and hygiene and sanitation promotion activities (WASH). A single borehole will be drilled near the dispensary and will pipe water to two sim tanks leading to a community tap and the dispensary's existing piping system. Expansion of the dispensary's piping system may also be completed to allow for running water access to additional rooms. Long term maintenance will be conducted by SPP/KS Well Maintenance Program and funded by Lukani village.

3.3 Project Implementing Organizations

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Name: Kilolo Star Drillers – Bore holes, Hand pumps
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3.4 Project Location

Lukani is a village 40km Southeast of Iringa town in the Iringa region. The Lukani dispensary is located at the following GPS coordinates: -8.0786° Latitude, 35.828° Longitude. It is surrounded by a sub village called Isengavakiwa. Figure 1, below, is a satellite image of the dispensary and nearby well. The well is indicated by the yellow pin and the dispensary is the largest building immediately to the left of the yellow pin. The distance between the dispensary and the well is approximately 50 m.

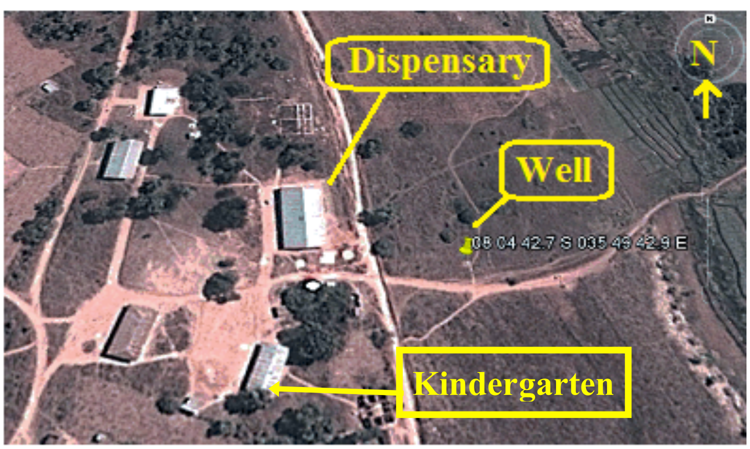


Figure 1: Dispensary and Well Satellite Image
(Image taken from Google Maps/Google Earth)

3.5 Beneficiaries Information

Figure 2: Lukani Dispensary

The beneficiaries of this project include the dispensary and all its patients, which amounts to 15-18 patients per day. Figure 2 is a picture of the dispensary. These patients travel from Lukani and other villages around the area to receive treatment at the Lukani dispensary. In addition to the dispensary patients, the immediate community surrounding the dispensary would also benefit from this proposal. The population surrounding the dispensary totals around 720 people. Finally, there is a kindergarten directly adjacent to the dispensary (shown in Figure 1) which will also greatly benefit from a close, reliable water source. Therefore, the sum total of all the beneficiaries would be 738, but all calculations were made assuming the number to be 750 in order to be conservative. All calculations can be found in Appendix 2.

3.6 Project Duration

Start date: July 2014
End date: October 2014

4.0 Detailed Summary

4.1 Overview

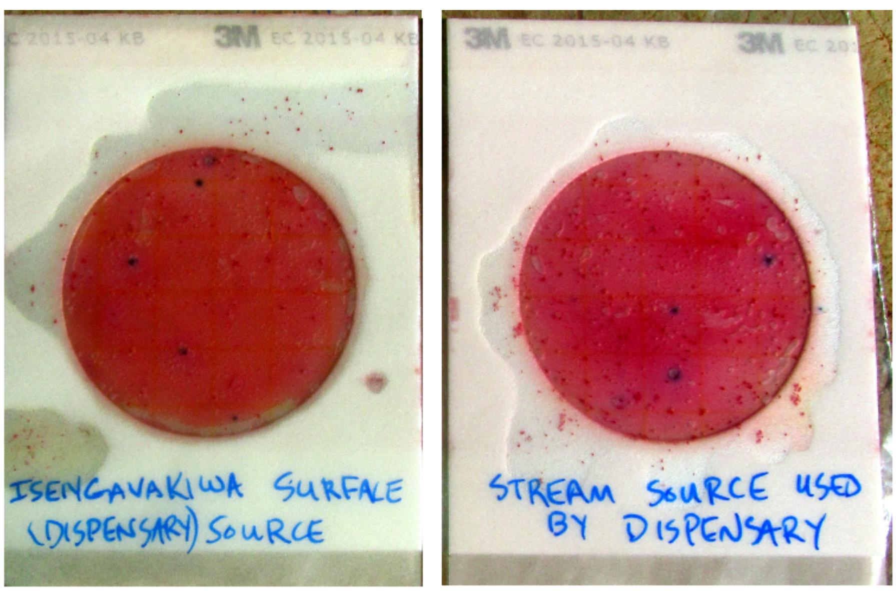
Lukani village is located 40 km Southeast of Iringa town. It is a conglomeration of multiple sub villages that are dispersed over a large area. The primary concern of this village is that the local dispensary does not have a reliable and safe source of water. A population of around 750 people is in need of this source of clean water including the dispensary. Previously water was retrieved from a nearby hand pump, but the well was dug too shallow and the water level has dropped so the pump is unable to draw water. In Figure 3 below, a picture of the hand pump closest to the dispensary is shown.

Figure 3: Afridev hand pump near the dispensary that is unusable (GPS Coords: 08° 04’ 42.7”, 035° 49’ 42.9”)

For this reason, the community fetches their water from multiple nearby surface sources, while the dispensary collects its water from one specific surface water source approximately 300m from the dispensary. This surface source can be seen in Figure 4, below. An example of the water problem is evident in the requirement that local women giving birth must provide their own water prior to even being admitted to the dispensary because it is difficult to accommodate the necessary amount of water. In addition, this water is often not boiled before use despite containing E. coli and Coliform bacterium as pictured in Figure 5 below. Both sources tested positively for E. coli and Coliform as evidenced by the presence of blue and red dots, respectively, on the test kit.

It is important to note that the community members who obtain water from these same contaminated sources must walk great distances in addition to traversing large changes in elevations to collect and carry the water back to their homes.

Figure 4: Common water source used by Lukani doctor and local residents. The testing results for this source is pictured in Figure 5A.



5A) 5B)

Figure 5A: 3M Water Test Kit Result for surface source used by the dispensary
Figure 5B: 3M Water Test Kit Result for surface source nearest the dispensary

The organizations that will be involved in implementing this proposed project include St. Paul Partners (SPP) and Kilolo Star Drillers. They will work closely with the Lukani water committee members to ensure proper installation and maintenance of the proposed system.

After completing this project, a large portion of the Lukani village will have access to a reliable source of potable water. In addition, the dispensary will have safe, running water available throughout the building for easy access during patient visits and procedures. A component of this plan will allow for additional piping to be placed in rooms other than the maternity ward, where there are existing pipes and bathroom fixtures. Clean and safe water will also be available for the adjacent kindergarten. Water will be stored in the form of two sim tanks for dispensary and community use.

In the past, at least some of the wells in Lukani were only drilled to about 15m with a water level of 11m, resulting in fully functional pump mechanisms in inadequate boreholes. This renders these hand pumps to be effectively useless. In contrast, the proposed design will be a solar-powered submersible pump system consisting of a 45m deep borehole, sim tank tower with two sim tanks for water storage, and piping to connect the pump to the sim tanks, between sim tanks, and from the sim tanks to the dispensary. A main feature of this design allows for the community to tap from their own sim tank only when the dispensary's sim tank is full. This ensures that the dispensary will always have running water as a priority over the community.

Furthermore, occasionally a water tap may be left open accidentally which causes the sim tank to empty. A method to mitigate this occurrence would be to install a spring-loaded or self-closing spigot that would only release water when the handle is manually held open. If this option is not desired, it is important to note that in the proposed system even if the tap is left on for an extended period of time, the worst case scenario would be that only the community tank would empty as it does not fill unless the dispensary's tank is full. The connection at the top of the 2,000 L tank ensures that it will not drain into the next tank unless it is full.

A significant benefit of the solar powered system is that the dispensary is already currently utilizing two solar panels for their electricity, so there is existing storage space for the equipment and also security is in place to make sure the panels are not stolen or removed. This project will be ongoing from July 2014 to its target completion date in October 2014. Given this time frame it is estimated that this project will cost approximately $14,000 USD. Implementation of this project would greatly help the Lukani community by creating access to safe water and improving the quality and safety of care provided at the dispensary and the kindergarten.

4.2 Background on St. Paul Partners (SPP) and Kilolo Star Drillers

St Paul Partners (SPP) was established in 2002 and serves primarily residents of the Iringa region, southern highlands, Tanzania. SPP is a faith based organization but independent 501C3 tax exempt US organization and works in partnership with the

Lutheran church in Iringa (KKKT Iringa Diocese) as well as local NGOs in the region. Their operating model is to work with local communities, leveraging their ties to the church, to deliver safe and sustainable water supplies along with hygiene and sanitation training. Specifically SPP meets with villages before and after projects to insure village involvement, sets up water committees, conducts hygiene and sanitation training and follows up periodically to support sustainable village practices. SPP currently has three full time employees (Heute Andrew, Village Outreach Manager, Hanael Gandwe, Operations Manager, and Peter Mwakatundu, Driver) who provide these services. At all stages of the development of village water programs the local communities play an essential role and are ultimately owners of the projects.

Kilolo Star Well Drillers are the selected local NGO for the proposed Lukani Dispensary Solar System project. Kilolo Star will drill a borehole and install a submersible solar-powered pump. Kilolo Star Well Drillers was established in 2007 and is a partnership of Ron Reed, an attorney from Chico, California, and Castor Sanguya from Tanzania, a well driller licensed through the Tanzanian Government. It was organized for the purpose of training young men and women to drill water wells to provide clean water for the villages of the Kilolo District of Tanzania. Kilolo Star has successfully drilled over one hundred wells with hand pumps in the Kilolo and Iringa regions of Tanzania.

4.3 Existing Situation

The Lukani dispensary is a relatively new facility finished in 2012. Currently there is no running water in the building, but piping does exist in the maternity ward along with bathroom fixtures and is ready to be hooked up. There is a hand pump well located about 50m away from the dispensary, but the water level has dropped below the level of the pump, rendering it unusable. For this reason the doctor at the dispensary and also many villagers collect their water from two natural sources nearby. At least one of these surface water sources is viable year round. Both of the natural surface sources are highly contaminated with both E. coli and Coliform bacterium and are therefore very dangerous (see Figure 5A and 5B). One of the main reasons that the surface sources are so contaminated is because they are open to animals and feces which are present in this subsistence farming community. In addition, these open sources are typically only standing water which is a more hospitable condition for bacteria growth. Some community members know to boil the water before usage, but some do not take this precaution. Water that is not boiled may spread bacteria and promote infection, especially when used for medical procedures and washing hands. The dispensary is built on a hill, necessitating that the water be carried up a hill from either source to be used. Not only are women walking long distances, they are often walking up and down hills while doing so. This is a huge problem that could be alleviated with a closer water source. Currently the water is carried by the bucketful in order for the doctor to wash his hands in between patients. Because water is difficult to obtain, women that give birth in the dispensary must provide their own water prior to being admitted, which is evidence of the difficulties experienced by the dispensary in obtaining water.

As stated earlier, there is a large population that would benefit from the implementation of this system. Adding the dispensary's patients and the community surrounding it together yields a total of approximately 750 people that are in need of potable water from this system. Typical water consumption for the average person in a single day is approximately 20 L/day. In order to be conservative, this system should attempt to supply around 15,000 L/day in order to satisfy the water demands of both the dispensary and the village. It is important to note that all of the following calculations incorporated an average of 6 hours of sunlight in which the necessary amount of water could be delivered. In addition, an insolation value (incident solar radiation) value of about 6.0 kWh/m^2-day

The dispensary has 13 rooms, as shown in the floor plan in Figure 6.   Currently the building uses 17 light bulbs that are being supplied with electricity generated by two solar panels. There is a large equipment room that contains the current solar panel's equipment (indicated with the rectangle labeled with a 1 in the figure), but there is also an ample amount of space for additional equipment for this proposed system. The dispensary floor plan is shown below. The rooms are labeled with what they were intended to function as. It is important to note that, although there is a sink shown in most of the rooms this is not the case for all but the bathroom in the maternity ward (labeled as rectangle 2 in the figure).

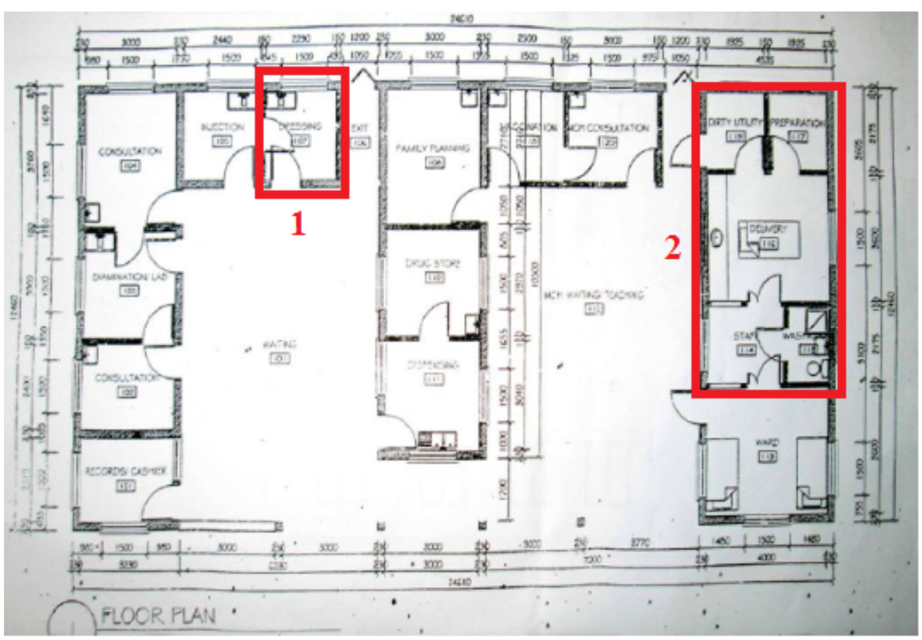


Figure 6: Floor plan of Lukani Dispensary

These sinks are not attached to running water currently. Perhaps not all of the rooms need running water; such as, family planning or counseling rooms, the drug store, rooms that house refrigerated vaccines, and the room housing the solar panel equipment. If running water and sinks were put into the two consultation rooms and examination room on the left, dispensing room in the middle, and preparation room and delivery room in the maternity ward, six additional sinks would be necessary.

4.4 Program Objectives

- Provide potable water for the population of Lukani surrounding the dispensary (about 750 people)
- Provide running, safe water to Lukani's dispensary, including a water storage system
- Provide running water throughout the dispensary including the maternity ward(showers, bathroom sink) as well as to the other side of the dispensary
- Provide a safe, reliable water source to the nearby Kindergarten
- Expand piping in dispensary (past the existing piping in the maternity ward (as mentioned above)
- Ensure that the pump is drilled correctly and to the necessary depth to mitigate future issues such as the water level below pump/recharge rate insufficient for application
- Utilize security at the dispensary to prevent thievery so the solar panels continue to remain safe and secure
- Educate and properly train workers regarding maintenance of solar panels and water pump system
- Educate water committee on management and maintenance

4.5 Program Deliverables

- Drill a borehole and install a solar powered pump inside the borehole.
- Install 5 120 W solar panels to the dispensary rooftop.
- Install a sim Tank tower to hold a 2000L and a 10,000L tank.
- Connect 2000L sim tank to existing piping in the maternity ward of the dispensary.
- Install additional piping within the dispensary to allow for access to running water throughout the building.
- Attach a spigot to the 10,000L holding tank for public use. The dispensary will receive priority access to the water (See Figure 7).
- Cooperate with and train Water and Sanitation Committees in Lukani, including instructions to call Kilolo Star maintenance group.
- Instruct in the use of their existing bank accounts for each water committee to collect 15,000 TSH each month per well for use in future repairs (final village contribution subject to negotiation). *

  ***Note:** These funds should be held separately from general village accounts and authorized by both the water committee chair and a village leader prior to any withdrawals.

The proposed location for the borehole is just down the hill from the dispensary. The borehole will be drilled 45 meters deep in order to ensure the well can continuously and reliably provide this high volume of water without drying up as the neighboring, more shallow wells have. The borehole site is about 6 meters lower in elevation relative to the dispensary and about 50 meters away. The piping from the borehole to the base of the dispensary and sim tank tower will be buried underground to prevent damage to the pipes. The sim tank tower will be built to a height of about 5 meters so that the base of the sim tanks is at the top of the dispensary roof. The water from the borehole will feed directly into the 2000 liter sim tank, which is reserved for the dispensary's use only. There is a pipe that will attach each of the sim tanks at the top. This way, the 10,000 liter tank for the community to use will only fill up after the dispensary sim tank is full. Also by design, when the community tank is empty, the community cannot tap into the dispensary water supply. A pipe will feed out of the bottom of the smaller dispensary sim tank and through the roof of the dispensary and be hooked up to the existing piping of the maternity ward and the newly constructed additional piping throughout the rest of the building. Another pipe (pictured in Figure 7) will feed out of the bottom of the larger community sim tank to a spigot about 1 meter off the ground. This spigot will be accessible to the public.

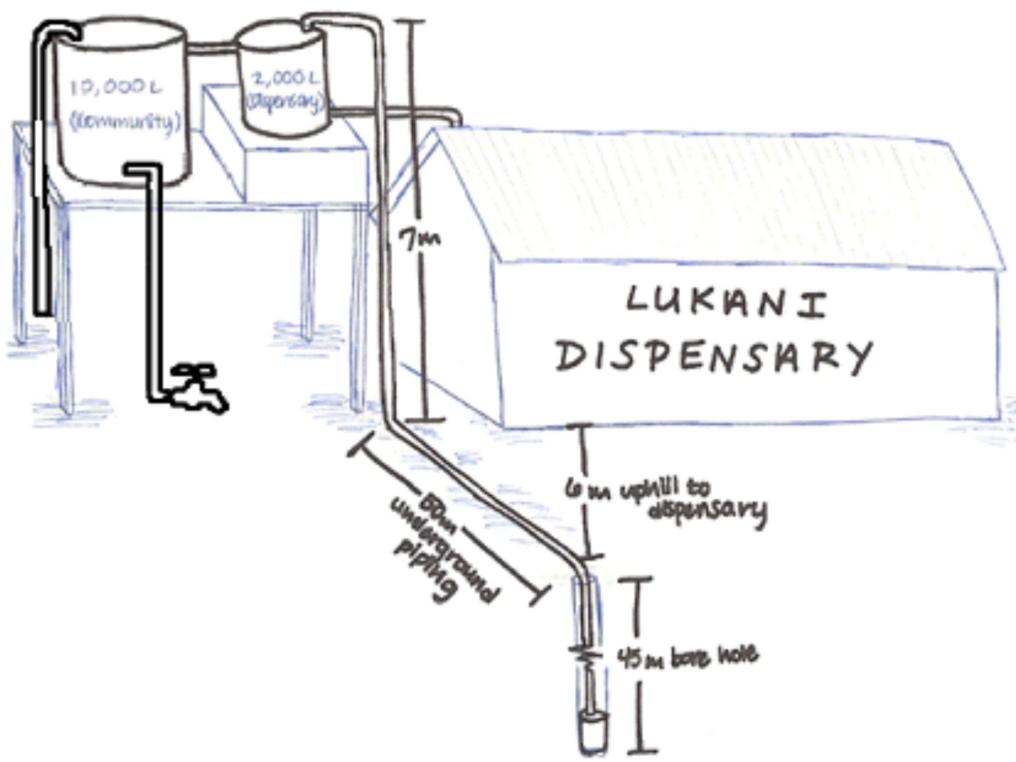


Figure 7: System Schematic

4.6 Impact Goals

- To provide access to clean water to the sub-village of Isengavakiwa in Lukani village as well as patients utilizing the dispensary (total 750 people) and nearby kindergarten
- Collaborate with Water and Sanitation Committees in Lukani to provide training in order to increase knowledge of basic sanitation practices and well/pump maintenance
- Increase the health practices performed at the Lukani dispensary by providing clean water for the maternity ward as well as the potential for increased power supplies in the future so other electronic tools can be utilized

4.7 Implementation Plan

- Conduct meetings with village leaders, the Lukani water committee, women, and elders prior to drilling to establish village buy in and in kind payments
- Lukani water committee consists of 3 men and 4 women and they will be primarily responsible for the organizing the maintenance and upkeep of the wells via SPP-Tanzania
- All mobilization of drilling equipment including drilling of the well and installation of solar pump will be performed by Kilolo Star drillers with SPP supervision
- Communities will contribute through the provision of labor, construction materials for the platform and tower, management of the completed water point, and security of the solar powered system
- The well will be fitted with a solar pump that will provide flow of water during the daylight to a sim tank located in close proximity to the Dispensary. The primary beneficiary is the Dispensary; water supplied to the community is secondary in priority
- Any maintenance that takes place either by the village or by affiliates of Kilolo Star will have signed records that include any monetary transactions

4.8 Project Site

The area around the dispensary in Lukani that will be used to implement the solar powered water system is shown below in figure 8. The underground piping is estimated to cover about 50 meters of horizontal distance, along with a slight incline that should be accounted for in the 50 meter estimate. The 2000 L Dispensary-only sim tank will be hooked to existing piping that has never been used but was put into the maternity ward when the dispensary was built in 2012. Locating the sim tanks on the same side of the building as the maternity ward has the added benefit of being able to hook to the main system before installation of pipes throughout the rest of the dispensary is completed.

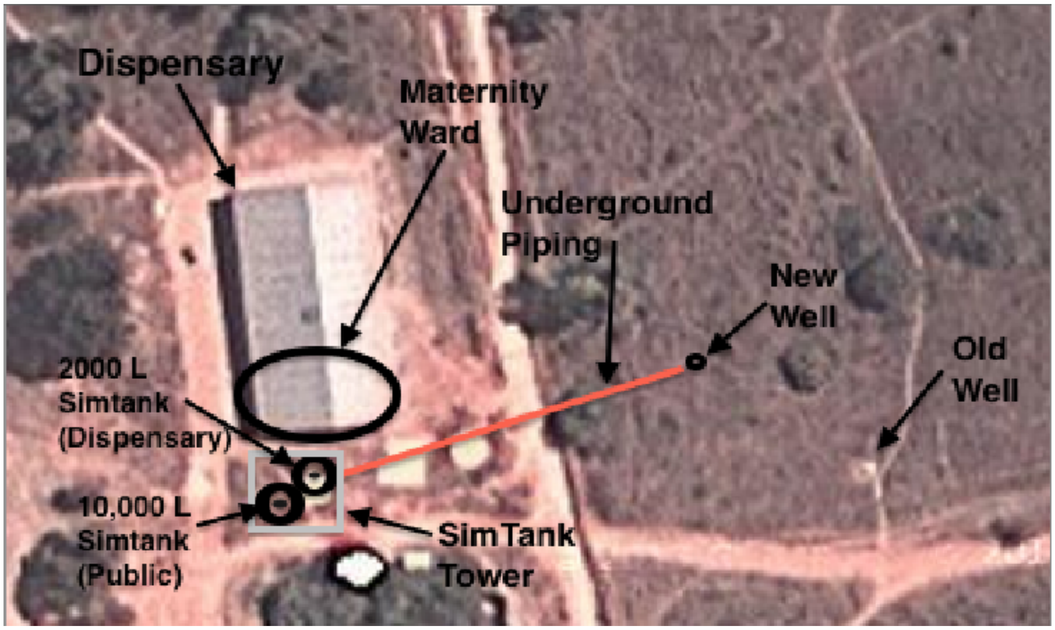


Figure 8: Plan for Layout of Well and sim tanks
(Image taken from Google Maps/Google Earth)

5.0 Shallow Boreholes Construction Process

A shallow borehole will be drilled with a truck mounted mud-drilling rig to a maximum depth of 45 meters and cased with 6 inch PVC casing. If the drilling location proves to be unfavorable for the mud-drilling technique, an air-hammer drilling technique will be used instead. Borehole yields will be tested for accuracy using pump-testing equipment. Kilolo Star currently uses Taifu 3TSSO.76-55-24/120 solar pumps that can deliver up to 3 GPM of water. This pump will be readily available for use in Lukani, however it does not deliver the desired flow rate. In order to achieve the desired flow rate of about 11 GPM, a 1 horsepower Grundfos pump will need to be implemented. This was recommended in a quote from ArtiEnergy out of Dar es Salaam, Tanzania. Kilolo Star, with SPP support and supervision, will mobilize the necessary workforces for the well construction utilizing existing personnel from its drilling staff. Masons and daily laborers required during construction and proper finishing of the water point will be sourced from the community.

6.0 Project Sustainability

The principle of the people's full participation in the development process is the cornerstone of the St Paul Partners approach. For SPP, participation comes from recognition of "the centrality of people's ownership of and involvement in their own development process, without which no sustainable, equitable, or appropriate development can succeed." In line with SPP policy, a participatory approach was adopted in the process of assessing the needs of the community and formulating the project. In this particular project, the community will share by contributing room and board for drilling technicians, locally available materials such as sand and bricks, and contributing unskilled labor for the construction of the solar pumping and storage system. It is important to realize that this community is extremely proactive and interested in bettering their village and quality of life. The village of Lukani completely built their dispensary without any government aid in 2012 under the agreement that the government would staff it. They have shown great interest in this project and value the importance of clean, reliable water sources for their community.

SPP in collaboration with the village of Lukani will monitor the quality and progress of work. After completion of the well, SPP will complete hygiene and sanitation training and verify operation of the water committee. SPP will then work with village leaders and the water committee to hand over ongoing operational leadership. SPP will remain available for follow up training as well as assistance in major maintenance needs.

Kilolo Star or affiliates will have regular meeting times with regards to upkeep up the system and will be available for contact in the case of emergencies. To ensure the proper exchange of services and money, paper contracts will be signed by chosen water committee members and by members of the maintenance team. In addition, it is our recommendation that the bank account used to provide maintenance funding to the system should be separate from that of the general village funds to minimize any potential of ill-use. Furthermore, it is recommended that a policy be enacted that requires the signatures of both the water committee chair and village leader before withdrawing any funds related the water system.

7.0 Project Budget – Bill of Materials

Table 1: Solar Panel System and Piping

Product	Unit	Quantity	Rate (TZS)	Amount (TZS)	Rate (USD)	Amount (USD)
Sim Tank (2000L)	Pcs	1	325,000	325,000	$200	$200
Sim Tank (10000L)	Pcs	1	1,940,000	1,940,000	$1235	$1235
Charge Controller (45A)**	Pcs	1	455,000	455,000	$280	$280
HDPE 50mm OD Class E piping w/ 18% VAT+	150m	1	900,000	900,000	$555	$555
1.5”OD Schedule 40 galvanized steel pipe	10 ft	3	203,000	610,000	$125	$375
1 hP Solar Submersible Pump++	Pcs	1	1,500,000	1,500,000	$925	$925
Solar Battery (100 AH)**	Pcs	5	207,000	1,035,000	$127	$635
Solar Panel (120 W) **	Pcs	5	300,000	1,500,000	$185	$925
Solar installation accessories	Pcs	1	2,000,000	2,000,000	$1230	$1230
Sink*	Pcs	3	333,000	1,000,000	$205	$615
Spigot (8”)***	Pcs	1	114,000	114,000	$70	$70
Horizontal Mount Liquid-Level Float Switch*	Pcs	1	65,000	65,000	$40	$40
Elbows (1.5”)***	Pcs	20	5,750	115,000	$3.50	$70
Fittings (1.5”)***	Pcs	20	2,850	57,000	$1.75	$35
U-Clips*	Box of 50	1	16,000	16,000	$10	$10
TOTAL	--	--	--	**10,504,500**	--	**$6465**

*** Prices found from Menards
** Prices found from ArtiEnergy, Dar es Salaam
* Prices found from McMaster Carr
+ Prices from Dpi Simba Ltd, Dar es Salaam
++ Pump is a 1HP Grundfos Pump. Price was obtained from a quote used at Illula, TZ hospital

Table 2: Sim Tank Tower

Description	Unit	Quantity	Rate (TZS)	Amount (TZS)	Amount (USD)
Stones	Lory	1	100,000	100,000	$60
Coarse Aggregates	Lory	0.5	200,000	100,000	$60
Sand	Lory	0.5	100,000	50,000	$30
Cement	Bags	10	17,000	170,000	$105
12 mm Dia Iron Bars	nr	2	18,000	36,000	$21
Binding Wires	kg	1	3,000	3,000	$2
Bricks	Lory	1	200,000	200,000	$120
Sand	Lory	1	100,000	100,000	$60
Cement	Bags	15	17,000	255,000	$160
Scaffolds	Item	1	200,000	200,000	$120
12 mm Iron Bars	nr	3	18,000	54,000	$35
Binding Wire	KG	1	3,000.00	3,000.00	$2
Cement	Bags	5	17,000	85,000	$50
Sand	Lory	0.5	100,000	50,000	$30
Coarse Aggregates	Lory	0.5	200,000	100,000	$60
Total Tower Mat. Cost				**1,506,000**	**$921**
Labor Charges				4,518,000	$2775
Transportation				325,000	$200
Installation of Water Supply System				2,000,000	$1230
Total Sim Tank Cost				**2,004,405**	**$5855**

Source of sim tank tower costs: The numbers shown above in Table 2 were acquired from a previous proposal implementing a sim tank tower at Image Dispensary. These estimates were prepared by Amos Lulapangilo Mkuye, the Diocese Building Technician.

Table 3: Drilling Costs

Type of Drilling Method	Component	Quantity	Rate (TZS)	Amount (TZS)	Amount (USD)
Mud Rotary	All materials and drilling costs without hand pump installed	--	--	--	$2800
	Total	--	--	4,550,000	**$2800**
Air Hammer					
	Mobilization to Site	--	--	1,000,000	$615
	Cost/m	40 m	120,000	4,800,000	$2950
	Screen and Casing	39 m	55,000/3m	715,000	$440
	Gravel Pack			150,000	$95
	Well Development and Pump Test			1,000,000	$615
	Miscellaneous			350,000	$215
	Total			**8,015,000**	**$4930**

Source of Drilling Costs: Mud rotary drilling cost with SPP pricing without a hand pump is from SPP. The costs given for air hammer drilling are estimates from Ken. (A quote should be requested if air hammer drilling is needed.)

Table 4: Total Cost

Item	Amount (TZS)	Amount (USD)
Tower	8,349,000	$5120
Solar Panel System	11,685,600	$7200
Drilling	4,550,000	$2800
SPP Oversight and Training	1,625,000	$1000
10% Contingency	2,340,000	$1440
Grand Total	**28,499,880**	**$17,560**

We would like the village to contribute an additional 20% of the cost, which would result in a final total of $14,048 for the project.

Overall Cost $17,560 − **Village Contribution (20%) $3,512** = **SPP Contribution $14,048**

Appendix 1: Additional Input

The purpose of this section is to look at additional implementations that could be made in the village, Lukani. These are recommendations that are not included in this project proposal or budget, but are alternatives/additional systems that could improve the quality of life for the villagers. Ideas include:

- **Utilizing a rainwater harvesting system onto the dispensary rooftop**

This would be beneficial because a rainwater harvesting system is low maintenance that does not require any electrical components. This would be appropriate to add with the system we are proposing above in case there is a problem with one of the mechanical components or the submersible pump has an electrical issue. The downside of a rainwater harvesting system is it would be unusable during the dry season.

- **Maintenance on existing wells**

It would be beneficial for the water committee and drilling company to do research and maintenance on each of the nonworking wells in the village. This would be beneficial because the water committee can have a better understanding as to why the wells are not working. Unusable pumps could be due to a mechanical issue (like a seal being broken) or if it is unusable due to improper drilling. It was noted that multiple boreholes were dry because they were not drilled deep enough. If the water committee and drilling company were aware of this problem, it would act as a precaution to the drilling company that they need to drill bore holes deeper than what they have done in the past.

- **Adding additional solar panels to the dispensary**

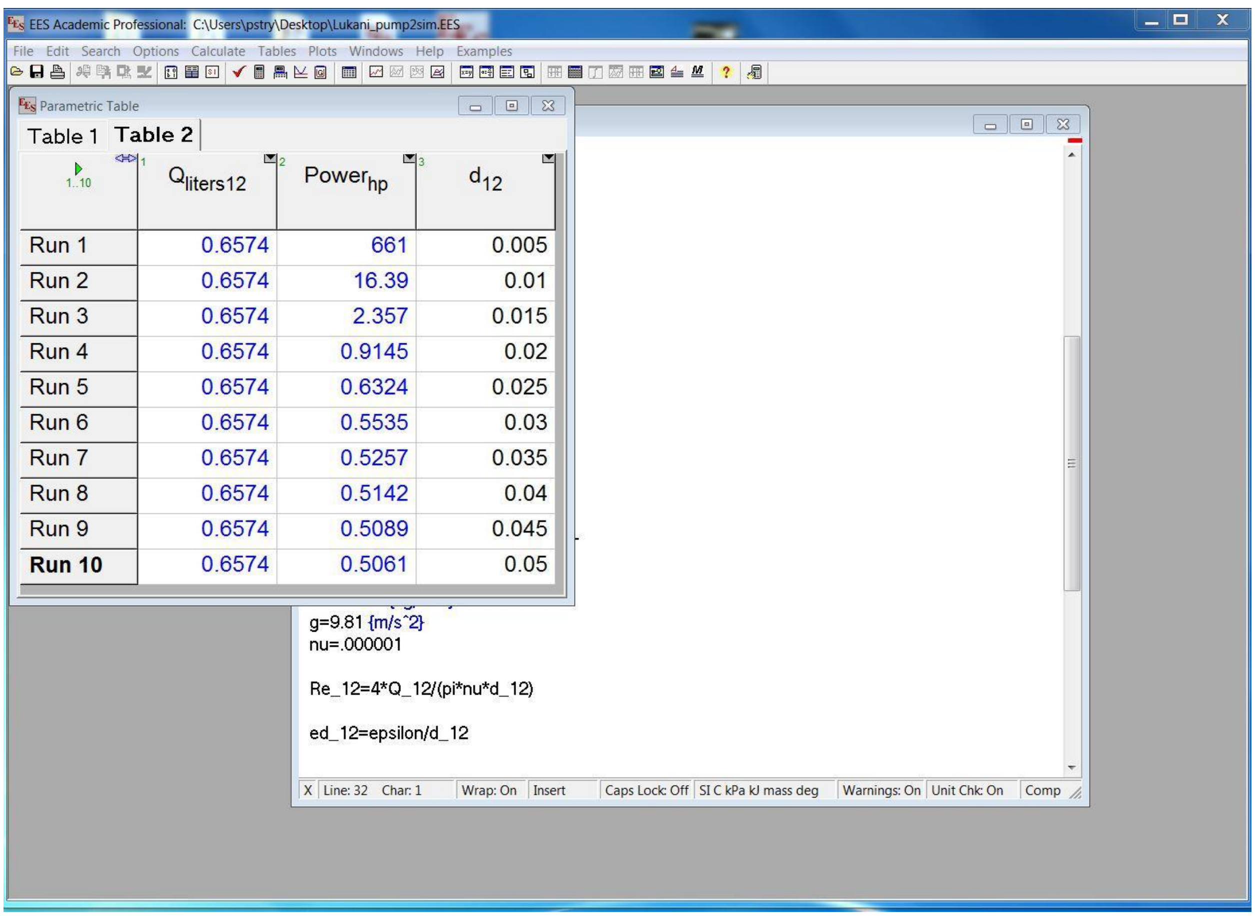
Currently, the dispensary only utilizes the solar panels for 17 light bulbs. Adding more solar panels would be beneficial because more electronic tests could be completed at the dispensary.

Appendix 2: Finding optimal pipe diameter using EES

In this program we modeled our system using Bernouilli's law between the bottom of the borehole (pump level) and the sim tank. Using known distances (calculated from elevation changes, etc), known amount of users to determine required flow rate, and a finite amount of sunlight to deliver the flow rate, we were able to approximate the optimal pipe diameter needed for this system. We chose to vary the flow rate and computed the diameter and pump horsepower. In addition, we chose an arbitrary amount of fittings and elbows that may be used to help estimate our total losses. The results of this code indicated that the optimal diameter that would yield our desired flow rate with minimal pressure is 1.25". This is the final pipe diameter that we recommended for use in this proposal.

```
{Modeling Lukani Solar Water System - by Alyssa, Adam, Kelsey, Kali}
A_12=pi/4*d_12^2

{d_12=0.079}

epsilon=0.2/1000

v_12=Q_12/A_12
number_people = 710
wateruse=number_people*20/1000 {m^3}
hours_sun=6 {hrs}
seconds_sun=hours_sun*3600
Q_12=wateruse/seconds_sun {m^3/s}

{Q_12=0.00175}


Q_liters12=Q_12*1000


kv_12=0
Num_elbows=10
kl_elbow=1.3
elbowloss=kl_elbow*Num_elbows

L_12=102 {m}


z_1=0 {m}
z_2=58 {m}


{P_1=101325 {Pa}
P_delta=P_2-P_1}

z_delta=z_2-z_1
z_delta = Power/(rho*Q_12*g)-h_L
Power_hp=Power/745 {hp}

rho=1000 {kg/m^3}
```

```
g=9.81 {m/s^2}
nu=.000001

Re_12=4*Q_12/(pi*nu*d_12)

ed_12=epsilon/d_12


h_L=v_12^2/(2*g)*(f_12*L_12/d_12+kv_12+elbowloss) {m}

{friction factor calculation}

f_12=.02

{AA_12 = -2*log10(ed_12/3.7 + 12/Re_12)
B_12 = -2*log10(ed_12/3.7 + 2.51*AA_12/Re_12)
C_12 = -2*log10(ed_12/3.7 + 2.51*B_12/Re_12)
f_12 = 1 / (   AA_12 - (B_12-AA_12)^2/(C_12 - 2*B_12 + AA_12)   )^2  }
```



1..10	$Q_{liters12}$	$Power_{hp}$	d_{12}
Run 1	0.6574	661	0.005
Run 2	0.6574	16.39	0.01
Run 3	0.6574	2.357	0.015
Run 4	0.6574	0.9145	0.02
Run 5	0.6574	0.6324	0.025
Run 6	0.6574	0.5535	0.03
Run 7	0.6574	0.5257	0.035
Run 8	0.6574	0.5142	0.04
Run 9	0.6574	0.5089	0.045
Run 10	0.6574	0.5061	0.05

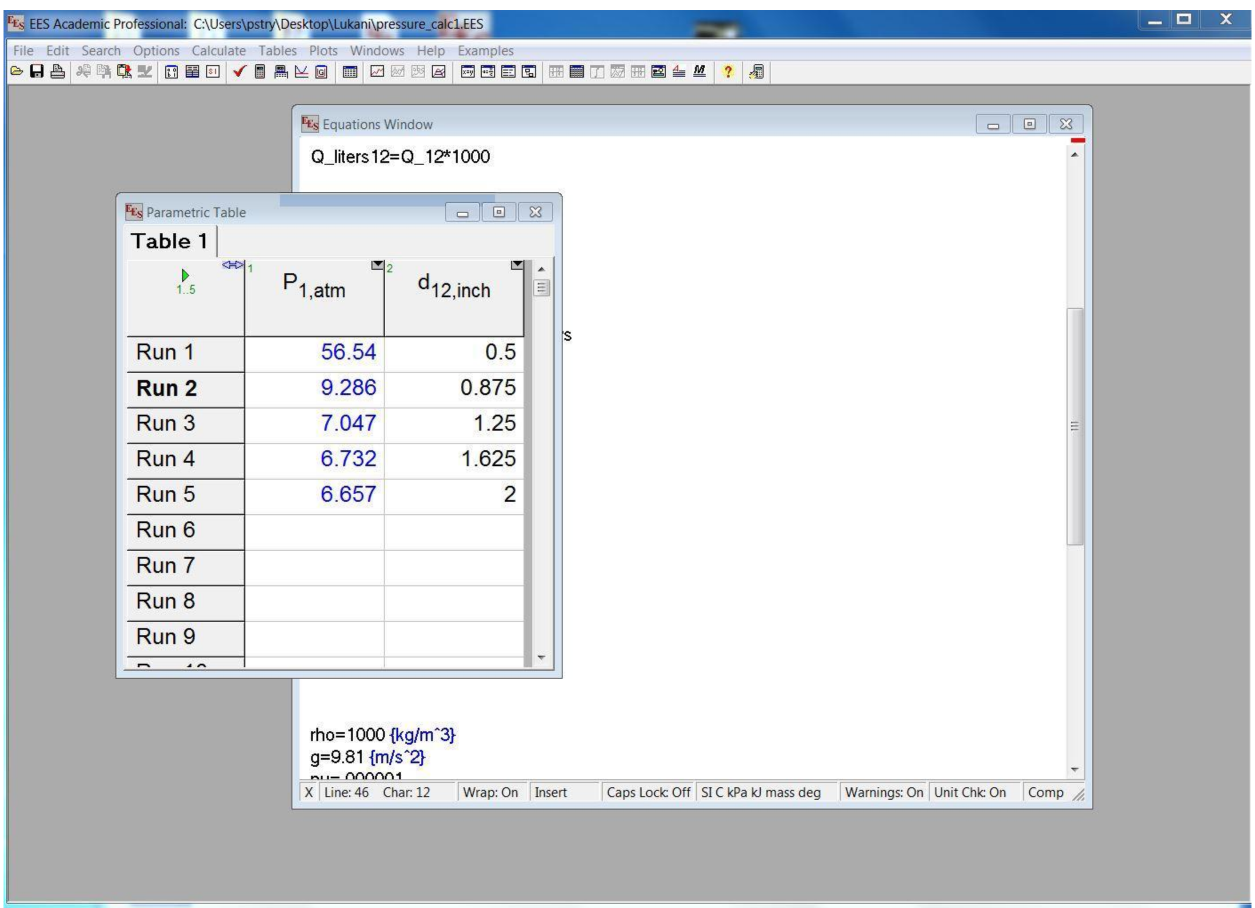
{----------------------------------

Appendix 3: Finding maximum pipe pressure using EES

This code is similar to the previous Appendix 2, but outputs different variables. Instead of varying flow rate to calculate the desired diameter, we varied the diameter to calculate the optimum pipe pressure in the system. After running the code with varying diameters, including the 1.25" diameter we recommended we found a maximum burst pressure of approximately 7atm. Using this information we chose to recommend PVC piping.

```
{Modeling Lukani Solar Water System - by Alyssa, Adam, Kelsey, Kali}
A_12=pi/4*d_12^2

{d_12=0.079}

epsilon=0.2/1000

v_12=Q_12/A_12
number_people = 710
wateruse=number_people*20/1000 {m^3}
hours_sun=6 {hrs}
seconds_sun=hours_sun*3600
Q_12=wateruse/seconds_sun {m^3/s}

{Q_12=0.00175}


Q_liters12=Q_12*1000

{d_12=.025 {m}}
d_12_inch=d_12/.0254 {inch}
{d_12_inch=1.5 {inch}}
kv_12=0
Num_elbows=10
kl_elbow=1.3
elbowloss=kl_elbow*Num_elbows

L_12=102 {m}


z_1=0 {m}
z_2=58 {m}


P_2=101325 {Pa}
P_delta=P_2-P_1
P_1_atm=P_1/P_2 {atm}

z_delta=z_2-z_1
z_delta+P_delta/(rho*g) = -h_L



rho=1000 {kg/m^3}
```

```
g=9.81 {m/s^2}
nu=.000001

Re_12=4*Q_12/(pi*nu*d_12)

ed_12=epsilon/d_12


h_L=v_12^2/(2*g)*(f_12*L_12/d_12+kv_12+elbowloss) {m}

{friction factor calculation}

{f_12=.02}

AA_12 = -2*log10(ed_12/3.7 + 12/Re_12)
B_12 = -2*log10(ed_12/3.7 + 2.51*AA_12/Re_12)
C_12 = -2*log10(ed_12/3.7 + 2.51*B_12/Re_12)
f_12 = 1 / (   AA_12 - (B_12-AA_12)^2/(C_12 - 2*B_12 + AA_12)   )^2


{---------------------------------}
```



Appendix 4: Finding approximate number of solar panels using EES

In order to calculate the number of solar panels required for our system we first found approximate values for average yearly insolation for the Iringa region. From this value we were able to convert to power and essentially compare our desired required power to the amount of power actually available on average. We approximated that the insolation would occur over a period of 6 hours of optimal sunlight to power our pump. In addition, we incorporated approximate efficiency values for both solar panels and solar batteries to attempt to calculate losses. As explained in our proposal, we wanted to provide enough "optional" additional power for the dispensary to utilize in the future if they wanted to acquire more electronic medical equipment such as centrifuges, x-ray machines, or sterilization machines. This additional amount of power was added to our required power to yield a total amount of required power that our system must deliver. After running the process below and varying pipe diameter, we estimated that we would require at least 5 solar panels to power our system.

The average solar insolation values were found from the following website: http://solarelectricityhandbook.com/solar-irradiance.html. Similarly, the approximate efficiency values for the batteries and solar panels were found from the following source: http://www.solar-wind.co.uk/deep-cycle-dryfit-batteries-battery-uk.html.

```
{Modeling Lukani Solar Water System - by Alyssa, Adam, Kelsey, Kali}
A_12=pi/4*d_12^2

d_12=0.0381

epsilon=0.2/1000

v_12=Q_12/A_12
number_people = 750
wateruse=number_people*20/1000 {m^3}
hours_sun=6 {hrs}
seconds_sun=hours_sun*3600
Q_12=wateruse/seconds_sun {m^3/s}

{Q_12=0.00175}


Q_liters12=Q_12*1000


kv_12=0
Num_elbows=10
kl_elbow=1.3
elbowloss=kl_elbow*Num_elbows

L_12=102 {m}


z_1=0 {m}
z_2=58 {m}
```

```
{P_1=101325 {Pa}
P_delta=P_2-P_1}

z_delta=z_2-z_1
z_delta = Power_req/(rho*Q_12*g)-h_L
Power_hp=Power_req/745 {hp}

panel_eff  = 0.1
{battery_eff = .85}

Power_extra = 200 {W}

Insolation = 5.980 {kWh/m^2 day}
Area_solar = 1.*1.5 {m^2}
Insolation_perday = (Insolation/6)*1000 {W/m^2}
Power_solarpanel = panel_eff * Insolation_perday * Area_solar {W}

Power_totalreq = Power_req + Power_extra {W}

Num_panels = Power_totalreq / Power_solarpanel

rho=1000 {kg/m^3}
g=9.81 {m/s^2}
nu=.000001

Re_12=4*Q_12/(pi*nu*d_12)

ed_12=epsilon/d_12


h_L=v_12^2/(2*g)*(f_12*L_12/d_12+kv_12+elbowloss) {m}

{friction factor calculation}

f_12=.02

{AA_12 = -2*log10(ed_12/3.7 + 12/Re_12)
B_12 = -2*log10(ed_12/3.7 + 2.51*AA_12/Re_12)
C_12 = -2*log10(ed_12/3.7 + 2.51*B_12/Re_12)
f_12 = 1 / (   AA_12 - (B_12-AA_12)^2/(C_12 - 2*B_12 + AA_12)   )^2  }


{----------------------------------}
```

Unit Settings: SI C kPa kJ mass deg

$Area_{solar}$ = 1.5

A_{12} = 0.00114

d_{12} = 0.0381

ed_{12} = 0.005249

elbowloss = 13

ε = 0.0002

f_{12} = 0.02

g = 9.81

$hours_{sun}$ = 6

h_L = 1.258

Insolation = 5.98

$Insolation_{perday}$ = 996.7

kl_{elbow} = 1.3

kv_{12} = 0

L_{12} = 102

ν = 0.000001

$number_{people}$ = 750

Num_{elbows} = 10

Num_{panels} = 4.038

$panel_{eff}$ = 0.1

$Power_{extra}$ = 200

$Power_{hp}$ = 0.5419

$Power_{req}$ = 403.7

$Power_{solarpanel}$ = 149.5

$Power_{totalreq}$ = 603.7

Q_{12} = 0.0006944

$Q_{liters12}$ = 0.6944

Re_{12} = 23207

ρ = 1000

$seconds_{sun}$ = 21600

v_{12} = 0.6091

wateruse = 15

z_1 = 0

z_2 = 58

z_δ = 58