

Sustainable Water Solutions



Report to Tenwek

December 2, 2009

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PRESENTATION OUTLINE

- Team & Project Overview
- Design Goals
- Complete System Design
 - Rainwater Harvesting System
 - Pump & Transport System
 - Solar Water Heater System
- Design for Cost Optimization

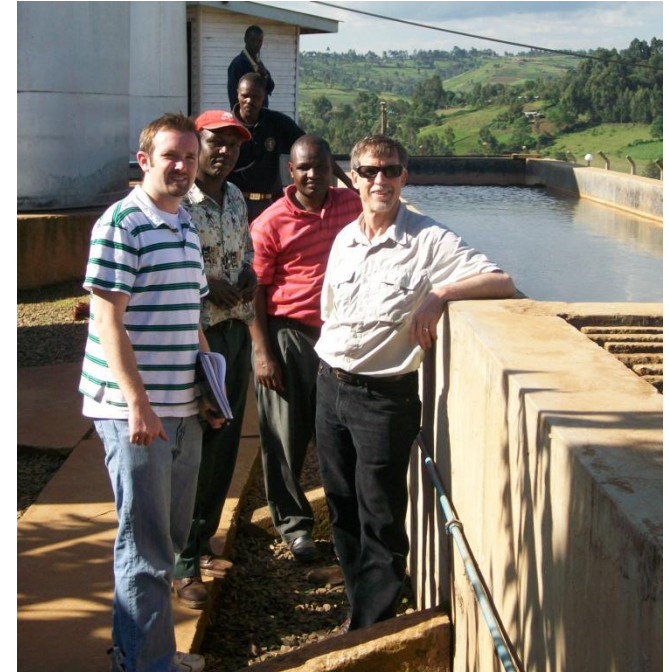


TEAM ORGANIZATION



PROJECT BACKGROUND

- Engineers for a Sustainable World Project
- Tenwek Hospital
 - Missionary Hospital
 - Rift Valley Province
 - Bomet, Kenya
 - Provides primary healthcare for 600,000 Kenyans
 - 308 beds for in-patient ward
- Assessment trip in June 2009
- Currently harvesting from 2 Buildings
 - Administration building used for IV production
 - Surgical building supplements in-patient ward supply



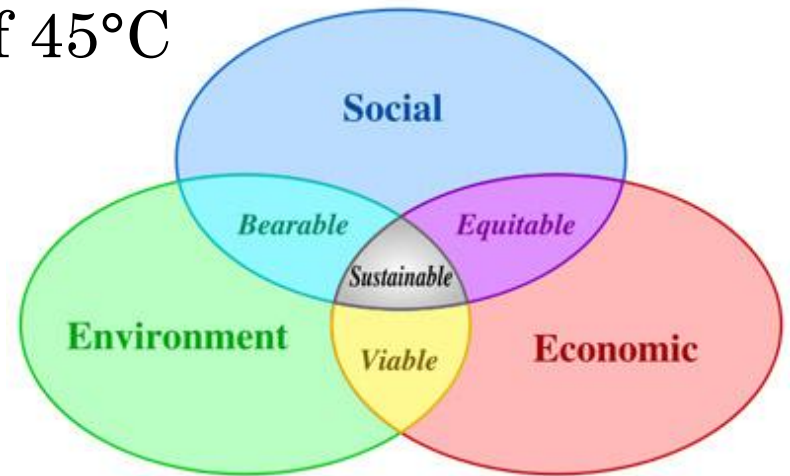
MISSION STATEMENT

- Develop a sustainable rainwater harvesting and solar water heating system with the capability to accommodate varying priority demands to sufficiently fulfill the hot water needs for the in-patient ward at Tenwek Hospital.



DESIGN GOALS

- Minimal Environmental Impact
- Meet the daily in-patient ward hot water demand of **4,000L**
- Final delivery temperature of 45°C
- Low Maintenance
- Low Operating Cost
- Utilize existing structures to harvest rainwater

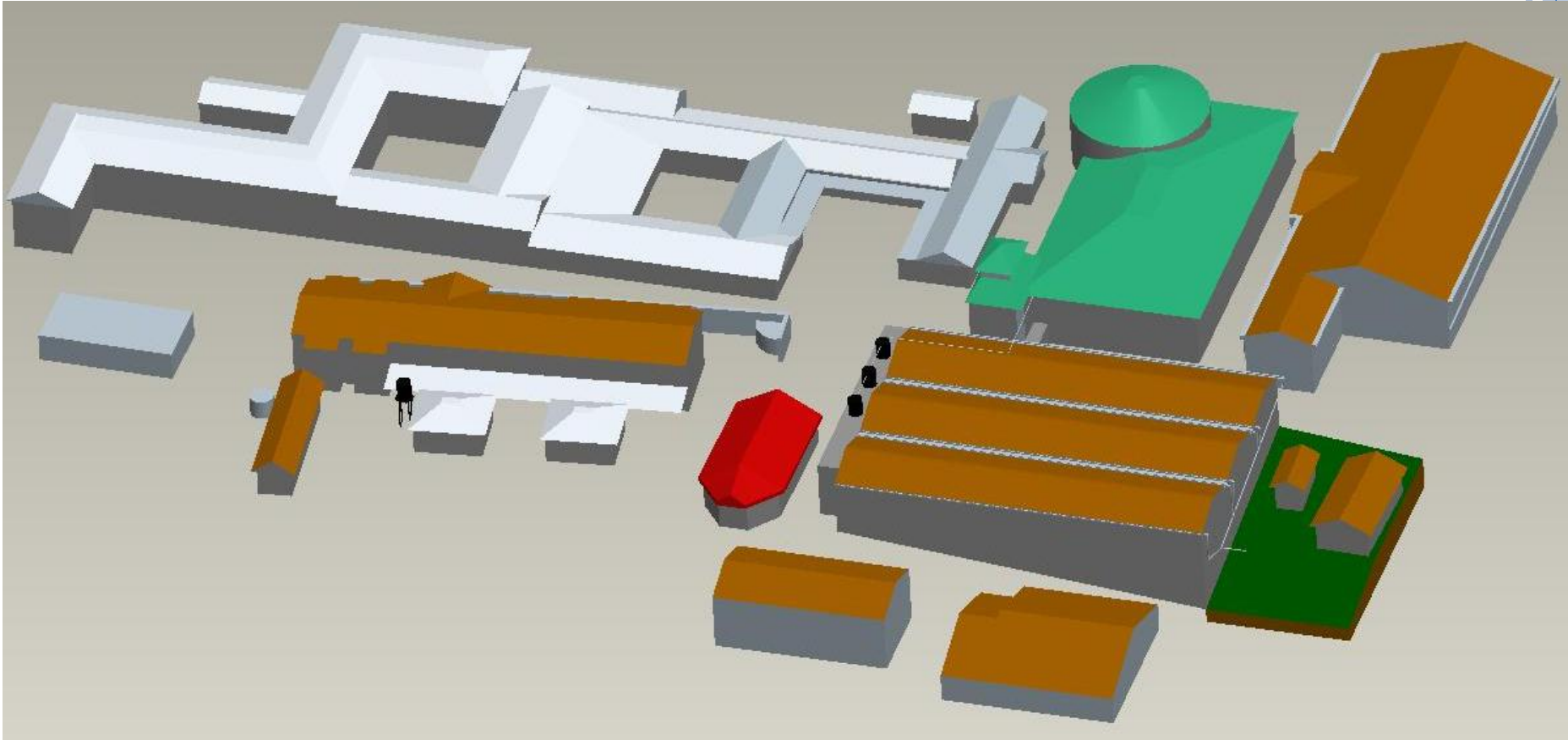


Source: "Sustainable development" : "Author : " Johann Dréo ([User:Nojhan](#))
: "Translator : " ([User:Pro_bug_catcher](#)) : "Date : " March 9 2006/ Translated January
21 2007 : "Notes : " Inspired from [fr:Image:Developpement_durable.jpg](#). Transl)

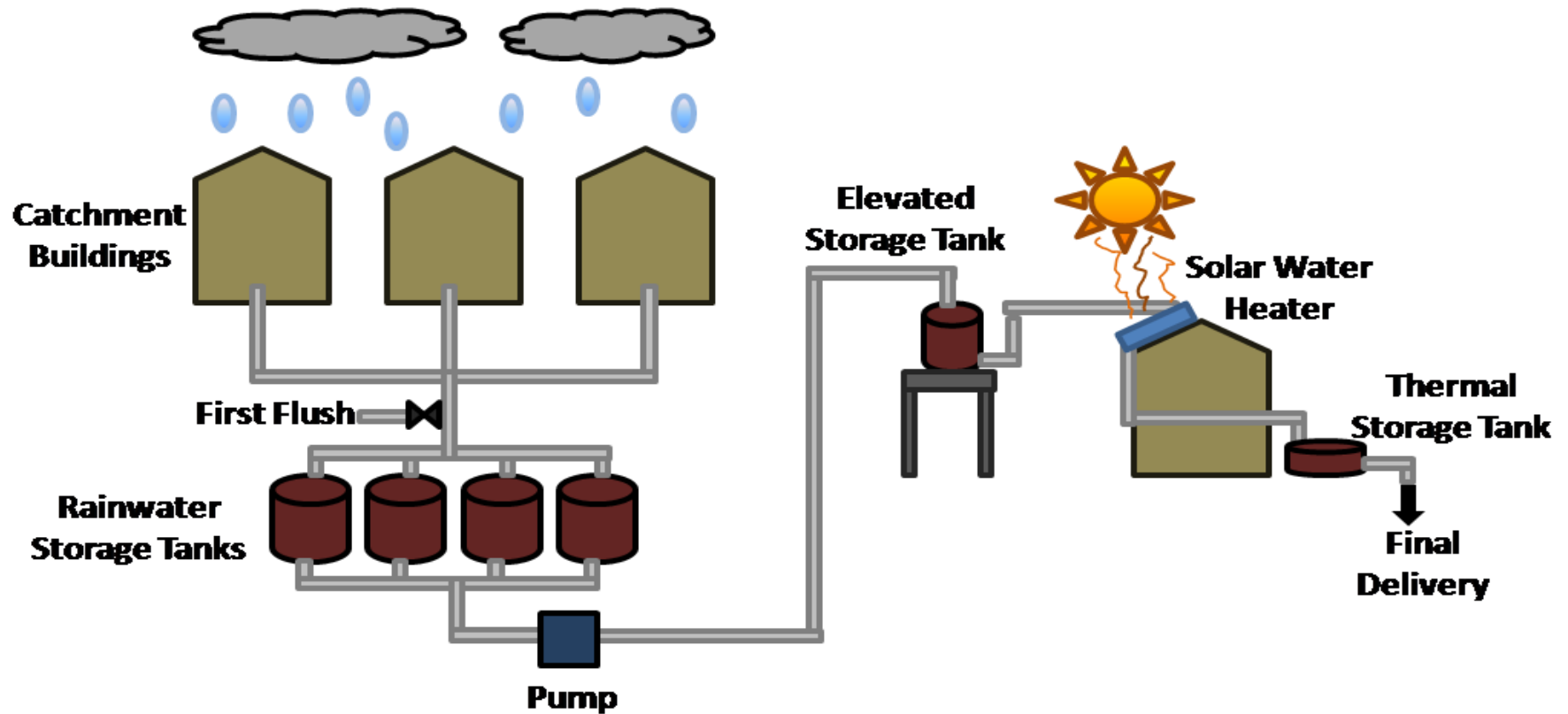


COMPLETE SYSTEM DESIGN

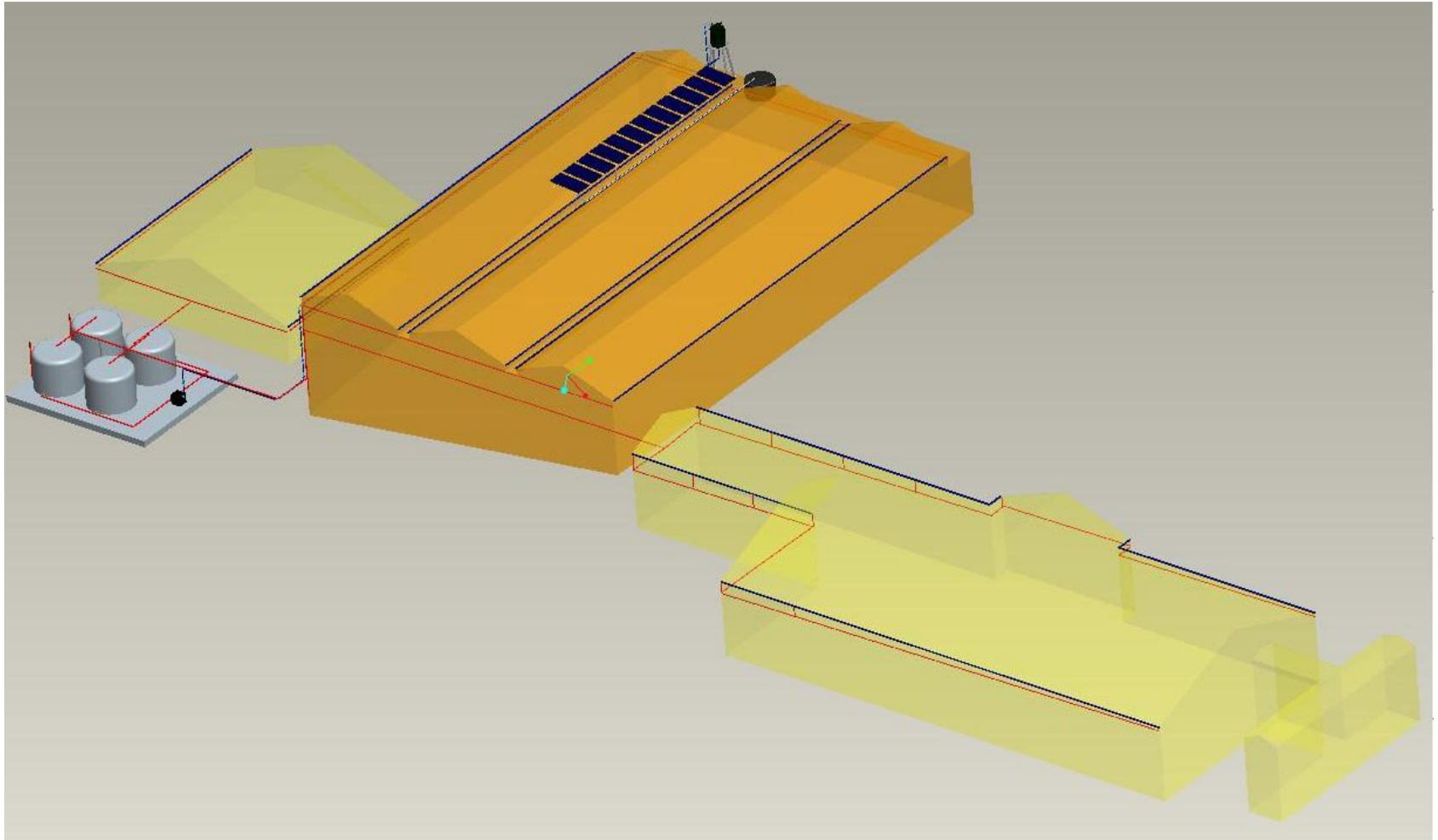
- Complete CAD model of entire campus



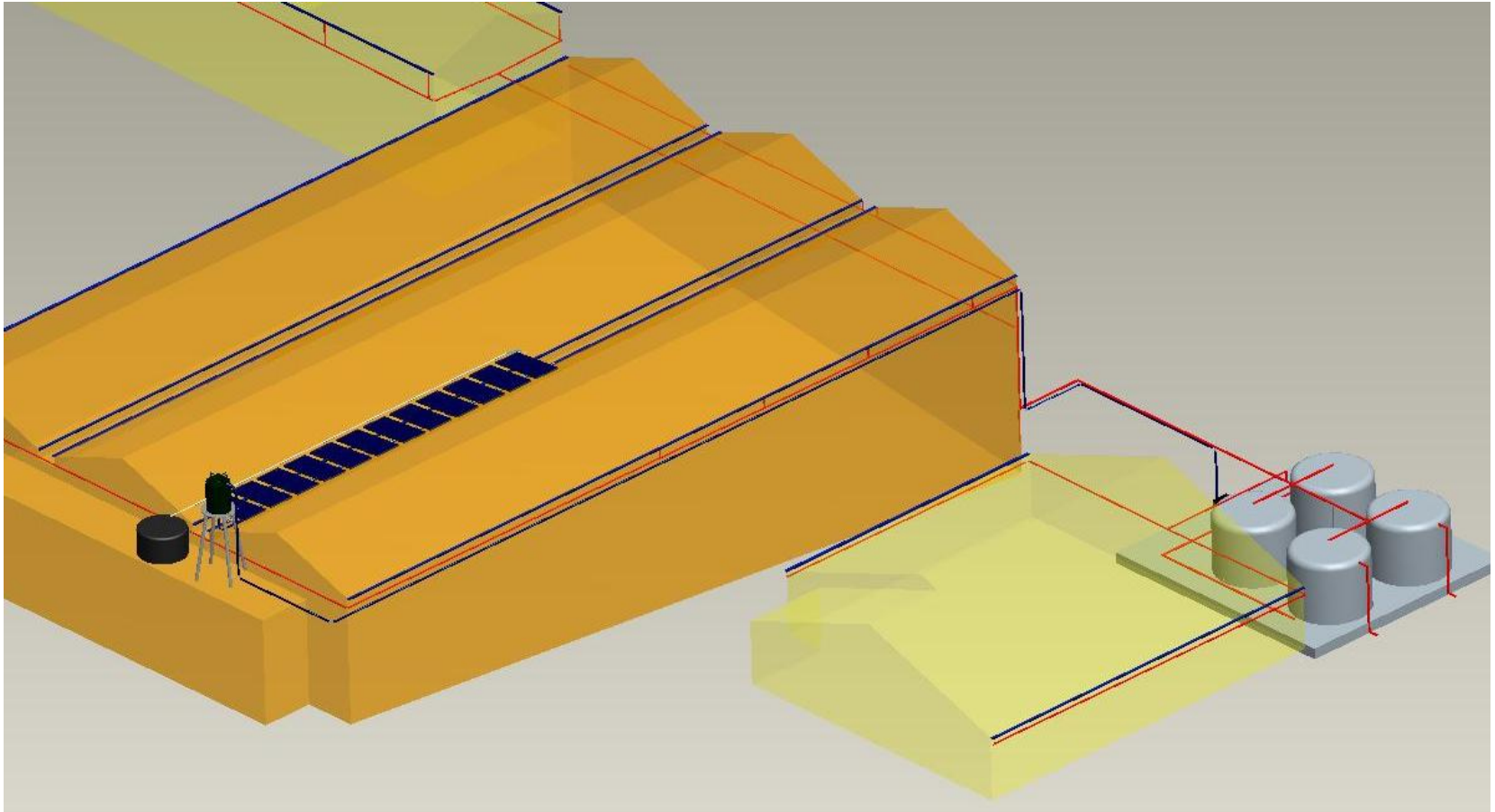
COMPLETE SYSTEM DESIGN



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COMPLETE SYSTEM DESIGN

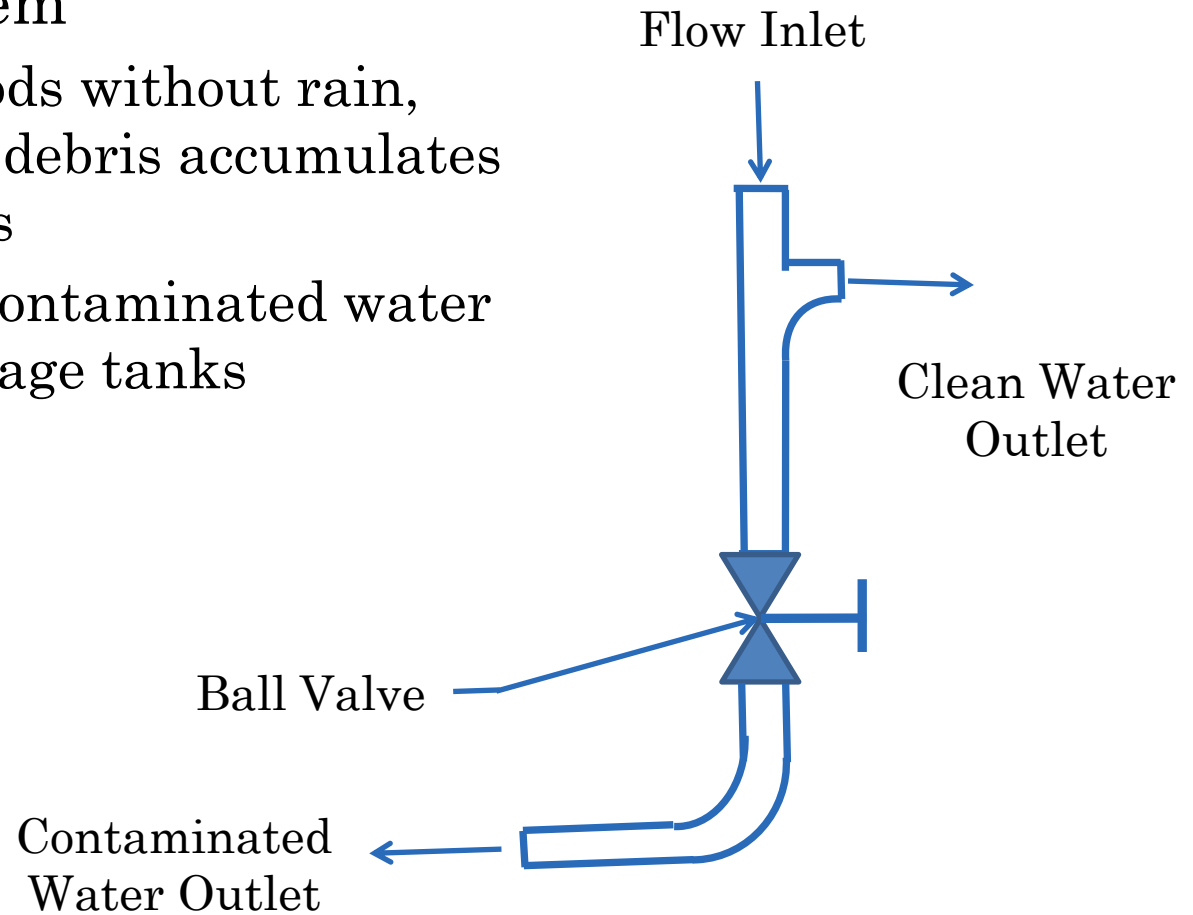


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RAINWATER HARVESTING ANALYSIS

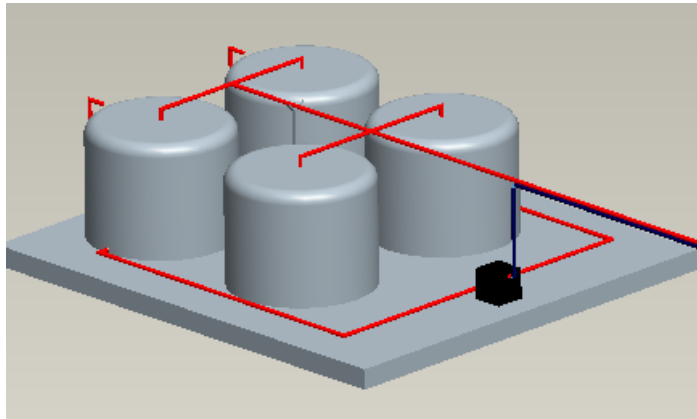
○ First flush system

- Over long periods without rain, dust and other debris accumulates on roof surfaces
- Diverts dirty, contaminated water away from storage tanks



RAINWATER HARVESTING ANALYSIS

- A tank sizing program was made to optimize tank size based on desired daily demand
- Storage tanks up to $\frac{3}{4}$ of total system cost

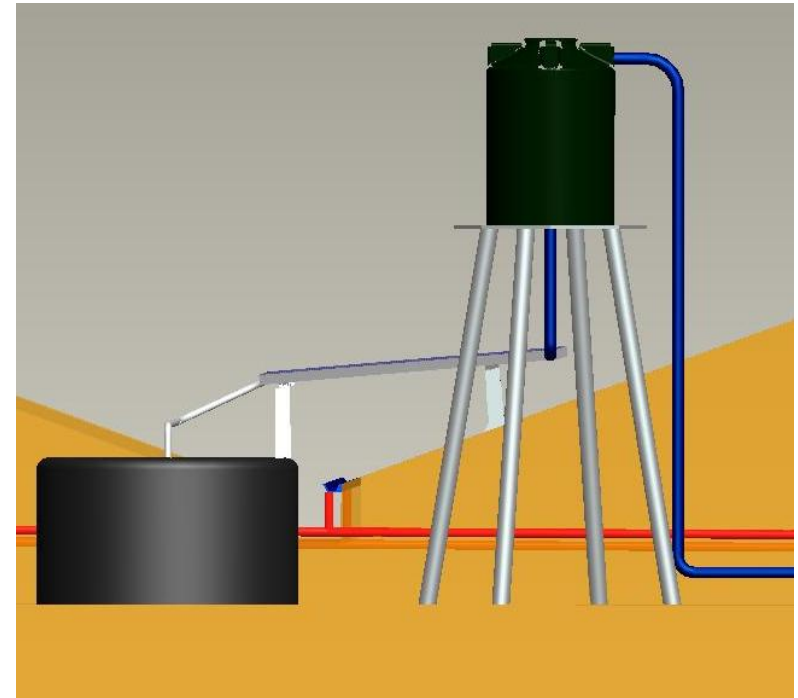


Source: www.kentainers.com



PUMP & TRANSPORT

- Pump Supplying Up-tank
 - Gravity Fed System
 - Pump will transport water from rainwater storage tank to elevated tank above solar water heating system
 - Pump will fill elevated tank from rainwater storage tank to be discharged throughout the day
 - Pump will only be used during initial fill, thus requiring less power than pump driven system
 - 4000 L Kentank will be stored 2 meters above the heated water storage tank



PUMP & TRANSPORT

○ Water Delivery through Heating System

- A Mark 130 Constant Flow Regulator will be used to set the required flow rate from the up tank through the solar water heaters
- Allows elevated storage tank to properly deliver water to the solar water heater and heated water storage tank

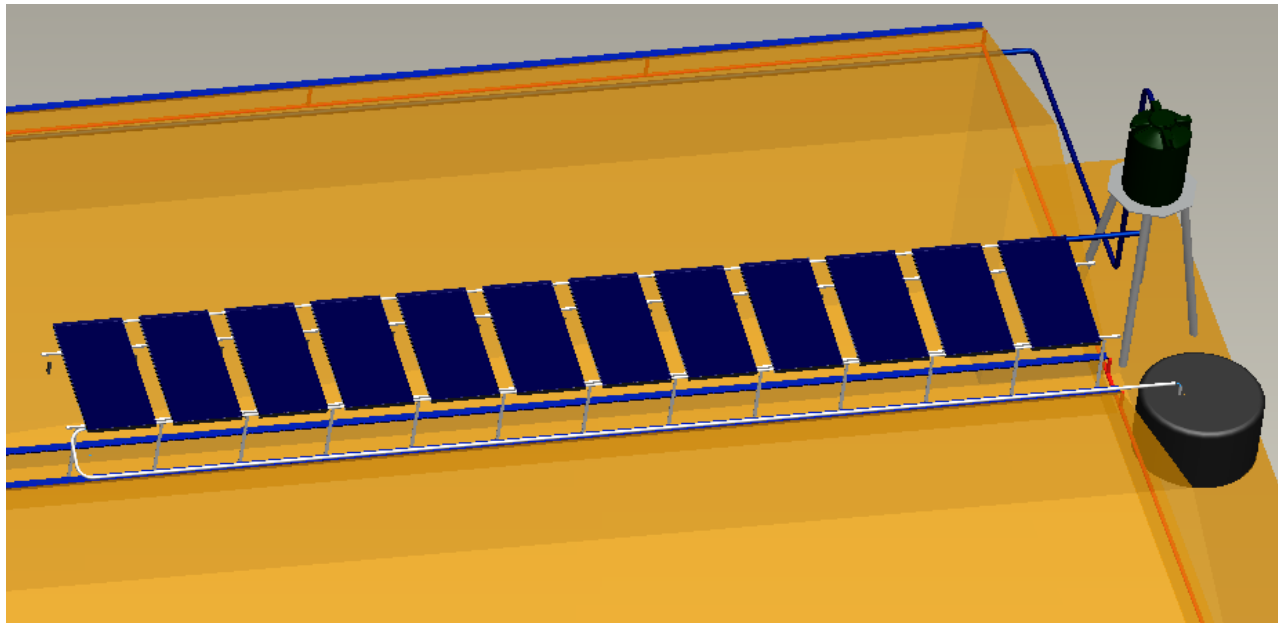


SOLAR WATER HEATING

○ Open-Loop Solar Water Heaters

• General Operating Principles

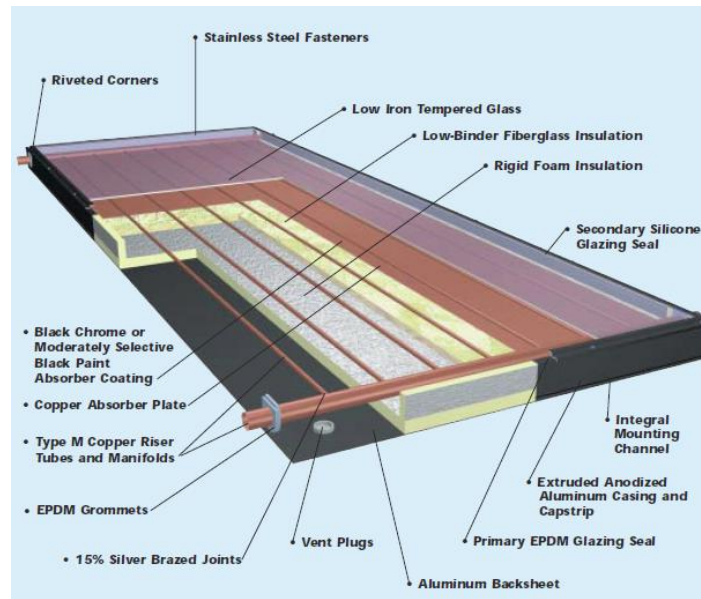
- Solar Water Heaters absorb solar radiation, transferring thermal energy to the water as it passes through the system
- These controlled factors determine the heated water temperature
 - More collectors increase the amount of solar energy available to the system
 - A slower flow rate provides more time for the water to absorb this available energy



Solar Heater Array:
Water travels through the system, absorbing the solar energy as it passes through the array.

SOLAR WATER HEATING

- Active Open-Loop Solar Water Heater
 - Ensure the model has:
 - a low-iron glass cover
 - With glazing
 - an anodized aluminum casing
 - An example of this type of panel:



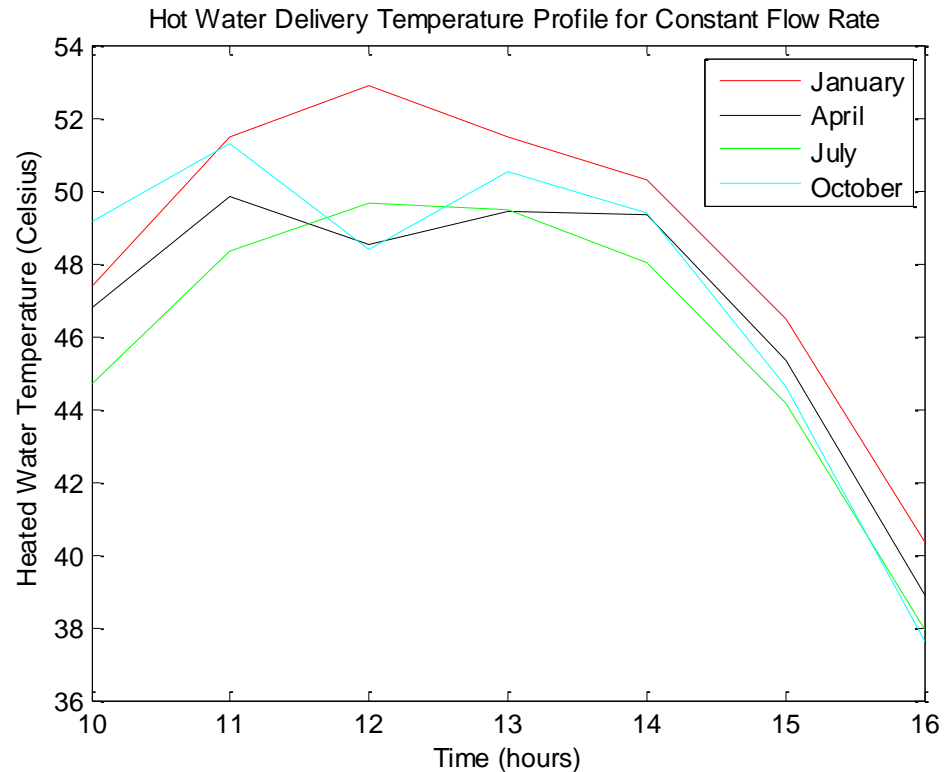
Source: SunEarthInc.com



SOLAR WATER HEATING

○ System Performance

- Because we are fixing the flow rate, the temperature output of the solar water heating system depends on the available energy from the sun.
- We have designed the system to meet provide at least an average of 45°C water over the day, all times of year.
 - Eleven Solar Collectors with a 3 m² surface area are needed for the 4000 L system
 - As the figure shows, sometimes the water will be hotter than the target, sometimes cooler



Temperature profile for the case of 4000L delivered over a 6 hour period, with 11 2.97m² solar panels. When cloud cover occurs, the system performance will decrease, such as in this simulation for October at 12pm.



COMPLETE 4,000L SYSTEM SUMMARY

- Rainwater collection
 - Four 24,000 L Kentanks for rain collection and storage
 - Gutters for maternity ward and hostel
 - First flush system
- Water feeding system for solar heating
 - Pump
 - Flow Regulator
 - 4000L Kentank
- Solar water heating
 - Eleven Solar Collectors with a 3 m² surface area
 - 4000 L Hot Water Storage tank
- Total Costs: \$41,044.43



COST OPTIMIZATION APPROACH

- An initial design was first completed to satisfy a demand of 4000L/day
- Design variations were performed to the initial system to optimize system components to available roof area
 - Multiple cases were generated as a result of this analysis



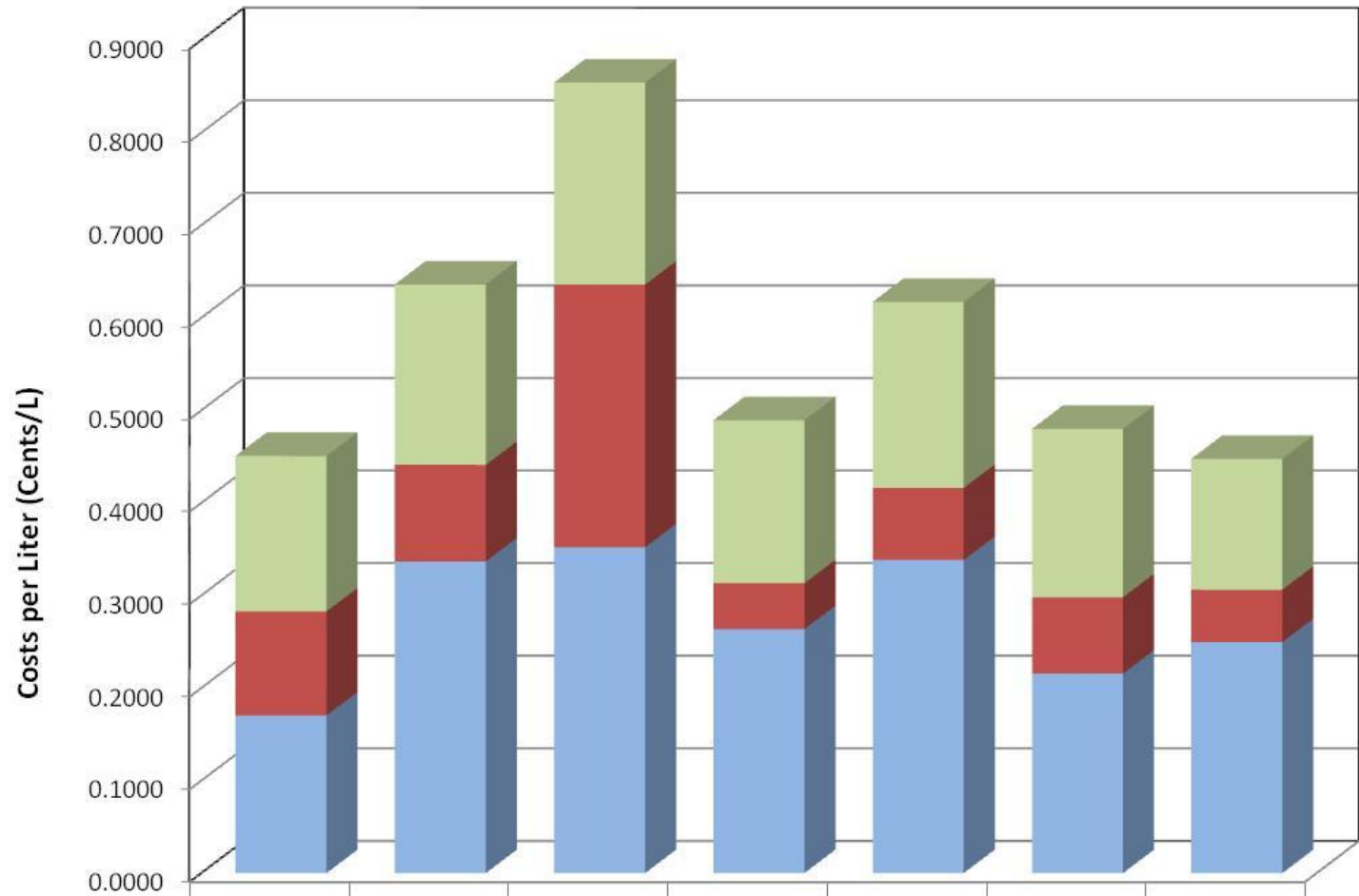
DESIGN FOR COST OPTIMIZATION

- Each case optimized for lowest cost
- Total system cost consists of:
 - Solar Water Heating System
 - Rainwater Harvesting System
 - Water Transport System

Case #	Building(s)	Optimal Daily Supply (L)	Tank Size (L)	Total System Costs	System Cost Per Liter **
0*	All Three	4000	96000	\$41,044	\$0.0059
1	Inpatient Ward	1300	19000	\$10,158	\$0.0045
2	Maternity Ward	1400	33000	\$15,439	\$0.0064
3	Hostel	500	13000	\$7,405	\$0.0085
4	All Three	3100	54000	\$26,299	\$0.0049
5	Hostel, Maternity Ward	1900	45000	\$20,334	\$0.0062
6	Hostel, Inpatient Ward	1800	30000	\$14,980	\$0.0048
7	Maternity Ward, Inpatient Ward	2700	48000	\$20,957	\$0.0045
* Overall system meeting 4000L demand					
** Over a 5 year time span					



DESIGN FOR COST OPTIMIZATION



	1	2	3	4	5	6	7
Solar Water Heater Costs	0.1680	0.1949	0.2183	0.1761	0.2011	0.1819	0.1415
Water Transportation Costs	0.1125	0.1044	0.2838	0.0496	0.0779	0.0825	0.0565
Rainwater Harvesting Costs	0.1703	0.3367	0.3521	0.2636	0.3383	0.2156	0.2496

Case



LOOKING FORWARD

December
2009

- Final Report Delivered to Tenwek
- Project Handover to ESW Organization

Spring 2010

- Re-evaluate system & make necessary design & engineering modifications

Fall 2010

- Provide engineering support as necessary



Thank you for your time.
Questions?



CRITICAL DESIGN REVIEW APPENDIX

- Appendix A: ESW Overview
- Appendix B: Global Hub Overview



APPENDIX A: ESW OVERVIEW

- Engineers for a Sustainable World
- USA-based, international non-profit network
- Established in 2002
- Currently comprised of 2,000+ students, university faculty and professionals

- For more information: *esustainableworld.org*



APPENDIX A: ESW OVERVIEW

○ ESW Purdue Chapter

- Founded in Summer 2008
- Dan Hirleman, Advisor
- Tyler Williams, Graduate Advisor
- Tim Kendrick, President
- University Chapter of ESW-USA (20 total)
- Purdue University Student Organization



Engineers for a Sustainable World
PURDUE UNIVERSITY CHAPTER

○ Organization's Mission:

- To engage engineers in reducing poverty by improving environmental, social, and economic sustainability worldwide.



APPENDIX B: GLOBAL HUB OVERVIEW

- Online global collaboration and teaming website
- 1 of 14 inaugural Engineering Virtual Organizations (EVO) funded by the National Science Foundation in 2007
- Mission “is to facilitate a cyber-community of scholars, practitioners, and students that advances global engineering education, eliminates barriers for students seeking a global education, and helps prepare a workforce of globally competent engineers.”
- Based on both Purdue-developed and existing open-source software



APPENDIX B: GLOBAL HUB OVERVIEW

- Acts as the public face of ESW-Purdue and GTIA
 - <https://globalhub.org/groups/tenwekproject>
 - Serves as the central share point for all research, scheduling, and other information generated by the project.
 - Information is posted and stored using a “wiki” format
 - Goal: easy access to all project information no matter where you are in the world
- The Tenwek Water project posts all major documentation, presentations, & programs

