Sustainable Water Solutions

Rainwater Harvesting and Solar Water Heating

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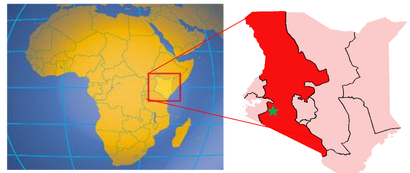
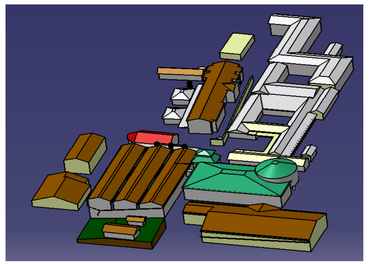
Engineers for a Sustainable World
PURDUE UNIVERSITY CHAPTER

Project Background

- Tenwek Hospital
  - Missionary Hospital
  - Rift Valley Province
  - Located in Bomet, Kenya
  - Provides primary healthcare for 600,000 Kenyans
  - 308 beds for in-patient ward
- Assessment trip in June 2009
- Currently harvesting from two buildings
  - Administration building harvesting for IV production
  - Surgical building supplements the in-patient ward
  - *Only 25% of the in-patient housing is currently being supplied with hot water*



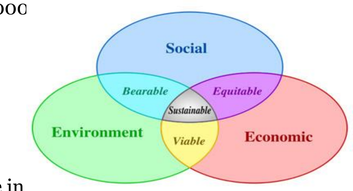


Mission Statement

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

- Meet a daily in-patient ward hot water demand of 4,000
- Deliver heated water temperature of 45°C
- Minimize operating cost
- Utilize existing structures to harvest rainwater
- Minimize maintenance
- Minimize environmental Impact
- Develop globally utilizable design tools for future use in international design projects



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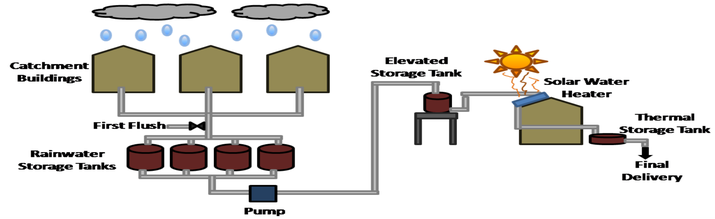
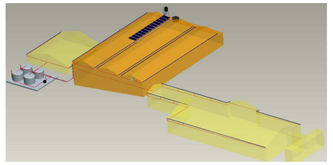
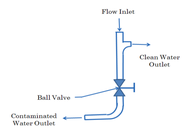
Complete System Design



Rainwater Harvesting

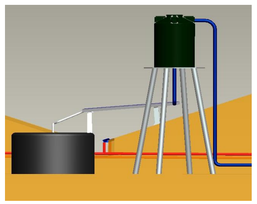
- Water is collected off of existing buildings
- A tank sizing program was made to optimize storage capacity based on desired daily demand and available collection surface area
- 24,000 L Kentanks will be used
- First flush system
  - Over long periods without rain, dust and other debris accumulates on roof surfaces
  - Diverts dirty, contaminated water away from storage tanks





Water Transport

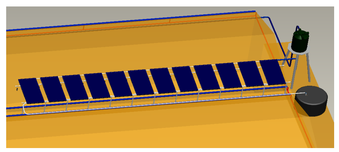
- Pump Supplying Up-tank – Gravity Fed System
- Pump will transport water from rainwater storage tank to elevated tank above solar water heating system
- Pump will fill elevated tank from rainwater storage tank to be discharged throughout the day
- Pump will only be used during initial fill, thus requiring less power than pump driven system
- A Constant Flow Regulator will be used to set the required flow rate from the up tank through the solar water heaters



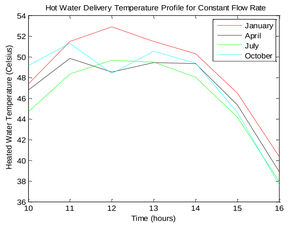
Solar Water Heating

- Active Open-loop Solar Water Heaters
  - Solar water heaters absorb solar radiation, transferring thermal energy to the water as it passes through the array
  - Governing equation: 1st Law of Thermodynamics for Open Systems
- After heat transfer analysis, a sizing program was developed to determine the number of solar heating units based on:
  - Desired output temperature
  - Demand volume
  - Distribution time
  - Inlet temperature

$$T_{out} = T_{in} + \frac{\dot{Q}_{in} A_c}{\dot{m} C_p}$$



Results



- As we are fixing the flow rate, the temperature output of the solar water heating system depends on the incident solar flux
- 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

- An initial design was first completed to satisfy a demand of 4000L/day
  - Design variations to the initial system were analyzed to optimize system components to available roof area
- Each case optimized for lowest cost

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**

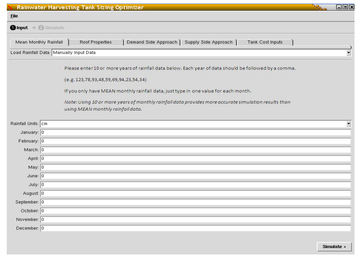
* Overall system meeting 4000L demand
** Over a 5 year time span

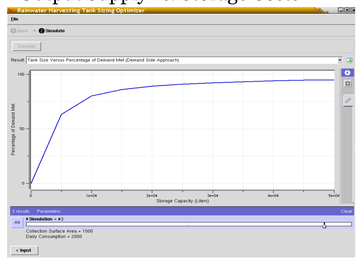
Global Simulation Tools

Rainwater Harvesting Storage Capacity Optimization Tool

Inputs
- Monthly rainfall data
- Roof properties
- Daily consumption
- Desired % Demand Met

Outputs
- Pseudo-daily rainfall data
- Tank size vs. % Demand Met
- Output Supply vs. Storage Capacity
- Output Supply vs. Storage Costs





Daily Solar Flux Profile Generator Tool

Inputs
- Latitude &Longitude
- UTC
- Atmospheric conditions
  - Referenced from NASA database

Outputs
- Daily flux profile on a month-month basis for the following cases:
  - Cloudless day
  - Most frequent cloudy day

Conclusion

In summation, we have developed an application-specific rainwater harvesting and solar water heating system to meet the needs of Tenwek Missionary Hospital, as well as globally applicable design tools for utilization in future projects.