INVESTIGATION OF SOLAR WATER HEATING SYSTEMS FOR INDUSTRIAL APPLICATIONS IN NORTHERN ETHIOPIA

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ISES World Congress, August 2011, Kassel, Germany

Outline of Presentation

- Introduction
- Hot Water Demand in the Factories
- Solar Radiation Measurement and Estimation Models
- Overall Solar Energy System Design and Sizing
- Economic Analysis of the Solar Energy Systems
- Conclusions and Recommendations

INTRODUCTION

- Low temperature water heating for industrial process is one of the ideal applications for solar energy.
- The study was conducted at four factories, namely, a tannery, a particleboard factory, a textile factory and an edible oil factory.
  - The factories use hot water for different processes,
  - The daily hot water consumption is high but require low temperature hot water (<80^{0}C).
  - The current source of energy for water heating mainly furnace oil.

INTRODUCTION

- Sheba Tannery: Sheep and goat skins= 6,000 pcs/day
  Hides = 500-600 pcs/day
- Maichew Particleboard Factory: 80 tons/day
- Bahirdar Textile Factory: Fabrics =12 million m^2/year
  Yarn =1000 tons/year
- Ashraf Edible Oil: 150,000 liters of refined edible oil/year

Hot Water Demand in the Factories

- A study was made during regular operation of the factories for one week and includes identifying:
  - process demanding hot water,
  - working temperature of the process,
  - hourly consumption of hot water and
  - current source of energy for heating water.

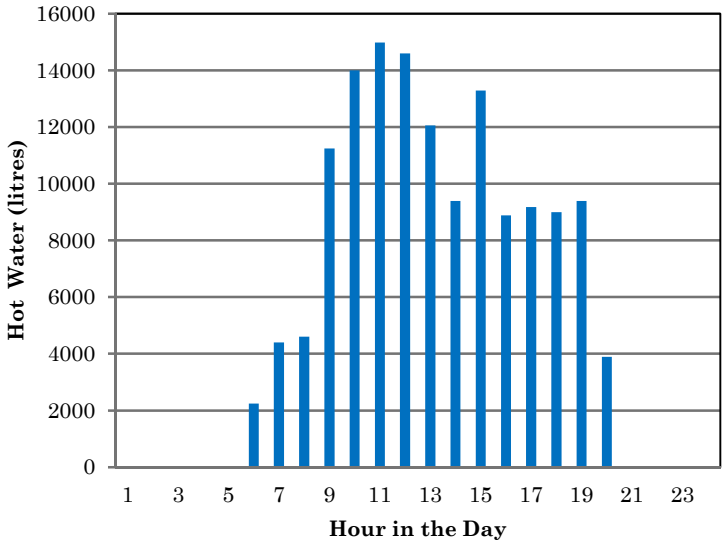
Hot Water Demand in the Factories

Summary of results of the study:

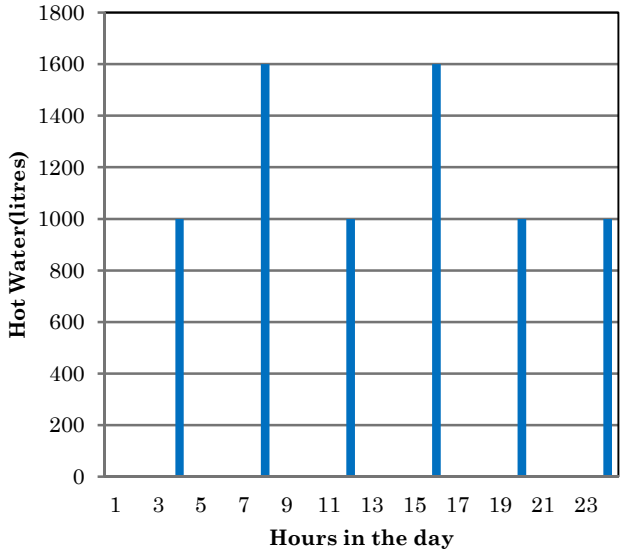
No.	Factory	Process	Working Temperature (^{0}C)	Consumption (m^3/day)	Current Source of Energy
1.	Sheba Tannery	Skin Tanning Skin Re-tanning Hide Tanning Hide Re-tanning	35 50 40 65	18.4 66.6 29.3 27.0	Furnace oil for a steam boiler
2.	Maichew Particleboard	Glue preparation Impregnation	40 55	6.0 1.2	Furnace oil, fire wood
3.	Bahirdar Textile	Pre-heater Washing Chemical Preparation	60 70 80	36.0 7.8 5.2	Furnace oil for a steam boiler
4.	Ashraf Edible Oil	Conditioning Degumming Neutralization Washing	85 90 90 70	6.0 5.0 5.0 7.7	Furnace oil for a steam boiler

Hot Water Demand in the Factories

Variation of the demand during a day:



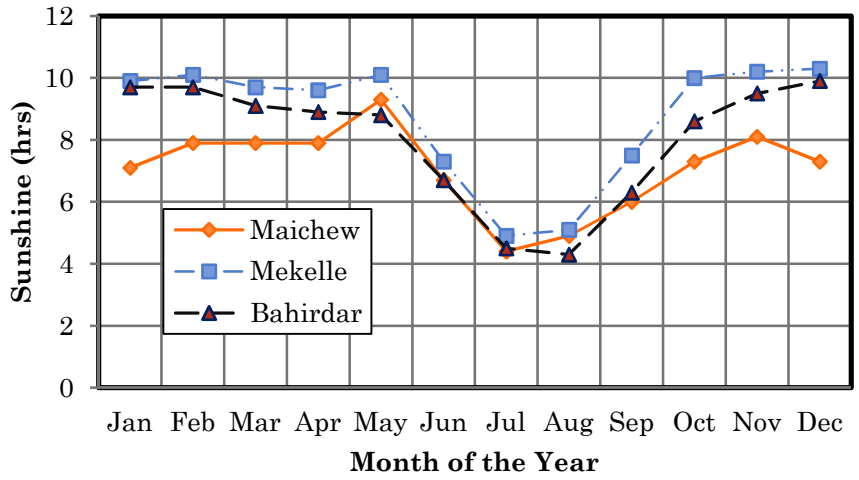
Sheba Tannery



Maichew Particleboard

Solar Radiation Measurement and Estimation Models

- Long term solar radiation data is scarce in the country,
- The National Metrological Agency has long term monthly average sunshine hour data:

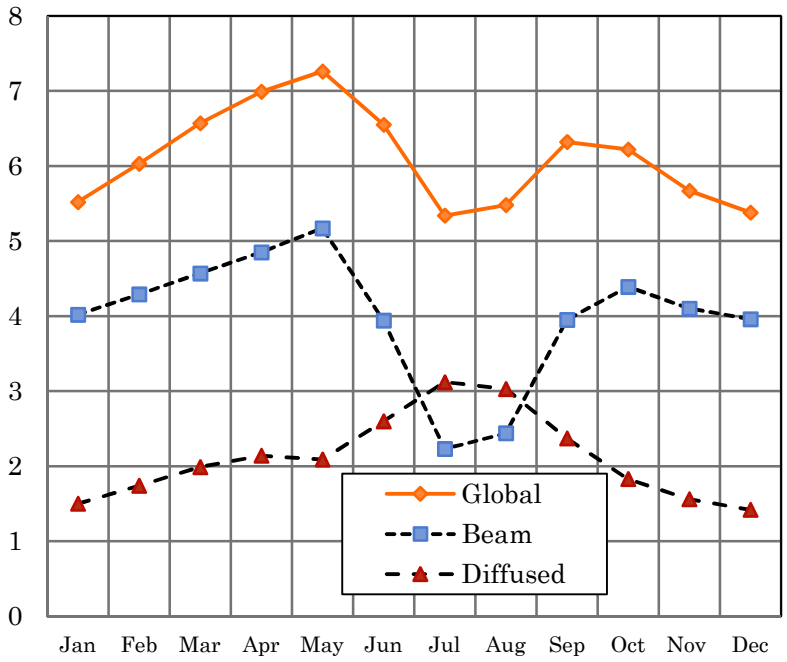


Solar Radiation Measurement and Estimation Models

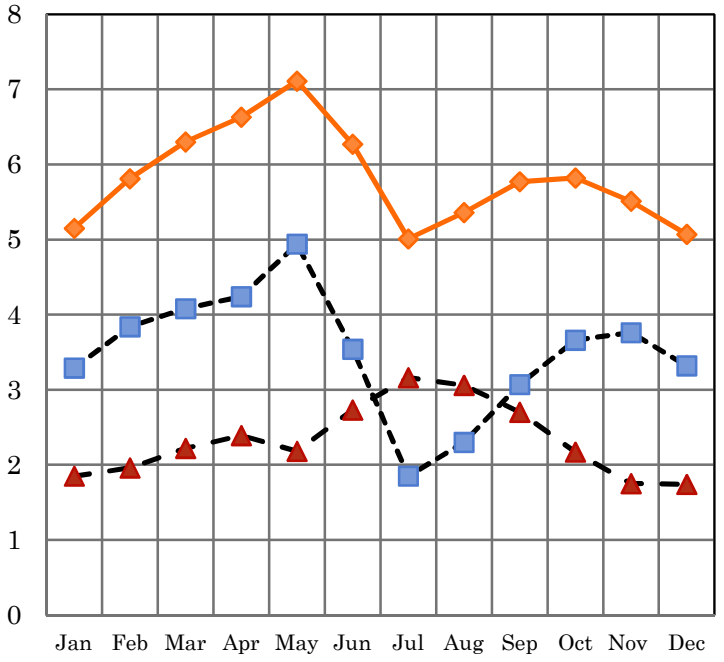
- Pyrheliometer and Pyranometer were installed at Mekelle University.
- Pyranometer data for one year was compared with estimation model data.

Solar Radiation Measurement and Estimation Models

- Angstorm – Page estimation model was employed to find the monthly average daily solar radiation (kWh/m^2 day).
- Similarily, model of Liu and Jordan was to estimate the beam and diffuse components.



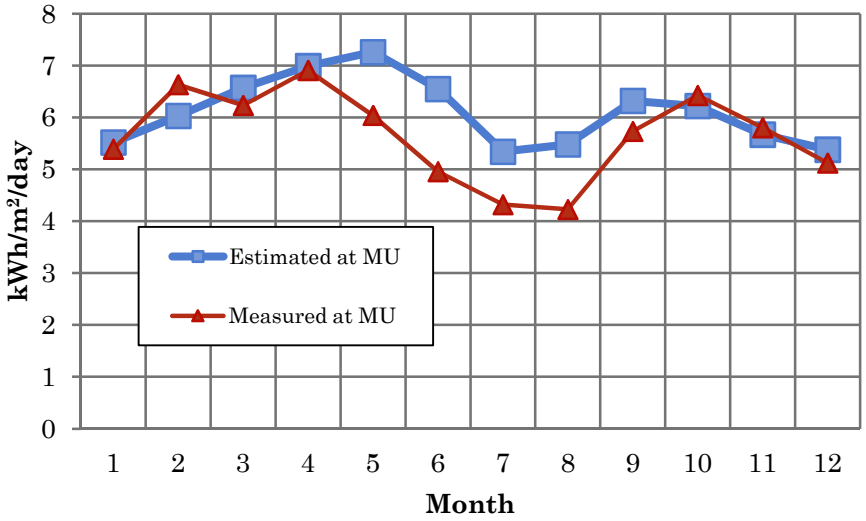
Mekelle



Maichew

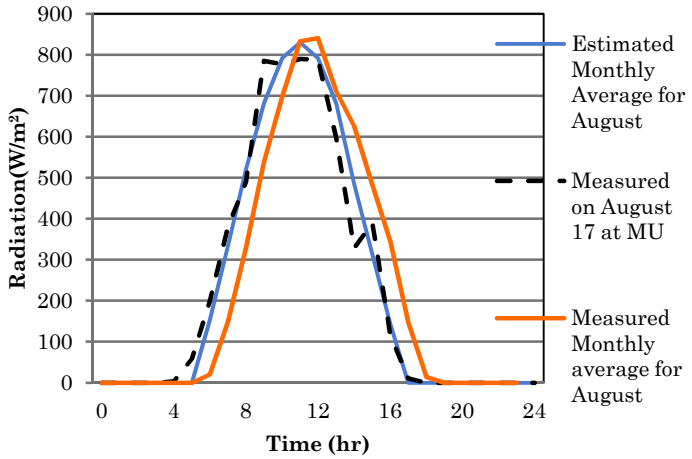
Solar Radiation Measurement and Estimation Models

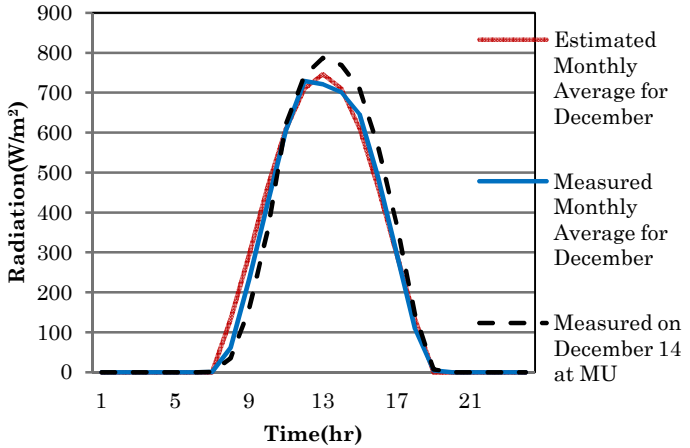
- Comparison of the measured and result from estimation model at Mekelle:



Solar Radiation Measurement and Estimation Models

- A method proposed by Collares-Pereira and Rabl based on the disaggregation of daily data in to hourly data has been used:





Overall Solar Energy System Design and Sizing

- A unit flat-plate collector with a collector area of 2 m^2 is assumed in the design.

Collector Area (A_c)[m^2]	**2**	**Tube Material**	**Copper**
Collector Perimeter [m]	**6**	**No. of Tubes**	**8**
Depth of the Collector [m]	**0.095**	**Tube Diameter [m]**	**0.022**
Absorber Material	**Steel**	**Insulation Material**	**Mineral wool**
Thickness of the Absorber [m]	**0.002**	**Edge Insulation Thickness[m]**	**0.025**
Number of Glass Cover	**1**	**Back Insulation Thickness[m]**	**0.05**
Glass Thickness [m]	**0.004**		

- The overall heat loss coefficient for the collector (U_c) in the expected temperature range of application was found to be 8.6 $W/m^2\ ^0C$. Similarly the heat removal factor (F_R) was found to be 0.85.

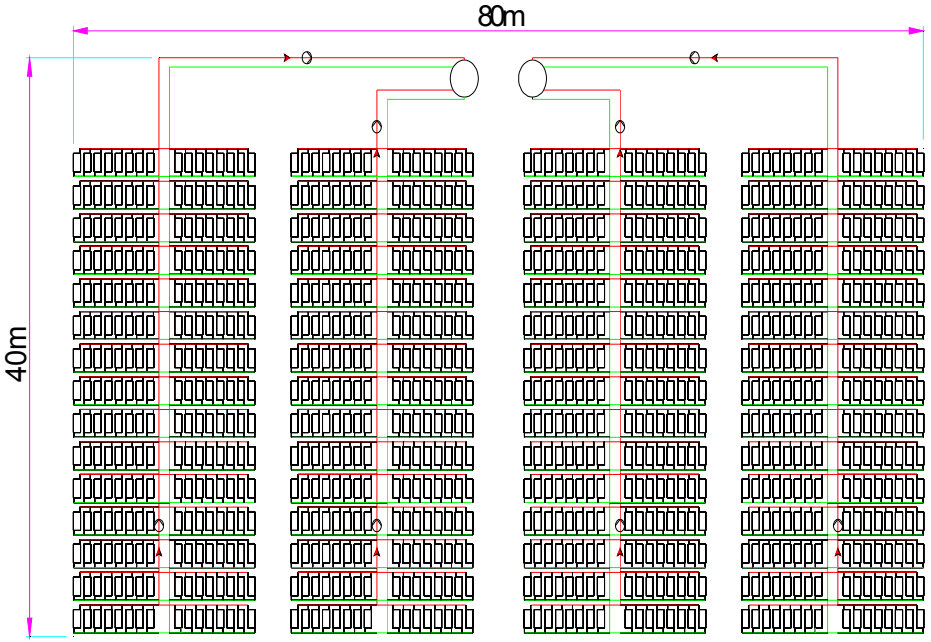
Overall Solar Energy System Design and Sizing

- Based on the unit size of the collector and the hot water demand discussed previously, the number of collectors needed and the space requirement were calculated.

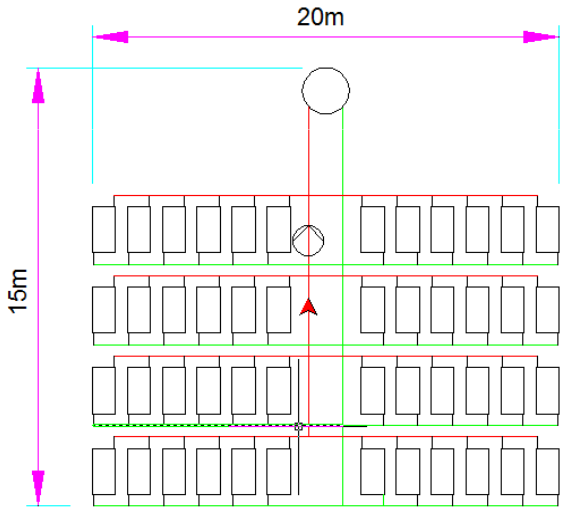
Factory	Energy Demand (GJ)	Useful Heat Gain Unit Collector (MJ/m^2)	Number of Collectors	Space requirement (m^2)	Storage Tank (m^3)
ST	11.2	12	960	3200	2x50
BTF	5.2	13.5	384	1500	1x24
AEF	3.6	15	240	800	1x15
MPF	0.5	11	48	300	1x3.2

Overall Solar Energy System Design and Sizing

Layout of the SHW systems



Sheba Tannery



Maichew Particleboard

Economic Analysis of the Solar Energy Systems

- The factories in the study use mainly furnace oil for heating water. The heating value of furnace oil is about 35 MJ/liter and the price during the study period was USD 0.69 per liter.
- Assuming typical combustion efficiency of 0.8, the cost of energy becomes 0.09 USD/kWh.
- The following cost assumtions were made for the SWS

Assumption	Value
Unit cost of 2 m^2 collector	USD 250
Life of the SWH system	15 years
Manufacturing and labor cost	10%
Operation and Maintenance	2%
Interest rate	10%

Economic Analysis of the Solar Energy Systems

- The investment cost estimates were found for each factory.

No.	Cost item	Estimated cost in USD			
		ST	AEF	BTF	MPF
1	Collectors	240,000	96,000	60,000	12,000
2	Storage tanks, pipelines and fittings	14,000	2,500	3,000	1,000
3	Manufacturing and Labor	30,000	12,000	8,000	1,600
	Total	**284,000**	**110,500**	**71,000**	**14,600**

Economic Analysis of the Solar Energy Systems

- The cost of energy includes: i) investment cost for the SWH collectors, storage tanks, pumps and pipelines, ii) manufacturing and labor cost, iii) operation and maintenance cost.
- Payback period (PBP) and Life Cycle Cost (LCC) calculations were made.

Factory	SWH LCC (USD)	SWH LCS (USD)	Cost of Energy (USD/kWh)		Percentage Savings
			SWH	Furnace Oil only	
ST	293,873	105,250	0.05	0.09	26%
AEF	118,496	58,480	0.05	0.09	33%
BTF	76,666	28,463	0.05	0.09	27%
MPF	15,875	6,652	0.05	0.09	30%

Conclusions and Recommendations

- There is high hot water demand in tanneries and edible oil factories, medium demand in textile factory and low demand in particle board factory.
- The cost of SWH is about 5 USD cents per kWh and the payback period will be 6 – 7 years.
- Clean energy at the same time 26-33% savings.

- It is recommended that after some detail optimization, factories may implement the study phase by phase.