How to Better Provide Domestic Water Heating

by
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ZESCO LtD
Introduction

- Currently some PIESA countries are using up to 45% of the Residential sector electricity needs on heating up water.
- Historically, this has been acceptable due to abundance of cheap electricity.
- A few countries recognised the savings that can be made in terms of energy security from careful control of this end use demand for MD control.
Introduction (Cont’d.)

- Times have changed: we now have
  - electricity rationing
  - massive rural electrification efforts
  - scarce financing for major electricity infrastructure
- the ripple control schemes alone may not suffice.

We must go back to the fundamental questions of what is it is that ultimately we are delivering as a service.
For domestic hot water, it is here proposed that in fact instead of just control we could do an entire energy switch to solar heating as our region is well endowed with solar irradiation.

Using an Integrated Energy Resource Planning approach, we shall briefly look at:

- The overall picture of energy supply demand in selected PIESA countries
- The summary of general financing of energy sector
- Availability of RE resources
Energy Provision & Demand (Cont’d.)

- Use of solar energy for heating
- The Zesco Solar Geyser Programme
- Possible Rebound Effect
  - Standards
  - Conclusion
Fig. 1, Final Energy Consumption from PIESA Countries

Adapted from B. Merven, A. Hughes & S. Davies – ERC,
Cape Town Journal of Energy in Southern Africa • Vol 21 No 1 • February 2010
## Availability of Renewable Energy Resources in Selected PIESA Countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Small Hydro</th>
<th>Biomass</th>
<th>Wind Potential</th>
<th>Solar (kWh) Irradiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angola</td>
<td>Potential 152 TWh/a</td>
<td>Fuel wood, up to 1020 mill cubic m/a)</td>
<td>Poor-average</td>
<td>4-7</td>
</tr>
<tr>
<td>Botswana</td>
<td>No hydropower</td>
<td>Fuel wood, current not sustainable</td>
<td>Poor</td>
<td>5-7</td>
</tr>
<tr>
<td>DRC</td>
<td>100 GW potential</td>
<td>122 mill ha of forest</td>
<td>Poor</td>
<td>3-6</td>
</tr>
<tr>
<td>Lesotho</td>
<td>Potential for 3GW pumped storage</td>
<td>Pot.: Fuel wood (39,000 ha)</td>
<td>20MW potential</td>
<td>Av. 5.5</td>
</tr>
<tr>
<td>Madagascar</td>
<td>Potential of 49 000 GWh/year</td>
<td>Forest area of 12 800 ha</td>
<td>Good along the coast</td>
<td>4-6</td>
</tr>
<tr>
<td>Malawi</td>
<td>Estimated potential of 900MW</td>
<td>Ethanol (7% of liquid fuel, 12 million litres pa)</td>
<td>Poor</td>
<td>4-6, av 5.8</td>
</tr>
<tr>
<td>Mauritius</td>
<td>59MW existing, almost fully tapped</td>
<td>Bagasse, fuel wood and charcoal</td>
<td>Good</td>
<td>Av 6</td>
</tr>
<tr>
<td>Mozambique</td>
<td>14GW potential (18%developed)</td>
<td>3.5 – 4 bill tonnes</td>
<td>Average</td>
<td>4-6, av 5.2</td>
</tr>
</tbody>
</table>
### Availability of Renewable Energy Resources in Selected PIESA Countries

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<tr>
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<th>Wind Potential</th>
<th>Solar (kWh) Irradiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Namibia</td>
<td>Hydro potential along the borders</td>
<td>Abundant in north scarce in south</td>
<td>Good along the coast</td>
<td>5-8, av 6</td>
</tr>
<tr>
<td>South Africa</td>
<td>668MW installed capacity</td>
<td>Bagasse, fuel wood</td>
<td>Good capacity factor &gt;25%</td>
<td>4-8</td>
</tr>
<tr>
<td>Swaziland</td>
<td>300 GWh/a 30% developed</td>
<td>Potential from bagasse, 25 tapped</td>
<td>Poor</td>
<td>4-6</td>
</tr>
<tr>
<td>Tanzania</td>
<td>Potential 4.7GW 12% developed</td>
<td>Fuel wood forests and plantations</td>
<td>Good along the coast</td>
<td>4-7</td>
</tr>
<tr>
<td>Zambia</td>
<td>6,600MW at various sites</td>
<td>Fuel wood and charcoal</td>
<td>Poor</td>
<td>4 -7</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>Possible 37TWh, 25% harnessed</td>
<td>13 mill tonnes fuel wood</td>
<td>Poor</td>
<td>5-7</td>
</tr>
</tbody>
</table>
Fig. 2, Usage Vs. Investment for RETs in a Typical PIESA Country

Adapted from (6)

Energy Use in a Typical PIESA Country

Large Scale Technologies

Mainly used by the non_poor or big industry

Energy Investment in a Typical PIESA Country

Large Scale Technologies

Small Scale & Renewable Energy Technologies
Fig. 3, Energy Efficiency possible for Water Heating from Various Sources

- **T&D 80%**
- **Generator 80%**
- **Diesel Engine 30%**
- **Fuel**
- **Fuel Extraction & Refining**

**Primary Sources**:
- **Electric Geyser 75%**
- **Generator 80%**
- **Solar Geyser**

**Secondary Sources**:
- **Hot Water**
- **Collector 50%**
- **Solar Radiation**

**Efficiency Rates**:
- **T&D 80%**
- **Electric Geyser 75%**
- **Generator 80%**
- **Solar Geyser**
- **Collector 50%**

**Fuel Efficiency**:
- **Fuel Extraction & Refining ~14%**
Fig. 4 Life Cycle Effects of Solar Heater

Oil Field Waste

Mining/agriculture

Energy/Emissions

Manufacture

Overheated Plastic Fumes

Use/Operation

Land Fill?

Recycling

Reuse

Reuse

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# Solar Thermal Heaters - Installed

<table>
<thead>
<tr>
<th>Country</th>
<th>Installed Capacity (m sq.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Botswana</td>
<td>50</td>
</tr>
<tr>
<td>Malawi</td>
<td>4.8</td>
</tr>
<tr>
<td>Mauritius</td>
<td>40</td>
</tr>
<tr>
<td>Namibia</td>
<td>24</td>
</tr>
<tr>
<td>South Africa</td>
<td>500</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>10</td>
</tr>
<tr>
<td>Zambia</td>
<td>100 (350)</td>
</tr>
</tbody>
</table>

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C. Silavwe  
PIESA 2011 Lilongwe
Flat Plate Collector DSWH
Incidence angle effects in evacuated tubular arrays
a) At normal incidence some radiation is lost by reflection back thru’ the tube array
b) At high incidence angles all radiation falls on the high efficiency collector surface
General Principle of Operation

- The principle of solar heat is age old.
- Any body > 0K emits radiant energy.
- The solar collector therefore collects from both long wave and short wave radiation.
- Direct solar insolation is more effective than diffuse long wave irradiation.
- At inclines of less than 45', longwave radiation from the ground has little influence on the collector temperature.
General Principle of Operation

- Long term performance estimate of long wave radiation $G_{LC}$ under partially cloudy skies can be evaluated from dew point temperature and cloud cover as follows:

$$G_{LC} = (\hat{\varepsilon}_{sky} - 1)\hat{\sigma}T_a^4 \times \left(\frac{C-8}{8}\right)$$

Where $\hat{\varepsilon}_{sky} =$ Sky Emissivity
$\hat{\sigma} =$ Effective Area of Insolation
$T_a =$ Ambient Temperature
$C =$ Cloud Cover in $1/8$’s

- The maximum (Stagnation) temperature experienced by a collector can be determined from condition for zero efficiency i.e. when solar gain = heat loss.
ISO 9802(1995) defines extreme ambient conditions that solar collectors should be able to withstand for satisfactory performance in different climates e.g. 1200W/m² and 40°C for clear dry climates.
Effect of load pattern on energy delivery on a horizontal solar heater
# Observed DSM Rebound Effect

<table>
<thead>
<tr>
<th>Study</th>
<th>Focus of the Study</th>
<th>Rebound Effect (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greene (1992)</td>
<td>Vehicle efficiency improvement in US</td>
<td>5-15</td>
</tr>
<tr>
<td>Greening et al. (2000)</td>
<td>Space cooling (based on 35 case studies in various countries)</td>
<td>10-50</td>
</tr>
<tr>
<td>Jones (1993)</td>
<td>Passenger vehicle use and rebound effect in US</td>
<td>60</td>
</tr>
<tr>
<td>Khazzoom (1987)</td>
<td>Use of energy efficient appliances in US</td>
<td>75</td>
</tr>
<tr>
<td>Murck et al. (1985)</td>
<td>Policy simulation to reduce wood use in Sudan</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td>Efficient lighting in households (based on 4 case studies)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Water heating based on 5 case studies</td>
<td></td>
</tr>
<tr>
<td>Ronald and Haugland (1994)</td>
<td>Energy conservation in commercial/household sectors in Norway</td>
<td>10-40</td>
</tr>
<tr>
<td>Zein-Elabdin (1997)</td>
<td>Improved stoves programs in Sub-Saharan Africa</td>
<td>50</td>
</tr>
</tbody>
</table>
SOLAR HEATER PERFORMANCE TESTING

Materials for key components on solar heaters

- **Cover Materials**: Polycarbonate, PET, Perspex, Teflon, Uvex
- **Collector Materials**: Black cobalt, black nickel, black CuO, anodized Al
- **Absorber Materials**: HDPE, EDPM, PVC, PC, Cu, Fe, Al

The Standards
- **ISO 12952 (2000)**: Absorber Surface Durability Assessment
- **ISO 9495 (2000)**: Ageing Test to Assess Transparent Covers under Stagnant Conditions
- **ISO 9553 (1997)**: Assessment of Performed Rubber Seals & Sealing Compounds used in Connectors
- **ISO 9808 (1990)**: Assessment of Elastomeric Materials for Absorbers, Connecting Pipes & Fittings
Conclusion

• It is practical in the PIESA region to do away with electrical water heating entirely
  – in the process
    • save a lot of energy,
    • create jobs
    • enhance energy security.

• The concept should rest on the three pillars sustainable development: social economic, and the environment linked by effective government institutions.
Conclusion

• What are needed are realistic guidelines towards these aspirations.
  – Energy security policies that take advantage of locally available primary energy resources
  – In many cases data available from the weather stations in their current form may not be sufficient to help realise these goals
  – The fact that the benefits realised may not exactly match with the projections should not discourage the doers from starting;
    • it should instead be a call to fine tune and sensitise the populace.
References

2. Solar Collectors & Solar Water Heating, GL Morrisson
7. A mobile solar water heater for rural housing in Southern Africa, MN Nieuwoudt & EH Mathews NW University RSA, Science Direct 2004
8. www.zesco.co.zm