Experimental Study on Performance of Solar Thermal Driven Cooling System Versus a Hybrid Mechanical Compression Refrigeration-Solar Thermal Assisted System in Hot Areas

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Energy flow diagram providing an overview of this procedure
Africa
1,122m tonnes of CO₂ in 2009
Down 3.1% on 2008

12 South Africa
450
6.7%

27 Egypt
192
3.5%

46 Nigeria
77.7

37 Algeria
114
6.2%

71 Morocco
36.5

80 Tunisia
22.9
<table>
<thead>
<tr>
<th>Refrigerant</th>
<th>Composition</th>
<th>Application</th>
<th>GWP ((CO_2 = 1))</th>
<th>Safety class</th>
<th>Boiling point °C</th>
<th>Vapour pressure at 50°C (dew) bar (abs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCFC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R.22</td>
<td>CHClF_3</td>
<td>HT, MT</td>
<td>1810</td>
<td>A1</td>
<td>-41</td>
<td>19.4</td>
</tr>
<tr>
<td>HFCs chlorine free</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R.134a</td>
<td>C_F_3CH_2F</td>
<td>HT, MT</td>
<td>1430</td>
<td>A1</td>
<td>-26</td>
<td>13.2</td>
</tr>
<tr>
<td>R.125</td>
<td>C_F_2CHF_2</td>
<td>Blends</td>
<td>3800</td>
<td>A1</td>
<td>-48</td>
<td>25.5</td>
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<tr>
<td>R.143a</td>
<td>C_F_3CHF_2</td>
<td>Blends</td>
<td>4470</td>
<td>A2</td>
<td>-48</td>
<td>23.2</td>
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<tr>
<td>R.32</td>
<td>CH_2F_2</td>
<td>HT</td>
<td>625</td>
<td>A2L</td>
<td>-52</td>
<td>31.5</td>
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<tr>
<td>R.404A</td>
<td>R.143a/125/134a</td>
<td>LT</td>
<td>3822</td>
<td>A1</td>
<td>-47</td>
<td>23.0</td>
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<tr>
<td>R.410A</td>
<td>R.32/125</td>
<td>HT</td>
<td>2038</td>
<td>A1</td>
<td>-51</td>
<td>30.5</td>
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<tr>
<td>Other R.32 Blends</td>
<td>R.32 + HFCs</td>
<td>LT</td>
<td>1770–2280</td>
<td>A1</td>
<td>-46 to -48</td>
<td>21 to 25</td>
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<tr>
<td>Other R.125 Blends</td>
<td>R.125 + HFCs</td>
<td>LT, MT, LT</td>
<td>1830–3300</td>
<td>A1</td>
<td>-43 to -48</td>
<td>18 to 25</td>
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<tr>
<td>HFOs</td>
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<td></td>
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<tr>
<td>R.1234yf</td>
<td>CH_2 = CRCF_3</td>
<td>MAC, HT</td>
<td>4</td>
<td>A2L</td>
<td>-29</td>
<td>13.0</td>
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<tr>
<td>R.1234yz/E</td>
<td>CHF = CHCF_3</td>
<td>HT</td>
<td>6</td>
<td>A2L</td>
<td>-19</td>
<td>10.0</td>
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<td>HFC/HFO Blends</td>
<td>R.1234yf/E/134a</td>
<td>Various</td>
<td>600–1500</td>
<td>A1</td>
<td>-20 to -50</td>
<td>Various</td>
</tr>
</tbody>
</table>

(Continued)

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<tr>
<td>R.290</td>
<td>C_3H_8</td>
<td>HT, MT</td>
<td>3</td>
<td>A3</td>
<td>-42</td>
<td>17.1</td>
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<tr>
<td>R.1270</td>
<td>C_2H_6</td>
<td>MT</td>
<td>3</td>
<td>A3</td>
<td>-48</td>
<td>20.6</td>
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<tr>
<td>R.600a</td>
<td>C_6H_10</td>
<td>MT</td>
<td>3</td>
<td>A3</td>
<td>-12</td>
<td>6.8</td>
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<tr>
<td>R.290 Blends</td>
<td>R.290 + HC_3</td>
<td>HT, LT, MT</td>
<td>3</td>
<td>A3</td>
<td>-30 to -48</td>
<td>10 to 18</td>
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<tr>
<td>Other halogen free</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
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<tr>
<td>R.717</td>
<td>NH_3</td>
<td>LT (MT, HT)</td>
<td>0</td>
<td>B2</td>
<td>-33</td>
<td>20.3</td>
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<tr>
<td>R.744</td>
<td>CO_2 Carbon Dioxide</td>
<td>HT, MT, LT</td>
<td>1</td>
<td>A1</td>
<td>-57*</td>
<td>74**</td>
</tr>
</tbody>
</table>
Energy planning with R&D

Implementation

Regulatory stage

Policy Level

Strategic Level

???

???
Figure 4-13 The percentages of thermal adaption within different climate regions.
In hot arid countries, indoor cooling during summer time is essential.
Solar Cooling

8 kW cooling capacity, 0.6 therm. COP

72°C in 65°C out

Solar panel

32°C out 27°C in

Heat-Rejection

12°C out 14°C in

Residential Cooling

VS.

Residential Scale Solar thermal driven Cooling System in Assiut, Egypt

Criteria
- performance evaluation
- electrical energy consumption
- environmental benefits
- long-run costs

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Hybrid schematic and photographs diagram of the main components of the solar cooling system: (1) collectors’ field (2) hot water storage tank (3) adsorption chiller (4) cold water storage tank (5) cooling tower(s) (6) six-variable speed pumps (7) cooling load- fan coils and (8) intermediate heat exchanger.
Performance of a small-scale solar-powered adsorption cooling system


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screen shot from the data logger for driving hot water temperature inlet and outlet from the chiller (HT), chiller cooling water temperature inlet and outlet from the chiller (MT) and chilled water temperature outlet and inlet to the chiller and (c) screen shot from the data logger for the chiller driving thermal power, chilling power and heat rejected power (CW power)
Solar thermal driven cooling system

Off-grid Photovoltaic driven DC air-conditioning system

Conventional AC driven grid connected air-conditioning system

Analysis between three residential scale A/C in hot arid areas cooling capacity 8 kW and 18 hours daily operation in the cooling session.
The results clearly indicate that:

• The solar thermal driven cooling system has an energy consumption of 10.94%, with TEWI of 9.96% and cost per kW cooling higher by 295.96%.

• While, the off grid PV driven DC air conditioning system has an energy consumption of 0%, with TEWI of 0.648% and cost per kW cooling less by 54.88%.

<table>
<thead>
<tr>
<th>System type</th>
<th>Grid required Energy Consumption in MWh</th>
<th>TEWI, equivalent Tons CO₂</th>
<th>Cost per kW cooling in US$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar Thermal Cooling System</td>
<td>79.5</td>
<td>45.6</td>
<td>8,790</td>
</tr>
<tr>
<td>Off-Grid PV Driven DC Air Conditioning System</td>
<td>0</td>
<td>2.7</td>
<td>1,630</td>
</tr>
<tr>
<td>Conventional Air Conditioning System</td>
<td>757.7</td>
<td>416.7</td>
<td>2,970</td>
</tr>
</tbody>
</table>

The main finding is that compared with conventional vapor AC driven air-conditioning system, the solar thermal driven cooling system offers a significant energy and cost efficiency advantage, while the off grid PV driven DC air conditioning system is highly efficient in terms of energy consumption and cost.
Solar assisted vapor compression cooling systems
## Energy Saving

According to the 2017 kWh price of 0.62LE

Thus, for 1 years of operations the save 2,300 LE and payback period is 3.35 Years

<table>
<thead>
<tr>
<th>Product</th>
<th>Btu</th>
<th>Cooling (W)</th>
<th>Power (W)</th>
<th>EER</th>
<th>Saving Rate (W/H)</th>
<th>1 h</th>
<th>1 Day / 10 h</th>
<th>1 Month</th>
<th>1 Year</th>
<th>5 Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal LG 72GW A/C</td>
<td>24,000</td>
<td>7,200</td>
<td>2,900</td>
<td>2.50</td>
<td>/</td>
<td>2,900</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>ULG 72GW Solar A/C</td>
<td>24,000</td>
<td>7,200</td>
<td>1,885</td>
<td>3.82</td>
<td>35.00%</td>
<td>1,885</td>
<td>1.02</td>
<td>10</td>
<td>305</td>
<td>3,705</td>
</tr>
</tbody>
</table>
Ground water
Under Ground Earth Heating and Cooling
Results

Performance of an underground earth cooling system using air as heat transfer medium
Conclusions and gained experiences

However, among many others gained experiences the following are the main points to be considered:

• As the heat rejection from the all system has the higher impact the performance parameters of the chiller in hot arid area, therefore, the re-cooling sub-system should be based on other alternative heat sink recourses techniques than the ambient air whenever is applicable.

• Underground earth cooling system is a good alternative heat sink recourses techniques than the ambient air whenever is applicable

• Many installed underground earth cooling and heating systems used for schools and other building in EU. Therefore, a joint project need to established and funded for prototyping performance, coast, environmental benefits for long run.
Thank you
As researchers or practitioners what are the possible interactions/collaboration with practitioners resp. researchers to improve/upscale your activities
What are the potential aspects of the research that can be transformed into practice?