Potential for Solar Thermal in India

The Forgotten Solar: Solar thermal and its development

Dated: 04-02-2016

V.S. Sharma: General Manager – Renewable Energies
Steag Energy Services India Pvt. Ltd.
• Steag and it’s activities
• Advantages of Solar thermal – Surety of potential
• Solar thermal potential areas
  o Power generation
  o Industrial Heating applications - Textiles, Pharma, Dairy, Paper, Metal treatment etc.
  o Desalination applications – Using MED and other processes
  o Hybridization with Conventional plants – Coal fired, Gas fired etc.
  o Cooling applications – Air conditioning, cold storage etc.
• Solar Thermal – Factors for realization of potential
Steag’s Activities

**Steag Germany - Key figures** (as of Dec. 2011)

- External sales 3,066 € m
- Capital expenditure on fixed assets 1,283 € m
- Employees 5,800

**Steag India Activities**

- Engineering Consultancy
- O&M services – ~ 5000 MW
- System Technology – Simulators and Plant optimization systems
- Training and advisory services

**Steag India – Solar activities**

- Several DPRs and feasibilities
- Ebsilon Solar – Proprietary thermodynamic design software
- Solar simulator - with Trax
- Owners Engineer NTPC Anta
- Training on Solar – With IITJ
STEAG holds a strong position in the renewable energy market

- Sites of Evonik New Energies GmbH
- Subsidiaries

### Steag Projects

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind</td>
<td>• 300 MW of wind in Turkey &amp; Romania</td>
</tr>
<tr>
<td>Solar</td>
<td>• 50 MW plant at Arenales</td>
</tr>
</tbody>
</table>

### Biomass

- • since 2002
- • #3 in Germany

<table>
<thead>
<tr>
<th></th>
<th>MW$_{el}$</th>
<th>MW$_{th}$</th>
<th>Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biogas</td>
<td>66</td>
<td>154</td>
<td>13</td>
</tr>
</tbody>
</table>

### Biogas

- • since 2007
- • First own biogas plant commissioned

### Mine gas

- • since 1908
- • #1 in Germany

<table>
<thead>
<tr>
<th></th>
<th>MW$_{el}$</th>
<th>MW$_{th}$</th>
<th>Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine gas</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>177</td>
<td>139</td>
<td>108</td>
</tr>
</tbody>
</table>

### Geothermal

- • since 1994
- • #1 in Germany

<table>
<thead>
<tr>
<th></th>
<th>MW$_{el}$</th>
<th>MW$_{th}$</th>
<th>Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geothermal</td>
<td></td>
<td>71</td>
<td>2</td>
</tr>
</tbody>
</table>

### Contracting

- • since 1961
- • #2 in Germany

<table>
<thead>
<tr>
<th></th>
<th>MW$_{el}$</th>
<th>MW$_{th}$</th>
<th>Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contracting</td>
<td></td>
<td>905</td>
<td>100</td>
</tr>
</tbody>
</table>

### Total

<table>
<thead>
<tr>
<th></th>
<th>MW$_{el}$</th>
<th>MW$_{th}$</th>
<th>Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>319</td>
<td>1,271</td>
<td>223</td>
</tr>
</tbody>
</table>
Steag’s Arenales 50 MW plant in Spain

- Steag has a 26% stake
- O&M shall be done by Steag themselves
- Technical concept comparable to Andasol 3
- Capacity of the plant: 49.9 MW
- Wet cooling tower implemented
- Solar field with 156 Loops Parabolic Collectors
- Thermal Storage (salt) for up to 7h of full load operation
- Gross electricity production: about 170 GWhel p.a.
- Planned operation period: 40 years

➤ The implemented technical concept is state of the art for CSP plants in Spain
Topics for discussion

- Steag and its activities

- **Advantages of Solar thermal – Surety of potential**

- Solar thermal potential areas
  - Power generation
  - Industrial Heating applications - Textiles, Pharma, Dairy, Paper, Metal treatment etc.
  - Desalination applications – Using MED and other processes
  - Hybridization with Conventional plants – Coal fired, Gas fired etc.
  - Cooling applications – Air conditioning, cold storage etc.

- Solar Thermal – Factors for realization of potential
Advantages of Solar thermal over other RE sources

- The only RE power that is fully Dispatch able.
  - Dispatch when you need the most.
  - Big advantage as the peak hours are not necessarily the same as production hours.

- Can act as a base load plant
  - Possible with adequate storage
  - Example – Gemasolar plant

- Storage helps in steady power during the day also.
  - Grid stability. There is a limit on other types of RE power
  - Important for ABT regime.

- Possibility of hybridization with conventional power
  - Better efficiency – no start-up losses
  - Lower cost – no separate power block.
### SOLAR FIELD

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heliostat Solar-Field Aperture Area:</td>
<td>3,04,750 m²</td>
</tr>
<tr>
<td># of Heliostats:</td>
<td>2,650</td>
</tr>
<tr>
<td>Heliostat Aperture Area:</td>
<td>120.0 m²</td>
</tr>
<tr>
<td>Heliostat Manufacturer:</td>
<td>Sener</td>
</tr>
<tr>
<td>Heliostat Description:</td>
<td>Sheet metal stamped facet</td>
</tr>
<tr>
<td>Heliostat Drive Manufacturer:</td>
<td>Sener</td>
</tr>
<tr>
<td>Tower Height:</td>
<td>140 m</td>
</tr>
<tr>
<td>Receiver Manufacturer:</td>
<td>Sener</td>
</tr>
<tr>
<td>Heat-Transfer Fluid Type:</td>
<td>Molten salts (sodium and potassium nitrates)</td>
</tr>
<tr>
<td>Receiver Inlet Temp:</td>
<td>290C</td>
</tr>
<tr>
<td>Receiver Outlet Temp:</td>
<td>565C</td>
</tr>
<tr>
<td>Receiver Temp. Difference:</td>
<td>275C</td>
</tr>
</tbody>
</table>
## THERMAL STORAGE

<table>
<thead>
<tr>
<th>Storage Type:</th>
<th>2-tank direct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage Capacity:</td>
<td>15 hour(s)</td>
</tr>
<tr>
<td>Thermal Storage Description:</td>
<td>One cold-salts tank (290°C) from where salts are pumped to the tower receiver and heated up to 565°C, to be stored in one hot-salts tank (565°C). Annual equivalent hours = 6,500.</td>
</tr>
</tbody>
</table>
### POWER BLOCK

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbine Capacity (Gross):</td>
<td>19.9 MW</td>
</tr>
<tr>
<td>Turbine Capacity (Net):</td>
<td>19.9 MW</td>
</tr>
<tr>
<td>Cooling Method:</td>
<td>Wet cooling</td>
</tr>
<tr>
<td>Fossil Backup Type:</td>
<td>Natural gas</td>
</tr>
<tr>
<td>Backup Percentage:</td>
<td>15%</td>
</tr>
<tr>
<td>TOTAL PROJECT COST</td>
<td>EURO 230,000,000</td>
</tr>
<tr>
<td>Construction Job-years</td>
<td>800</td>
</tr>
<tr>
<td>O &amp; M Jobs</td>
<td>45</td>
</tr>
</tbody>
</table>
Cost of thermal storage vs Battery storage

- Tanks: 56%
- Insulation: 6%
- Foundation: 12%
- Salt: 10%
- Hx: 22%
- Pumps: 5%
- BOS: 8%

<table>
<thead>
<tr>
<th>Total Cost</th>
<th>50 MW with 6 hours Storage</th>
<th>$70,000,000 or 450 Crores</th>
<th>550 Crores with 7 yrs Lifetime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equivalent Battery storage</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Topics for discussion

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• Solar thermal potential areas
  o **Power generation**
  o Industrial Heating applications - Textiles, Pharma, Dairy, Paper, Metal treatment etc.
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  o Cooling applications – Air conditioning, cold storage etc.
• Solar Thermal – Factors for realization of potential
Solar Resource in India

DNI Map

This map depicts model estimates of annual average direct normal irradiance (DNI) at 10 km resolution based on hourly estimates of radiation over 7 years (2002-2008). The inputs are visible imagery from geostationary satellites, aerosol optical depth, water vapor, and ozone.
## TECHNICAL POTENTIAL – SOLAR THERMAL

<table>
<thead>
<tr>
<th>Zones</th>
<th>DNI</th>
<th>Area</th>
<th>Technical Potential</th>
<th>Economic Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Km²</td>
<td>Billion Units/year</td>
<td>Rs. (Crores)</td>
</tr>
<tr>
<td>Zone 1</td>
<td>High</td>
<td>23,185</td>
<td>1,600</td>
<td>14,000</td>
</tr>
<tr>
<td>Zone 2</td>
<td>Moderate</td>
<td>175,667</td>
<td>10,500</td>
<td>105,000</td>
</tr>
<tr>
<td>Zone 3</td>
<td>Acceptable</td>
<td>444,415</td>
<td>25,000</td>
<td>266,000</td>
</tr>
<tr>
<td>Zone 4</td>
<td></td>
<td>151,106</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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Solar potential across processes industry – International figures

Technological developments and commensurate policy support will give fillip for fast deployment

Source: ECOHEATCOOL (IEE ALTENER Project), European Solar Thermal Industry Federation
60 TO 70% OF INDUSTRIAL ENERGY USE IS IN THERMAL FORM

INDIA USES 100 MILLION TONS OF OIL ANNUALLY

40% OF THIS OIL CONSUMPTION IS IN INDUSTRY (40 MT)

About 15 MILL TONS OF OIL IS USED IN INDUSTRY BELOW 250 °C.

30% OF THIS REQUIREMENT CAN BE MET THROUGH SOLAR THERMAL CONCENTRATORS, LEADING TO SAVINGS OF ABOUT 4.5 MILLION TONS OF FURNACE OIL OR LDO OR DIESEL PER YEAR
Multiple technology solutions in solar thermal for vast applications in industrial sector

**Low Temperature Collectors**
- Temperature: -70°C to 120°C
- Suitable for flat as well as inclined roof
- No tracking hence low maintenance
- Applications:
  1) Pasteurization
  2) Boiler feed water heating
  3) LPG Vaporiser

**Parabolic Dish Collectors**
- Temperature: -100°C to 150°C
- Dual axis tracking
- Fixed as well as moving focus
- Applications:
  1) Oil Heating
  2) Double Effect Cooling
  3) Various Process Heating Applications

**Mini-Parabolic Troughs**
- Temperature: -160°C to 210°C
- Single axis tracking
- Fixed line focus
- Applications:
  1) Power Generation
  2) Triple Effect Cooling
  3) Various Process Heating Applications

**CLFR**
- Temperature: > 200°C
- Single axis tracking
- Fixed line focus
- Applications:
  1) Power Generation
  2) Spray Drying
  3) Triple Effect Cooling

---

200+ °C
### Industries with Potential to Use Solar Energy – Ranked as per the potential

<table>
<thead>
<tr>
<th>Rank</th>
<th>Industry</th>
<th>Energy Saving Potential (ktoe/annum)</th>
<th>Monetary Saving Potential (Rs. Million / Annum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Textile (Finishing)</td>
<td>383</td>
<td>7692</td>
</tr>
<tr>
<td>2</td>
<td>Pulp and Paper</td>
<td>45</td>
<td>1700</td>
</tr>
<tr>
<td>3</td>
<td>Pharmaceuticals</td>
<td>9</td>
<td>NOT AVAILABLE</td>
</tr>
<tr>
<td>4</td>
<td>Leather</td>
<td>17</td>
<td>1026</td>
</tr>
<tr>
<td>5</td>
<td>Food processing</td>
<td>80</td>
<td>1782</td>
</tr>
<tr>
<td>6</td>
<td>Dairy</td>
<td>27</td>
<td>916</td>
</tr>
<tr>
<td>7</td>
<td>Textile (Spinning and Weaving)</td>
<td>20</td>
<td>740</td>
</tr>
<tr>
<td>8</td>
<td>Electroplating/Galvanizing</td>
<td>21</td>
<td>NOT AVAILABLE</td>
</tr>
<tr>
<td>9</td>
<td>Automobile</td>
<td>10.5</td>
<td>607</td>
</tr>
<tr>
<td>10</td>
<td>Agro malls</td>
<td>4.3</td>
<td>160</td>
</tr>
</tbody>
</table>

Source: GIZ - MNRE
Pulp & Paper Making Process

Debarking → Chipping → Digesting → Washing

Paper Machine / Pulp Drier → Cleaning → Bleaching → Screaming

Source: GIZ - MNRE
Dairy

Raw Milk Reception
Cleaning - Clarification / Filtration
Cold storage - Pre Chilling

Homogenisation
Pasteurisation / Sterilisation

Separation
Churning
Thawing

Liquid Milk
Chilling / Cold Storage
Packaging

Distribution
Butter

Standardisation
Pre-heating
Evaporation

Milk Powder
Cold storage - Pre Chilling

Source: GIZ - MNRE
5% of the heat load can be replaced which is 9 ktoe / annum

Source: GIZ - MNRE
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• Solar thermal potential areas
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  o Industrial Heating applications - Textiles, Pharma, Dairy, Paper, Metal treatment etc.
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• Solar Thermal – Factors for realization of potential
According to the central water commission, the total utilisable water per capita is 1022.7 cubic metres every year. The per capita demand in 2000 was 634 cubic metres and is projected to go up to 1,093 cubic metres by 2025.
Computer model of a 12MWe Combined Solar Biomass Desalination Plant including Air Cooled Condenser – Concept by Steag
Exterior View of the 12MWe Combined Solar Biomass Desalination Plant from the Solar Field side - Concept by Steag
WHAT IS SPECIAL ABOUT THIS PROJECT

**SOLAR THERMAL FIELD**
- 10% of Heat

**BIOMASS FLOW RATE**
- 12.8 TPH
- JULI FLORA up to 100%
- COTTON STALK 20%

**Solar Biomass Hybrid Power Plant with Desal WTP**
- 12MW

**Process Flow Diagram**
- BOILER
- TURBINE
- DEAERATOR
- FEED WATER STORAGE TANK
- Desalination unit

**Water Production**
- 160 M3/DAY DM
- WATER QUALITY

**Additional Information**
- BLOW DOWN 2.6 t/h
- MAKE UP 2.6 t/h
- 52 t/h, 68 Kg/cm², 480°C
- 46.7 t/h
  - 0.18 Kg/cm²
- 5.3 t/h
  - 5 Kg/cm²
Solar desalination in Ramanathapuram district of Tamil Nadu

- 1,44,000 litres per day of desalinated water
- Solar field – CLFR 1400 sqm of mirror
- Project developer – KG Design Services Coimbatore
- Source of water – Bay of Bengal
- Purity of water – 2 ppm
- Usage of water – Drinking in nearby villages
- Co-developer – national Institute of Ocean Technologies
- Funding – DST
- Scalability - Good
- One Kg of steam produces approx 8 kg of desalinated water
Solar desalination in Ramanathapuram district of Tamil Nadu

Multiple effect distillation

Solar field
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NTPC ANTA - SOLAR FIELD LAYOUT FOR CCPP INTEGRATION

13 MW Capacity, 132 Collectors, Solar Field Size Optimized Based On Margin Available In Existing Anta CCPP
1. Steam Turbine maximum main steam flow limited to 488 tph to HP-Turbine and 601 tph to LP-Turbine as per heat balance diagram “peak load”.

2. Condenser main steam flow limited to 601 tph as per heat balance diagram.

3. ST generator transformer rated at 195MVA
INTEGRATION OPTIONS

1. Solar Steam integration in to HP Drum of each of 3 existing HRSGs

2. Solar Steam integration in to HP Super Heater of each of 3 existing HRSGs

3. Solar Steam @ 370°C integration in to HP Main Steam Header (485°C) before Steam Turbine

4. Solar Steam with separately fired Super Heater and Integrating in to HP Main Steam Header before Steam Turbine

5. New BPST integrated at existing LP main steam header


7. Standalone Power Plant.
Proposal

- Integration of a 5 MW solar field in a 15 MW turbine
- The turbine is fed from six waste heat recovery boilers which get heat from flue gases of the cement kilns
- Injection point is at HP steam header
- The water extraction is either from CEP outlet or BFP inlet
5 MW proposed Solar integration at Shree Cement

Ebsilon model of the integrated system
Hybridization could become the largest market for CSP. STEAG Energy Services has investigated CSP Topping for the following plants:

- 2 x 660 MW coal-fired power plant Sugözü in Turkey
- 165 MW coal-fired power plant Termopaipa in Colombia
- Coal-fired power plants in Brazil
- 1X15 MW Anta project of NTPC
- 1X5 MW Shree Cement plant at Rajasthan
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• Thermax has designed and commissioned a first-of-a-kind solar air conditioning system at the Solar Energy Centre in Gurgaon, Haryana.

• The capacity of solar field is 100 kw

• The solar collectors have been designed to harness sun’s energy in an effective manner to provide temperatures from 140 °C to 210 °C.

• Solar Collector area : 288 sq mtr

• This heat is used in Vapour Absorption Machine to generate 7 °C Chilled water which in turn circulates through the Fan coil unit installed in the thirteen rooms.

• A solar cold storage demo is also in progress at SEC
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Multifarious applications of ST would give economy of scale in mid term future although currently the cost curves are better in PV. Industrial process heat, Solar AC, Desalination, hybrid plants beyond the regular power production.

Costs will further reduce with indigenization of technology and increase in Domestic content.

Support from Govt. Capital subsidy, tax subsidy, RECs, state funded demo plants and other favourable policies not only for the developers but for the entire eco-system of Solar thermal

Positive consideration of financial institutions

Positive consideration from industry to accept the industrial applications
## Indigenization Benefit

<table>
<thead>
<tr>
<th>COST SAVING ESTIMATES</th>
<th>/ 100 MW</th>
<th>International Cost</th>
<th>Expected indigenous Cost</th>
<th>Total Cost Saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel (MT)</td>
<td>25,000</td>
<td>$ 4,000 / MT</td>
<td>$ 2 - 2.50 / Kg</td>
<td>$56,250,000</td>
</tr>
<tr>
<td>Concrete (CBM)</td>
<td>30,000</td>
<td>$ 50 / CBM</td>
<td>$ 20 - 25 / CBM</td>
<td>$6,75,000</td>
</tr>
<tr>
<td>Glass (MT)</td>
<td>15,000</td>
<td>$ 40 / m2</td>
<td>$ 15 - 20 / MT</td>
<td>$2,50,00,000</td>
</tr>
<tr>
<td>EPC (% of project cost)</td>
<td>15%</td>
<td>6,00,00,000</td>
<td>7% - 9%</td>
<td>$3,20,00,000</td>
</tr>
<tr>
<td>Manpower (% of project cost)</td>
<td>20%</td>
<td>8,00,00,000</td>
<td>10% - 12%</td>
<td>$3,60,00,000</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td>Potential cost saving @ $ 1,500 / KW</td>
<td></td>
<td>$14,99,25,000</td>
</tr>
</tbody>
</table>
Effect of plant size on costing

- 25 MWe: 139%
- 50 MWe: 115%
- 100 MWe: 100%
- 250 MWe: 90%
Effect of deployment on costing

- Current: 100%
- 1000MW: 93%
- 2000MW: 87%
- 4000MW: 81%
Solar thermal is a long term player because:

- It is the only RE power that can be dispatched at desired time
- Can act as a base load plant
- Can give steady power during the day also – Grid stability, ABT
- Hybridization with conventional power is easily possible

The following are key to success of ST in India:

- Multifarious applications would give economy of scale
- Indigenization and Domestic content shall reduce the cost
- Support from Govt. Capital subsidy, tax subsidy, RECs, state funded demo plants
- Positive consideration of financial institutions
- Positive consideration from industry
Thank You

... Ideas & Solutions for Tomorrow