From Moses Mabhida Stadium to Solar Power Generation in South Africa

Dipl. Ing. (FH) Markus Balz
Managing Director
schlaich bergermann und partner are independent consulting civil and structural engineers.

We strive to design sophisticated engineering structures ranging from wide-span lightweight roofs, a diversity of bridges and slender towers to innovative solar energy power plants. Our ambitions are efficiency, beauty and ecology.

For the sake of holistic solutions we seek the collaboration with architects and engineers from all fields of expertise who share our goals.
Nelson Mandela Bay Arena Port Elizabeth, South Africa
Soccer City Stadium Johannesburg, South Africa
Greenpoint Stadium Cape Town, South Africa
(My) Conclusions of working in South Africa

- Wide experience in all building technologies
- Experienced contractors that know how to handle large projects (….and international subcontractors)
- Real team work between parties involved (client, architects, engineers, contractors)
- Make a plan (…but really not too early)
- Contractors listen to good advise
- Building risks involved are considered and accepted
- Fun!
A growing team, **sbp sonne gmbh**, is working on making advantage of renewable energies.

The technologies within this field are the Dish-Stirling-applications for decentralised and small-scale power plants. Central receiver systems, Parabolic trough and the solar updraft tower technology is used in large scale application.

Our highly qualified, motivated and constantly growing team is willing to contribute in research and development of any kind of Technologies.
Consultancy for client, owner and contractor

Feasibility studies

Efficiency calculation of power generation

Structural concept, calculation and optimization

Optics evaluation and optimization

Concept and calculation of controls and drives

Planning of prototype and series production

Supervision and quality management
Consulting Engineers for Renewable Energy

Metrology (Solar Radiation and Wind statistics)

Optics

Structural Engineering

Software Development (FEM – Optics and solar tracking)

Mechanical Engineering (Drives and Thermodynamics)

Electrical Engineering (Control system)

Series Production (Automotive)

Technical Expertise
Global resource of conventional energies and yearly solar radiation

Global fossil fuel reserves
The global supply of natural/renewable resources and economical potential to exploit it with present technologies – primary energy
Global use of primary energy (EJ/a)

Source: Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen
Current Solar Technologies – sorted by size
Current solar technologies – dispachable (storable) solar energy generation
Solar plants electric output (yearly mean) vs electric demand of South Africa
Capacity Trends of Renewable Energy Systems
CSP Technology Choice
Solar thermal power plants

- Point focusing
  - Dish/Stirling / Dish/PV (CPV)
  - Power Tower (CRS)

- Line focusing
  - Parabolic trough / Linear Fresnel

- Non concentrating
  - Solar Updraft Tower (SUT)

Solar Thermal Electricity Principles
Solar Updraft Tower

- Non concentrating
Solar Updraft Tower Principle
Prototype Manzanares, 1982, Castilla - La Mancha
Solar Updraft Tower Conceptual Design
Solar Thermal Boosting
HelioFocus solar concentrator – 500m² fresnel dish
Prototype Dish HelioFocus, Israel
Prototype Dish HelioFocus, Israel
HelioFocus test site close to Wuhai/Huinong
29th October 2013 Inauguration of Heliofocus Test Site with 8 x 500 m² Dish units in China
Parabolic Trough Technology
<table>
<thead>
<tr>
<th><strong>EUROTROUGH</strong></th>
<th><strong>HELIOTROUGH</strong></th>
<th><strong>ULTIMATE TROUGH</strong></th>
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<tr>
<td><strong>Technology Development</strong></td>
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<td>Start of development: 1998</td>
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<td>1. <strong>Conceptual Design</strong></td>
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<td>2. <strong>Prototype:</strong></td>
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<td>- PSA/Spain 1998</td>
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<td>3. <strong>Test loop:</strong></td>
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<td>- EuroTrough Loop KJC: Kramer Junction, USA: 2003</td>
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<td>- Dortmund/Germany 2006</td>
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<td>3. <strong>Test loop:</strong></td>
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<td>- HelioTrough Loop KJC: Kramer Junction, USA: 2009</td>
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<td><strong>Current development: 2009</strong></td>
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<td>- Cologne/Germany 2011</td>
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<td>3. <strong>Test loop:</strong></td>
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<td>- UT Collector Trough Loop: Harper Lake, USA: 2012</td>
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<td><strong>Commercial Application</strong></td>
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<td><strong>Large Scale Power Projects</strong></td>
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<td>- 50 MW Power Plant Moron, Spain: 2011</td>
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<td>- 50 MW Power Plant Astexol, Badajoz, Spain: 2012</td>
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<td>- 50 MW Power Plant Extremasol, Badajoz, Spain: 2012</td>
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<td>- 125 MW Solar Combined Power Plant Kuraymat: Egypt, 2010</td>
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<td>- 50 MW Solar Power Plant, Rajasthan, Godawari, India; 2013</td>
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<td><strong>Designed for 4 x 250 MW Blythe, California: 2014</strong></td>
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<td><strong>Coming Projects in:</strong></td>
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<td>- South Africa</td>
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EuroTrough Collector:
- Standard technology
- Moderate complexity
- Good optical performance
- Higher demand of manpower

HelioTrough Collector:
- Reduction of numbers of elements
- Sophisticated complexity
- Currently highest optical performance
- Automized manufacturing processes

UltimateTrough Collector:
- Optimized manufacturing technology
- Sophisticated complexity
- Very high optical performance

Continuing Development – Size and optical quality does matter
Direct radiation

Glass tube

Absorber tube with selective coating

Parabolic concentrator with reflecting surface

Tracking system

Principle of a Solar Parabolic Trough Power Plant
Design development - wind tunnel testing
SKAL-ET loop integrated in the SEGS V plant in California
Andasol collector field, Spain
Commercial 50 MW Plants in Spain: Andasol 1, Andasol 2, Andasol 3 (under construction)
Andasol 1 power block
Parabolic trough power plant – thermal flow
On-site collector assembly hall
Assembly on Site
Parabolic Trough Technology
Ongoing Development
Procurement and erection cost breakup
(Estimated current cost ~220 M€ - European cost basis)

The Solar Field is the most important cost item of a Parabolic Trough Power Plant

Cost efficient Solar Field has a significant impact on the economics of the project

Within the Solar Field, the collector structure and mirrors account for 60% of the solar field costs

Significant savings can be realized with an economically optimized collector design

Cost efficient solutions for parabolic trough power plants:
An economically optimized collector design is a key to reduce CSP project costs
Technical optimization

Structural design
- geometry
- profiles
- material

FEA

Optical analysis

Optimization

Design and optimization procedures
Techno-economic optimization

Design and optimization procedures
Analysis of Ultimate Trough – Technology Identification of potential improvements

Expectations (development aims):

20 - 25 % reduction of solar field investment cost achieved by:
less investment and erection costs for solar field
higher collector performance (higher optical efficiency, lower auxiliary consumption)

In total:
Levelized Cost of Electricity (LCoE) will decrease by ~12 % compared to today’s parabolic trough technology.
Ultimate Trough Prototype  April 2011 Köln
Design: Mirrors are attached stress free to the collector metal structure
Measurement and validation: Optical assessment by 3rd party

- Optical assessment with deflectometry & photogrammetry – dual measurement for result validation
- Intercept factor - sun rays hitting the receiver under consideration of the sun shape
  - = 99.2% @ 94 mm HCE (for oil as HTF)
  - = 97.5% @ 70 mm HCE (for salt as HTF)
- Average focal deviation of assembled collector, FDx < 8 mm - combined deviation caused by mirrors and steel structure
Ultimate Trough Testloop - California
• One day per month evaluated and compared to model
• The actual performance is consistently better than the expected performance.
• There are still some uncertainties in the measurements which will be evaluated and corrected during the next weeks of operation.

Ultimate Trough – Test loop performance
Eurotrough, 510'000 m²

Ultimate Trough, 466'000 m²

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<th>Header piping</th>
<th>ET</th>
<th>UT</th>
<th>Ratio</th>
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<tbody>
<tr>
<td>north-south m</td>
<td>1'678</td>
<td>n/a</td>
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<tr>
<td>east-west m</td>
<td>6'840</td>
<td>3'757</td>
<td>55%</td>
</tr>
<tr>
<td>total m</td>
<td>8'518</td>
<td>3'757</td>
<td>44%</td>
</tr>
<tr>
<td>HTF Volume m³</td>
<td>1'813</td>
<td>1'353</td>
<td>75%</td>
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Significant cost reduction due to
- Less piping (material, installation, insulation)
- Less heat transfer fluid
Comparison of foundations
Central Receiver Systems
A diagram of a concentrated solar power plant. Solar radiation from multiple heliostats is directed to a receiver at the top of a tall tower. The heliostats are arranged in a field around the tower, and the direct radiation from the sun is focused on the receiver.
GemaSolar by Torresol 19 MW (17h storage)
Conventional heliostat
SBP / Steinmüller 150 m² metal membrane heliostat – optical quality
SBP 150 m² metall membrane heliostat – variable focal length
SBP Solar field efficiency – blocking and shading optimisation
Comparison of benchmark heliostat and current heliostat development

**Benchmark Solarfield**
- 60 MWel 13h storage
- ~115 mio. MWh Thermal Power on Receiver annually
- Solarfield Cost = 164 Mio $
- LCoE (project related) = 16,7 c$/kwh

**Evolution Design**
- higher optical efficiency
- reduction of drive costs
- new structural system

**Current Heliostat Development (Status 6/2013)**
- Solarfield Cost = 147 Mio $
- LCoE (project related) = 14,4 c$/kwh
- Cost reduction of solar field = 11%
Technology trends
Installed capacity: 100 MW

Site: North Africa

Linear fuel cost escalation as in 2000-2010, market prices

PV 2000 h/yr, 30 yr
Wind 2500 h/yr, 20 yr
no storage, no backup

CSP 5500 h/yr, 40 yr
incl. thermal energy storage and 10% hybrid operation with natural gas

LEC = levelized electricity cost

Source: German Aerospace Center DLR, 2012

LEC ($/kWh)

Year

2005 2010 2015 2020 2025

Wind PV CSP Coal, Gas

CSP, PV, Wind, Fuels: cost of generation in MENA
Load: 100 MW, 5500 h/y, 40 yr

Site: North Africa

Linear fuel cost escalation as in 2000-2010, market prices

PV, Wind incl. pump storage; 10% backup by natural gas combined cycle

CSP incl. thermal energy storage and 10% hybrid operation with natural gas

LEC = levelized electricity cost

Source: German Aerospace Center DLR, 2012

CSP, PV, Wind, Fuels: cost of flexible power in MENA
sbp Sonne GmbH - ULTIMATE TROUGH® – The next generation collector for parabolic trough power plants
LCOE* €ct/kWh
-9%
scale-up of components

ET

UT
scale-up of plant size and 

LCOE* €ct/kWh

16,9 -9% 15,4 -10% 13,9

50 MW ET UT UT 100 MW
LCOE* (€ct/kWh):

- Oil HTF: 16.9
- Oil HTF: 15.4
- Oil HTF: 13.9
- Molten Salt: 11.2
- Molten Salt: 10.2
- HypoHightec: 9.9

Plant size effects:

-9% - 10% - 20% - 10%
CSP in South Africa
Significance to South Africa

High growing power demand

Very fortunate DNI and vast amount of land not competing with agriculture

Creating jobs

Develop local knowledge and high local content

Technology export
Technology hub of southern Africa

Represent a greener and sustainable country

Reduce environmental impact

Rising costs of fossil fuels

Less carbon intensive energy production
Solar field costs – South African local content

Local content 2012 approx. 60%

Local content 201? approx. 80%

SCA Foundations; 4.4%
Metal Support Structure (incl. Huckbolts); 24.2%
SF Assembly & Erection; 10.6%
SCE Assembly Line incl. Photogr.; 3.0%
SF Cabling (Supply & Installation); 2.4%
SF Power Supply; 0.3%
LOC, FSC & Meteo Station; 1.3%
Sensors & Pylon Cabling; 0.7%
Drive Units; 1.2%
Swivel Joints assemblies; 1.7%
Header Piping Material; 4.5%
Header Piping Installation; 2.1%
Inter Loop Piping Material; 3.2%
Inter Loop Piping Installation; 2.8%
Monitoring; 0.2%
HTF; 4.7%
Mirrors; 13.9%
HCE; 17.1%
License (Collector Drawings); 1.4%
Conclusions for South Africa

- CSP is the answer for many of SAs needs and requirements (Grid requirements, Flexibility, local content, unemployment, solar resources etc.)

- SA has recognised the value of CSP (allocation 200MW/year and two tear feed in tariff), but it is very conservative facing technological/financial risks

- SA building contractors do not get in gear – why?

- SA has the manufacturing capabilities the technological institutions to support growth and significant development within this field
Thank you!

Contact
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