The Feasibility of Solar Thermal Process Heat for the Sugarcane Industry in South Africa

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Overview

• Overview of the S.A. Sugar Industry
• Raw Sugar Production
• Drivers of Innovation
• SPH Technology & Low Hanging Fruit
• Potential of SPH Integration
• Expected Results
The S.A. Sugar Industry

Location

South Africa, Lesotho and Swaziland

Annual sum of global horizontal irradiation, average 1994-2010

[Map of South Africa with locations marked]
The S.A. Sugar Industry
The S.A. Sugar Industry

Overview

Location: KZN & Mpumalanga
Production: > 2m tons/a (20m tons cane)
Season: March - December
Contribution: R12b per year
Employment: 79 000 | 12 750
Sugar Milling: 14 Raw Sugar Factories
Market: Highly Regulated Prices
SMRI: Profitability, Efficiency & Innovation
The S.A. Sugar Industry

**Diagram:**
- Sugarcane to Juice Extraction (27 °C, 1 bar)
- Bagasse to Utilities (360 °C, 28.6 bar)
- Coal to Utilities (129 °C, 2.6 bar)
- Make-Up Water to Utilities (25 °C, 1 bar)
- Utilities to Evaporation (59 °C, 0.2 bar)
- Lime to Sludge (20 °C, 1 bar)
- Imbibition Water to Juice Extraction (57 °C, 3 bar)
- Filter Cake to Utilities (130 °C, 2.6 bar)
- Electricity

**Flow:**
- Sugarcane to Juice Extraction
- Juice Extraction to Clarification (60 °C, 1 bar)
- Juice to Clear Juice (99 °C, 2.4 bar)
- Clear Juice to Evaporation
- Evaporation to Crystallization & Centrifugation (55 °C, 1 bar)
- Crystallization & Centrifugation to Raw Sugar
- Sludge to Molasses (47 °C, 1 bar)
- Syrup to Crystallization & Centrifugation (52 °C, 0.2 bar)
- Draft Juice to Clear Juice (60 °C, 1 bar)
- Filter Cake to Utilities (130 °C, 2.6 bar)

**Temperature/Pressure:**
- Sugarcane: 27 °C, 1 bar
- Juice Extraction: 60 °C, 1 bar
- Imbibition Water: 57 °C, 3 bar
- Lime: 20 °C, 1 bar
- Sludge: 59 °C, 0.2 bar
- Molasses: 47 °C, 1 bar
- Utilities: 129 °C, 2.6 bar
- Make-Up Water: 25 °C, 1 bar
- Filter Cake: 130 °C, 2.6 bar
- Evaporation: 80 °C - 110 °C, 0.4 - 1.3 bar
- Crystallization & Centrifugation: 55 °C, 1 bar
- Raw Sugar: 55 °C, 1 bar
The S.A. Sugar Industry

Drivers of Innovation

Economic Pressure: Low Prices, Rising Input & Operational Costs

→ Reduce Operational Costs
  - Reduce Coal Consumption

→ Explore Alternative Income Streams
  - Bagasse By-Products
  - Bio-Ethanol
  - Electricity Cogeneration
Solar Process Heat Integration

Technology Characteristics

Temperatures:  25 - 450 °C
Pressure:     Up to 40 bar
Integration:  Supply Level / Process Level
Power and gain: 700 $W_p/m^2$ peak power
Potential Gain: Up to 1 MWh/m² per annum
System size:   No technical limit (Area, Capital)

Flat-Plate Collectors
Evacuated Tube Collectors
Fresnel Collector
Parabolic Trough Collector
Central Tower Receiver
Stationary Concentrating Collector
Solar Process Heat Integration

Potential for the Sugar Industry

Objective: Identify & Assess Suitable SPH Integration Points

Methodology:
1. Develop a flow diagram of a generic sugar mill
2. Analyse the energy consumption
3. Identify potential SPH integration points
4. Assess & rank the integration points
5. Develop concept designs
6. Estimate the potential solar gains
7. Assess the techno-economic feasibility
Solar Process Heat Integration

Low Hanging Fruits

• Low Process (Return) Temperature
• High Temperature Lift
• High & Constant Heat Demand
• Demand Concurs with High Irradiance
Solar Process Heat Integration

Boiler

Make-Up Water

Live Steam
360 °C
28.6 bar

Cane

Prime Movers

Turbo-Alternators

Let-Down Valve

Exhaust Steam
130 °C
2.6 bar

Diffuser

Clarification

Evaporator 1

Evaporator 2

Evaporator 3

Evaporator 4

Boiling House

Drying

Raw Sugar

Condensate

Vapour 1
120 °C
2 bar

Vapour 2
110 °C
1.4 bar

Vapour 3
95 °C
0.8 bar

Coal

Water
Solar Process Heat Integration

Entry Barriers

• Low Cost of Energy: Bagasse
• Heat Distribution: Exhaust, Vapour
• Seasonality: March – December
• Relatively Low Irradiation: 2000 kWh/m²
• Area Requirements: Limited Area
# Solar Process Heat Integration

## Potential Integration Points

<table>
<thead>
<tr>
<th>Heat Sink</th>
<th>Fuel / Heat Source</th>
<th>Process Temperature</th>
<th>Temperature Lift</th>
<th>Mean Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Live Steam Injection</td>
<td>Bagasse &amp; Coal</td>
<td>360 °C</td>
<td>N/A</td>
<td>90 MW</td>
</tr>
<tr>
<td>Feed Water Pre-Heating</td>
<td>Bagasse &amp; Coal</td>
<td>129 °C</td>
<td>230 °C</td>
<td>75 MW</td>
</tr>
<tr>
<td>Make-Up Water Pre-Heating</td>
<td>Bagasse &amp; Coal</td>
<td>25 °C</td>
<td>335 °C</td>
<td>N/A</td>
</tr>
<tr>
<td>Evaporation</td>
<td>Exhaust Steam</td>
<td>114 °C</td>
<td>7 °C</td>
<td>58 MW</td>
</tr>
<tr>
<td>Clear Juice HEX</td>
<td>Exhaust Steam</td>
<td>100 °C</td>
<td>14 °C</td>
<td>4 MW</td>
</tr>
<tr>
<td>Sugar Drying</td>
<td>Exhaust Steam</td>
<td>25 °C</td>
<td>55 °C</td>
<td>0,6 MW</td>
</tr>
<tr>
<td>Bagasse Drying</td>
<td>Bagasse &amp; Coal</td>
<td>72 °C</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Thank You

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