Biomass Power: High Efficiency Boiler Technology for Sugar Industry

Seminar on Renewable Energy Technology Implementation in Thailand

October 4, 2012
What is Biomass?

Biomass is organic matter which can be converted into energy. Common examples of biomass include crops for energy, crop residues, wood waste and animal manure.
Carbon Life Cycle for Biomass Power Plant

Electricity from Biomass = Neutral Carbon Emission
Technologies Converting Biomass to Energy

- Biomass
  - Bio-Fuel
    - Gasification + Fisher Tropsch
    - Hydrolysis + Fermentation
  - Heat & Power
    - Co-Firing with coal
    - Biogas + Gas Engine
    - Gasification + Gas Engine
    - Boiler + Turbine
    - Boiler + Turbine
    - Gas Engine
    - Boiler + Turbine
Biomass Boiler Turbine Generator

Mitr Phol Group and Renewable Energy

Sugar: Mitr Phol is the largest sugar producer in Thailand crushing about 18 million tons cane per year from 5 sugar mills.

Bio Power: Bagasse from sugar production is used in biomass power plants with total capacity of 307 MW in which 177 MW is fed to national grid around 1,000 GWH annually.

Bio Fuel: Molasses from sugar production is used to produce ethanol approximately 250 million liters annually.
## World’s Sugar Cane Production 2011

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>AREA HARVESTED (Ha)</th>
<th>PRODUCTION RANKING</th>
<th>YIELD (tonnes/ha)</th>
<th>PRODUCTION (tonnes)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>BRAZIL</td>
<td>8,490,000</td>
<td>1</td>
<td>73.03</td>
<td>620,000,000</td>
<td>GAIN Report</td>
</tr>
<tr>
<td>INDIA</td>
<td>4,810,000</td>
<td>2</td>
<td>70.80</td>
<td>340,540,000</td>
<td>GAIN Report</td>
</tr>
<tr>
<td>CHINA</td>
<td>1,780,000</td>
<td>3</td>
<td>69.66</td>
<td>124,000,000</td>
<td>GAIN Report</td>
</tr>
<tr>
<td>THAILAND</td>
<td>1,200,000</td>
<td>4</td>
<td>79.75</td>
<td>95,700,000</td>
<td>GAIN Report</td>
</tr>
<tr>
<td>PAKISTAN</td>
<td>1,011,000</td>
<td>6</td>
<td>53.41</td>
<td>54,000,000</td>
<td>GAIN Report</td>
</tr>
<tr>
<td>MEXICO</td>
<td>675,000</td>
<td>5</td>
<td>67.33</td>
<td>45,450,000</td>
<td>GAIN Report</td>
</tr>
<tr>
<td>AUSTRALIA</td>
<td>353,000</td>
<td>8</td>
<td>77.76</td>
<td>27,450,000</td>
<td>GAIN Report</td>
</tr>
<tr>
<td>PHILIPPINES</td>
<td>390,000</td>
<td>7</td>
<td>66.41</td>
<td>25,900,000</td>
<td>GAIN Report</td>
</tr>
<tr>
<td>USA</td>
<td>359,766</td>
<td>9</td>
<td>64.71</td>
<td>23,281,082</td>
<td>USDA</td>
</tr>
<tr>
<td>COLOMBIA*</td>
<td>171,633</td>
<td>10</td>
<td>118.12</td>
<td>20,272,600</td>
<td>FAO Database</td>
</tr>
<tr>
<td>CUBA*</td>
<td>431,400</td>
<td>11</td>
<td>26.19</td>
<td>11,300,000</td>
<td>FAO Database</td>
</tr>
</tbody>
</table>
Thailand Biomass-Based Power Generation Potential

Potential Electricity Capacity (MW)

- Palm oil residues: 43 MW
- Coconut: 43 MW
- Distillery slop: 49 MW
- Corn cob: 54 MW
- Rice husk: 100 MW
- Wood residues: 950 MW
- Biogas: 1185 MW
- Bagasse: 1900 MW

## Advantages of High Pressure Boiler

90% of sugar mill boilers in Thailand are below this category

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Unit</th>
<th>45 Kg/cm² (a)</th>
<th>66 Kg/cm² (a)</th>
<th>87 Kg/cm² (a)</th>
<th>105 Kg/cm² (a)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>440°C 515°C</td>
<td>485°C 515°C</td>
<td>515°C 540°C</td>
<td>515°C 540°C</td>
</tr>
<tr>
<td>Feed Water temp to boiler</td>
<td>°C</td>
<td>105</td>
<td>150</td>
<td>170</td>
<td>220</td>
</tr>
<tr>
<td>(without HP Heater)</td>
<td></td>
<td>(with 1 HP</td>
<td>(with 1 HP</td>
<td>(with 1 HP</td>
<td>(with 2 HP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Heater)</td>
<td>Heater)</td>
<td>Heater)</td>
<td>Heater)</td>
</tr>
<tr>
<td>Bagasse Quantity</td>
<td>TPH</td>
<td>43.51</td>
<td>46.18</td>
<td>41.78</td>
<td>42.89</td>
</tr>
<tr>
<td>Steam /Fuel ratio</td>
<td></td>
<td>2.29</td>
<td>2.16</td>
<td>2.39</td>
<td>2.33</td>
</tr>
<tr>
<td>Gross Power output</td>
<td>MW</td>
<td>24.8</td>
<td>28.8</td>
<td>26.5</td>
<td>28.9</td>
</tr>
<tr>
<td>Net Power Output</td>
<td>MW</td>
<td>22</td>
<td>25.2</td>
<td>23.4</td>
<td>25.3</td>
</tr>
<tr>
<td>Specific Steam consumption</td>
<td>Kg/KW-hr</td>
<td>4.03</td>
<td>3.46</td>
<td>3.77</td>
<td>3.46</td>
</tr>
<tr>
<td>Power Generation per ton of Bagasse</td>
<td>KW/Ton</td>
<td>Base +9.5%</td>
<td>+ 11.4%</td>
<td>+18.3%</td>
<td>+ 21.4%</td>
</tr>
<tr>
<td>Heat Rate</td>
<td>Kcals/KW-hr</td>
<td>3983</td>
<td>3640</td>
<td>3579</td>
<td>3370</td>
</tr>
</tbody>
</table>

(Calculations shown above are based on a 100 TPH Travelling Grate boiler with 69% efficiency (on GCV 2270 Kcal/Kg Basis) and Turbine exhaust at 0.1 Kg/Cm² (a))

**HIGHER THE CYCLE PARAMETERS- HIGHER THE OUTPUT**

More power output with same input quantity of fuel
Power Cogeneration in Sugar Mills

Sugar Cane → Bagasse 27% → Sugar Mill → New Power House → National Grid

- Juice 73%
- Bagasse Storage
- Fuel
- Power and Steam
- Excess Power
- Sugar
## Cogeneration by Sugar Mills in Thailand

<table>
<thead>
<tr>
<th>Before Year 2006</th>
<th>After Year 2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Mostly low-pressure boilers (&lt; 25 bar) and are very old (&gt; 30 years)</td>
<td>• Use of medium-pressure boilers and high efficiency turbine</td>
</tr>
<tr>
<td>• Mostly within the sugar mill.</td>
<td>• Excess electricity export to the grid.</td>
</tr>
<tr>
<td>• Boilers have been designed deliberately with low efficiency.</td>
<td>• Professional approach in project development.</td>
</tr>
<tr>
<td>• Purchase of used equipment are common.</td>
<td>• Use of special purpose company</td>
</tr>
</tbody>
</table>
Process Diagram for New Plant

STEAM AND ELECTRICITY SUPPLIED BY HIGH PRESSURE BOILERS AND EXTRACTION - CONDENSING TURBO-GENERATORS

Fuel

Steam Pressure 70 kg/cm²

Boiler

Demin Water

Extraction-Condensing Turbo-generator

Steam Transformer 1.0 kg/cm², 120°C

Sugar Process

Sugar

Condensate Tank

1.7 kg/cm², 130°C

G

41 MWe

In-house Factory

25-27 MWe

Sell to Grid

Condensate Water

Steam Transformer
## Major Technical Development

<table>
<thead>
<tr>
<th>Aspects</th>
<th>Previous</th>
<th>Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment Pressure Level</td>
<td>16-30 bar 380 °C</td>
<td>70-100 bar 520 °C</td>
</tr>
<tr>
<td>Boiler Efficiency</td>
<td>&lt; 80%</td>
<td>&gt; 90%</td>
</tr>
<tr>
<td>Plant Thermal Efficiency</td>
<td>&lt; 60%</td>
<td>&gt; 70%</td>
</tr>
<tr>
<td>Flexibility in load change</td>
<td>low</td>
<td>High</td>
</tr>
<tr>
<td>Multi Fuel Firing</td>
<td>no</td>
<td>Yes</td>
</tr>
<tr>
<td>Control System</td>
<td>Manual or Semi Auto</td>
<td>Full Computerized</td>
</tr>
<tr>
<td>Operators’ Skill</td>
<td>Fair</td>
<td>Trained &amp; Skilled</td>
</tr>
<tr>
<td>Project Management</td>
<td>Unorganized</td>
<td>Professional</td>
</tr>
</tbody>
</table>
Transformation from Sugar Power House to Biomass Power plant

**Before**
- Steam 16 bar
- New Boiler
- Steam 30 bar
- Steam Turbine
- T/G # 1, 2, 3, 4 (3, 2.5, 2.5, 5 MW)
- Steam 1 bar
- T/G # 5 (12 MW)
- Steam 70 bar
- New T/G (41 MW)

**After**
- Mechanical force to shredder and milling
- Sugar mill
- Sale to Grid 6 MW
- Sale to Grid 37 MW
- 12 kWh/ton cane
- 70 kWh/ton cane

Strictly Confidential, Internal Use Only
How does a High Pressure System Work?

Sugar Mill

- 280 kg. Bagasse
- 30 bar 380° C

- 0.65 ton steam @ 30 bar

Low Pressure Boiler and TG

- 1 ton Cane
- 36 kWh
- 0.45 ton steam @ 1.2 bar
- 23 kWh

Sugar Mill

- 280 kg. Bagasse
- 100 bar 510° C

- 0.65 ton steam @ 100 bar

High Pressure Boiler and TG

- 1 ton Cane
- 35 kWh
- 0.45 ton steam @ 1.2 bar
- 100 kWh
Energy Balance Comparison

High Pressure Boiler and TG
- Process Steam: 28.9%
- Process Used Power: 16.9%
- Exported Power: 5.9%
- Loss: 48.3%

Low Pressure Boiler and TG
- Process Steam: 41.7%
- Process Used Power: 6.1%
- Exported Power: 3.9%
- Loss: 48.3%
Current Status of Power Co-Generation of Thailand’s Sugar Mills

<table>
<thead>
<tr>
<th></th>
<th>Number of mills</th>
<th>Installed Capacity, MW</th>
<th>Exported Power, MW</th>
<th>Exported Unit, GWH</th>
<th>Sugar Cane, million ton</th>
<th>Exported Power, kWh/TC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total</strong></td>
<td>47</td>
<td>1008</td>
<td>397</td>
<td>1626*</td>
<td>95.35</td>
<td>17</td>
</tr>
<tr>
<td>With High Pressure</td>
<td>2</td>
<td>105</td>
<td>76</td>
<td>577</td>
<td>7.99</td>
<td>72</td>
</tr>
<tr>
<td>With Medium/low Pressure</td>
<td>45</td>
<td>903</td>
<td>321</td>
<td>1049*</td>
<td>87.36</td>
<td>12</td>
</tr>
</tbody>
</table>

*Estimated from these assumptions:
- SPP firm : 330 day running with 95% Plant Factor
- SPP non-firm & VSPP : 150 running day with 80% Plant Factor
- Countercheck with database from EPPO
Development of Bagasse Power Plants in Thailand

1992
First SPP regulation was announced

1994
First Biomass Power Plant supply to grid 8 MW non-firm by a sugar mill

2001
Start feasibility study of high pressure co-generation

2004
First high pressure (70 bar 510 °C co-generation in biomass power plant

2012
First 105 bar 520 °C co-generation in biomass power plant

First PPA achieving firm contract with 29 MW
What led to the change?

**OLD PARADIGM**
Biomass is free and have little commercial value

**NEW PARADIGM**
Biomass has high commercial value

- **Oil Price**
- **Renewable Energy Policy**
- **Fossil Fuel Crisis**
- **Electricity price**
- **Adder or feed in premium**
- **Affordable high eff. equipment**
- **CERs Price**
- **New Technology**
- **CDM Potential**
- **Climate Change**

**CDM Potential**

**Climate Change**
Favorable Environmental Impacts

Stack emission: Cleaner air
- Particulate: 20 - 50 ppm (120)
- NOx: 120 - 160 ppm (350)
- SOx: 0 - 8 ppm (320)

Solid waste: Recycle back to farm
ashes from boiler can be used as soil improvement substance.

Global Warming: Reduce green house gas
- Grid emission factor: 500 kg CO₂/ 1 MWH
Socio-Economic Benefits

- Increased business activities in the local community
- More jobs have been created
- Created value added to many agricultural waste
- New technology transfer to the industry
- Reduction of the nation’s import of fossil fuel for power generation
Challenges

Technical Challenges

Operational Challenges

Management Challenges

Financial Challenges
Technical Challenges: Seasoning Operation

<table>
<thead>
<tr>
<th></th>
<th>Crushing</th>
<th>Remelting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam Consumption, ton/hr</td>
<td>550</td>
<td>160</td>
</tr>
<tr>
<td>Power Consumption, MW</td>
<td>18</td>
<td>6</td>
</tr>
<tr>
<td>Bagasse Production, ton/day</td>
<td>8700</td>
<td>0</td>
</tr>
<tr>
<td>Operation Period, months</td>
<td>4 (Dec-Mar)</td>
<td>8 (Apr-Nov)</td>
</tr>
</tbody>
</table>

What capacity should the biomass power plant be?
## Technical Challenges: Technology Consideration

<table>
<thead>
<tr>
<th>Basic Design</th>
<th>Type of Boiler</th>
<th>Type of Turbine</th>
<th>Water System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firm vs Non-firm</td>
<td>Heat recovery system</td>
<td>Back pressure + condensing VS extraction condensing</td>
<td>Deminerization: Conventional Resin bed VS Reverse Osmosis</td>
</tr>
<tr>
<td>Bagasse fuel with or without supplementary fuel</td>
<td>Emission control system: wet scrubber, ESP, bag filter</td>
<td>Single shaft or dual casing turbine</td>
<td>Condensate return: Direct mix or separate water circuit</td>
</tr>
<tr>
<td></td>
<td>Supplemental fuel: rice husk, cane leaves, wood chips</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Operational Challenges: Priority - Internal vs. External

<table>
<thead>
<tr>
<th>Components</th>
<th>Sugar Mills</th>
<th>National Grid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process type</td>
<td>Batch + Continuous type</td>
<td>Continuous</td>
</tr>
<tr>
<td>Main parameter</td>
<td>Steam pressure and flow</td>
<td>Electrical Power</td>
</tr>
<tr>
<td>Load characteristics</td>
<td>High load variation</td>
<td>Stable load</td>
</tr>
<tr>
<td>Flexibility</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Maintenance period</td>
<td>Short</td>
<td>Long</td>
</tr>
<tr>
<td>Defaults Event</td>
<td>Negotiable</td>
<td>Penalty</td>
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</table>

Who should have the priority?
Operational Challenges: Fuel Handling System

- Fire protection
- Storage area
- FIFO system
- Moisture control
- Dust control
- Transportation
Operational Challenges: Supplementary Fuels

Rice husk
- High silica content
- High demand: competition with other rice husk users

Cane leaves
- High chloride content
- Difficult to handle: shredding, fire

Wood chips
- High lignin content
- Limit supply: competition with pulp mills
### Management Challenges

<table>
<thead>
<tr>
<th></th>
<th>Current</th>
<th>New Scheme</th>
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<tbody>
<tr>
<td>Main Concern</td>
<td>Internal production</td>
<td>External customer</td>
</tr>
<tr>
<td>Efficiency</td>
<td>Less priority</td>
<td>Major concern</td>
</tr>
<tr>
<td>Engineering</td>
<td>In-house</td>
<td>Out-source</td>
</tr>
<tr>
<td>Investment</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>People</td>
<td>Sugar industry</td>
<td>Power plant</td>
</tr>
<tr>
<td>• Recruitment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Compensations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Communication</td>
<td>Informal</td>
<td>Formal</td>
</tr>
</tbody>
</table>

Need a new management concept!