Western Forest Economists
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Biomass Energy Economics

Presented by
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John Martin
Background & Experience

• B.S. and M.S. Mechanical Engineering
• 42 Years in Thermal Power Systems
  - Gas Turbine Design
  - Electric Power Plant Design & Construction
  - Cogeneration
  - 15+ Biomass Power Projects - past 19 years
• At Pacific Energy Systems – 19 years
Pacific Energy Systems, Inc.

- Energy Consulting Firm
  - Industries
  - Utilities/Independent Power Producers
  - Colleges and Universities
  - Banks and Financial Institutions
- Focus on Electric Power and Steam Generation
- Extensive Experience with Biomass Energy
Biomass Energy Economics
Scope of Discussion

Large Industrial and Utility Energy Facilities
- Industrial Steam Systems (100,000 lb/hr & greater)
- Thermal Electric Power (10 to 50 MW)
- Combined Heat & Power (5 to 50 MW)
Brief Biomass Energy History
Large Industrial/Utility Systems

• Early 1900’s - District Heating and Power
• 1900’s to Present - Numerous applications - forest products
• 1950’s through 1980 - Fewer applications for power production (cheap electricity and fossil fuels)
• Late 1980’s - Resurgence based on mandated contracts
• After 1994 - few if any new plants
• 2000’s - Resurgence based on:
  ▪ Increasing cost of fossil fuels - oil and natural gas
  ▪ Global warming/greenhouse emissions
  ▪ Government mandate for renewable energy resources
Characteristics of Biomass Steam Systems

Capital - $5 to $15 Million
Fuel for 50,000lb/hr avg. - 65,000 green tons/yr
Efficiency - 70%+
Jobs - Fuel supply
Economic Development - local industry
Incentives(Oregon) - BETC’s, SELP, HB2210
Global Warming - Positive impact, if sustainable
Significant space for fuel storage and equipment
Additional operating staff compared to gas/oil
Non-fuel O&M Costs greater than gas/oil fuels
## Comparison of Steam Fuel Cost

<table>
<thead>
<tr>
<th>Factor</th>
<th>Natural Gas</th>
<th>Biomass b</th>
<th>Oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assumed Fuel Cost</td>
<td>$11.00 per MMBtu</td>
<td>$20.00 per Ton c</td>
<td>$3.00 per Gallon</td>
</tr>
<tr>
<td>Fuel Cost per MMBtu</td>
<td>$11.00</td>
<td>$2.14 b</td>
<td>$19.23</td>
</tr>
<tr>
<td>Assumed Boiler Efficiency</td>
<td>82.0%</td>
<td>72.0%</td>
<td>84.0%</td>
</tr>
<tr>
<td>Fuel Cost per 1,000 lb of steam</td>
<td>$13.41</td>
<td>$2.98</td>
<td>$22.89</td>
</tr>
<tr>
<td>Annual Cost - 50,000 lb/hr</td>
<td>$5,875,610</td>
<td>$1,303,200</td>
<td>$12,032,967</td>
</tr>
<tr>
<td>Annual Biomass Fuel Savings – 50,000 lb/hr Average</td>
<td>$4,572,410</td>
<td>Base</td>
<td>$10,729,768</td>
</tr>
</tbody>
</table>

a. Assumed steam condition 150 psia, saturated, and 1,000 Btu/lb of steam produced.
b. Based on 45% moisture and higher heating value of 4,688 Btu/lb wet.
c. Wood cost delivered at 45-percent moisture.
Biomass Fuel Cost Savings

Compared to Natural Gas ($11.00/MMBtu) and Oil ($3.00/gal)

Average Annual Steam Production of 50,000 lb/hr
Thermal-Electric Power Production

Fuel required for 40 MW – about 527,000 green tons/yr

Capital cost $90 to $110 million

Efficiency – 23%

Construction jobs – 40 to 80

Construct duration – 18 mo.

Jobs for plant operation – 21

Jobs for fuel production - numerous

Incentives– (Oregon) BETC’s, SELP and RPS, and Federal Production Tax Credits?

Global Warming- Positive, if sustainable

Requires about 20 acres minimum
Biomass Power Plant Characteristics

• Minimum Plant Size – 10 MW
• Maximum Plant Size – 50 MW
• Strong Economy of Scale Favors Larger Plants
  — Capital Cost
  — Operation & Maintenance Staffing Cost
  — Performance (More Efficient)
## Biomass Power Plant Fuel Requirement

<table>
<thead>
<tr>
<th>Plant Capacity MW</th>
<th>Heat Rate Tons/MWh&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Annual Fuel Tons&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>2.0</td>
<td>165,000</td>
</tr>
<tr>
<td>20</td>
<td>1.70</td>
<td>280,000</td>
</tr>
<tr>
<td>40</td>
<td>1.60</td>
<td>527,000</td>
</tr>
</tbody>
</table>

<sup>a</sup> Based on a fuel moisture of 45% and a higher heating value of 8,400 Btu/lb dry.

<sup>b</sup> Based on the design output, heat rate, and an annual capacity factor of 94%.
Fuel Cost, O&M Cost, and Profit Margins
Biomass Power Generation-$/MWh

- Estimated Market Price of Electricity-$70.00/MWh
- Maximum Fuel Cost
  - 10 MW Plant
  - 20 MW Plant
  - 40 MW Plant
Electrical Heat Rate Efficiency

- Natural gas combined-cycle: 7,500 Btu/kWh, 45.5%
- Coal-fired steam-electric: 10,000 Btu/kWh, 34.1%
- Biomass-fired steam-electric: 15,000 Btu/kWh, 22.7%

Typical Thermal Power Plant Efficiencies

- Thermal Power Plant: Electrical Power 25% to 40%, Waste Energy 60 to 75%
- Fuel: 100%
Combined Heat & Power Production

Fuel for 200,000 lb/hr steam & 5 MW? About 280,000 ton/yr @ 45% Moisture.

Capital cost $20 to $40 million

Efficiency – 70%

Construction jobs – 40 to 80

Construct duration – 18 mo.

Jobs for plant operation – 10

Jobs for fuel production - numerous

Incentives – (Oregon) BETC’s, SELP and RPS. Federal Production Tax Credits?

Global Warming- Positive-if sustainable

Requires between 10 and 15 acres
Biomass High Efficiency CHP Advantages

- Lower Capital Cost
- Lower Operation & Maintenance Costs
- Higher Efficiency for Power Generation

<table>
<thead>
<tr>
<th>Annual Fuel-Tons</th>
<th>Steam Produced</th>
<th>Estimated Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>165,000</td>
<td>100,000 lb/hr</td>
<td>2,450 kW</td>
</tr>
<tr>
<td>280,000</td>
<td>200,000 lb/hr</td>
<td>5,700 kW</td>
</tr>
<tr>
<td>527,000</td>
<td>392,500 lb/hr</td>
<td>11,200 kW</td>
</tr>
</tbody>
</table>
Typical Power Plant Efficiencies

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Thermal Power Plant</th>
<th>Useful Thermal Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>25% to 40%</td>
<td>40% to 50%</td>
</tr>
<tr>
<td></td>
<td>60% to 75%</td>
<td>25 to 35%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Heat Rate</th>
<th>Electrical Efficiency</th>
<th>Overall Efficiency</th>
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<tr>
<td>Natural gas combined-cycle</td>
<td>7,500 Btu/kWh</td>
<td>45.5%</td>
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<tr>
<td>Coal-fired steam-electric</td>
<td>10,000 Btu/kWh</td>
<td>34.1%</td>
</tr>
<tr>
<td>Biomass-fired steam-electric</td>
<td>15,000 Btu/kWh</td>
<td>22.7%</td>
</tr>
<tr>
<td>Biomass-fired CHP</td>
<td>8,500 Btu/kWh</td>
<td>40.1%</td>
</tr>
</tbody>
</table>
Funding and Incentives

• Oregon Business Energy Tax Credit (BETC’s)- Tax credit of 50% of qualified costs.
• Oregon Bio-fuels Act of 2007 (HB 2210)- $10.00 per green ton transferable tax credit for “collectors” of waste biomass used for fuel.
• Oregon State Energy Loan Program (SELP)
• Oregon Renewable Portfolio Standard (RPS)
• Energy Trust (Oregon)
• Climate Trust
• Federal Energy Production Tax Credits?
Important Conclusions

• Biomass energy is an important economic resource.
• High efficiency biomass CHP is very attractive from an economic and energy efficiency prospective.
• Neutral greenhouse gas if done sustainably.
• Development of biomass energy systems will depend on the a robust and reliable biomass fuel supply-target price between $20.00/BDT and $40.00/BDT.
• Biomass energy systems are very capital intensive.
• Biomass O&M is higher than other fuels.
• Large incentives for collectors of fuels/feedstock.
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Thank You!

John R. Martin