Energy Efficiency Considerations

The Future of the Hardwood Lumber Industry Conference

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Presentation Overview

• CHP opportunities

• Boiler opportunities

• Steam distribution system opportunities

• WERC Wood Energy Technical Assistance Team
Menominee Tribal Enterprises Biomass CHP District Energy System

- $3.8 M project cost
- $0.5 M annual savings
- 85,000 mmBtu/yr wood use (100% of demand)
- 1,000 MWh renewable electric generated (24% of demand)
- 115 tons PM reduction

- ~2,000 lf underground steam and hot water piping
- 7 buildings / 150,000 sf connected / 6 dry kilns
- 25 and 9 mmBtu/hr biomass boilers
- 190 kW backpressure steam turbine
Key project components

- Residual storage (bark, dust, chips)
- 8.5 mmBtu/hr boiler
- 270# steam
- 20# steam
- 190 kW turbine/generator
- Electric
Thermally-led CHP can provide electric at <\$0.02/kWh \text{\ (energy cost)}\n
Commercially Available Closed Cycle Biomass Power Generation Options

• Backpressure steam (~5-10% electrical efficiency)

• Organic Rankine Cycle (~15-20%)

Tips:
• Use behind the meter to maximize value of electric generated
• Year-round load helpful to economics
• Lower quality heat needed onsite = better CHP potential
Sizing based on detailed load modeling

Daily average thermal demand (mmBtu/hr) is typically what can reasonably be modeled with available data.

**Useful data:**
- Fuel use records/bills
- Recorded heat production
- Portable Btu meter
- Building or process model
- Operating parameters
- Local weather data
CHP word of caution - oversizing

- Many idle turbines at plants
- BPS turbine trips out when dropping below ~25% of capacity
- Sizing needs to understand this
Boiler Opportunities

• Improve efficiency to save money, reduce emissions
  – Combustion controls
  – Boiler tunings
  – Minimize operating pressures

• Fuel flexibility
  – Use the least valuable residual
What is wood?

<table>
<thead>
<tr>
<th>Constituent</th>
<th>% by Weight (dry basis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon (C)</td>
<td>47.1 – 51.6</td>
</tr>
<tr>
<td>Hydrogen (H)</td>
<td>6.1 – 6.3</td>
</tr>
<tr>
<td>Oxygen (O)</td>
<td>38.0 – 45.2</td>
</tr>
<tr>
<td>Nitrogen, Potassium, Calcium, Phosphorous, Sulfur, Magnesium, etc.</td>
<td>~1.0</td>
</tr>
</tbody>
</table>

Approximately 76-86% is volatiles (e.g. methane, other hydrocarbons)
Wood Boiler Tunings
Goal Is Two-Stage Combustion

• Gasification Stage = low O2/temp
  – Flue gas recirculation
  – Control of air / temp

• Combustion Stage = high O2/temp
  – Time / Temp / Turbulence
  – Control of air / temp

Image courtesy Viessmann USA
Major emissions issues – smoke / permitting issues

Boiler lacks ability to control combustion – measured efficiency of ~25%

Lack of automation requires full time boiler operator

20,000 tons residuals per year used
Added Boiler Control System for ~$200,000

- Seal combustion chamber and fuel feed (air lock)
- Control fuel feed based on maintaining steam pressure and control air based on fuel feed
- Control ID fan to maintain slight negative pressure in firebox
- Conservative 10% point increase in efficiency by reducing excess air from 1,000% to 100%

- Image of boiler running after system install
- Reduced fuel use by over 5,700 tons/yr
- Savings of $160,000/yr
- Conservatively under 1.5 yr payback
WV Sawmill Situation

- Major emissions issues – black smoke / permitting issues
- Using dust valued at ~$25/ton
  - Bark sold for $6/ton
- Boiler lacks ability to control combustion – estimated efficiency of ~38%
- Safety issues with sparks leaving boiler through stack and out of gaps in combustion chamber
Added Combustion Control for $75,000

- Seal leaks in combustion chamber
- Install new motors and VFDs on
  - fuel feed, ID fan, combustion air fans
- Reduce open tubes in cyclone
- Control scheme
  - Run ID fan to maintain slight negative pressure in combustion chamber (safety fix)
  - Match fuel feed to maintain steam pressure
  - Match combustion fans to fuel feed
- Increased boiler efficiency by 20% points, reduces fuel use from 8,100 to 5,300 tons per year or $70,000 in savings

Boiler tuning and maintenance are important

Follow up tuning two years later showed baffles on cyclone removed, ash blocking combustion air openings in firebox, O2 readings ~20.6%
Wood Boiler Tunings

- Only boilers with ability to control combustion can be tuned and have it stick for a reasonable period of time.
- Must be able to match fuel feed to heat demand, and air flow to fuel feed.
- Recommended that boiler operators have a combustion analyzer (~$1,000).

Please Note: Efficiency number from combustion analyzer is not efficiency over time.
Wood Boiler Tunings - Savings

- A 10% change in excess air is 1% point efficiency

- Example
  - Assuming increase from 60-70%
  - 10,000 tons at $20/ton = $200,000/yr boiler fuel
  - Drops to 8,570 tons = $171,400/yr boiler fuel
  - ~$29,000 savings

- If boiler does not have combustion controls, regular tuning can save more than this
VA Manufacturing Plant with Dry Kilns

- Manual control of fuel feed to maintain steam pressure at boiler ~90 psig
- ID fan set high to match full fuel/air rates
- Steam pressure immediately reduced by PRV to 30 psig and sent to kilns (600,000 fbm)
Lack of Control Results

- Relief valves on boiler blowing off (see pic)
  - Estimated 4.8 mmBtu/hr or ~$20/hr
- Higher steam pressure than needed
  - ~2% points eff
  - $6,000 lost per year
- Operator time spent in boiler room
- Excess air is too high virtually all the time (big loss, but difficult to estimate)

Residual value is $28/ton for 15% MC wb dust (14.6 mmBtu/ton)
Steam Distribution Opportunities

• Reduce operating pressure
  – 40°F of stack temp = 1% point efficiency
• Steam leaks typically paybacks well under 2 years
• Condensate leaks typically have paybacks well under 4 yrs
• Insulation of steam piping typically has a payback on the order of 1 year
• Insulation of condensate piping typically has a payback on the order of 2 years

Uninsulated condensate tank, with openings in the top

Energy loss of $4,600 annually, cost of fix at $8,000 ($20-25/ton residuals) at SC veneer mill
It is expensive NOT to track efficiency indicators!

Relatively Simple Things to Track

• Makeup water metering
• Fuel use tracking (can be tough)
• Combustion analyzer spot checks
• Boiler feed water metering (flow and temp)
WERC Wood Energy Technical Assistance Team

- Help Facility Owners Evaluate and Implement Wood Energy Projects

- Technology and Vendor Neutral

http://www.na.fs.fed.us/werc/
## WERC Wood Energy Technical Assistance Team Results

<table>
<thead>
<tr>
<th>Item</th>
<th>Annual Value</th>
<th>25-yr Value</th>
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</thead>
<tbody>
<tr>
<td>Projects Implemented</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>Annual Energy Usage Evaluated, mmBtu</td>
<td>1,015,967</td>
<td>25,399,183</td>
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<tr>
<td>Fuel Oil Gallon Equivalents, gallons</td>
<td>7,256,909</td>
<td>181,422,735</td>
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<tr>
<td>Heating Cost for Evaluated Facilities</td>
<td>$9,349,033</td>
<td>$233,725,830</td>
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<tr>
<td>Combined Costs of Projects</td>
<td>$66,299,462</td>
<td>$66,299,462</td>
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<tr>
<td>Operational Savings Achieved</td>
<td>$5,857,346</td>
<td>$146,433,642</td>
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<tr>
<td>Electric Generated/Offset, kWh</td>
<td>6,306,972</td>
<td>157,674,300</td>
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<tr>
<td>Woody Biomass Utilization Achieved, green tons</td>
<td>84,081</td>
<td>2,102,019</td>
</tr>
<tr>
<td>Direct Impact to Local Forest Products Industry ($35/green ton)</td>
<td>$2,942,826</td>
<td>$73,570,649</td>
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<tr>
<td>Net CO2 Reductions, mtonne/yr</td>
<td>36,614</td>
<td>915,351</td>
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</tbody>
</table>

- Driver of efficiency in commercial wood energy systems
- Driver of district energy and combined heat and power
- Driver of improved hydronic design practices
- Driver of improved emissions profiles
# Example Steam Leaks

<table>
<thead>
<tr>
<th>Leak</th>
<th>Estimated Loss Rate</th>
<th>Energy Loss</th>
<th>Annual Cost of Makeup Water</th>
<th>Annual Cost of Steam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety Valve Blowoff</td>
<td>4,000 pph 11,511 gpd 172,662 gpy</td>
<td>4.76 mmBtu/hr 1,712 mmBtu/yr</td>
<td>$691</td>
<td>$7,239</td>
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<tr>
<td>Keeler Boiler Room Header</td>
<td>29 83 30,460 0.03 301</td>
<td>$122</td>
<td>$1,272</td>
<td></td>
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<tr>
<td>PRV Bypass</td>
<td>5 14 5,252 0.01 51</td>
<td>$21</td>
<td>$215</td>
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<tr>
<td>DA Vent / Relief Valve</td>
<td>75 216 78,777 0.09 780</td>
<td>$315</td>
<td>$3,298</td>
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</table>
## Example Condensate Leaks

<table>
<thead>
<tr>
<th>Leak</th>
<th>Estimated Loss Rate</th>
<th>Energy Loss</th>
<th>Annual Cost of Makeup Water</th>
<th>Annual Cost Energy Loss</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>gpm</td>
<td>gpd</td>
<td>gpy</td>
<td>Btu/hr</td>
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<tr>
<td>IBC Boiler Trim</td>
<td>0.5</td>
<td>720</td>
<td>262,800</td>
<td>0.0006</td>
</tr>
<tr>
<td>Combined Leaks Kiln Control</td>
<td>0.5</td>
<td>720</td>
<td>262,800</td>
<td>0.0006</td>
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