RECYCLING ENERGY: USING STEAM TURBINES TO CONVERT BOILER WASTE INTO FREE ELECTRICITY

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Too many lumber drying mills leave $20 bills on the ground.

Economic theory says $20 bills are never on the ground: experience says otherwise.

Conventional dry kiln/sawmill design leaves dollars on the table by failing to convert energy waste into high-value electricity.
♦ Potential to generate zero-marginal cost electricity in most lumber mills.
♦ Reduce mill operating costs/boost mill profitability.
♦ Can be used to enhance reliability of mill electric supply.
♦ Can be used to enhance power factor of mill electricity
   (avoid $/kVAR charges, get more useful kWh/kWh purchase)
♦ Can create cost-effective means of mill waste disposal
♦ Reduces environmental impact of mill operations (eligible for $ support of CO₂ offsets in some cases).

Understanding 75% of U.S. Power Generation in 30 Seconds or Less.....

The Rankine Power Plant

Diagram of Rankine Power Plant
Understanding Lumber Mill Energy Plants in 30 Seconds or Less...

**Lumber Mill Energy Plant**

![Diagram of Lumber Mill Energy Plant]

**The Opportunity**

![Diagram of Steam Turbine Generator]

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Several Non-Intuitive Benefits of This Approach

The presence of the lumber kiln makes this generation ~3x as efficient as the central power it displaces.
- Average Rankine plant converts only 33 percent of fuel into useful energy - 2/3rds goes to cooling power.
- Use of heat in dry kiln eliminate this efficiency penalty.
- Ensures that marginal generation cost is always less than utility kWh.

Since 75% of the power plant is already built, the capital costs per kW installed are much less than central stations, despite the relative diseconomies of scale.
- 1,000 MW Rankine plant typical capital costs ~$1 billion ($1,000/kW)
- 1 MW steam turbine generator integrated into existing lumber mill typical capital costs ~ $500,000 ($500/kW)

Similar logic applies to non-fuel operating costs
- Rankine power plant typical O&M costs ~ 1 c/kWh
- Long term Turbosteam service contract on 1 MW unit ~ 0.1 c/kWh

Other Design Possibilities

If waste wood supply is able to produce more steam than is needed in kilns, can make economic sense to reduce pressure of some or all steam further in a condensing turbine-generator to make more lbs/kW

Value can be enhanced by boosting boiler pressure and/or reducing kiln pressure to increase kW production per lb of steam. (Often possible without modifying existing equipment simply by easing back on operating pressure margins built into existing designs).

**Condensing (C) Configuration**

**Backpressure/Condensing (BP+C) Configuration**

Generator can be designed to provide ancillary benefits in addition to kWh savings (e.g., enhance reliability, power factor).
Turbosteam has installed 102 Systems in the U.S., and 167 worldwide since 1986.

Eighteen of These Installations are in the Lumber and Wood Products Industries.
Cos Interior, Inc., is a Campbellsville, KY manufacturer of poplar, oak and cherry interior wood products. It was founded in 1983 and has 750 employees. They manufacture a variety of wood products (stairs, doors, mantels, etc.) in 500,000 square feet facility in Campbellsville, Kentucky. Wood-waste is combusted in boilers to raise steam for process thermal loads.

**Description of CHP Project**

- Four MW condensing turbine installed in 1990. Boiler operates on wood waste generated in plant to produce ~11.3 million kWh/year.

- One MW backpressure system installed in 2002 reduces 45,000 lbs/hr of steam from 235 psig/490 degrees F at boiler down to 30 psig to dry lumber (peak capacity = 1.4 million board-feet). Pressure to kilns is reduced to 15 psig in summer to boost turbine-generator power output per lb of steam.

- **Economics (backpressure only)**
  
  Total installed cost = $500,000
  Electricity generation in 2003=2,077,414 kWh
  Energy savings in 2003 = $120,490
  Twenty-three percent 15-year return on assets (projected)

- In total: on-site generation produces 61% of on-site power needs, saves $775,000 in expenses per year.

- Environmental bonus: displacement of dirtier generation from the grid reduces CO₂ emissions by 15,000 tons/year.

**A Final Observation on System Design:** The Key to a Successful Project is to Customize Equipment for Specific Site Objective.

Example: Midwest Steel Mill (now in design stage)
PRV reduces 900 psig steam down to 150 psig for plant-wide distribution
Our Approach is to Identify and Design to Customer-Specific Financial Objectives

1. Identify design with most rapid capital recovery
   • Below this flow, incremental gains in turndown efficiency are offset by sacrificed peak power and higher $/kW costs.
   • 180,000 lbs/hr design flow
   • 6.5 MW rated power output
   • $1.44 million/year annual savings
   • 2.2 year simple payback (46% ROA)

2. Identify design with highest annual energy cost savings.
   1. Above this flow, incremental gains in peak power production are offset by sacrificed low-end efficiency
   2. 275,000 lbs/hr design flow
   3. 10 MW rated power output
   4. 1.59 million/year annual savings
   5. 2.5 year simple payback (40% ROA)

These Points Bound the Financial Opportunity, but Do Not Identify the Optimum Financial Design

Optimal system is designed here to balance desires for rapid capital recovery, high annual cash generation AND effective use of free cash.
The Final Design Selected is Customized to Balance Technical, Financial and Operational Constraints

**Final Design**
- 7.8 MW
- 216,000 lbs/hr design flow
- 900 psig / 825 inlet => 150 psig exhaust

**Financial Performance**
- 45.6 million kWh/year generation
- $1.5 million/year annual energy savings
- 45% gross ROA
- 21% marginal ROA

**Key points**
- Good CHP plants are necessarily custom-designed
- Optimum design must factor in variable thermal loads, energy rates, financial objectives, turnover curves and subcomponent-vendors product limitations / "sweet spots"
- Designing strictly for a payback or cash generation runs the risk of leaving money on the table OR making poor use of final capital dollars.
- Similar logic applies to "power-first" CHP plants.
- Find a partner who has the ability to help you work through these design constraints.

So, Is There an Opportunity in Your Facility?

<table>
<thead>
<tr>
<th>Target Financial Return</th>
<th>Typical Values</th>
<th>Extreme Values</th>
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<tbody>
<tr>
<td>Inlet Steam Pressure</td>
<td>&gt;150 psig</td>
<td>15 psig</td>
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<tr>
<td>Pressure drop across turbine-generator</td>
<td>&gt;100 psig</td>
<td>15 psig</td>
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<tr>
<td>Steamflow</td>
<td>&gt;10,000 lbs/hr</td>
<td>2,500 lbs/hr</td>
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<tr>
<td>Annual steam load factor</td>
<td>&gt;6 months/year</td>
<td>3 months/year</td>
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<tr>
<td>Local electricity rate</td>
<td>&gt;4 c/kWh</td>
<td>&gt;1.7 c/kWh</td>
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