RECYCLING ENERGY: USING STEAM TURBINES TO CONVERT BOILER WASTE INTO ELECTRIC POWER

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TURBO STEAM

Creating Value from Steam Pressure

TURBO STEAM

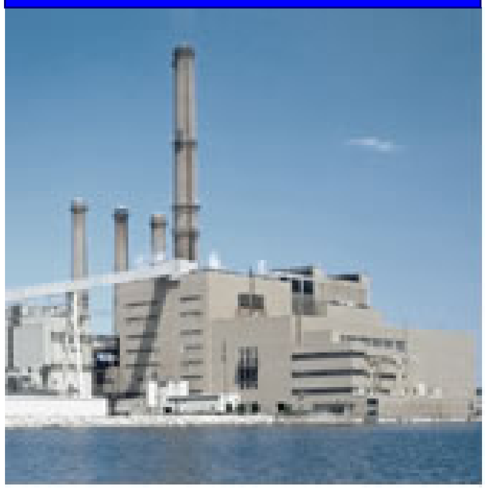
Too many lumber drying mills “leave $20 bills on the ground”.

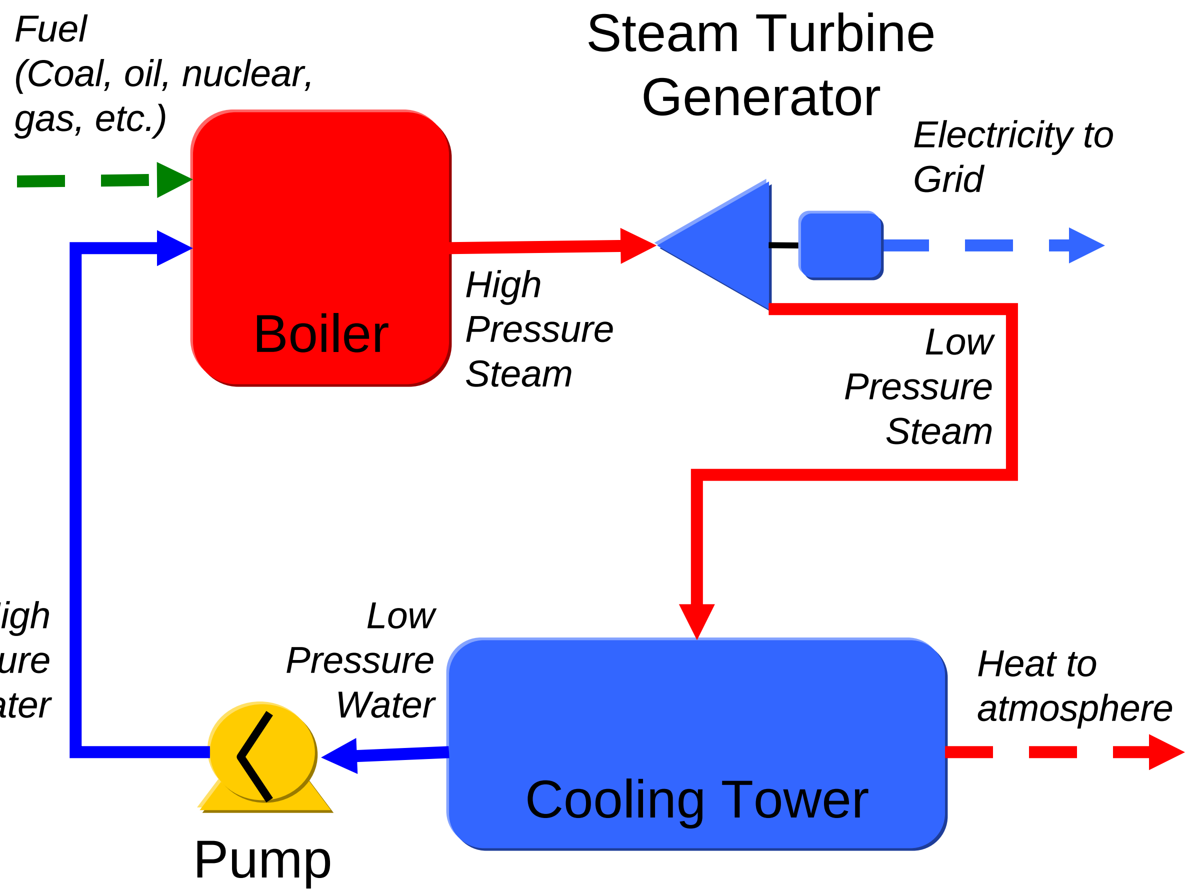
- Economic theory says $20 bills are never on the ground – experience says otherwise

- Conventional dry kiln/sawmill design leaves $ 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 from CO_2 offsets in some cases).

Understanding 75% of US power generation in 30 seconds or less…

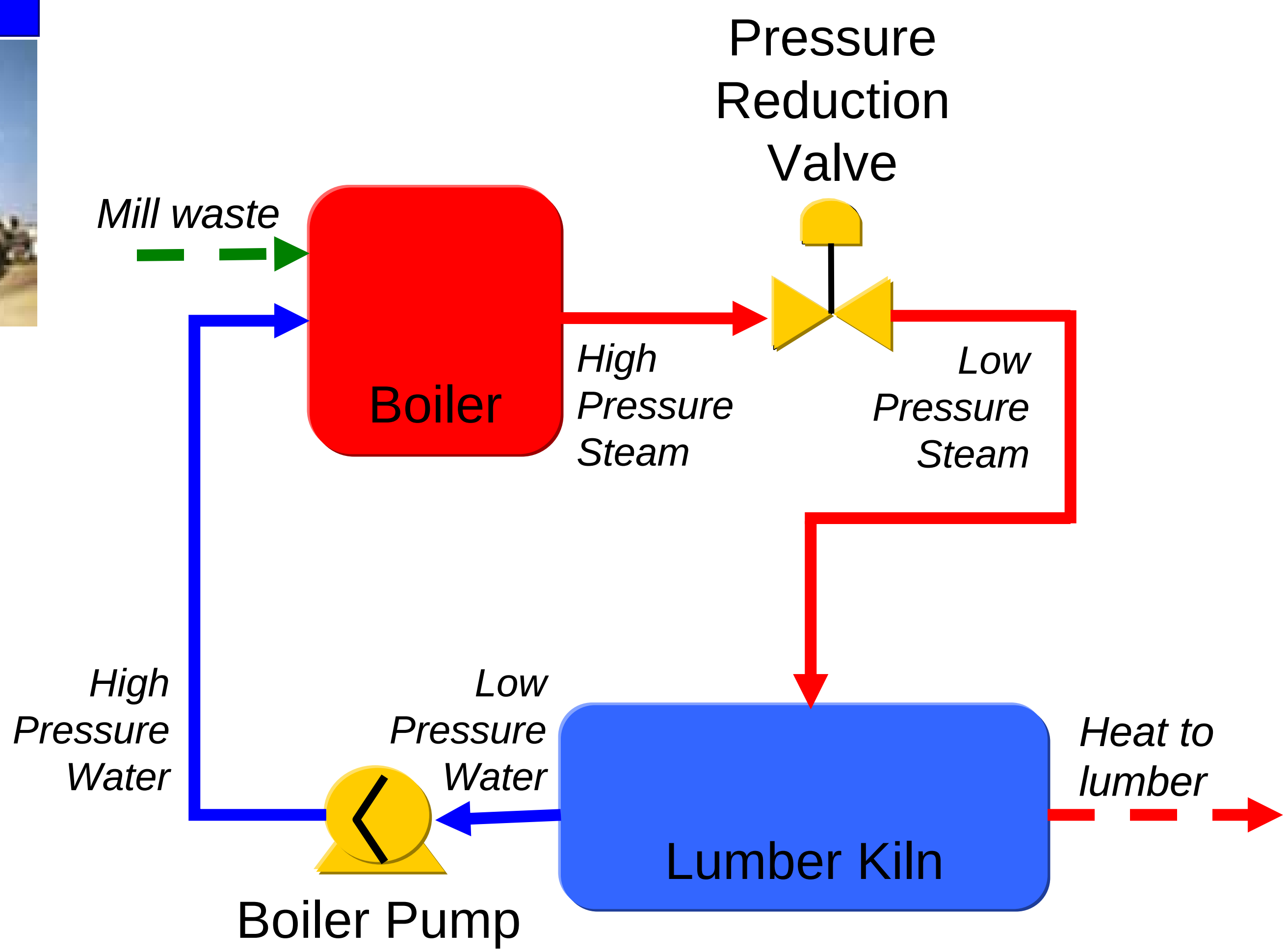
The Rankine Power Plant



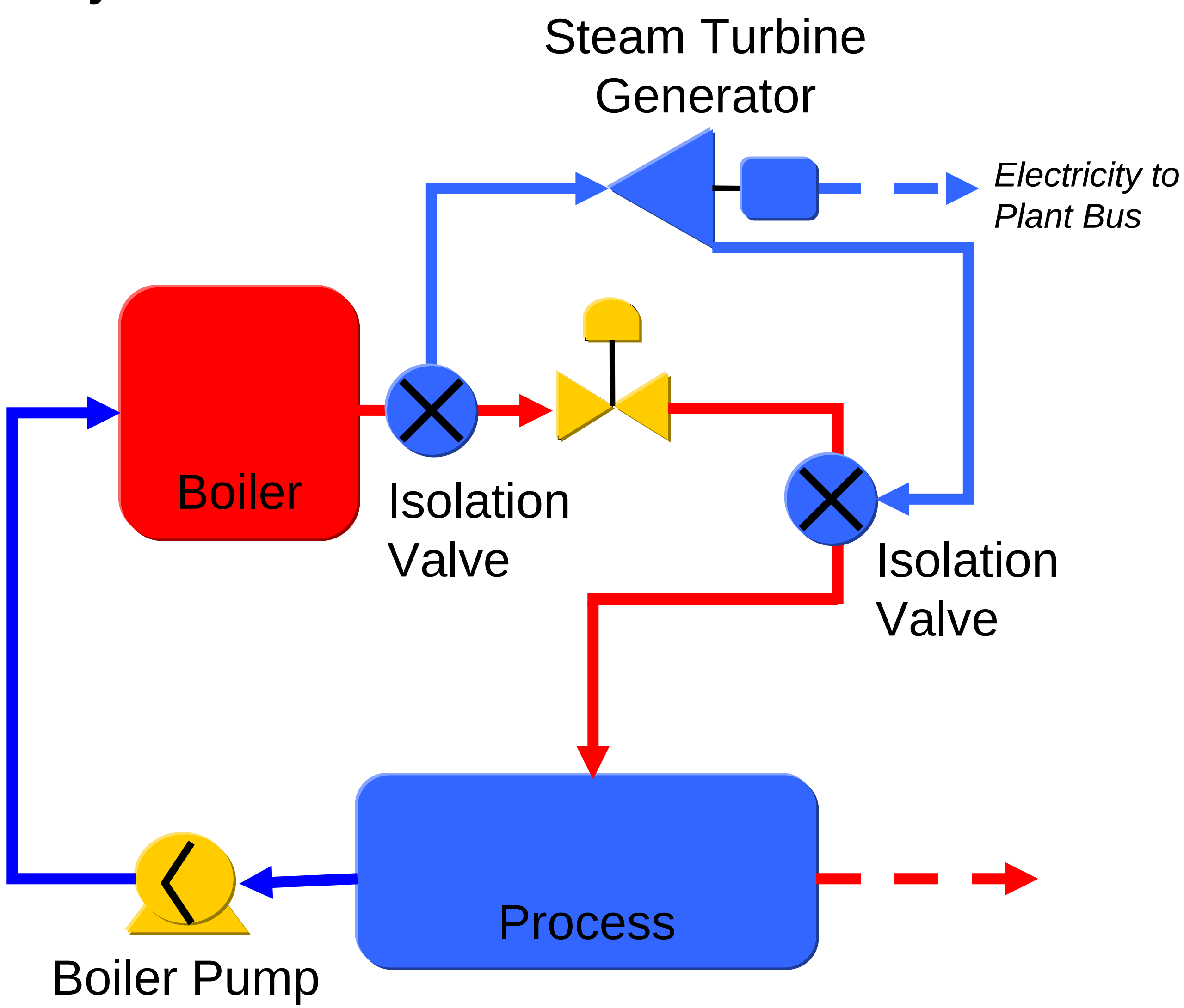


Understanding lumber mill energy plants in 30 seconds or less…

Lumber Mill Energy Plant



The opportunity



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% of fuel into useful energy – 2/3rds goes to cooling tower.
  - Use of heat in dry kiln eliminates this efficiency penalty
  - Ensures that marginal generation cost is always less than utility kWh.

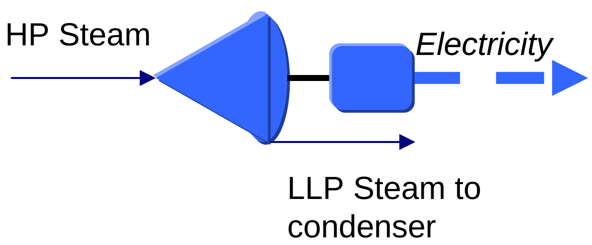
- Since 75% of the power plant is already built, the capital costs per kW installed are much less than central stations, despite the relative diseconomies of scale.
  - 1,000 MW Rankine plant typical capital costs ~ $1 billion ($1,000/kW)
  - 1 MW steam turbine generator integrated into existing lumber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

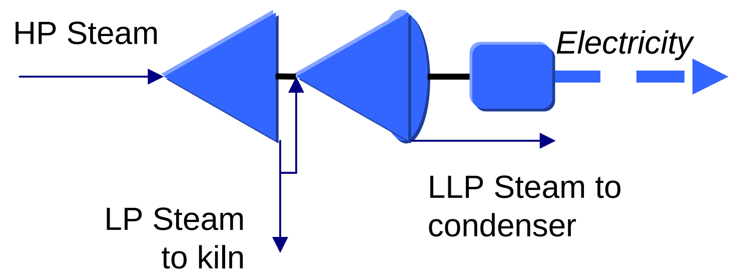
Other design possibilities

- 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

Condensing (C) Configuration



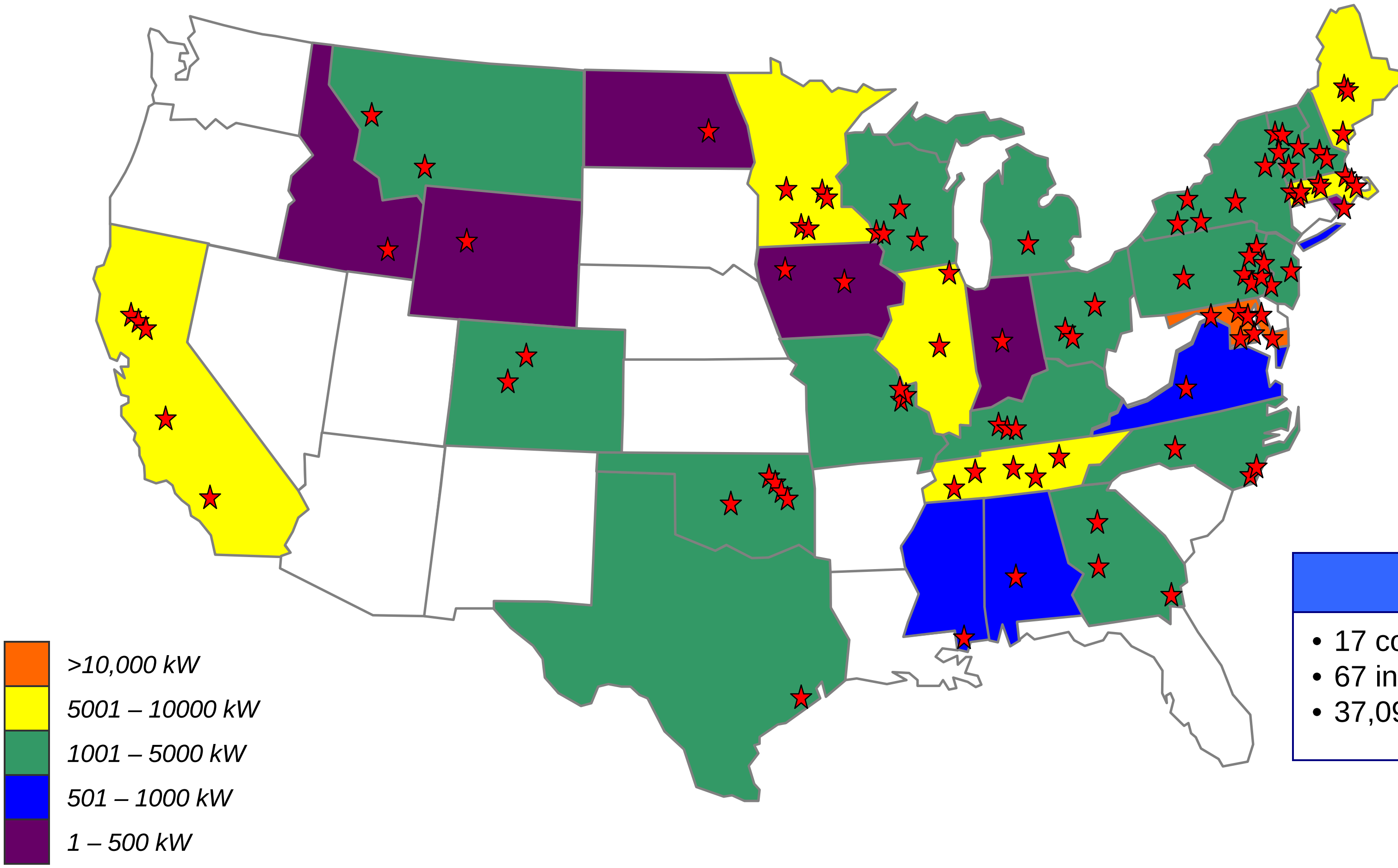
Backpressure/Condensing (BP+C) Configuration



- 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)

- Generator can be designed to provide ancillary benefits in addition to kWh savings (e.g., enhance reliability, power factor)

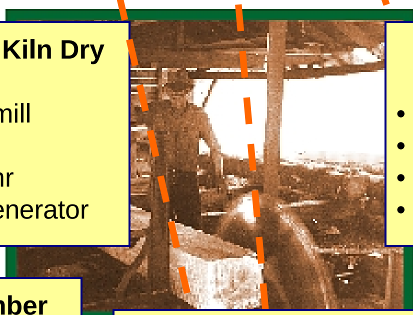
We have installed 109 systems in the U.S., and 176 worldwide.

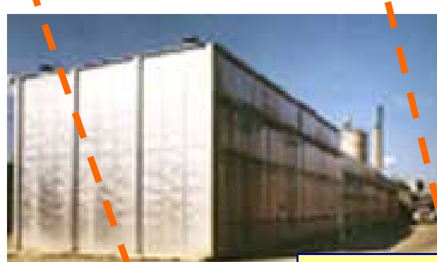


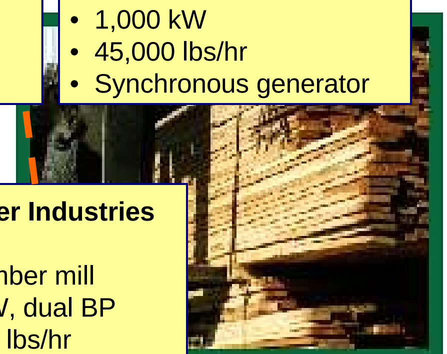
Non-U.S.
• 17 countries • 67 installations • 37,091 kW

18 of these installations are in the lumber and wood products industries.

1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001







Brattleboro Kiln Dry

- VT lumber mill
- 380 kW
- 18,000 lbs/hr
- Induction generator

Bell-Gates Lumber

- VT sawmill
- 75 kW
- 4,600 lbs/hr
- Induction generator

Young Mfg Company

- KY millworks facility
- 120 kW
- 13,000 lbs/hr
- Synch. generator

Aristokraft

- TN furniture mfr
- 825 kW BP+C design
- 34,000 lbs/hr
- Induction generator

Young Mfg Company

- KY millworks facility
- 200 kW
- 8,000 lbs/hr
- Synch. generator

Pompanoosuc Mills

- VT furniture mfr
- 50 kW
- 3,900 lbs/hr
- Induction generator

Bertch Cabinet Mfg

- IA cabinet mfr
- 279 kW BP+C design
- 15,525 lbs/hr
- Induction generator

Marcel Lauzon

- Quebec sawmill
- 335 kW BP+C design
- 17,000 lbs/hr
- Synch. generator

Bruce Hardwoods (2)

- TN flooring mfr
- 525 kW + 3250 kW
- 40,000 lbs/hr + 50,000 lbs/hr
- Synch. generators

Fitzpatrick & Weller

- NY furniture mfr
- 450 kW
- 24,150 lbs/hr
- Synch. generator

Buehler Lumber

- PA lumber mill
- 462 kW
- 20,700 lbs/hr
- Induction generator

Webster Industries

- WI lumber mill
- 550 kW, dual BP
- 27,600 lbs/hr
- Induction generator

Wightman Lumber

- NY lumber mill
- 96 kW
- 5,000 lbs/hr
- Induction generator

Cox Lumber

- KY hardwood products mill
- 1,000 kW
- 45,000 lbs/hr
- Synchronous generator

Cox Interior, Inc. is a Campellsville, KY manufacturer of poplar, oak and cherry interior wood products.

- Founded in 1983
- Manufactures variety of wood products (stairs, doors, mantels, etc.) in 500,000 sq. ft. facility in Campbellsville, KY
- 750 Employees
- Wood-wastes combusted in boilers to raise steam for process thermal loads

www.coxinterior.com

TURBO STEAM

Description of CHP project

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

- 1 MW backpressure system installed in 2002 reduces 45,000 lbs/hr of steam from 235 psig/490ºF 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 2004 = 2,077,414 kWh
  - Energy savings in 2004 = $120,490
  - 23% 15-year return on assets (projected)

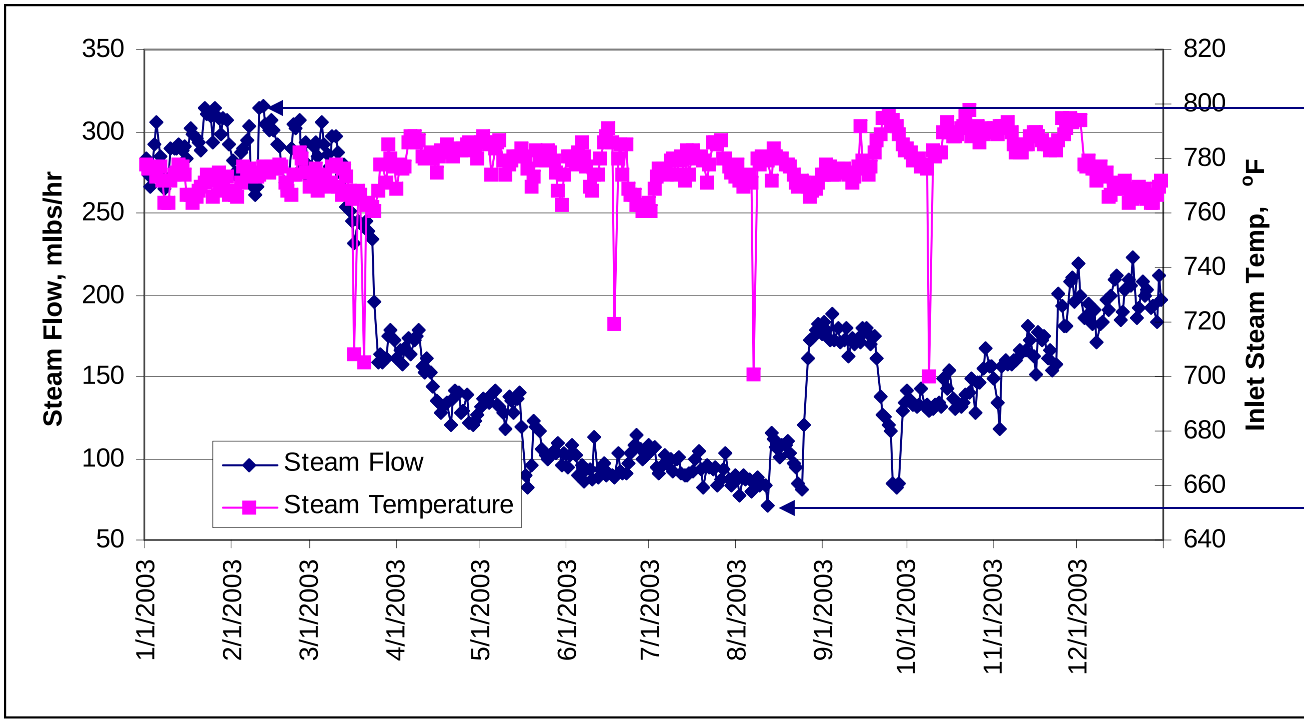
- In total: On-site generation produces 61% of on-site power needs, saves $775,000 in expenses per year.

- Environmental Bonus: Displacement of dirtier generation from the grid reduces CO_2 emissions by 15,000 tons/year

Cox Interior, Inc.
www.coxinterior.com

A final observation on system design: the key to a successful project is to customize equipment for specific site objectives.

Example: Midwest Steel Mill (Now in design stage)
PRV reduces 900 psig steam down to 150 psig for plant-wide distribution



Design for Peak flow?
- 11.9 MW rated power
- 43.3 million kWh/yr
- $1.4 million annual savings
- 3 year simple payback

Design for baseload?
- 2.4 MW rated power
- 21.0 million kWh/yr
- $672 K annual savings
- 2.7 year simple payback

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

- Above this flow, incremental gains in peak power production are offset by sacrificed low-end efficiency
- 275,000 lbs/hr design flow
- 10 MW rated power output
- $1.59 million/year annual savings
- 2.5 year simple payback (40% ROA)

The final design selected is customized for 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 <u>necessarily</u> custom-designed • Optimum design must factor in variable thermal loads, energy rates, financial objectives, turndown 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?

	Typical Values	Extreme Values
Target Financial Return	**<2 years simple payback from energy savings**	**Above-market returns and/or Non-financial drivers**
Inlet Steam Pressure	>150 psig	15 psig
Pressure drop across turbine-generator	>100 psig	15 psig
Steam flow	>10,000 lbs/hr	2,500 lbs/hr
Annual steam load factor	>6 months/year	3 months/year
Local electricity rate	>4 c/kWh	>1.7 c/kWh