TECHNOLOGIES FOR BIOMASS CHP

Presentation to
Northeast Regional Biomass Steering Committee Meeting
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TURBO STEAM

Creating Value from Steam Pressure

TURBO STEAM

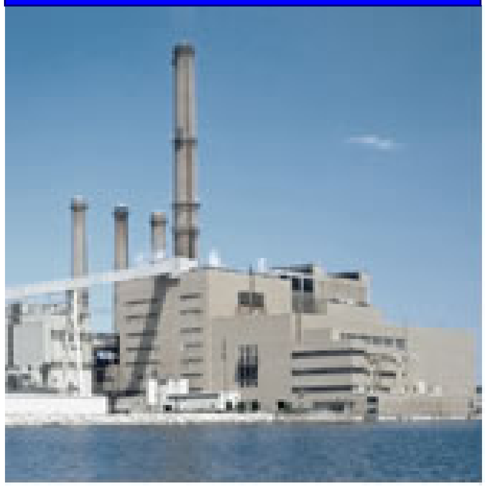
Some thoughts on biomass as a fuel for combined heat and power generation.

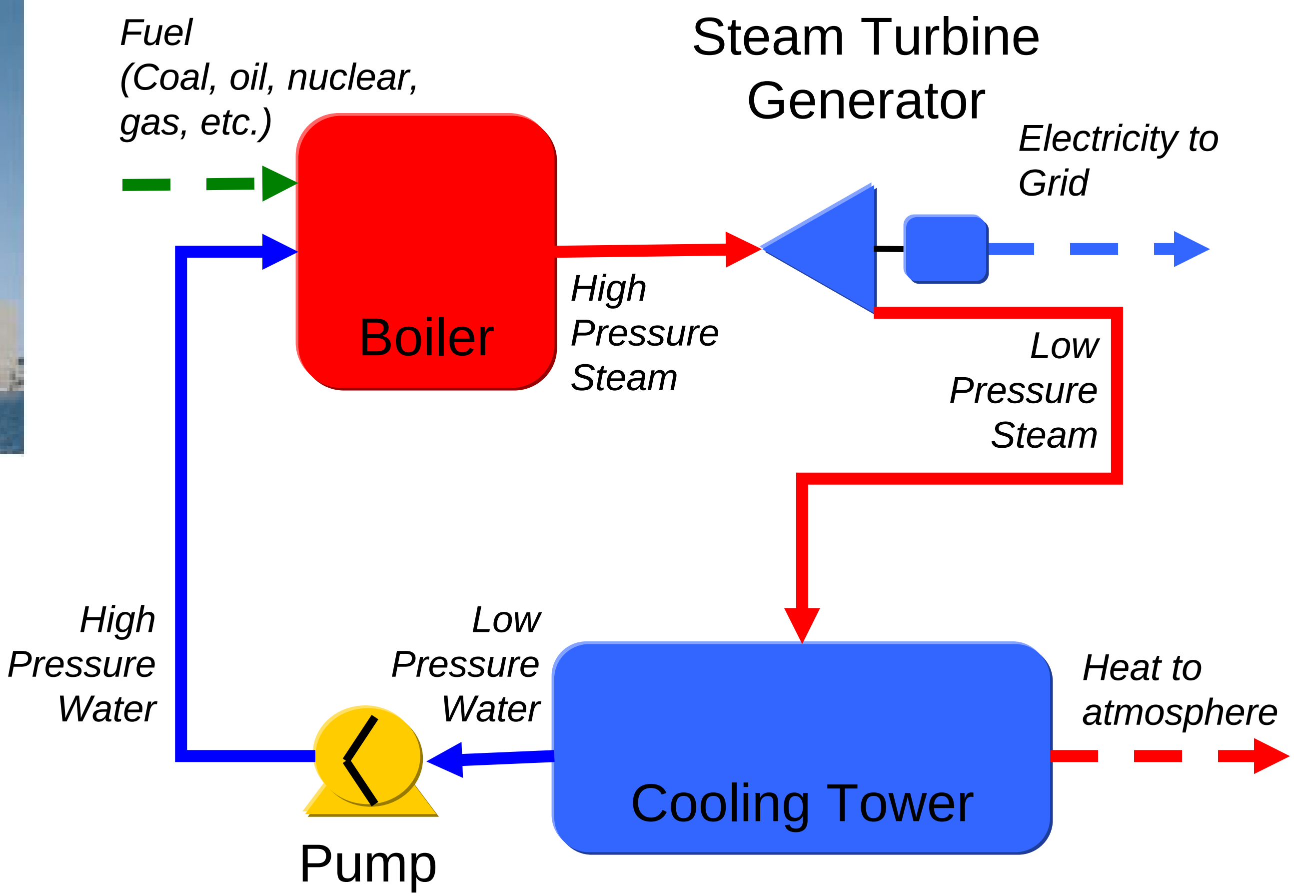
The Bad News	The Good News
• Without advances in gasifiers, you can't burn it in the sexy power generation technologies • Gas turbines • Fuel cells • Microturbines • Etc.	• The technologies biomass is suited to are also those used by the overwhelming majority of US power gen • 75% of all US power plants • 32% of all dedicated CHP plants

The "problem" with biomass is common to almost all opportunity fuels, all of which are becoming ever more economically attractive as fuel and electric costs rise.

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

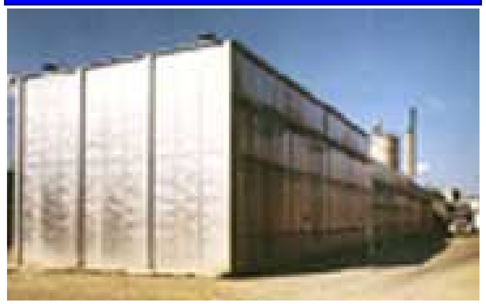
Rankine Power Plant

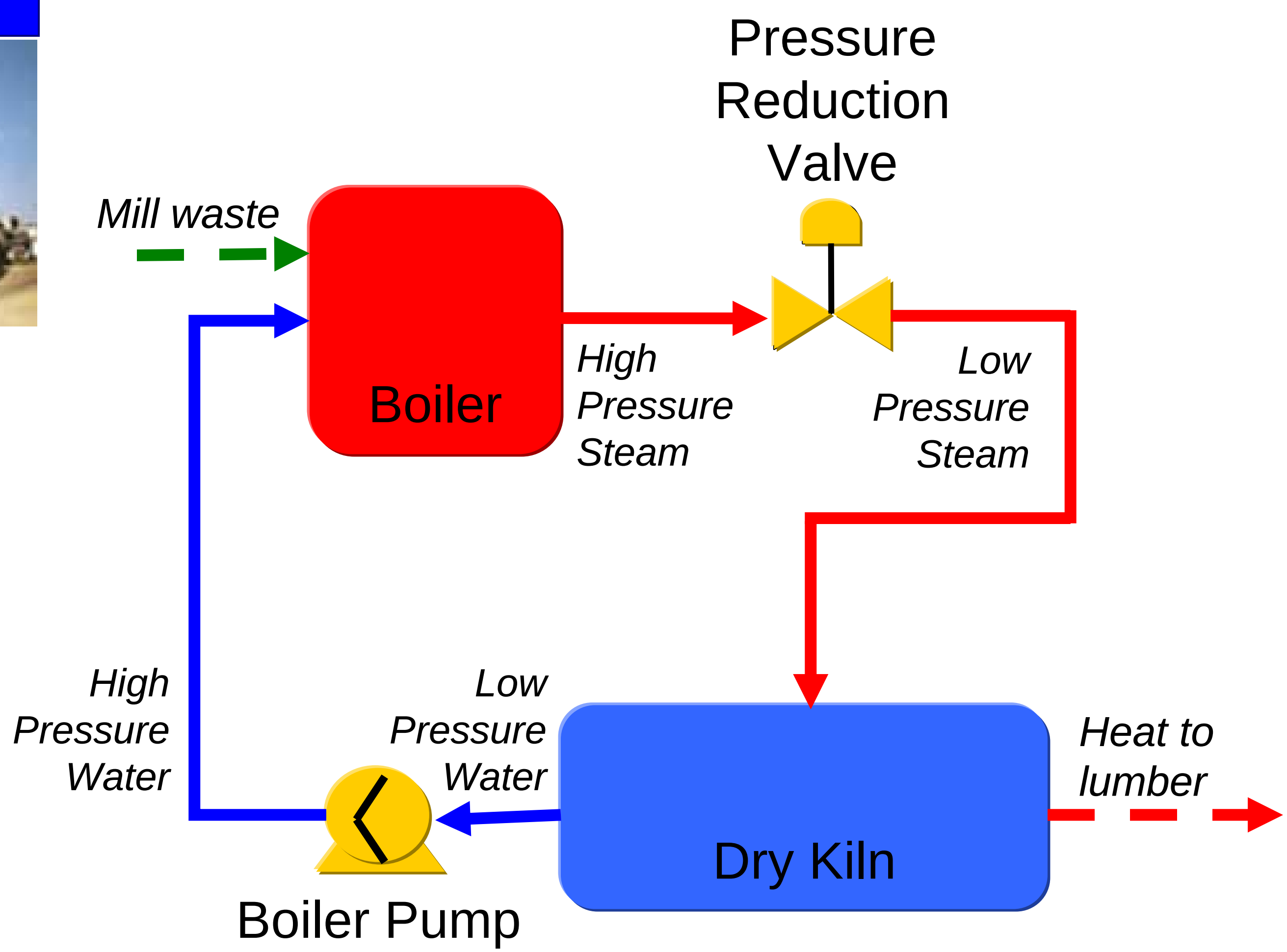




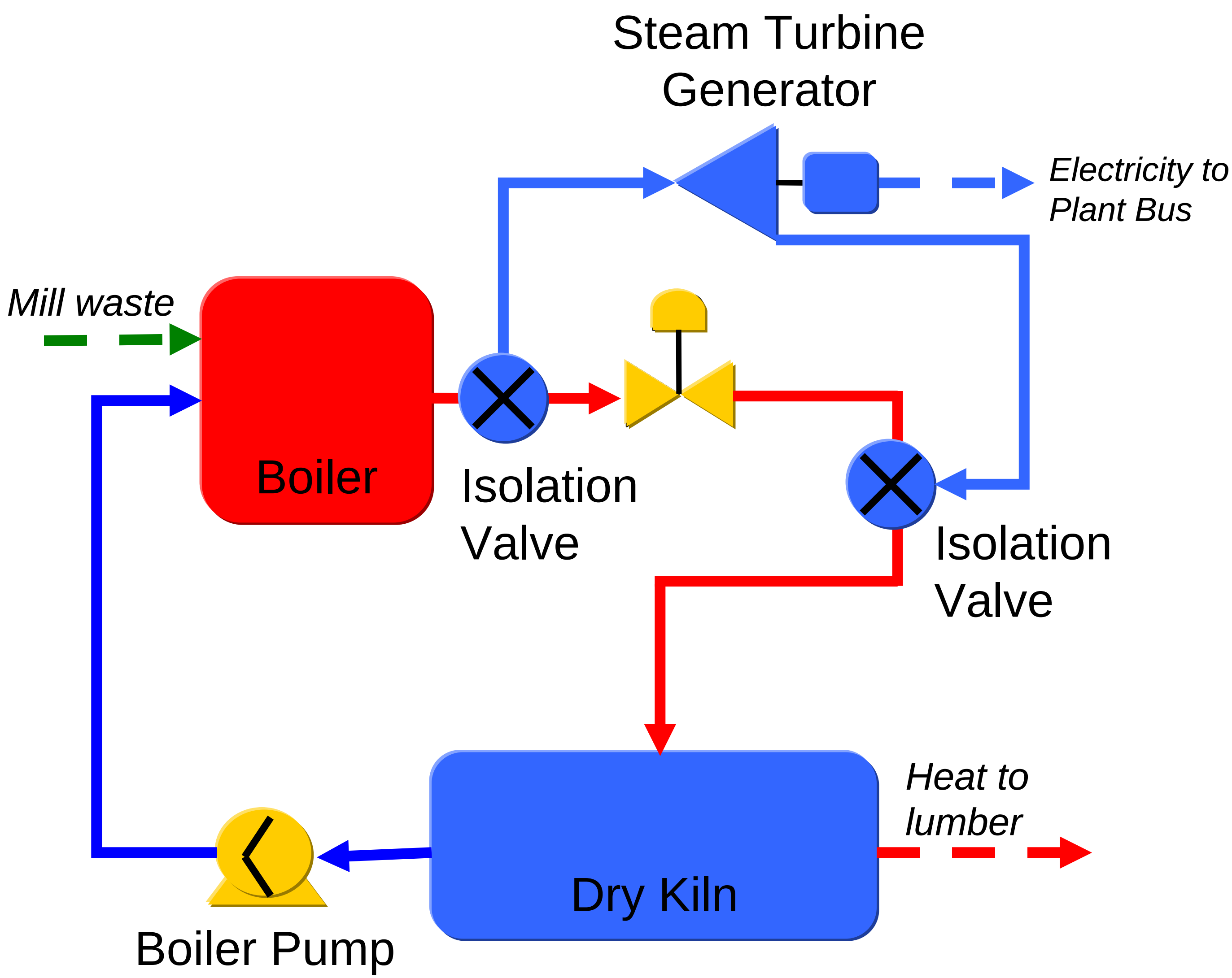
Understanding biomass thermal energy plants in 30 seconds or less…

Lumber Mill Energy Plant





The opportunity – convert H plants into CHP plants.



Several non-intuitive benefits of this approach.

- Operating Savings: The presence of the thermal load makes this generation ~ 3X as efficient as the central power it displaces.
  - More efficient than most other CHP technologies because all of input energy is recovered (comparable to a gas turbine that uses 100% of hot exhaust gas as hot air for a process).

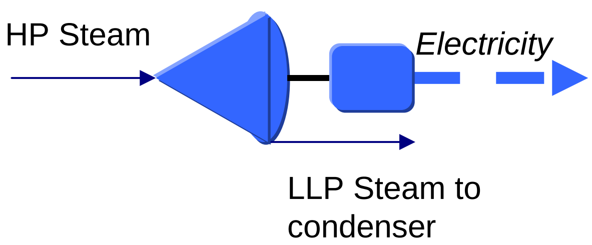
- Capital Savings: Since 75% of the power plant is already built, the effective (marginal) capital costs are quite low.
  - 1,000 MW Rankine plant typical capital costs ~ $1 billion ($1,000/kW)
  - 1 MW steam turbine generator integrated into existing facility typical installed capital costs ~ $500,000 ($500/kW)
  - Turbosteam has done fully installed systems for as little as $300/kW

- Similar logic applies to non-fuel operating costs, since most of Rankine cycle O&M are in the boiler and cooling tower. Turbine-generator O&M costs are negligible.
  - Long term Turbosteam service contract on 1 MW unit ~ 0.1 c/kWh

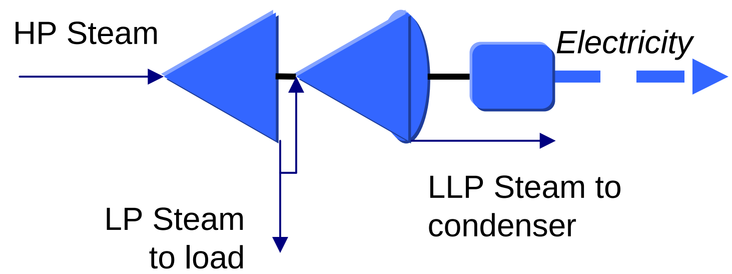
Steam turbines come in two flavors – with infinite variety: backpressure (BP) and condensing (CX).

- Thermal balance & fuel costs sometimes lead to excess steam in certain applications. When this happens, can make economic sense to combine BP and CX approaches to maximize power.

Condensing (CX) Configuration

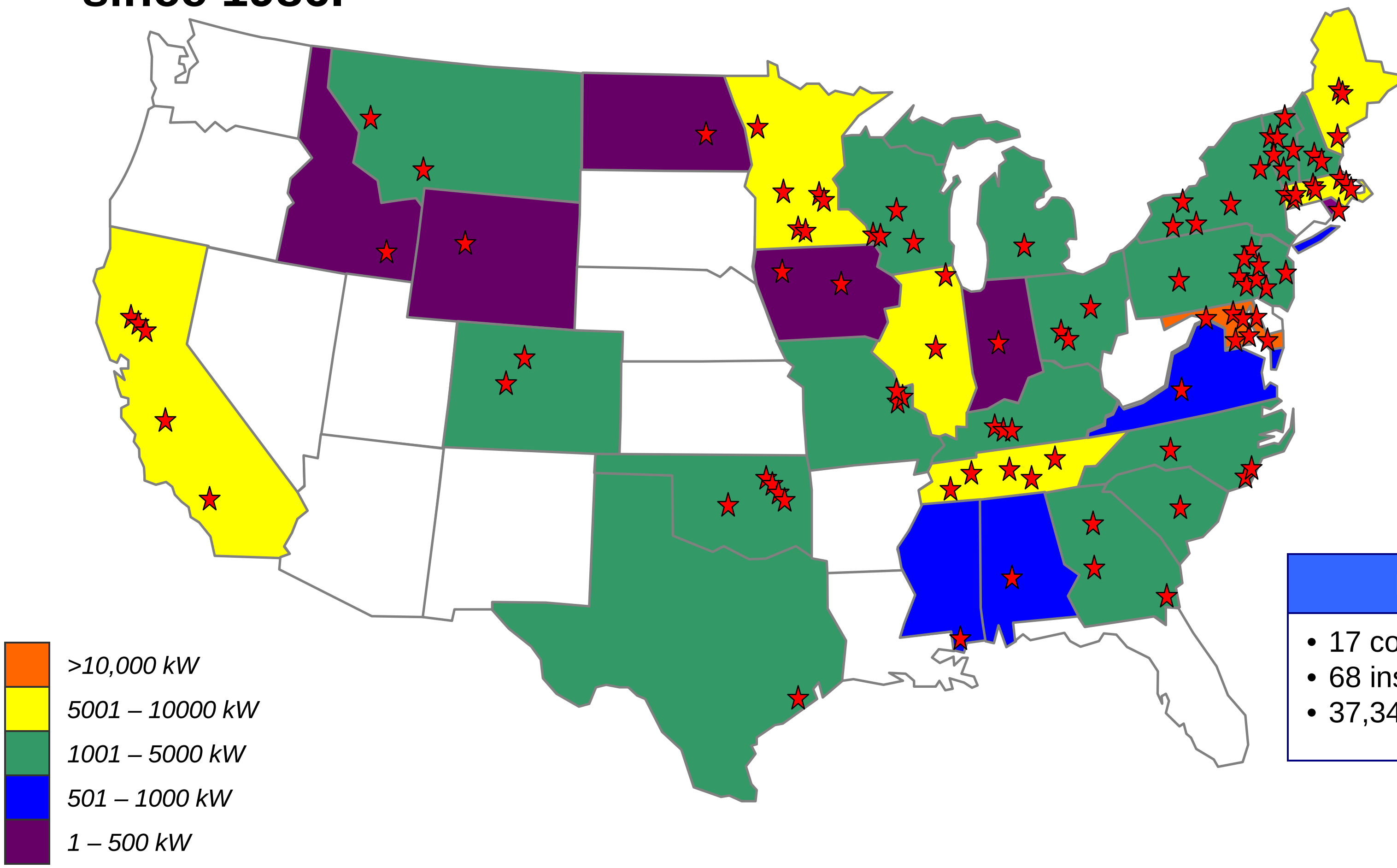


Backpressure/Condensing (BP+CX) Configuration



- Thermal plants are usually suboptimally designed for CHP. BPTG design often includes increases in boiler pressure and/or reductions in distribution pressure to boost power output. At the (confusing) extreme, this can enable condensing turbines in backpressure operation.
- Pure CX is NOT a CHP application, but can make economic sense where fuel is free/cheap.

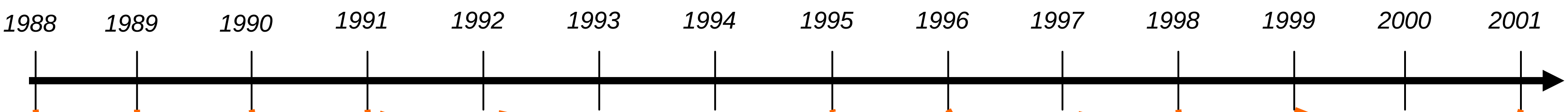
We have installed 112 systems in the U.S., and 180 worldwide since 1986.



Non-U.S.

- 17 countries
- 68 installations
- 37,343 kW

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



Brattleboro Kiln Dry

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

Pompanoosuc Mills

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

Marcel Lauzon

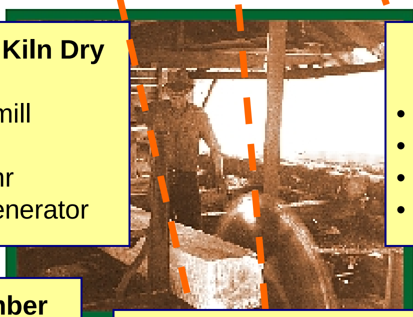
- Quebec sawmill
- 335 kW BP+C design
- 17,000 lbs/hr
- Synch. generator

Buehler Lumber

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

Wightman Lumber

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

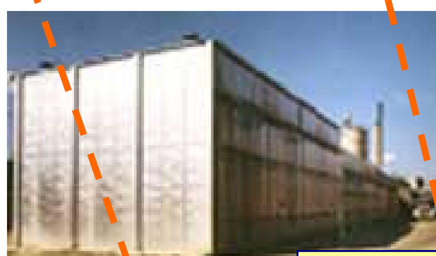


Bell-Gates Lumber

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

Aristokraft

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

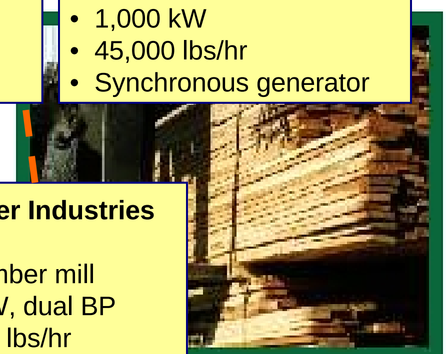


Fitzpatrick & Weller

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

Cox Lumber

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



Young Mfg Company

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

Young Mfg Company

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

Bertch Cabinet Mfg

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

Bruce Hardwoods (2)

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

Webster Industries

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

Not shown: Kendrick Forest Products (50 kW, IA) and Ethan Allen (616 kW, VT)

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Worldwide installations, by industry

Chemical/Pharmaceuticals	28
Food processing	22
Lumber & Wood Products	**20**
District Energy	19
Petroleum/Gas Processing	17
Colleges & Universities	16
Pulp & Paper	**11**
Commercial Buildings	11
Hospitals	8
Waste-to-Energy	**6**
Military Bases	5
Prisons	2
Textiles	1
Auto manufacturing	1

Capex & Opex Considerations

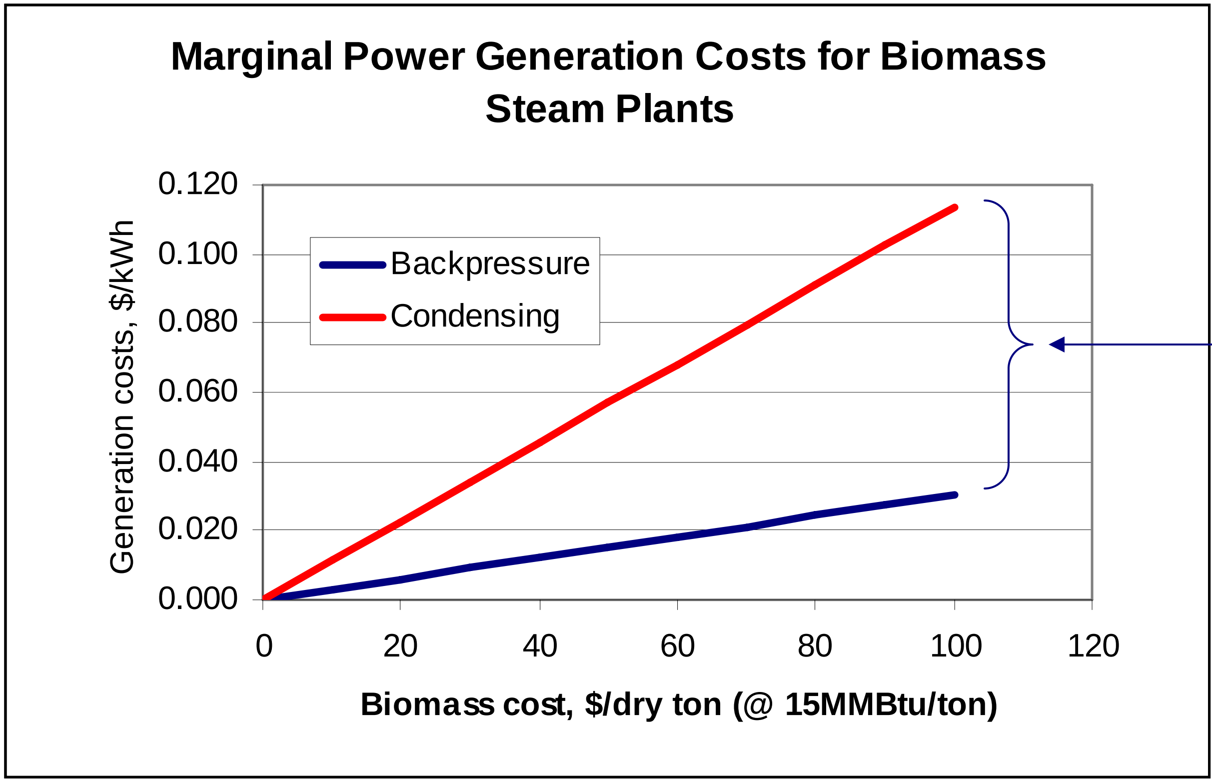
Capex

- >1 MW, STG costs are reliably $500/kW or less (below this level, fixed engineering costs predominate)
- Does not include boiler, condenser, piping costs. This alone makes the economics of backpressure much more compelling than condensers since the remaining infrastructure already exists.
- Compare: modern central power plant typically costs $500 – 1500/kW. T&D adds another $1300.

Opex

- For BP, fuel efficiency = boiler efficiency (75%+ in biomass applications).
- For CX, fuel efficiency is a direct function of inlet and exhaust pressure; at typical boiler pressures, efficiency is unlikely to exceed 20%.
- Compare to central power @ 33%. CX only favored when fuel is very cheap.
- Envt'l permitting tied to boiler; typically not required for BP applications
- Operator requirements usually tied to boiler (MA exception)

Marginal cost savings for backpressure and condensing steam turbine-generators.



Spread shows the value of heat recovery. As difference between these curves and elec value increases, more $ for cap recovery, profit, etc.

Assumptions: 75% efficient backpressure, 20% efficient condensing. Actual condensing efficiencies are quite variable; this is the high end for most biopower plants. Costs for fuel only; O&M and capital recovery not shown. Assumes 15 MMBtu/dry ton biomass energy density

A final idea – think like a CHP developer, and see how it changes your idea of how to make biopower work.

- Try not to chase PURPA. Displaced power purchases (e.g., size to less than or equal to facility load) make for much better overall project economics than power exporting generators.
  - Lots of rules of thumb about what biomass has to be to be economically competitive appear to undervalue the output energy.

- Calculate marginal generation costs, then see if you can justify capex. Don't "sell" projects based on your assumptions of capital costs & interest rates.
  - Give yourself the opportunity to be financially creative.

- Learn to love efficiency, including heat recovery.
  - Too many plants chase minimum efficiencies to get PURPA limits and leave $ on the table.

- In energy markets, economic self interest gets you to environmentally good things – but environmental concerns independent of $ get you to end-of-pipe controls and advanced technology. Learn to listen to your wallet.
  - Chase energy efficiency rather than tax credits – may boost long term economics even while it compromises short term incentives.
  - Cheap, proven technology is usually a better idea than expensive, unproven ones
  - The biggest opportunities are often in system-level designs, not component-level advances