Biomass Thermal & CHP
Project Feasibility Evaluation

MD Wood Energy Coalition Biomass Boot Camp

February 23, 2015

Dan Wilson, PE
Wilson Engineering Services, PC & BTEC

Presentation Overview

- Keys to evaluating project feasibility
  - Solving the thermal puzzle
  - Option development & analysis
    - Fuels, technologies, economics

- System sizing and design approach

- Example projects
Biomass benefits / Owner goals

- **Environmental and Social**
  - Renewable energy
  - Replace fossil fuel
  - Energy security
  - Markets for low-use wood (waste, forest residues)
  - Thermal/CHP is most efficient use of limited biomass resource
  - Considered carbon neutral

- **Economic**
  - Energy dollars stay local
  - Energy savings to owner

Piecing together the thermal puzzle, basis for feasibility evaluation

- Annual fuel use and cost
- Heat generation, distribution, and use
- Thermal load modeling
Tips:
- Ensure accurate accounting of current or projected annual fuel usage.
- Consider possibilities for future expansion or efficiency projects.
- Use reasonable fuel cost projections – no one really knows what fossil prices will be in the future.

How is the heat used? – Generation, Distribution, and Quality

Steam
- Temperature
- Pressure
- Uses (heating, humidification, etc.)
- Building or process operating schedule
- Allowable variance

Hot Water
- Required temperature
- Uses (pool, DHW, heating, laundry, drying, etc.)
- Building or process operating schedule
- Allowable variance

Forced Air
- Required temperature
- Required air flow
- Uses (heating, drying, etc.)
- Building or process operating schedule
- Allowable variance
Model the loads using all the puzzle pieces available – demand curve

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

Use portable metering equipment to help complete the puzzle

Measured 24-hr High School Heat Demand
With the thermal puzzle solved, now you need some biomass

- Biomass availability
  - What (type & quality), how much, what cost, sustainably available?
    - Opportunity fuels?

- Ask vendors and local/state resource agencies:
  - Fuel, quality, how much, what cost, sustainable?

- Where appropriate, perform a detailed resource assessment
  - Depends on system size and owner comfort with long-term availability

---

Look to add load (savings) with minor increases in capital cost
Thermally-led CHP can provide electric at $<0.02/kWh$ (energy cost)

Commercially Available Closed Cycle Biomass Power Generation Options
- Backpressure steam (~5-10% electrical efficiency)
- Organic Rankine Cycle (~15-20%)

Tips:
- Use onsite to maximize value of electric generated
- Year-round load helpful to economics
- Lower quality heat needed onsite = better CHP potential

Cooling - low cost heat / high electric cost

- Air Conditioning w/ Heat COPs (energy output / energy input)
  - Steam Turbine compressor = ~1.8
  - Absorption Chiller
    - Single-Stage (hot water or steam) = ~0.7
    - Two-Stage (steam) = ~1.3
  - Adsorption (hot water or steam) = ~0.7
  - Desiccant cooling (hot water or steam) = varies depending on climate [consumes water]
- Electric water cooled chiller COP = ~7
- Electric air cooled chiller COP = ~4

COP values presented are approximate for illustration purposes. Actual values vary widely depending on actual conditions.
Escalation Rates:
- Oil: -6.0%
- Wood: -2.7%
- General Inflation: -2.7%

Biomass District Heating (hot water), Plymouth, NH

- 16,000 lf underground hw piping
- 25 buildings connected
- 5 and 2 mmBtu/hr biomass boilers
- 4,000 gals thermal storage
- $4.5 M project ($0.3 M grants)
- Replace 95% annual fuel usage (fuel oil and propane)
- 4,800 thermal RECs annually
- $365,000 annual savings/REC revenue
- 1450 mtCO2/yr net carbon offset
Biomass boilers operate between 100 and 25% of rated capacity
~100% replacement with 23 mmBtu/hr & 13 mmBtu/hr wood boilers

Biomass Heating (Hot Water), Esopus, NY

• 165,000 sf Facility
• 4,2 mmBtu/hr & 1.8 mm Btu/hr Wood Chip Hot Water Boilers
• Two 2,500 gal Thermal Storage Tanks
• $2.22 Million Project Cost
• Replace 87,000 gal Fuel Oil/year (100%)
• 1,600 tons Wood Chips/year
• $271,300 Annual Energy Savings
Below-grade chip storage, rake reclaim system

1.8 & 4.2 mmBtu/hr hot water boilers

5,000 gallons thermal storage
Biomass boilers operate between 100 and 25% of rated capacity.  
85% replacement with 23 mmBtu/hr wood boiler.

### Thermally-led Biomass CHP District Heating (steam) – Lacrosse, WI

- 1,100,000 sf hospital complex
- 28 mmBtu/hr wood chip 450 psig steam boiler
- 350 kW steam turbine/gen set
- Replace 157,000 mmBtu gas per year (90%)
- 18,000 tons wood chips per year
- $470,000 annual energy savings ($6.5/mcf)
- 1,600 MWh/yr generated (9%)
- 9,500 mtCO2/yr net carbon offset

[www.na.fs.fed.us/werc](http://www.na.fs.fed.us/werc)
Thermal storage increases biomass thermal efficiency

Buffer between fluctuating load and biomass unit

Allows operation further into the shoulder months for space heating applications

Biomass Heating (Hot Water),
Berlin, NH

- 8,353 sf
- 2 - 0.2 mmBtu/hr Pellet Boilers
- 300 gal. Thermal Storage
- 12 ton Pellet Storage Room
- $90,000 pellet installation,
  $65,000 upgrade to HVAC system
- Replace 4,800 gal #2/yr (100%)
- 34 tons Wood Pellets/year
- $9,930 Annual Savings ($3.79/gal)
- 25.9 mtCO2/yr net carbon offset
300 bed medical center
- 20 mmBtu/hr biomass steam boiler, 450 psig
- 350 kW turbine
- 200 ton absorption chiller
- 15,000 tons biomass annually
- Replace 140,000 mmBtu/yr natural gas (90%)
- 1,600,000 kWh/yr renewable electricity
- $900,000 annual operating cost savings ($10/mcf gas, –now $8)
- 9,250 mtCO2/yr net carbon offset

Image Sources: VA, Wellons, FEI & IDEA 2011 – Woolpert Presentation

- 5.0 mmBtu/hr Wood Chip Boiler (150 psig)
- 40 kW Steam Turbine/Gen Set
- $3.0 Million Project Cost
- Replace 120,000 gal Fuel Oil /year (95%)
- Replace 5,000 gal Propane /year
- 1,900 tons Wood Chips/year
- $296,000 Annual Energy Savings ($3.25/gal)
- 137 MWh/yr Generated
Biomass District Heating (steam) – Rockingham, NH

- 300,000 sf of conditioned space
- 7 mmBtu/hr wood chip boiler
- $3.5 Million project cost
- Replace 250,000 gal fuel oil per year (81%)
- 4,000 tons wood chips per year
- $500,000 annual energy savings ($3.0/gal)
- 2,500 mtCO2/yr net carbon offset

- 37,000 gal/yr propane
- $0.6 Million project cost
- 530 tons wood chips per year
- $60,000 annual savings
- 210 mtCO2/yr net carbon offset
Summary

- Establish owner goals & focus scope of study
- Solving the thermal puzzle is the key to biomass thermal studies
- Identify fuel sources that are reliably available, plan for fuel flexibility
- Look for opportunities to make the best project
  - Adding loads, CHP, cooling, etc.