Overview of biomass heat systems in public buildings

Woody Biomass and Small Log Workshop:
From Feedstock to Product

September 19-20, 2007
College of the Siskiyous
Weed, California

Rob Williams
Biological and Agricultural Engineering
California Biomass Collaborative
University of California, Davis

Topics

- Estimated number of facilities in the US
- System components and conversion technologies
- Update on some 'Lessons Learned'
- Economics
- Emissions
- Conclusions and Recommendations
- References

Partial estimate of US public facility biomass boilers*

Facility Type	Number
Schools	**52**
Hospitals	**29**
Civic	**30**
Total	**111**

Selected Facilities*

Town	State	Building Type	Output Capacity (MM Btu/hr)	Year Installed
Rock	MI	School	3.2	1985
Kingsley	PA	School	10.8	1985
Moscow	ID	University	60	1987
Wakefield	MI	School	3.2	1987
Calumet	MI	High School	8	1990
Mt. Pleasant	MI	University	50	1990
Chaldron	NE	State College	8	1991
Dickinson	MI	School	2	1991
Paradise	MI	School	1.35	1991
Powers	MI	School	3.9	1993
Middlebury	VT	Courthouse	3	1994
Gardner	MA	College	8	2002
Darby	MT	K-12 school	3	2003
Saint Paul	MN	Whole City	Huge	2003
Phillipsburg	MT	School	3.9	2004
Victor	MT	School	2.6	2004
Ely	NV	School	3	2004
Newport	VT	Hospital	7	2005
Thompson	MT	School	1.6	2005
Council	ID	K-12 school	1.9	2006
Burns	OR	Hospital	0.8	2006
Bennington	VT	College	13.9	2007
Bismarck	ND	City offices	1	2007
Craig	AK	School & pool	4	2007
Eureka	MT	K-12 school	5	2007
Kalispell	MT	High School	6	2007
Kellogg	ID	School	2	2007
Troy	MT	School	0.7	2007
Dillon	MT	College	13.4	2007
Charleston	SC	University	72	2007
Browning	MT	High School	5	Developing
Plains	MT	Hospital	2	Developing

30+ schools in Vermont

7-9 schools in MT

*CTA Group (2006) Biomass Boiler Market Assessment -Montana

Estimated number of US public facility biomass boilers*

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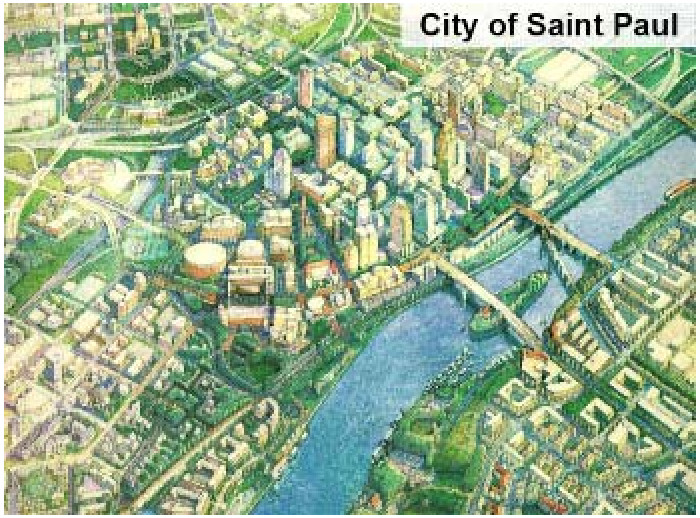
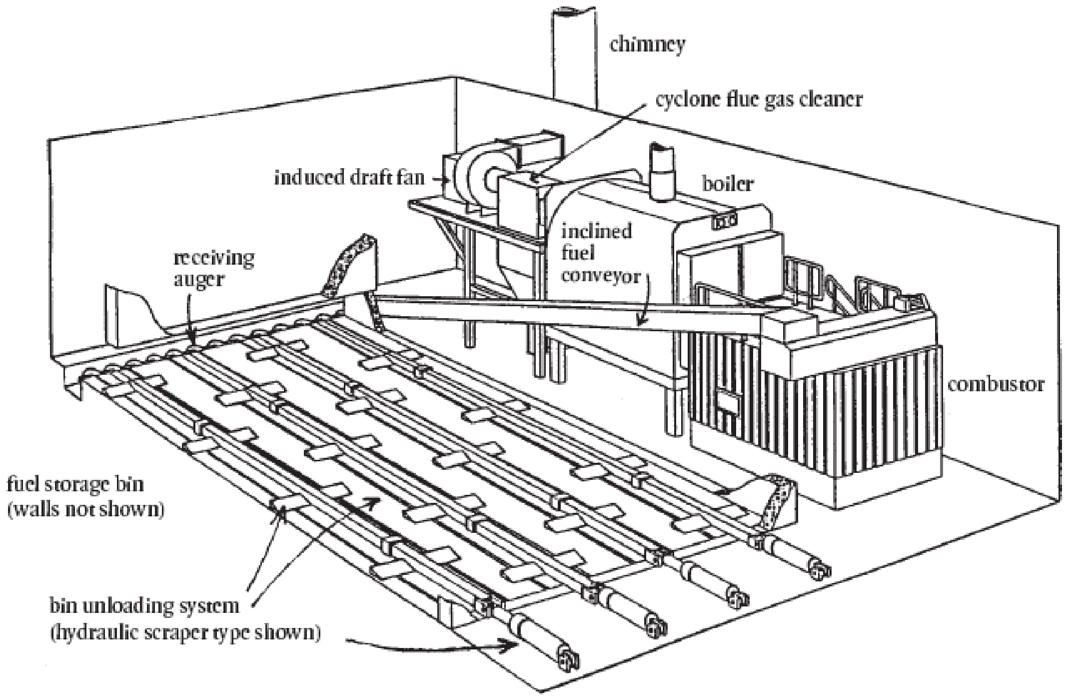
*CTA Group (2006) Biomass Boiler Market Assessment -Montana

District Energy Saint Paul

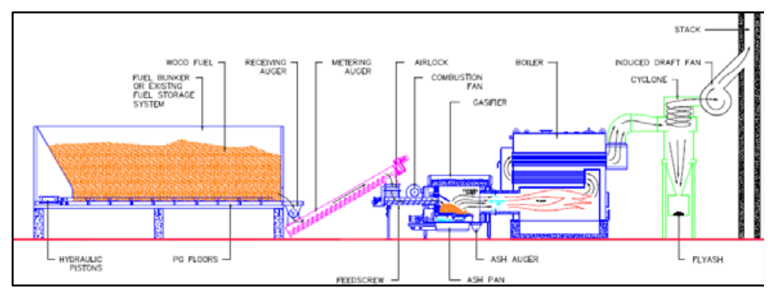


- Largest hot water district heating system in North America
- Serves 80% of buildings in downtown and surrounding area
- District Cooling serves 60% of buildings
- 25 MWe biomass combined heat and power (CHP) plant provides more than 60% of district heat and cooling energy (Operational in 2003)
- Urban and rural wood sources

System Components



- Fuel receiving and storage
- Fuel handling and conveyance (maybe processing)
- Conversion (combustor, gasifier)
- Boiler (steam or hot water, pressure or not)
- Building to house boiler
- Control system
- Ash conveyance, storage, disposal
- Fans, pumps, exhaust stack

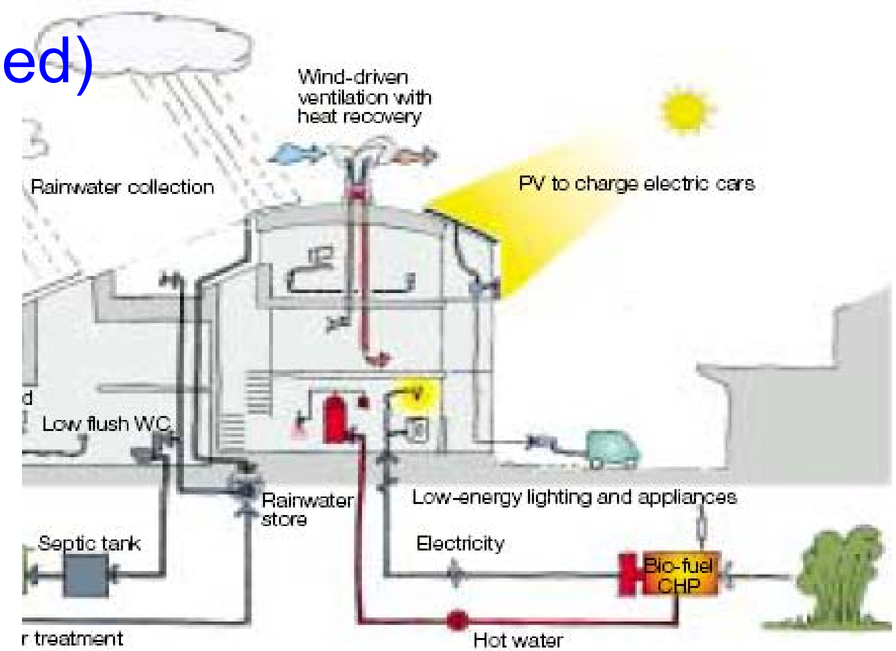


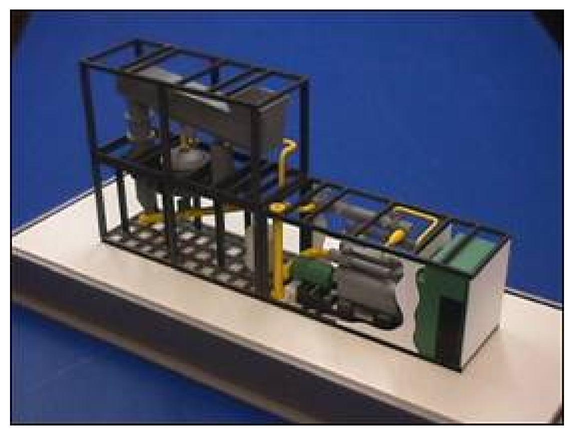
Wood Chip Heating Guide. Tim Maker. BERC VT. Photos: Tim Maker, Schematic--Chiptec

Some Gasifier Heat and Power Systems

Beddington Zero Energy Development Project (Bed Zed)

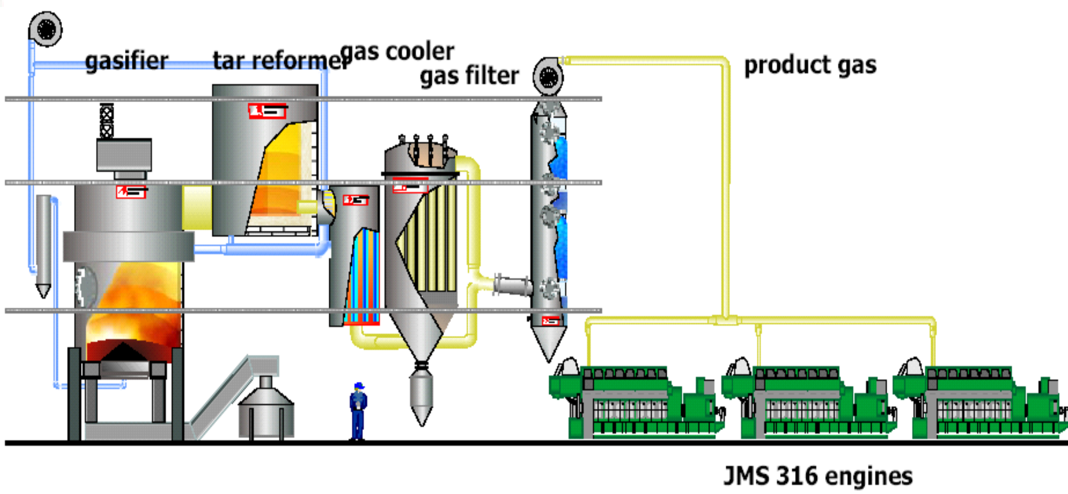
- London
- Mixed live – work space; Opened in 2002
- Exus Energy 130kWe biomass gasification CHP unit for building heat and electricity
- Over 2,000 hours of operation (according to web site*).
- Haven't confirmed





* http://ws.exusenergy-host.me.uk/beddington.htm

Kokemäki, Finland CHP plant



- Hot water from engine cooling jacket and exhaust
- Was undergoing commissioning in Winter 06-07 (don't know current status)

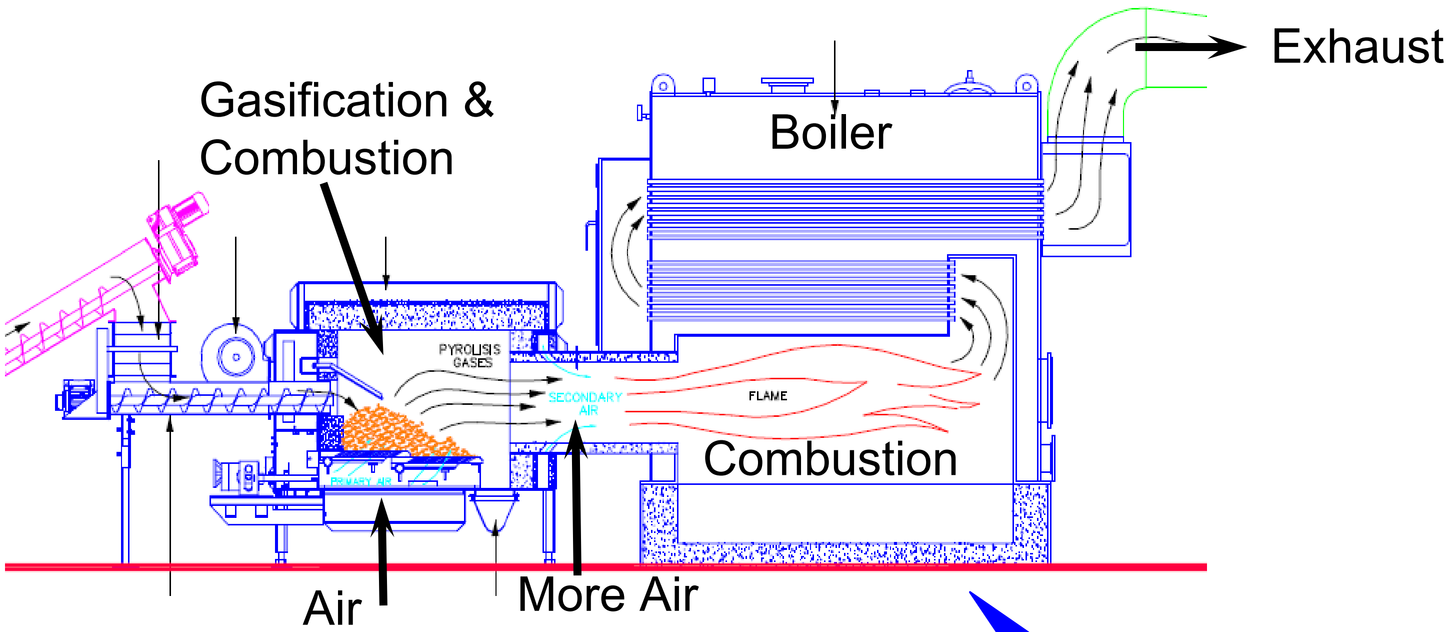
CHP, 1.8 MWe, 3.1 MW thermal (10.6 MBtu/h)

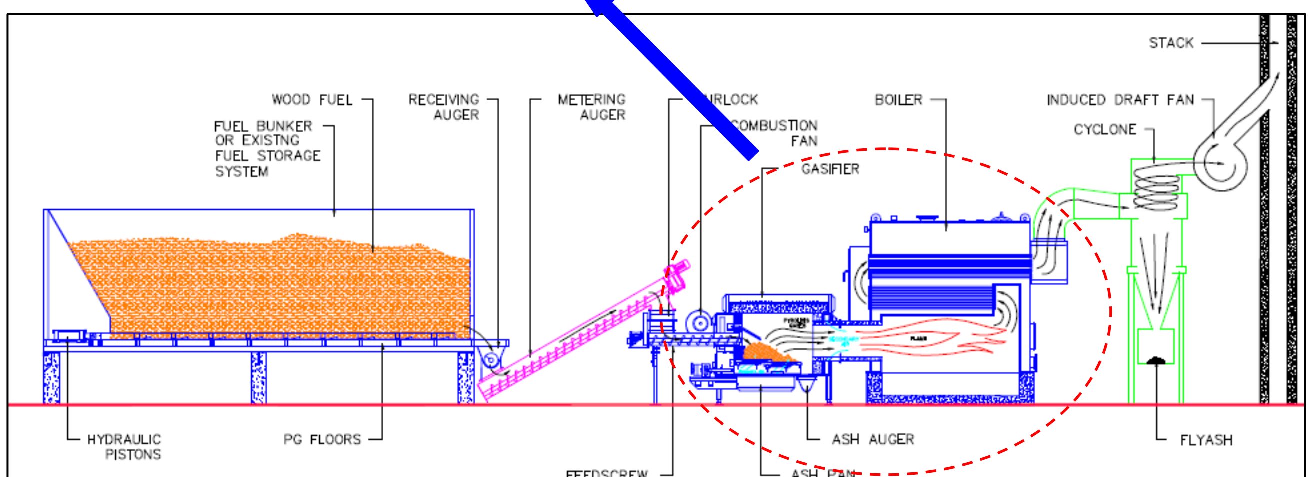
		Normal Operation	With Auxiliary Boiler
Fuel input	kW	6200	7200
Electricity Production	kW	1836	1836
Heat Production	kW	3100	4300
Fuel Drying (from existing separate heat plant)	kW	429	429
η_e*	%	29.6	25.5
η_{th}	%	50.0	59.7
$\eta_{overall}$	%	79.6	85.2

* η = efficiency (useful energy or work output divided by energy input)

- There are other biomass gasification for district heating in Europe (Güssing, Austria, Bioneer plants in Finland, Skive, Denmark, etc.)
- Large number of wood chip and pellet combustion systems for heat in Europe

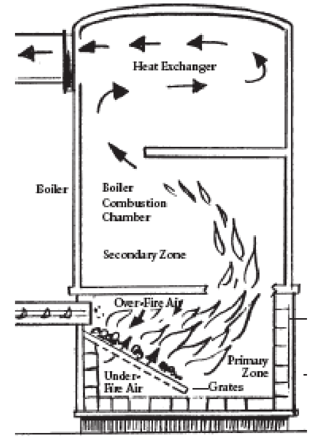
Gasifier-close-coupled-combustion (Chiptec)

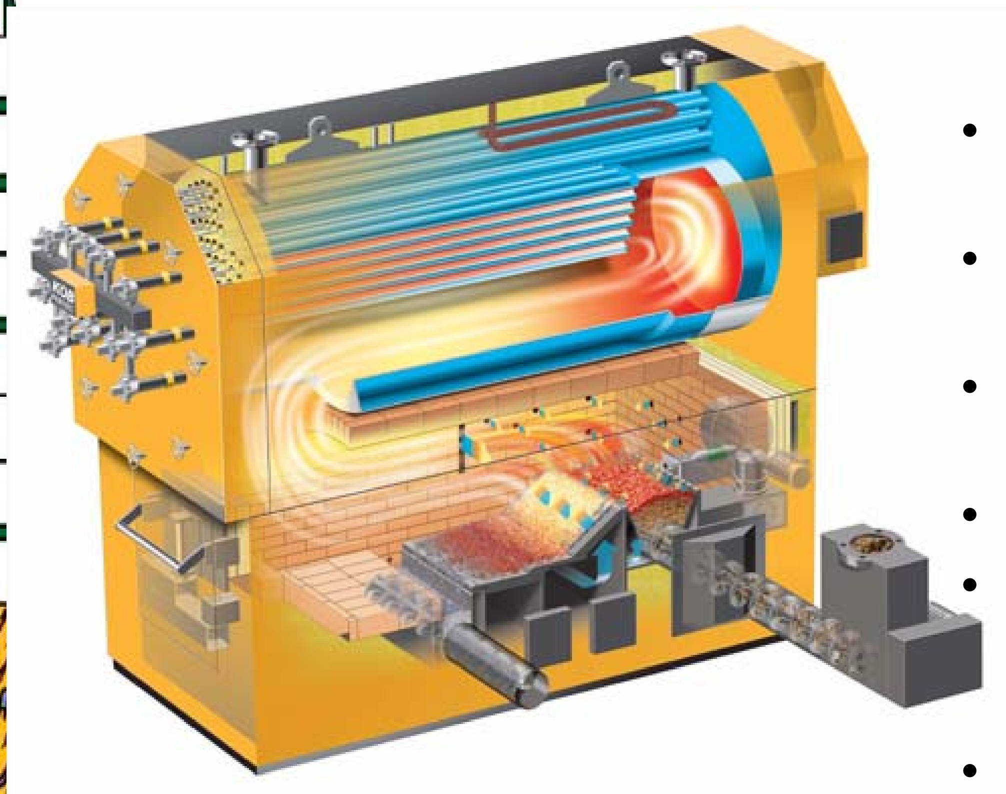




Source: Chiptec:
http://www.chiptec.com/

Typical Wood Chip Boilers (fire box and boiler)





KÖB "Pyrtec"
1.7-4.3 MBtu/hr outputs
(500 – 1250 kW)

- Examples include Messersmith, Challenger and KÖB
- Grate Combustion ("Fire Box") [KÖB uses moving grate]
- Over-fire air to complete combustion above the grate
- Boiler is overhead
- Automatic control of fuel and air to meet load and reduce emissions
- KÖB systems allow flue gas recirculation for NOx control

Image Sources: http://www.koeb-holzfeuerungen.com/
http://www.biomasscenter.org/pdfs/Wood-Chip-Heating-Guide.pdf

Community Power Corporation Biomax

- Fixed bed downdraft gasifier
- Automotive spark ignition engine –generator
- Gas cooled to ~ 120 F & filtered to reduce tar and particulate matter for engine (no liquid scrubber- this is positive feature)
- 12,15 & 50 (75?) kWe systems demonstrated
- 3-way automotive catalytic converter for emissions control

Image Source: Community Power Corp. http://www.gocpc.com/

Greenhouse heating at Northern Arizona University Arboretum

- ~1 acre greenhouse
- Pellet fueled boilers
- Hot water boiler system (136,000 Btu/hr)
- Displaces propane
- System Start-up: 2005
- Forest Energy Systems LLC, Show Low, AZ

http://www.forestenergysystems.com/completed%20files/applications.html

Update on “Lessons Learned”

(Tahoe Workshop, 1 June 2007)

White Pine School District, Ely NV (Paul Johnson)

- $1M project-- 3 MBtu/hr capacity hot water system
- Two seasons operation
- $35/ton wood, several years supply stored near by in field (desire covered storage)
- Power surge knocked out computer control system, black plume from stack,
- Manual control difficult & poor support from boiler manufacture led to use of stand-by oil system
- Air permit not needed.

Boiler house and School, Ely NV

Correctional Facility, Carson City, NV (Lori Bagwell)

- $9M project-- 1 MWe (steam turbine) plus heat
- Intent is to supply most heat and power for facility
- Could have used full time person to coordinate project from inception to day-to-day operation”
- Performance guarantees for equipment but not on project overall financial performance
- Fuel price now uncertain, expected to rise: project assessed on $29/ton chipped wood supply contract but fuel source (thinning projects) did not develop as expected
- Overall economics are quite sensitive to fuel price
- Continuous emissions monitoring (CEM)

Boiler Installation, Correctional Facility, Carson City, NV

CPC Biomax 15- Some Results from Truckee Donner Demonstration*

Community Power Corp. http://www.gocpc.com/

- Expensive (a prototype)
  - $240,000 total capital cost (equipment, sitework, engineering: ~$120k for gasifier) *
  - $16,000/kW-installed vs. $2,500/kW for 25MW biomass boiler
  - Levelized cost of electricity =$0.70/kWh* (natural gas power plant LCOE ~ $0.08/kWh, 25 MW biopower ~$0.08- 0.10/kWh)
- Sensitive to fuel moisture and chip size (15% m.c. to gasifier; system uses some engine heat for drying)
- "Free fuel" cost $80/ton due to labor intensive chip screening
- Power output was measured 9-11 kW*
- Fuel consumption ~ 3 lbs/kWh (15% moisture) => 1.3 BDT/MWh (about 15% energy efficiency)
- Emissions data? Can't find independent emissions testing from various demo projects.
- Need much lower installed cost (<$5,000/kWe (CHP)) and demonstration of 5,000 hours or more to be considered commercial

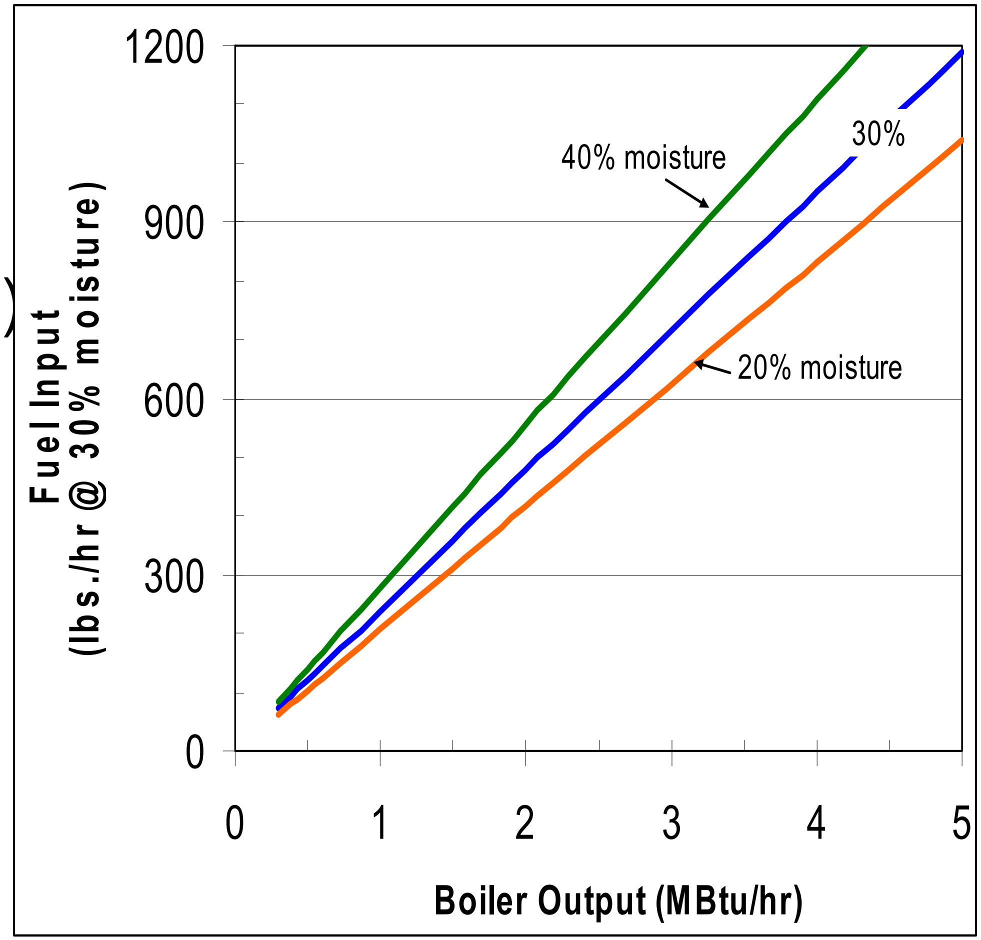
* Scott Haase (2005). McNeil Technologies CEC-PIER/Hetch Hechy Renewables Project . CEC Contract 500-01-042

Energy Performance
(Typical Combustion Units in US)

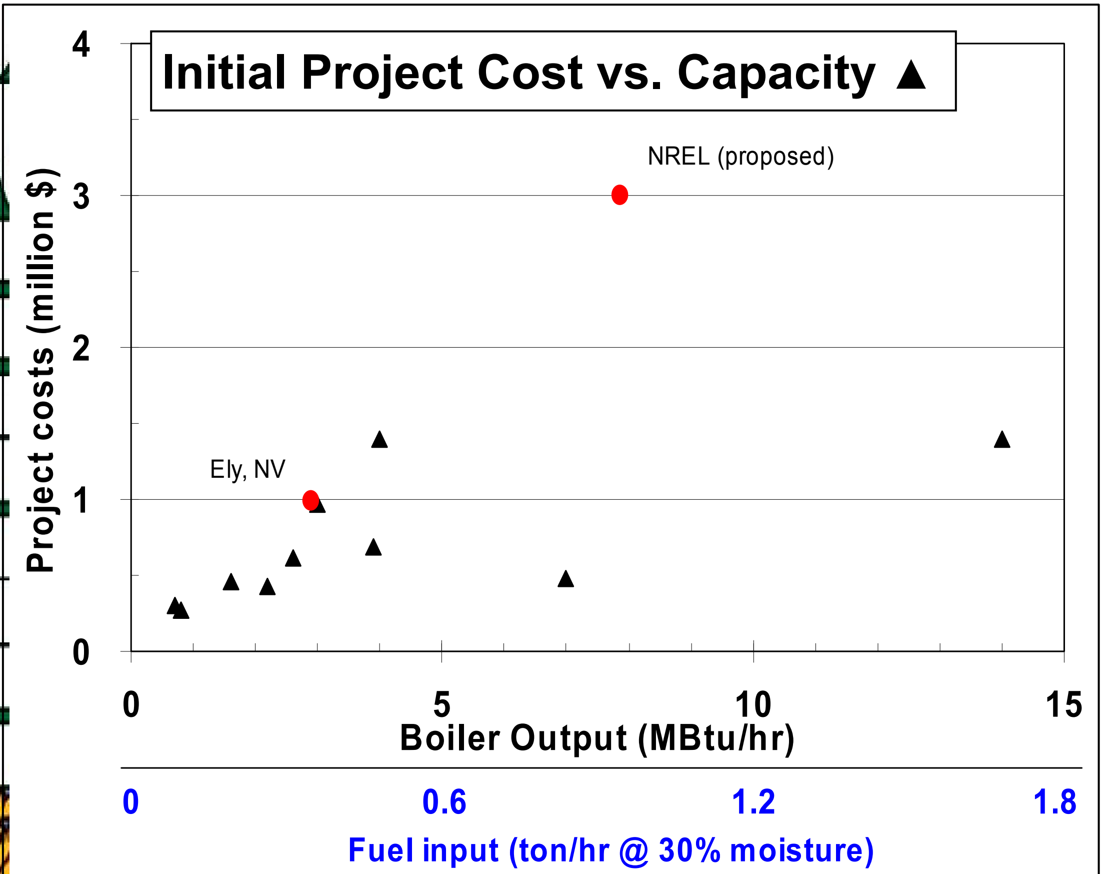
Common Assumptions

- 70% Energy Conversion efficiency (useful heat in water/wood energy input)
- 8600 Btu/dry-lb (Higher heating value of dry wood)
- 6000 Btu/lb for wood at 30% moisture

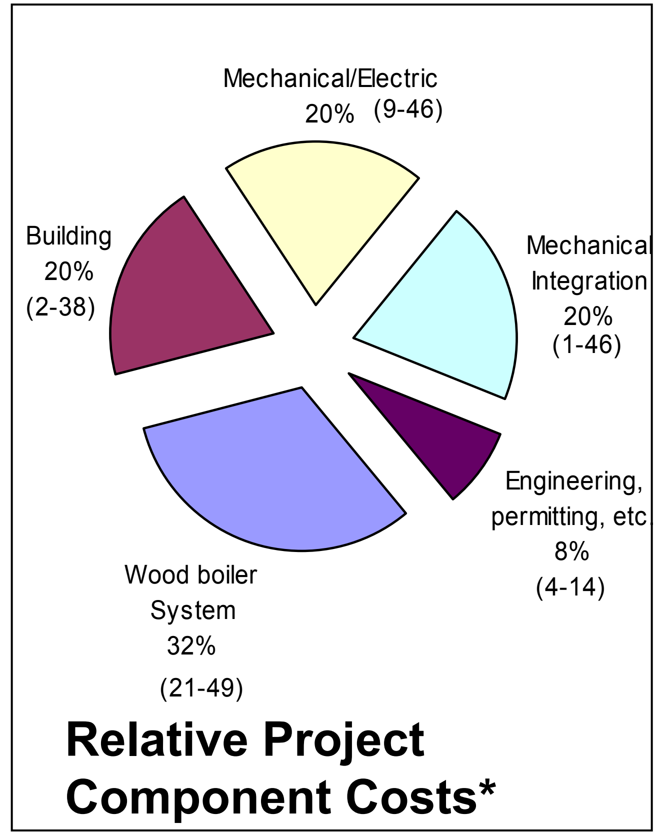
Wood Input vs. Boiler Output



Economics



▲ From Table 1 in Biomass Boiler Market Assessment –Montana. CTA Group (2006)



* Based on eight case studies where biomass boilers were added to existing steam or water building heating systems --CTA Group (2006)

'Simple payback'** estimates generally ranged from 10 years for 10MBtu/hr systems to >30 yrs (or never) for small < 1MBtu/hr systems**

**Assumes no grant for capital buy-down, site specific-every project is different- highly sensitive to fuel costs (both wood and displaced fuel)

On-line Economic Viability Model*

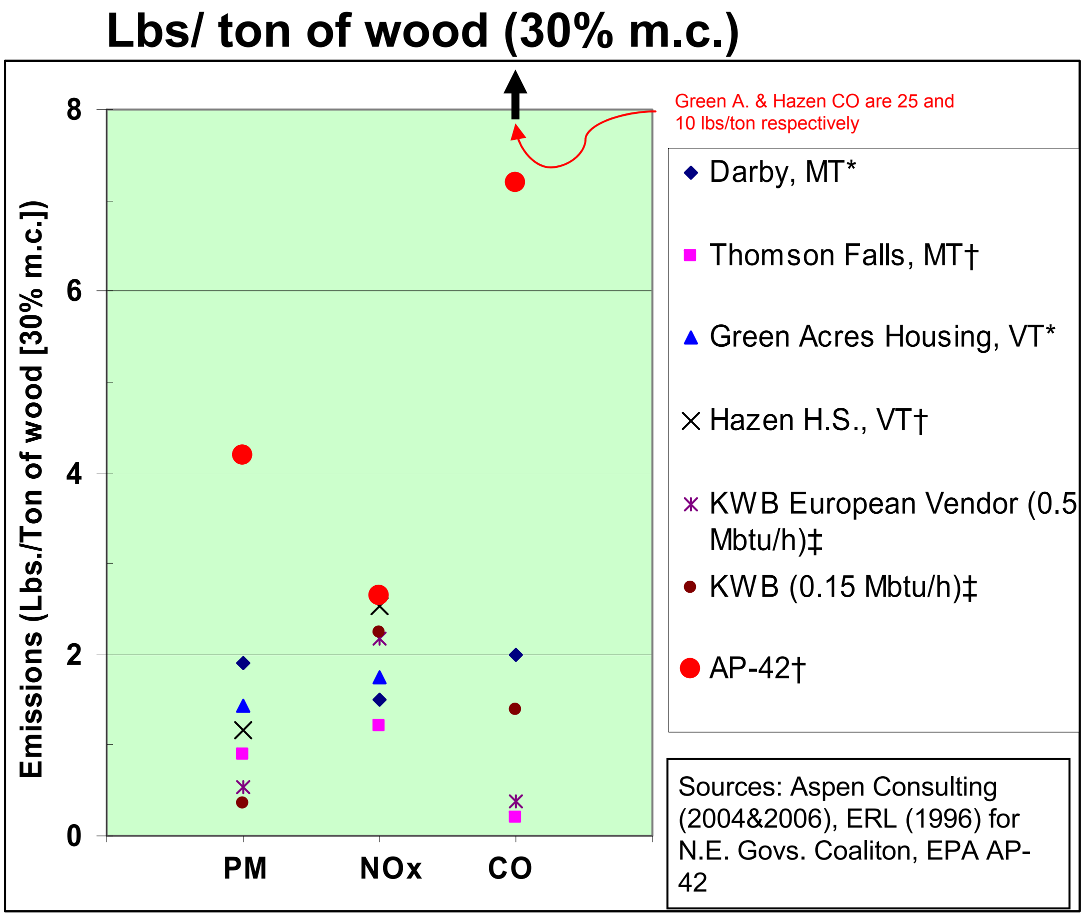
- Coming soon (in a couple of weeks)
- to Southeast Michigan Resource Conservation & Development (RC&D) Council website:

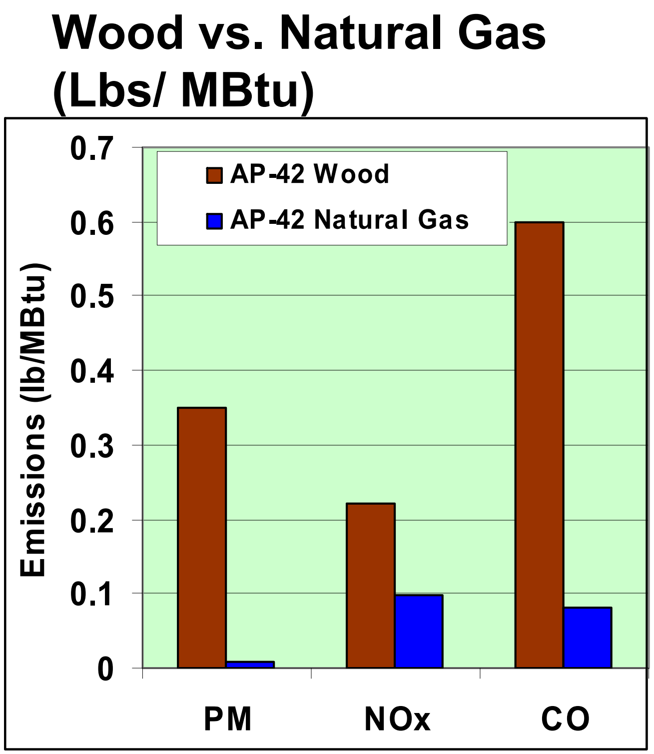
http://www.semircd.org/

*Developed by CTA Architects and Engineers

http://www.ctagroup.com/

Air Emissions





- Many existing smaller facilities (i.e., schools) have not needed air permits or source testing.
- Regions with winter temperature inversions may require cyclone separators for PM reduction.
- Some PM_{10} emissions data is available, but there is very little $PM_{2.5}$ data
- Toxic emissions and health impact/risk assessments should be considered for school sites (or use tall stack to reduce ground level concentrations

National Workshop on
Implementing Biomass Boiler Systems-
Making Wood Work: Local Energy Solutions
16-18 October, 2007, Missoula, Montana

- Feasibility, planning, design
- Technologies
- State and Federal Policies
- Financing
- Fuel Supply and Quality
- Operations Experience from existing projects
- Environmental Considerations
  - Air Emissions
  - Life-cycle carbon considerations
  - Nutrient and habitat aspects
- Field Trip on 3rd day

http://fuelsforschools.org/ws_about_workshop.html

Conclusions and Recommendations

- Biomass for building and distributed heat systems is viable and appropriate in many instances (more than 100 such systems in public and institutional settings in the US).
- Combustion and staged combustion boilers are commercial in the US and Europe. Gasifiers for heat, power, and CHP are employed in Europe
- For those contemplating switching to biomass heat, need to understand the issues (real cost, risks, operational effort and potential problems).
- Accurate information about existing projects and demonstrations is needed
  - For example, critical evaluation of installed systems by competent, independent firm could help insure new systems are appropriately spec'd.
  - Obtain long-term operational data on CPC system(s) [monitor mass and energy flows, emissions over time, document operating costs, etc.]
- Measure and model $PM_{2.5}$ (and other) emissions for a range of systems operating at full and partial loads using a variety of fuel types and conditions

Potential Useful Information

- Links to some manufacturers and consultants

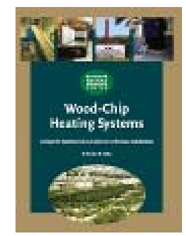
  http://www.fuelsforschools.org/manu_consult.html

- Biomass Boiler Market Assessment for Montana, CTA Group (2006)

  http://www.fuelsforschools.org/pdf/Final_Report_Biomass_Boiler_Market_Assessment.pdf

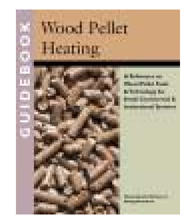
- Wood Chip Heating systems

  http://www.biomasscenter.org/pdfs/Wood-Chip-Heating-Guide.pdf



- Wood Pellet Heating

  http://www.mass.gov/Eoca/docs/doer/pub_info/doer_pellet_guidebook.pdf



- Fuels for Schools Case Study, Darby MT (2007)
  - USDAFS FPL-GTR-173

  http://treesearch.fs.fed.us/pubs/28239

Emissions References

- Air quality issues –wood boilers. http://www.fuelsforschools.org/pdf/AirQualityInfo_FFS.pdf
- Julie Tucker (USDA Forest Service) & Aspen Source test reports (2004, 2006)
- Evaluation of Control Technologies for small wood-fired boilers. Resource Systems Group (2001) http://www.rsginc.com/pdf/R_Wood_Bact_Sept_2001.PDF
- Wood fired furnaces testing project. N.E. Govs. Coalition. Environmental Risk Ltd. (1996) http://www.nrbp.org/pdfs/pub14.pdf
- Impact Assessment of proposed renewable heating plant for NREL. Trinity Consultants (2006). Available from USDOE Golden Field Office.

Thank You

Rob Williams
Development Engineer
Biological and Agricultural Engineering
California Biomass Collaborative
University of California, Davis

Email: rbwilliams@ucdavis.edu
Phone: 530-752-6623
Web: biomass.ucdavis.edu