Heating with Biomass

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Heating with Biomass – First Impressions

• What are the first impressions or images that come to mind when someone mentions the idea of heating with biomass?
Outline

• What is biomass?
• A vision for heating with biomass in the Northeast
• Costs of biomass heating
• What about emissions?
Renewable Energy as Share of Total Primary Energy Consumption, 2009

- Nuclear Electric Power: 8%
- Natural Gas: 25%
- Petroleum: 37%
- Coal: 21%
- Renewable Energy: 35%
  - Hydroelectric Power: 35%
  - Biofuels: 20%
  - Wood: 24%
  - Wind: 9%
  - Waste: 6%
  - Solar/PV: 5%
  - Geothermal: 1%

(EIA 2011)
What is Biomass?

• Recent organic material originally derived from plants as a result of the photosynthetic process or animals that is available on a renewable or recurring basis

• Stored chemical energy that is derived from solar energy through photosynthesis
  – Only a small portion of the incoming solar radiation (0.1 - 5%) that reaches the earth is captured and stored as terrestrial biomass
  – This small amount of captured energy is 5-7x the amount of primary energy used in the world

(Sims 2002)
Biomass for Thermal Energy

- A range of different types of biomass systems can be used to generate heat or used for cooling through:
  - Space heating/cooling
  - District heating/cooling
  - Industrial process heat
  - Combined heat and power (CHP)

- Different types and forms of biomass feedstocks can be used:
  - Chips
  - Pellets
  - Biogas derived from woody or herbaceous plant materials
  - Agricultural wastes and by-products
  - Other biomass feedstocks
# Biomass heating technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Automatic pellet heating</th>
<th>Modern firewood/pellet boilers</th>
<th>Automatic wood chip/pellet boilers</th>
<th>District heating</th>
<th>Combined heat &amp; power stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel</td>
<td>Pellets</td>
<td>Firewood/wood chips/ pellets</td>
<td>Wood chips/ pellets</td>
<td>Wood chips</td>
<td>Wood chips</td>
</tr>
<tr>
<td>Typical installed capacity</td>
<td>5-15 kW</td>
<td>20-40 kW</td>
<td>50-150 kW</td>
<td>100 kW-3 MW</td>
<td>&gt;1 MW&lt;sub&gt;el&lt;/sub&gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&gt; 10 MW&lt;sub&gt;th&lt;/sub&gt;</td>
</tr>
<tr>
<td>Users, customers</td>
<td>single-family homes</td>
<td>farm buildings</td>
<td>public &amp; commercial</td>
<td>all buildings</td>
<td>all buildings</td>
</tr>
<tr>
<td>Fuel supply</td>
<td>Bags/bulk delivery</td>
<td>Usually from own forest or bulk pellets</td>
<td>Local supplier</td>
<td>Multiple sources and suppliers</td>
<td>Multiple sources and suppliers</td>
</tr>
</tbody>
</table>

(Egger & Ortner 2011)
Why Biomass for Thermal Needs?

• Almost 1/3 of the energy use in the U.S. is for thermal needs
• Modern thermal conversion systems are very efficient and more convenient
• Others sources of energy used for heating often result in dollars, and associated jobs, being transferred out of the region or country
• Biomass system can make use of local sources with benefits to the local and regional economy
Why Biomass for Thermal Needs?

• Potential to mitigate environmental impacts such as climate change, acid precipitation
• Lower fuel cost than many other fossil fuels
• Lower fluctuations in fuel prices over time
• Opportunity to improve forest management practices by providing a market for low value material
Use of Heating Oil

Top Five Heating Oil Consuming States in 2009

- 80% of the homes that use heating oil are in the Northeast
- Consumers in the Northeast use about 3.7 billion gallons of heating oil per year


Sales of Residential Heating Oil by Region, 2009

- Northeast 84%
- Midwest 8.42%
- Southeast 4.6%
- Rocky Mountain <1%
- West Coast 2.8%

Percent of Households using Heating Oil (rank in US) (excluding Alaska)

- Maine (1)
- New Hampshire (2)
- Connecticut (3)
- Vermont (4)
- Rhode Island (5)
- Massachusetts (7)
- New York (8)
- Pennsylvania (9)

(Source: US Energy Information Administration, 2011), Analysis by FutureMetrics.

(Strauss 2011)
Natural Gas Use by Households (rank)

- Hawaii (50)
- Maine (49)
- Vermont (47)
- New Hampshire (46)
- Connecticut (42)
- Massachusetts (24)
- Rhode Island (23)
- Pennsylvania (22)
- New York (19)

(Source: US Energy Information Administration, 2011), Analysis by FutureMetrics.
#2 Distillate Fuel Use

EIA analysis shows that 78% of every dollar spent on heating oil leaves the region and much of this leaves the country (Strauss 2011)

<table>
<thead>
<tr>
<th>State</th>
<th>Number of Households</th>
<th>Average Gallons Used per Year by all Users</th>
<th>Average Total Expenditure Per Year (#2 at $3.65/gal)</th>
<th>Amount that Does not Stay in the State (EXPORTED)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connecticut</td>
<td>873,000</td>
<td>720,225,000</td>
<td>$2,628,821,250</td>
<td>$2,050,481,000</td>
</tr>
<tr>
<td>Maine</td>
<td>418,000</td>
<td>376,200,000</td>
<td>$1,373,130,000</td>
<td>$1,071,041,000</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>1,110,000</td>
<td>915,750,000</td>
<td>$3,342,487,500</td>
<td>$2,607,140,000</td>
</tr>
<tr>
<td>New Hampshire</td>
<td>409,000</td>
<td>368,100,000</td>
<td>$1,343,565,000</td>
<td>$1,047,981,000</td>
</tr>
<tr>
<td>New York</td>
<td>3,275,000</td>
<td>2,947,500,000</td>
<td>$10,758,375,000</td>
<td>$8,391,533,000</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>1,837,000</td>
<td>1,377,750,000</td>
<td>$5,028,787,500</td>
<td>$3,922,454,000</td>
</tr>
<tr>
<td>Rhode Island</td>
<td>208,000</td>
<td>166,400,000</td>
<td>$607,360,000</td>
<td>$473,741,000</td>
</tr>
<tr>
<td>Vermont</td>
<td>201,000</td>
<td>180,900,000</td>
<td>$660,285,000</td>
<td>$515,022,000</td>
</tr>
<tr>
<td>Total</td>
<td>8,331,000</td>
<td>7,052,825,000</td>
<td>$25,742,811,250</td>
<td>$20,079,393,000</td>
</tr>
</tbody>
</table>

### Loss of Jobs

<table>
<thead>
<tr>
<th>#2 Distillate Fuel use in Residential, Commercial, and Industrial (not Transportation)</th>
<th>Average Gallons per Year</th>
<th>Money Exported from Regional Economy at $3.65/gal</th>
<th>Lost Jobs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connecticut</td>
<td>720,225,000</td>
<td>($2,050,480,575)</td>
<td>-98,300</td>
</tr>
<tr>
<td>Maine</td>
<td>376,200,000</td>
<td>($1,071,041,400)</td>
<td>-64,189</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>915,750,000</td>
<td>($2,607,140,250)</td>
<td>-133,194</td>
</tr>
<tr>
<td>New Hampshire</td>
<td>368,100,000</td>
<td>($1,047,980,700)</td>
<td>-58,773</td>
</tr>
<tr>
<td><strong>New York</strong></td>
<td><strong>2,947,500,000</strong></td>
<td><strong>($8,391,532,500)</strong></td>
<td><strong>-415,023</strong></td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>1,377,750,000</td>
<td>($3,922,454,250)</td>
<td>-198,084</td>
</tr>
<tr>
<td>Rhode Island</td>
<td>166,400,000</td>
<td>($473,740,800)</td>
<td>-23,575</td>
</tr>
<tr>
<td>Vermont</td>
<td>180,900,000</td>
<td>($515,022,300)</td>
<td>-30,219</td>
</tr>
</tbody>
</table>

| **Total** | **7,052,825,000** | **($20,079,392,775)** | **-1,021,357** |

Analysis by FutureMetrics

(Strauss 2011)
A Renewable Heating Vision

- 25% of all heating needs in the Northeast met with renewable energy
  - 75% of this met with renewable biomass
  - 25% from solar thermal and geothermal
Current energy sources for thermal energy

Vision of energy sources for thermal energy in 2025

(Niebling 2010)
Start with a Renewable Feedstock Supply

- Vision is based on forest and agricultural sources
- Estimate annual forest growth across seven states
- Subtract % not available for harvest (30%)
- Subtract current and future consumption for all forest products
- Remaining % available for biomass energy
- Cut this % in half to be conservative
- Repeat exercise for agricultural sources

(Niebling 2010)
Renewable Feedstock Supply

Flow Diagram of Sustainable Biomass for New England and New York
(in green tons)
Analysis by FutureMetrics

Potential Annual Sustainable Forest Harvest
55,400,000 Green Tons

Potential Annual Dedicated Energy Crops Harvest
23,304,000 Green Tons

Potential Forest Biomass for Energy: 7,440,000 Tons

Total Potential Annual Biomass for Energy Applications
19,092,000 Green Tons

Potential Crop Biomass for Energy: 11,652,000 Tons

Not Available for Harvest
16,939,000 Tons

Sawlogs
8,391,000 Tons

Pulpwood
14,935,000 Tons

half of remaining potential removed to keep estimate conservative
7,440,000 Tons

half of potential energy crops removed to keep estimate conservative
11,652,000 Tons

(Niebling 2010)
Economic Benefits of 2025 Vision

• Displace the use of over **1.14 billion gallons of heating oil annually** by 2025.
  – Over 20% of all heating oil consumed in the Northeast
• Conversion of source of energy for heating in **1.39 million homes and businesses**
• Retention of more than **$1.6 billion in annual income** in our economy instead of exporting to other economies
• Injection of **$4.5 billion new dollars per year** into the regional economy by 2025
• Retention of income and expansion of the biomass thermal industry will result in a total of **140,200 permanent jobs**

(Niebling 2010)
Benefits of Biomass - Costs

• Biomass fuel often costs less than fossil fuel sources of energy for heating, especially heating oil and propane
• Biomass prices over time are less volatile than fossil fuel prices, making budgeting for energy costs easier
## Final Cost of Delivered Heat

<table>
<thead>
<tr>
<th>Fuel and Price</th>
<th>Typical Delivered Price</th>
<th>Fuel Heating Value (HHV)</th>
<th>Typical Combustor Efficiency (%)</th>
<th>Cost per Unit Energy ($/GJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cordwood, 30% moisture, Delivered</td>
<td>$150 per cord</td>
<td>14.1 MJ/kg</td>
<td>60</td>
<td>13.36</td>
</tr>
<tr>
<td>Clean, Green Wood Chips, 40% moisture</td>
<td>$50 per ton</td>
<td>12.1 MJ/kg</td>
<td>80</td>
<td>5.73</td>
</tr>
<tr>
<td>Dried Wood Chips, 20% moisture</td>
<td>$70 per ton</td>
<td>16.1 MJ/kg</td>
<td>80</td>
<td>5.72</td>
</tr>
<tr>
<td>Premium Hardwood Pellets, 5%</td>
<td>$6 per 22 kg bag</td>
<td>18.1 MJ/kg</td>
<td>80</td>
<td>18.83</td>
</tr>
<tr>
<td>Switchgrass Pellets, 5% moisture</td>
<td>$6 per 22kg bag</td>
<td>17.2 MJ/kg</td>
<td>80</td>
<td>19.82</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>$12 per 1000 cf</td>
<td>38.3 MJ/m3</td>
<td>80</td>
<td>15.35</td>
</tr>
<tr>
<td>Fuel Oil</td>
<td>$3.50 per gallon</td>
<td>36.4 MJ/litre</td>
<td>80</td>
<td>31.89</td>
</tr>
<tr>
<td>Coal</td>
<td>$110 per short ton</td>
<td>28 MJ/kg</td>
<td>75</td>
<td>5.12</td>
</tr>
<tr>
<td>Electricity (resistance heat)</td>
<td>$0.12 per kWh</td>
<td>3.6 MJ/kwh</td>
<td>100</td>
<td>33.33</td>
</tr>
</tbody>
</table>

(Jacobson 2011)
Fuel Cost Savings: Pellets vs. Heating Oil

($/MBtu)

((Strauss 2011))
Price Comparisons

• Paying $200 for a ton of pellets is the same as paying:
  – $1.67/gallon of heating oil
  – $1.18/gallon of propane
  – $0.04/kwh for electricity
  – $12.50/1000 cu ft of natural gas
Wood Chip System vs. Oil

Wood Chip System Cost Effectiveness Potential

Likely Cost Effective
Possibly Cost Effective
Unlikely Cost Effective

Existing Oil Cost/gallon

Annual Gallons Oil Heat Consumption

(Maker 2004)
Wood Chip System vs. Electric

Wood Chip System Cost Effectiveness Potential

(Maker 2004)
Wood Chip System vs. Natural Gas

Wood Chip System Cost Effectiveness Potential

- Likely Cost Effective
- Possibly Cost Effective
- Unlikely Cost Effective

Annual ccf Gas Heat Consumption

(Maker 2004)
Dramatic Improvements in Biomass Boilers

Results of emissions & efficiency of biomass boilers from more than 1,000 boiler tests

Source: FJ-BLT Wieselburg; Bioenergy 2020+

(Egger & Ortner 2011)
Total Pounds of CO₂ per Year

normalized to the equivalent of the BTU from 1000 gallons of heating oil per year

- Heating Oil: 30,716
- Propane: 23,240
- Natural Gas: 19,502
- Pellet Fuel: 4,004

Life Cycle Assessment of Pellet Burning Technologies, Thomas Willem de Haan, Univ. of Amsterdam, June 2010. Wood pellets are not entirely carbon neutral because some fossil fuels is required for the harvesting of trees and shipment. Extraction, refining, and transport emissions are included for each of the four fuel sources.
Total Pounds of Particulate per Year

normalized to the equivalent of the BTU from 1000 gallons of heating oil per year

Fireplace
3920.0

Uncertified Wood Stove
644.0

EPA Certified Wood Stove
196.0

Pellet Stove
68.6

Modern European Pellet Fuel Boiler
2.94

Gas Boiler
1.16

Old Oil Boiler (pre-1990s)
10.08

Modern Oil Boiler
2.52


(Strauss 2011)
Current Pellet Delivery System
Pellets: Bulk Delivery with Pneumatic Truck

• Convenient
• Clean
• Dust-free

On-board electronic scale

(Egger & Ortner 2011)
Pellets: Bulk Delivery with Pneumatic Truck

Presser vessel with pressurized air transport system

Preassurized air 0.5 - 1.0 bar

Filling capacity 5 minutes per 1 ton

Max. 96 ft

(Egger & Ortner 2011)
Pellets boiler: Storage Solutions

Fabric tank - capacity up to 9 ton

(Egger & Ortner 2011)

Patent registered EP 10155313.9 /17.03.2009
Modern Pellet Boilers: High Convenience

Automated cleaning system
- Very convenient
- No manual cleaning during the heating season
- Constant high efficiency

Electrical ignition

Automated ash compression system with external box

(Egger & Ortner 2011)
Pellet boilers: Commercial Heating

Cascade boiler

246,000 - 955,000 BTU/hr

(Egger & Ortner 2011)
High Efficiency Wood Chip Boilers
Wood Chip Systems: Commercial Applications

Cayuga Nature Center wood chip boiler

Middlebury College combined heat and power system run on wood chips
Pellet Boilers: Commercial Applications

Energybox
- Pre-fabricated
- Ready to plug-in

Cornish Elementary School
New Hampshire, USA

(Egger & Ortner 2011)

Forest cooperative
Quebec, Canada
Gateway building – CHP System

New “zero net energy” showcase building for campus. Design includes biomass combined heat and power, PV, green roof, passive solar and rain gardens.
Gateway Energy System

- 8,000 MBtu CHP Wood Pellet Steam Boiler
- 8,000 MBtu CHP Natural Gas Boiler
- 200 kW Back-pressure steam turbine
- Dual 65 kW CHP Natural Gas Micro-turbines
- 150-200 kW Solar PV array
Combined Heat and Power System

- CHP System is a 25% improvement to overall energy efficiency
  - Provides 75% of campus thermal needs and 20% of campus electrical needs.

- Offset 54,000 MMBTU Fossil Fuels Annually
  - 18,000 MMBTU from efficiency improvements
  - 36,000 MMBTU from fuel switching improvement

- System is projected to save ESF $450,000 annually, and provides a $1.5 million NPV over 15 years
Heating with Biomass

- Large potential to expand the use of biomass for heating applications
- Numerous benefits associated with changing from fossil fuels to biomass
  - Reduce flow of energy dollars out of state
  - Create permanent jobs in the local economy
- Need to deploy improved boiler and delivery systems
Questions