Compost Power!

Uncovering the current state-of-the-art in compost heat recovery (CHR)

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Jasper Hill Farm’s Green Machine
Webinar Outline

• Introductory material and concepts
• Review of existing technologies
• Comparison of existing technologies
• Summary of Compost Power’s grassroots research effort
• Closing remarks and Q & A
• Additional resources
A brief history of compost heat recovery (CHR)

– *Ancient China*: reported use of compost heat in BC era
– *1800s*: French glasshouse production
– *1960s – 1970s*: Jean Pain’s mounds
– *1980s*: New Alchemy Institute’s compost-heated greenhouse
– *Early 2000s*: Re-Vision Farm compost-heated greenhouses
– *Mid 2000s*: Diamond Hill Custom Heifers Agrilab system; at least 3 Agrilab systems are in operation in the Northeast
– *2010*: Compost Power Network grassroots experimentation
– *2012*: Highfields Center for Composting successful Kickstarter campaign for CHR R&D
Intro to Composting and CHR

• Why compost?
  – Recover and stabilize nutrients
  – Mitigate methane emissions from organic residues
  – Reduce farm/municipal waste volume
  – Destroy pathogens and weed seeds (thermophilic)
  – Generate soil amendment for fertilizer (OM,N,P,K), microbial ecology, water retention, soil structure and erosion control

• Why compost heat recovery?
  – Excess heat from composting (thermophilic)
  – Compost happens! – on farms and as business, and sometimes where heating loads exist
  – Generate local energy, keep nutrients local too
  – Baseload heat source for hot water and radiant heat; generates hot water up to 140°F
Intro to Composting and CHR

Key composting parameters

- Carbon: Nitrogen (C/N) ratio
  • Ideal range = 25:1 to 40:1
- Carbon accessibility / biodegradability
  • A diversity of carbon sources is recommended
- Porosity
  • Wood chips or thick stalky material are critical components
- Moisture content
  • Ideal range = 60% - 65%
- Temperature
  • Must attain 131°F for at least 3 days, keep under 140°F
- Critical mass
  • Surface:Volume ratio, heat loss, compost quality
Review of CHR Technologies

• Bio-thermal energy capture technology
  – Pre-1960s: China/France ➔ direct conductive and convective heat exchange
  – 1960s-70s: Jean Pain ➔ hydronic heat capture system
  – 1980s: New Alchemy Institute ➔ greenhouse heat, nitrification and CO₂ enrichment via air circulation
  – 2006: Diamond Hill Custom Heifers ➔ negative aeration composting coupled with Agrilab’s IsoBar thermosiphon heat exchange technology
Hydronic CHR Technology

~300 FT COIL, PLASTIC WATER PIPE

CONVECTIVE HEATER

~100 WATT PUMP

SOIL HEATING LOOP

Courtesy of Jason McCune-Sanders, Forest Enterprises
Foundation & Layering
First layer of coiled pipe
Half-way there...
Finished Mound
Mound insulated with hay bales
From Jean Pain’s “Another Kind of Garden”
From Jean Pain’s “Another Kind of Garden”
Temperature evolution at the center of pine wood chip piles

Adapted from Ferrero et. al. *Journal of Loss Prevention in the Process Industries*, 2009
Air Circulation CHR Technology

From the report “The Composting Greenhouse at New Alchemy Institute” by Bruce Fulford, Accessible at thegreencenter.net
Agrilab-Isobar CHR Technology

 Courtesy of Brian Jerose, Waste Not! Resources
Jasper Hill Farm’s Green Machine
## CHR Technology Comparison

<table>
<thead>
<tr>
<th>System type:</th>
<th>Feedstock:</th>
<th>Examples:</th>
<th>Heating performance:</th>
<th>Observed scale:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydronic in pile, passive aeration</td>
<td>Shredded wood, hardwood bark mulch</td>
<td>Jean Pain, VT Compost Co.</td>
<td>peak of 4 L/min of 140 F water from a 50 ton pile</td>
<td>10 to 50 tons per pile</td>
</tr>
<tr>
<td>Biofiltered air capture, forced aeration</td>
<td>Manure &amp; bedding</td>
<td>New Alchemy Insitute</td>
<td>Heated a 12' X 48' greenhouse through winter on Cape Cod</td>
<td>10 to 15 tons peak loading</td>
</tr>
<tr>
<td>Isobar in duct, negative aeration</td>
<td>Manure &amp; wood chips</td>
<td>Diamond Hill Custom Heifers</td>
<td>1000 btu/hr per ton of active compost</td>
<td>800 tons peak loading</td>
</tr>
</tbody>
</table>
## CHR Technology Comparison

<table>
<thead>
<tr>
<th>System type</th>
<th>Benefits</th>
<th>Drawbacks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydronic in pile, passive aeration</td>
<td>Lower capital costs; no windrow turning; suitable for small scale agricultural or homestead use</td>
<td>Labor intensive to build and disassemble; specific, high-carbon compost product</td>
</tr>
<tr>
<td>Biofiltered air capture, forced aeration</td>
<td>Lower capital costs; no windrow turning required; greenhouse CO₂ enrichment and nitrification</td>
<td>Potential greenhouse air quality issues; frequent loading of compost bins; high equipment down-time</td>
</tr>
<tr>
<td>Isobar in duct, negative aeration</td>
<td>Material can be added and removed without disturbing system; no windrow turning required; good for large scale, continuous operation</td>
<td>Relatively expensive and complex, not suitable for small scale or intermittent use</td>
</tr>
</tbody>
</table>
Hydronic Technology “Re-evaluation”

• Successful hydronic capture and utilization of bio-thermal energy from local biomass
  – Heated germination beds to 75°F in early spring
  – Some success with farm space heating (radiant floor)
  – Greater than 120°F duration up to 6 months
  – No continuous monitoring equipment

• Economic viability: cash flow projection
  – Driving factors: raw material costs, heat exchange efficiency, labor costs, thermophilic phase duration, compost value
  – Three scenarios of heat exchange efficiency
  – Note how net cash flow (ROI) is affected
## Cash Flow Projection

<table>
<thead>
<tr>
<th>Items</th>
<th>Q</th>
<th>UOM</th>
<th>$/Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Materials &amp; Construction</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bulk Agent</td>
<td>5</td>
<td>[yd³]</td>
<td>($50.00)</td>
<td>($250.00)</td>
</tr>
<tr>
<td>Labor</td>
<td>32</td>
<td>[man-hrs]</td>
<td>($15.00)</td>
<td>($480.00)</td>
</tr>
<tr>
<td>Fuel</td>
<td>5</td>
<td>[gal]</td>
<td>($3.50)</td>
<td>($17.50)</td>
</tr>
<tr>
<td>Pump</td>
<td>1</td>
<td>[EA]</td>
<td>($150.00)</td>
<td>($150.00)</td>
</tr>
<tr>
<td>Tubing</td>
<td>1</td>
<td>[EA]</td>
<td>($500.00)</td>
<td>($500.00)</td>
</tr>
<tr>
<td>Ancillaries</td>
<td>1</td>
<td>[EA]</td>
<td>($300.00)</td>
<td>($300.00)</td>
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<tr>
<td><strong>Operation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pump</td>
<td>540</td>
<td>[kWh]</td>
<td>($0.12)</td>
<td>($64.80)</td>
</tr>
<tr>
<td>Pump</td>
<td>1080</td>
<td>[kWh]</td>
<td>($0.12)</td>
<td>($129.60)</td>
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<tr>
<td>Scenario 1 Heat Captured</td>
<td>31.39 [mmBTU]</td>
<td>$27.00</td>
<td>$847.46</td>
<td></td>
</tr>
<tr>
<td>Scenario 2 Heat Captured</td>
<td>25.11 [mmBTU]</td>
<td>$27.00</td>
<td>$677.97</td>
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<tr>
<td>Scenario 3 Heat Captured</td>
<td>20.93 [mmBTU]</td>
<td>$27.00</td>
<td>$564.98</td>
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<tr>
<td>Scenario 4 Heat Captured</td>
<td>62.78 [mmBTU]</td>
<td>$27.00</td>
<td>$1,694.93</td>
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<tr>
<td>Scenario 5 Heat Captured</td>
<td>50.22 [mmBTU]</td>
<td>$27.00</td>
<td>$1,355.94</td>
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<tr>
<td>Scenario 6 Heat Captured</td>
<td>41.85 [mmBTU]</td>
<td>$27.00</td>
<td>$1,129.95</td>
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<tr>
<td><strong>De-Construction</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor</td>
<td>24</td>
<td>[man-hrs]</td>
<td>($15.00)</td>
<td>($360.00)</td>
</tr>
<tr>
<td>Fuel</td>
<td>5</td>
<td>[gal]</td>
<td>($3.50)</td>
<td>($17.50)</td>
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<tr>
<td>Compost</td>
<td>30</td>
<td>[yd³]</td>
<td>$25.00</td>
<td>$750.00</td>
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<tr>
<td>Salvage</td>
<td>1</td>
<td>[EA]</td>
<td>$475.00</td>
<td>$475.00</td>
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<tr>
<td><strong>Cash Flow Summary</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenario 1</td>
<td></td>
<td></td>
<td>($67.34)</td>
<td></td>
</tr>
<tr>
<td>Scenario 2</td>
<td></td>
<td></td>
<td>($236.83)</td>
<td></td>
</tr>
<tr>
<td>Scenario 3</td>
<td></td>
<td></td>
<td>($349.83)</td>
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<tr>
<td>Scenario 4</td>
<td></td>
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<td>$715.33</td>
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<tr>
<td>Scenario 5</td>
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<td>$376.34</td>
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<tr>
<td>Scenario 6</td>
<td></td>
<td></td>
<td>$150.35</td>
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</table>
Current Technical Status Summary

- Economic promise and environmental advantages motivate additional R & D
  - Check out Highfields Center’s Kickstarter project
- Consolidate performance data from existing CHR systems
  - Recipe, CHR technology, heat load, etc
- Compare performance of Isobar, air-capture, hydronic and other CHR innovations
  - Labor intensity, heat potential, compost quality, overall economic and environmental evaluation
  - How can performance be improved??
  - Matching technology with scale
- Broader impacts: Inform sustainable landscape-based eco-industrial “food web” evaluation and implementation
Methane Digester
Compost
Food/Feed Processing
Liquid-solid Separation
Bioshelter & Aquaponics
Livestock Agriculture
Raw and processed goods

Raw food/feed
Crop Agriculture

Biological wastes

Fedstock Processing

Biogas

Woody Biomass

Compost

Liquid-solid Separation

Manure Solids
(Potting/bedding media, mycoculture substrate)

Nutrient Stabilization
(Algae pond or lagoon)

Liquid effluent

Bioshelter products
(fish, plants)

Biogas

Internal Material (gas, liquid solid) flows

Internal Energy (thermal, mechanical) flows
Acknowledgements

• Sam’s funding from NSF Graduate Research Fellowship Program, advised by Drs. John Todd and Mary Watzin

• Some photos, drawings and diagrams courtesy of Compost Power Network, Jason McCune-Sanders and Brian Jerose, or available at the following links...
Useful & Interesting Links & References

– Diamond Hill Custom Heifers (1st ever Agrilab IsoBar system): http://www.biocycle.net/2006/08/extracting-thermal-energy-from-composting/
– New Alchemy Institute reports: http://thegreencenter.net/
– Composting technical materials: http://www.highfieldscomposting.org/techmaterials.htm
– Compost Power Network: http://compostpower.org/
– Jean Pain, Another Kind of Garden
– Northeast Regional Agricultural Engineering Service, On-Farm Composting Handbook, NRAES-54
– Sam’s Small Farms Quarterly article: http://smallfarms.cornell.edu/2012/10/01/compost-power/