Biomass Fuel Project
Topics

• Pop quiz
• Project background
• Industrial byproducts
• Wood
• Perennial energy crops
• Miscanthis plan
Pop Quiz

1. What is Iowa’s most valuable natural resource?
2. What role should ‘we’ play in preserving/enhancing that resource?
3. What is the “sustainable” cost of our purchased energy (coal, natural gas, electric power, biomass)?
4. What has been the biggest barrier to developing dedicated energy crop production in Iowa?
5. What is the value of avoiding CO$_2$ emissions from UI coal burning, on a $ per ton basis?

sustainability.uiowa.edu/biomass
Project Background
Triple Bottom Line

Environment

Economic

Social

Bearable

Equitable

Viable

Sustainable
2020 Vision - The University of Iowa's Sustainability Targets

2. Green Our Energy Portfolio

The UI will pursue a renewable energy supply strategy that optimizes long-term supply and fuel price stability while preserving an ability to test and take advantage of other potential fuels.

As we transition from our dependency on fossil fuels, we will increase the use of biomass, geothermal, solar, wind, landfill gas, gasification and other emerging energy alternatives to achieve the goal of 40% renewable energy consumption on the campus by 2020.
## 2010 Baseline Energy Use

<table>
<thead>
<tr>
<th>Energy Form</th>
<th>Quantity (MMBtu)</th>
<th>Percent</th>
<th>Cost</th>
<th>Unit Cost $/MMBtu</th>
<th>CO2 US tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>2,005,000</td>
<td>50%</td>
<td>$8,878,000</td>
<td>$4.43</td>
<td>241,000</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>742,000</td>
<td>18%</td>
<td>$3,690,000</td>
<td>$4.97</td>
<td>45,000</td>
</tr>
<tr>
<td>Purchased Electric</td>
<td>968,000</td>
<td>24%</td>
<td>$12,480,000</td>
<td>$12.89</td>
<td>258,000</td>
</tr>
<tr>
<td>Biomass</td>
<td>331,000</td>
<td>8%</td>
<td>$573,000</td>
<td>$1.73</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4,046,000</strong></td>
<td><strong>100%</strong></td>
<td><strong>$25,621,000</strong></td>
<td></td>
<td><strong>544,000</strong></td>
</tr>
</tbody>
</table>

[2010 Baseline Energy Use](sustainability.uiowa.edu/biomass)
Biomass Fuel Portfolio

1. Industrial byproducts (oat hulls, cardboard recycling sludge, scrap from furniture making)

2. Wood chips from timber (forest) stand improvement and opportunity wood (storms, EAB)

3. Dedicated perennial energy crops (miscanthus grass, short rotation woody)
Leopold Center for Sustainable Agriculture

• Biomass Partnership planning grant

• UI Fuel Sustainability Index development grant
Our Challenge

Transition from burning black rocks (weighing 55 pounds per cubic foot with an energy density of 11,500 Btu per pound) to burning organic material with vastly different physical and chemical properties, without major capital investment.
Two Main Campus Solid Fuel Boilers

Circulating Fluidized Bed
170,000 lbs. per hour @ 750°F 500 psig

Stoker
Densification

Miscanthus  Switchgrass  Corn stover
### University of Iowa - Quaker Oats Biomass Fuel Project Partnership

<table>
<thead>
<tr>
<th>Calendar Year</th>
<th>Tons of Coal Displaced</th>
<th>Avoided Coal CO2 Emissions Metric Tons</th>
<th>Avoided Fuel Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>11,511</td>
<td>25,632</td>
<td>$ 391,299</td>
</tr>
<tr>
<td>2004</td>
<td>16,636</td>
<td>37,045</td>
<td>$ 415,273</td>
</tr>
<tr>
<td>2005</td>
<td>24,290</td>
<td>54,088</td>
<td>$ 765,471</td>
</tr>
<tr>
<td>2006</td>
<td>27,424</td>
<td>61,068</td>
<td>$ 1,017,780</td>
</tr>
<tr>
<td>2007</td>
<td>23,324</td>
<td>51,939</td>
<td>$ 872,136</td>
</tr>
<tr>
<td>2008</td>
<td>17,929</td>
<td>39,924</td>
<td>$ 712,672</td>
</tr>
<tr>
<td>2009</td>
<td>15,666</td>
<td>34,886</td>
<td>$ 844,617</td>
</tr>
<tr>
<td>2010</td>
<td>15,206</td>
<td>33,862</td>
<td>$ 844,225</td>
</tr>
<tr>
<td>2011</td>
<td>16,929</td>
<td>37,698</td>
<td>$ 950,880</td>
</tr>
<tr>
<td>2012</td>
<td>14,309</td>
<td>31,864</td>
<td>$ 812,034</td>
</tr>
<tr>
<td><strong>10-Yr Total</strong></td>
<td><strong>183,225</strong></td>
<td><strong>408,005</strong></td>
<td><strong>$ 7,626,387</strong></td>
</tr>
</tbody>
</table>

Note: CY08 and CY09 adversely affected by 2008 flood at both UI Power Plant and Quaker Oats

The oat hull fuel project has given us a foundation on which to expand our use of biomass.

[The oat hull fuel project has given us a foundation on which to expand our use of biomass.](sustainability.uiowa.edu/biomass)
University Research Park Campus

600 HP 120 psig saturated steam
The University of Iowa Biomass Fuel Project

Fuel Portfolio: Industrial Byproducts
Industrial Byproducts

Is using this material as boiler fuel (energy production) a higher use, compared to alternative uses?

- Expired and off-spec corn and soybean seeds
- Oat hulls
- Paper sludge
- Wood furniture manufacturing
- Lignin from cellulosic processes
- Sawdust

sustainability.uiowa.edu/biomass
Completed Test Burns

- Seed corn
- Cardboard recycling plant sludge
- Proctor and Gamble production sludge
- Corn stover pellets
- Wood pellets
- Wood chips
- Manufactured energy pellets, produced from non-recyclable paper with plastic content (e.g. dipers)
Industrial Byproducts

- Opportunity for institution and industry partnerships
- Significant amount of plant based products in the local area
- Steady, predictable quantity
- Consistent physical and chemical properties
- Do not behave like coal in material handling and combustion, e.g. much higher volatile content and oxygen content

sustainability.uiowa.edu/biomass
The University of Iowa
Biomass Fuel Project

Fuel Portfolio: Wood
Timber Stand Improvement

• Qualified forester
• Landowner desires
• Management Plan
Kent Park conifer harvest

• Learning and partnership opportunity
• 20+ acres of dead, dying, diseased trees
• Planted in 1970’s for wildlife habitat
• Johnson County Conservation Board desires to restore to native prairie.
• No market for distressed timber
• Final delivered fuel cost:
  • $4.89 / MMBtu to RTC Muscatine
  • $1.47 / MMBtu RTC blend and deliver
Kent Park conifer locations
Did not estimate amount of wood from tops and limbs. Resulted in 30% over plan harvested material.
Clear-cutting into timber stand
Cut trees ready to be skidded to chipper
Chips in Muscatine facility ready to blend
Blending operations at Muscatine facility
Loading coal/wood mix for delivery to Main Power Plant.
Unloading at Main Power Plant
Emerald Ash Borer

All Iowa ash trees dead within 20 years:
State forester
– CR Gazette Dec. 27, 2013

• 55 million ash trees in Iowa
• 3.1 million urban ash trees, $1,000 per tree removal cost
• Entire State of Iowa quarantined
Wood chip sizing is critical. Long, stringy spears and branches bind up drag chain conveyors and force shutdowns and unplanned maintenance.
Perennial Energy Crops
Iowa Farmland

2013 average = $8,716 per acre
<table>
<thead>
<tr>
<th>Use</th>
<th>Acres</th>
<th>Percent of Total Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>13,417,418</td>
<td>37%</td>
</tr>
<tr>
<td>Soybeans</td>
<td>8,882,633</td>
<td>25%</td>
</tr>
<tr>
<td>Grassland</td>
<td>5,462,789</td>
<td>15%</td>
</tr>
<tr>
<td>D Forest</td>
<td>3,063,818</td>
<td>9%</td>
</tr>
<tr>
<td>Develop/open</td>
<td>1,938,346</td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td>32,765,004</td>
<td>91%</td>
</tr>
<tr>
<td><strong>Total Acres</strong></td>
<td>36,014,211</td>
<td></td>
</tr>
</tbody>
</table>
Marginal Land

- Corn Suitability Rating between 25 and 75
- Slope less than 12%
- Now in corn or bean production
- 380,000 acres

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Perennial Dedicated Energy Crops

- Positive impact on non-point source nutrient runoff
- Deep root system facilitates growth in low moisture years
- Increases soil quality and adds quantity
- Sequesters more carbon, compared to annuals
- Appropriate use of marginal cropland
- Revenue stream for farmer independent of corn and bean prices
# A year in the life of Miscanthus x giganteus (Mxg)

<table>
<thead>
<tr>
<th>April</th>
<th>May</th>
<th>August/September</th>
<th>November</th>
<th>December</th>
<th>February</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergence</td>
<td>Canopy Closure</td>
<td>Maximum biomass</td>
<td>Senescence</td>
<td>Dry Down</td>
<td>Over winter</td>
</tr>
</tbody>
</table>


sustainability.uiowa.edu/biomass
Muscatine County 2013 Pilot Planting
Pilot Project Knowledge Discovery

- NPK in boiler – slagging, fouling, $\text{NO}_x$ emissions increase
- Logistics – farm field to fuel yard to plant, densification
- Harvest – bale (round or square) or silage chop
- Storage – distributed or central, covered or not
Two Foot Elevations – 678ft. min to 700 ft. max
Corn Suitability Rating
April 1, 2013 - Lifting rhizomes in southern Georgia.
Rhizomes delivered May 15, 2013.

Intended to plant May 22/23.

Rain delayed planting until June 21.
Unloading super sacks of rhizomes from refrigerated trailer.
Rhizomes were kept wet by frequent watering.

When unpacked from super sacks, they were cool, moist, and supple.

Some had sprouted additional growth.
Rhizomes after six weeks storage in refrigerated trailer; they were watered frequently during storage.
Rhizomes after six weeks storage in refrigerated trailer; they were watered frequently.
Equipment used on planting day.
US modifications surrounded in red.
Planter hopper
Loading rhizomes into planter hopper.
Planting, note tractor driver looking backwards.

Field was rolled within 24-hours of planting.
Field Inspection

July 16, 2013
July 16, 2013

Field Inspection
July 16, 2013

Field Inspection
July 16, 2013

Field Inspection
October 20, 2013

Field Inspection
2013 establishment year cost was $1,847 per acre.
1. Assess project business plan; recommend changes and adjustments.
2. Develop modified cash-rent contracts, with provider serving as tenant.
3. Find landowners and place under long-term (10-year initial) contract.
4. Nutrient, pest, and weed management.
5. Risk management plan implementation and oversight.
6. Provide custom harvest management from the field to farm gate storage.
7. Cash flow to landowners (cash rent) and other custom farming service providers.
8. Invoice UI for project costs (land rent, custom harvesting, grower services, etc.).
9. Implement an automated system for agricultural field record keeping.

Ag Services Provider
Work-scope
2015 & 2016
Dedicated Energy Crop Planting

• 2,500 acres total
• Provide 25% of 2020 goal, or 10% of total energy
• 10-year financial analysis
## IRR Sensitivity with $15.00 per ton CO2, base case IRR = 3.4%

<table>
<thead>
<tr>
<th></th>
<th>Base Case</th>
<th>High</th>
<th>Low</th>
<th>IRR High</th>
<th>IRR Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land rent per acre per year</td>
<td>$200</td>
<td>$300</td>
<td>$175</td>
<td>-12.2%</td>
<td>6.6%</td>
</tr>
<tr>
<td>Grower Services (e.g. N)</td>
<td>$50.</td>
<td>$75.</td>
<td>$25.</td>
<td>0.1%</td>
<td>6.6%</td>
</tr>
<tr>
<td>Ag Services Per ton variable</td>
<td>$0.00</td>
<td>$0.00</td>
<td>$0.00</td>
<td>3.4%</td>
<td>3.4%</td>
</tr>
<tr>
<td>Miscanthus heating value (Btu/lb)</td>
<td>7,700</td>
<td>8,500</td>
<td>7,000</td>
<td>13.2%</td>
<td>-8.7%</td>
</tr>
<tr>
<td>Semi Tons per Load</td>
<td>22</td>
<td>25</td>
<td>20</td>
<td>4.2%</td>
<td>2.8%</td>
</tr>
<tr>
<td>Tons per acre @ full production</td>
<td>9.0</td>
<td>10.0</td>
<td>7.0</td>
<td>8.3%</td>
<td>-13.1%</td>
</tr>
<tr>
<td>Semi cost ($ per loaded mile)</td>
<td>$4.00</td>
<td>$5.00</td>
<td>$3.00</td>
<td>1.8%</td>
<td>5.0%</td>
</tr>
<tr>
<td>Average transportation distance (miles)</td>
<td>35</td>
<td>50</td>
<td>15</td>
<td>0.6%</td>
<td>6.9%</td>
</tr>
<tr>
<td>Fossil fuel cost $ per MMBtu</td>
<td>$5.00</td>
<td>$6.00</td>
<td>$4.75</td>
<td>16.4%</td>
<td>-0.7%</td>
</tr>
<tr>
<td>Bale Weight (lbs)</td>
<td>1,200</td>
<td>1,400</td>
<td>1,100</td>
<td>6.7%</td>
<td>1.3%</td>
</tr>
</tbody>
</table>
Note: this 10-year analysis includes field establishment cost at $900 per acre.
Miscanthus Production Costs

(establishment cost NOT included)

- Land rent: $200/acre
- Harvest: $234/acre
- Fuel Yard: $13/ton
- Nutrients: $50/acre
- Ag Services: $100,000/year
- Transport: $4.00/mile

9 tons per acre dry matter yield
7,700 Btu/lb Higher Heating Value

$5.60 per MMBtu total
Misanthus Production Costs
(establishment cost NOT included)

$86.30 per ton total

9 tons per acre dry matter yield
7,700 Btu/lb Higher Heating Value

Land rent $200/acre
Harvest $234/acre
Fuel Yard $13/ton
Nutrients $50/acre
Ag Services $100,000/year
Transport $4.00/mile

Transportation, $14.55
Fuel Yard, $13.00
Land Rent, $22.22
Fertilizer, $5.56
Ash disposal, $0.53
Ag Services Provider, $4.44
### Miscanthus and Coal Cost Comparison (establishment cost NOT included)

<table>
<thead>
<tr>
<th></th>
<th>Miscanthus</th>
<th>Fluid Bed</th>
<th>Stoker</th>
</tr>
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<tbody>
<tr>
<td>Transportation</td>
<td>$0.94</td>
<td>$0.94</td>
<td>$0.99</td>
</tr>
<tr>
<td>Ash disposal</td>
<td>$0.03</td>
<td>$0.18</td>
<td>0.07</td>
</tr>
<tr>
<td>Coal Cost</td>
<td></td>
<td>$3.01</td>
<td>$4.62</td>
</tr>
<tr>
<td>Ag Services Provider</td>
<td>$0.29</td>
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<tr>
<td>Land Rent</td>
<td>$1.44</td>
<td></td>
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</tr>
<tr>
<td>Fertilizer</td>
<td>$0.36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harvest</td>
<td>$1.69</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel Yard</td>
<td>$0.84</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limestone</td>
<td></td>
<td></td>
<td>$0.16</td>
</tr>
</tbody>
</table>

Cost per MMBtu