Assessment of Biomass Energy Potential in New Jersey

Draft Executive Summary

Spring 2007

The New Jersey Agricultural Experiment Station

DRAFT REPORT
The NJ Board of Public Utilities retained the New Jersey Agricultural Experiment Station to evaluate the state’s bioenergy potential

• The four major deliverables of this project are:
  — Assessment of the characteristics and quantity of New Jersey’s biomass resources;
  — Assessment of technologies (commercially or near commercially available) that are capable of producing bioenergy, in the form of electric power and transportation fuels from New Jersey’s biomass resources.
  — Development of the first statewide mapping of waste/biomass resources
  — Development of policy recommendations for moving New Jersey into the forefront of bioenergy innovation.

• These deliverables will result in the establishment of an outstanding capacity to further develop the bioenergy potential for New Jersey.
Study Team

- **Project Director** – Margaret Brennan
- **Waste Stream/Biomass Assessment**
  - Team Members: Brian Schilling (Team Leader), Priscilla Hayes (Co-Leader), Zane Helsel, Kevin Sullivan, Mike Westendorf, Dave Specca, Bob Simkins (Burlington County), Lucas Marxen
- **Bioconversion Technology Assessment Team**
  - Team Members: David Specca (team leader), A.J. Both, Donna Fennell, Priscilla Hayes, Mike Westendorf, Rhea Brekke (NJ CAT), Steve Paul (Princeton University), Bob Simkins (Burlington County)
- **Waste Stream/Biomass Mapping**
  - Team Members: David Tulloch (Team Leader), Caroline Phillipuk, Lucas Marxen
- **Policy Recommendations**
  - Team Members: Margaret Brennan (Team Leader), all members of project teams, Rutgers Center for Energy, Economic and Environmental Policy
- **Navigant Consulting**
  - Provided technology cost and performance data; developed interactive database with information provided by NJAES.
A range of biomass resources were examined; these were divided into 5 categories based on their physical characteristics.

<table>
<thead>
<tr>
<th>Feedstock Type</th>
<th>Definitions</th>
<th>Resources</th>
</tr>
</thead>
</table>
| Sugars/Starches      | Traditional agricultural crops suitable for fermentation using 1st generation technologies Some food processing residues are sugar and starch materials | • Agricultural crops (sugars/starches)  
   • Food processing residues (w/residual sugars) |
| Lignocellulosic      | Clean woody and herbaceous materials from a variety of sources Includes clean urban biomass that is generally collected separately from the municipal waste stream (wood from the urban forest, yard waste, used pallets) | • Agricultural residues  
   • Cellulosic energy crops  
   • Food processing residues  
   • Forest residues, mill residues  
   • Urban wood wastes  
   • Yard wastes |
| Biomass              | Traditional edible oil crops and waste oils suitable for conversion to biodiesel | • Agricultural crops (beans/oils)  
   • Waste oils/fats/grease |
| Solid Wastes         | Primarily lignocellulosic biomass, but that may be contaminated (e.g., C&D wood) or co-mingled with other biomass types | • Municipal solid waste (biomass component)  
   • Construction & Demolition (C&D) wood  
   • Food wastes  
   • Non-recycled paper  
   • Recycled materials |
| Other Wastes         | Other biomass wastes that are generally separate from the solid waste stream Includes biogas and landfill gas | • Animal waste (farm)  
   • Wastewater treatment biogas  
   • Landfill gas |
Executive Summary » Biomass Theoretical Potential

NJ produces an estimated 8.2 million dry tons (MDT) of biomass annually. Individual county amounts range from 210,000-680,000 DT.

<table>
<thead>
<tr>
<th>County</th>
<th>Sugar/Starch</th>
<th>Ligno</th>
<th>Bio-Oils</th>
<th>Solid Waste Recycled</th>
<th>Landfilled Biomass</th>
<th>C&amp;D non-recycled</th>
<th>Other Wastes</th>
<th>Totals (Tons)</th>
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</thead>
<tbody>
<tr>
<td>Atlantic</td>
<td>3,170</td>
<td>108,957</td>
<td>1,179</td>
<td>31,919</td>
<td>115,217</td>
<td>25,602</td>
<td>30,315</td>
<td>316,358</td>
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<td>Bergen</td>
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<td>87,455</td>
<td>3,779</td>
<td>169,401</td>
<td>294,436</td>
<td>69,209</td>
<td>115,775</td>
<td>740,060</td>
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<td>Burlington</td>
<td>29,787</td>
<td>255,697</td>
<td>23,040</td>
<td>60,576</td>
<td>149,554</td>
<td>32,570</td>
<td>130,609</td>
<td>681,833</td>
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<td>Camden</td>
<td>2,477</td>
<td>118,822</td>
<td>2,550</td>
<td>29,799</td>
<td>39,659</td>
<td>41,743</td>
<td>34,565</td>
<td>269,615</td>
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<td>Cape May</td>
<td>831</td>
<td>145,752</td>
<td>851</td>
<td>24,249</td>
<td>42,421</td>
<td>24,471</td>
<td>8,925</td>
<td>247,500</td>
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<tr>
<td>Cumberland</td>
<td>26,681</td>
<td>216,226</td>
<td>10,823</td>
<td>54,495</td>
<td>56,829</td>
<td>13,574</td>
<td>42,461</td>
<td>421,088</td>
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<tr>
<td>Essex</td>
<td>-</td>
<td>37,392</td>
<td>3,313</td>
<td>76,587</td>
<td>87,595</td>
<td>71,750</td>
<td>40,251</td>
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<td>Gloucester</td>
<td>15,206</td>
<td>173,089</td>
<td>11,462</td>
<td>27,420</td>
<td>42,495</td>
<td>13,574</td>
<td>58,327</td>
<td>321,229</td>
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<td>Hudson</td>
<td>-</td>
<td>7,949</td>
<td>2,527</td>
<td>109,051</td>
<td>191,915</td>
<td>41,639</td>
<td>19,328</td>
<td>372,410</td>
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<td>Hunterdon</td>
<td>25,370</td>
<td>138,574</td>
<td>5,985</td>
<td>11,304</td>
<td>42,090</td>
<td>56,986</td>
<td>31,986</td>
<td>312,295</td>
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<tr>
<td>Mercer</td>
<td>9,306</td>
<td>80,835</td>
<td>8,101</td>
<td>75,089</td>
<td>113,978</td>
<td>25,883</td>
<td>12,200</td>
<td>325,393</td>
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<td>Middlesex</td>
<td>11,212</td>
<td>95,451</td>
<td>8,216</td>
<td>169,437</td>
<td>260,179</td>
<td>81,044</td>
<td>52,927</td>
<td>678,466</td>
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<tr>
<td>Monmouth</td>
<td>11,537</td>
<td>151,043</td>
<td>8,639</td>
<td>92,865</td>
<td>199,296</td>
<td>49,677</td>
<td>54,940</td>
<td>567,996</td>
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<td>Morris</td>
<td>4,429</td>
<td>114,985</td>
<td>2,431</td>
<td>71,636</td>
<td>165,620</td>
<td>38,695</td>
<td>33,375</td>
<td>431,170</td>
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<tr>
<td>Ocean</td>
<td>2,239</td>
<td>156,619</td>
<td>2,833</td>
<td>85,768</td>
<td>221,097</td>
<td>43,008</td>
<td>17,981</td>
<td>529,543</td>
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<tr>
<td>Passaic</td>
<td>6</td>
<td>52,724</td>
<td>2,090</td>
<td>94,517</td>
<td>177,172</td>
<td>38,164</td>
<td>3,308</td>
<td>367,980</td>
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<td>Salem</td>
<td>59,560</td>
<td>135,424</td>
<td>18,675</td>
<td>5,396</td>
<td>17,035</td>
<td>14,625</td>
<td>37,777</td>
<td>288,492</td>
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<td>Somerset</td>
<td>9,267</td>
<td>67,465</td>
<td>2,282</td>
<td>40,404</td>
<td>104,843</td>
<td>1,482</td>
<td>14,546</td>
<td>240,289</td>
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<tr>
<td>Sussex</td>
<td>6,796</td>
<td>160,795</td>
<td>653</td>
<td>17,667</td>
<td>40,322</td>
<td>11,216</td>
<td>35,978</td>
<td>273,427</td>
</tr>
<tr>
<td>Union</td>
<td>5</td>
<td>42,242</td>
<td>2,225</td>
<td>46,261</td>
<td>60,536</td>
<td>48,164</td>
<td>10,022</td>
<td>209,455</td>
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<tr>
<td>Warren</td>
<td>48,006</td>
<td>135,236</td>
<td>5,014</td>
<td>10,588</td>
<td>11,150</td>
<td>7,822</td>
<td>53,302</td>
<td>271,117</td>
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<tr>
<td>TOTALS</td>
<td>265,887</td>
<td>2,482,731</td>
<td>126,666</td>
<td>1,304,429</td>
<td>2,406,613</td>
<td>757,346</td>
<td>838,899</td>
<td>8,182,570</td>
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</tbody>
</table>

• Biogas (in Other Wastes) is based in Tons Equivalent biomass, assuming 500 Btu/scf and 8000 Btu/lb
Although the theoretical potential is large, there are several reasons why it will not be practical to recover all of NJ’s biomass.

1. Lack of collection and transport infrastructure for certain feedstocks

New Jersey’s municipal solid waste and agricultural crops maintain a well established collection and delivery infrastructure. For agricultural and forestry residues, such a system may have to be created or revamped. Economic incentives may be needed to incentivize the owners of transportation vehicles to add to or convert their fleet for these purposes.

2. Co-mingling of significant quantities of biomass with other wastes

Further source separation practices will be needed if NJ is to take advantage of wastes that are now not fully separated, such as food waste and C&D wood.

3. Competition from existing uses

Much of NJ’s urban waste biomass is currently recycled and used in alternative markets. These markets are well established, and may offer a higher value than (today’s) energy cost (especially given the technology costs for converting that resource to energy).

NJ’s practically recoverable biomass resource is estimated at 5.2 MDT
A screening process was developed to help estimate how much of NJ’s theoretically available biomass might be recoverable.
Biomass is concentrated in the counties of central and northeastern New Jersey.

Almost 75% of NJ’s biomass resources is produced directly by the state’s population, much of it in the form of municipal solid waste.
Almost 75% of NJ’s biomass resource is produced directly by the state’s population, much of it in the form of municipal solid waste.

The chart on the left shows NJ’s total biomass. The chart on the right shows just the population-related biomass waste stream.

In the past, generating energy from solid waste typically involved incineration. Several new technologies described in Section IV are becoming capable of converting solid waste into energy without incineration.

1. This total includes biogas and landfill gas quantities converted to dry ton equivalents on an energy basis. Note that these are gross quantities, not taking into account differences in heat content per ton.
Agriculture and forestry management are important potential sources of biomass

- Biomass from agricultural sources include both crops and crop residues. The use of agricultural crops for energy production would require the decision to convert the current food supply chain into energy production, which could have other major policy implications. Crop residues, on the other hand, are generally underutilized and undervalued, which should allow for an easier decision to use these resources.

- In the case of energy crops, NJ would also need to decide whether to maintain the current crop varieties, or introduce new crops that may be better suited to energy production (eg. poplar or switchgrass).
Some biopower technologies are becoming cost competitive. Economics are driven by feedstock cost, incentives, and technology type.

<table>
<thead>
<tr>
<th>Feedstock Cost (Tipping Fee)</th>
<th>DC – Central</th>
<th>DC – CHP</th>
<th>Co-Firing with Coal*</th>
<th>Gasification - Combined Cycle</th>
<th>Gasification - IC Engine</th>
<th>Gasification - Microturbine</th>
<th>Food Waste AD</th>
<th>LFG</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
<td>$1$^2</td>
<td>$1$^2</td>
<td>$1$^2</td>
<td>$0</td>
<td>$0</td>
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<tr>
<td>$3</td>
<td>$1$^3</td>
<td>$1$^3</td>
<td>$1$^3</td>
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<td>$1$^3</td>
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<td>$1.5</td>
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<td>$1$^3</td>
<td>$1$^3</td>
<td>$1$^3</td>
<td>$1$^3</td>
<td>$1$^3</td>
<td>$1$^3</td>
</tr>
</tbody>
</table>

1: LCOE: The present value of the total cost of building and operating a generating plant over its economic life, converted to equal $/kWh unit payments. Costs are levelized in real dollars (i.e., adjusted to remove the impact of inflation).

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Incentives, feedstock costs, and possible tipping fees are also a key to promoting the production of biofuels.

Fuel Production Cost Comparison for Biofuels Options: 2007 with and without incentives

<table>
<thead>
<tr>
<th>Feedstock Cost (Tipping Fee)</th>
<th>FT Diesel</th>
<th>Dilute Acid Hydrolysis</th>
<th>Ethanol - Corn</th>
<th>Ethanol - Cellulosic</th>
<th>Biodiesel - Soy</th>
<th>Biodiesel - YG</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0</td>
<td>$3.0</td>
<td>$3.0</td>
<td>$2.5</td>
<td>$2.5</td>
<td>$2.2</td>
<td>$2.2</td>
</tr>
<tr>
<td>$47</td>
<td>$4.5</td>
<td>$4.5</td>
<td>$4.0</td>
<td>$4.0</td>
<td>$4.0</td>
<td>$4.0</td>
</tr>
</tbody>
</table>

1: in $/ton of biomass (unless specified)
2: assumes $40/ton tipping fee
3: in $/bushel of corn
4: in $/gallon of vegetable oil

Note: any incentives included are those that apply to producers (i.e., they affect production costs). Blenders excise tax credits, which affect market prices, are not included.
Executive Summary » Estimated Energy Potential

The energy that could be created if NJ’s recoverable biomass were converted to energy suggests substantial benefits can be achieved.

1. NJ’s 8.2 million dry tons/year of biomass represents a theoretical energy potential of almost 1,700 megawatts (MW) of electricity or 455 million gallons of gasoline equivalent (GGE)\(^1\) of biofuel\(^2\).

2. NJ’s estimated practically recoverable biomass resource of 5.2 MDT could deliver up to 1,075 MW of NJ’s electricity power demand or 290 million gallons of gasoline equivalent of transportation fuel consumed.

3. This practically recoverable energy potential equals approximately 9% of NJ’s electricity consumption or 5% of its transportation fuel consumed.

4. Bioenergy will likely require moderately high fuel prices, technology advances, and financial incentives to be commercially competitive.

5. Based on assumptions about population growth and efficiency improvements, the potential exists for this to grow to over 1,350 MW or 375 M GGE of biofuel by 2015.

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1. One gallon of gasoline contains approximately 125,000 Btu of energy. Biofuels have different volumetric energy densities (some lower, some higher). Estimates of biofuel yields have been converted to “gallons of gasoline equivalent” based on the ratio of volumetric energy densities, to allow for consistent comparisons among the various fuels.

2. The total energy potential from feedstock that could classify as Class II Renewables could potentially add up to 500 MW or 85 M GGE biofuels if it were included in these totals (it is not).
NJ’s large municipal waste biomass resource, combined with its proximity to a petrochemical infrastructure, makes it a good location to utilize advanced power and fuels technologies.

- Some technologies approaching commercial use appear better suited to exploit NJ’s largest biomass resources:
  - For fuels, emerging biomass-to-liquids technologies, such as cellulosic ethanol, Fischer-Tropsch (FT) diesel, dilute acid hydrolysis, and biogas to LNG/CNG present some of the best opportunities.
  - For power, direct combustion, biomass gasification and anaerobic digestion are among the most developed technologies to process waste biomass streams.
Technology development and commercialization proceeds through a number of basic stages.

<table>
<thead>
<tr>
<th>R&amp;D</th>
<th>Demonstration</th>
<th>Market Entry</th>
<th>Market Penetration</th>
<th>Market Maturity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial System Prototypes</td>
<td>• Research on component technologies</td>
<td>• Integrate component technologies</td>
<td>• Commercial demonstration</td>
<td>• Follow-up orders based on need and product reputation</td>
</tr>
<tr>
<td></td>
<td>• General assessment of market needs</td>
<td>• Initial system prototype for debugging</td>
<td>• Ongoing development to reduce costs or for other needed improvements</td>
<td>• Early movers or niche segments</td>
</tr>
<tr>
<td></td>
<td>• Assess general magnitude of economics</td>
<td>• “Technology” (systems) demonstrations</td>
<td>• Commercial demonstration</td>
<td>• Product reputation is initially established</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Some small-scale “commercial” demonstrations</td>
<td>• Full size system in commercial operating environment</td>
<td>• Business concept implemented</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Communicate program results to early adopters/selected niches</td>
<td>• Market support usually needed to address high cost production</td>
</tr>
<tr>
<td>10+ years</td>
<td>4 - 8 years</td>
<td>1 - 3 years</td>
<td>10 - 20 years</td>
<td>Ongoing</td>
</tr>
</tbody>
</table>

The time required to pass through any given stage can vary considerably. The values shown here are representative of a technology that passes successfully from one stage to the next without setbacks.
# Bioenergy Technology Summary

<table>
<thead>
<tr>
<th>Application</th>
<th>Core Technology Platform and typical applications</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 Direct Combustion</td>
</tr>
<tr>
<td>Power/CHP</td>
<td>●</td>
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<tr>
<td>Heat Only</td>
<td>●</td>
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<tr>
<td>Transportation Fuels</td>
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</tr>
<tr>
<td>Example Technologies</td>
<td></td>
</tr>
<tr>
<td>Typical Feedstocks</td>
<td></td>
</tr>
</tbody>
</table>

### Application:
- **Power/CHP**
- **Heat Only**
- **Transportation Fuels**

### Core Technology Platform:

1. **Direct Combustion**
2. **Thermo-chemical Conversion**
3. **Fermentation**
4. **Anaerobic Digestion**
5. **Physio-chemical Conversion**

### Example Technologies:
- Biomass boiler coupled to steam turbine generator
- Biomass gasifier coupled to IC engine generator
- Corn-ethanol Cellulosic ethanol
- Wastewater treatment plant (WWTP) biogas coupled to IC engine generator
- Biodiesel blended with petroleum diesel or heating oil

### Typical Feedstocks:
- Lignocellulosic biomass
- Solid wastes
- Sugars/starches (1st generation)
- Lignocellulosic biomass (2nd generation)
- Sewage sludge, manure, food waste, and landfill wastes (that produce landfill gas)

### Primary application ●
### Secondary Application ○
### Blank indicates generally not applicable.
Bioenergy will likely require moderately high fuel prices, technology advances, and financial incentives to be commercially competitive.

Biopower

- Some biopower technologies are becoming cost competitive. Economics are driven by feedstock cost, incentives, and technology type.
- By 2010 and 2015, cost reduction potential should bring additional technologies into the realm of commercial application.

Biofuels

- Incentives, feedstock costs, and possible tipping fees are also key to promoting the production of biofuels.
- Major cost reductions are expected over the next 3-8 years that will allow new biofuels technologies to become more cost competitive.

NJ’s large municipal waste biomass resource, combined with its proximity to a petrochemical infrastructure, makes it a good location to utilize advanced power and fuels technologies.
Next Steps:

— Identify environmental impacts of the bioenergy technologies discussed in this report.

— Develop the first statewide mapping of waste/biomass resources.

— Develop policy recommendations for moving New Jersey into the forefront of bioenergy innovation.