Biofuel Sources and Emerging Technologies

The Future of Biofuels in Minnesota
Minnesota Environmental Initiative
November 13, 2008
Overview:

1. Agricultural Research Station

2. Serve as Living Lab and Public Access Point

3. Developing Community Scale Renewable Energy Systems

4. Focus on Local Ownership
Community-Scale Renewable Energy Systems:

- Hybrid Wind System
- Biomass Gasification System
- Community Biogas System
- Renewable Energy / Green Office Building

Practical production systems with research and demonstration platforms

Focus on local ownership

“Destination Renewable Energy Research & Demonstration Systems”
We use a lot of energy!
5% of World population and use 23% of all energy

When a Redneck Wins the Lottery

University of Minnesota
Driven to Discover
Biomass Energy Systems are Improving
Production of Biofuels

Opening Comments:

1. Need diverse fuels for wide ranging applications

2. Need to make graduated steps as in the ethanol industry

3. Feedstock logistics may dictate utilization technology and scale

4. DOE projections tend to understate the value of biomass to producer ($35 per ton by 2012)

5. Biomass is inherently local energy
Production of Biofuels

Two Basic Platforms:

Biochemical Conversion
Biomass is broken down to sugars using either enzymatic or chemical processes and then converted to ethanol via fermentation.

Thermochemical Conversion
Biomass is broken down to intermediates using heat and upgraded to fuels using a combination of heat and pressure in the presence of catalysts.
Biomass Energy Systems

Types:

1. Fermentation (corn grain or corn stover ethanol)

2. Gasification (Wide range of feedstocks)

3. Pyrolysis
   - Liquefaction (Fast Pyrolysis)
   - Thermal Depolymerization (Hydrous Pyrolysis)

4. Biodiesel (Transesterfication)

5. Anaerobic Digestion

6. Others / Combinations (Fermentation of Syngas)
Fermentation

• **Starch-Based Ethanol**
  – Food of Fuel Debate
  – Oxygenated gasoline
  – Established process and feedstock supply

• **Cellulosic Ethanol**
  – SunOpta Bioprocess / Central MN Ethanol Partnership (Little Falls)
  – Abengoa (Kansas)
  – Feedstock supply is perhaps the biggest challenge
Gasification

- Handful of commercial systems for ag residues
- Several for wood
- Fuel flexible – Unlike cellulosic ethanol
- More manageable feedstock supply
- Shorter path to commercialization
- Thermal energy – district heating and cooling – process heat – electrical energy generation – transportation fuel
- Chippewa Valley Ethanol Company / Frontline Energy Gasifier and University of Minnesota, Morris system
Gasification

- Heat (and Cooling)- Combustion of gas to make steam
- Gases- Purify and store the CO and H$_2$
- Ethanol, Methanol, Butanol, DME, Fisher Tropsch Gas and Diesel
- Electricity- Using Steam to power a turbine
UMM Biomass Gasification System

- High natural gas prices have been crippling to Universities and other public entities
- UMM Biomass Gasification System is a model for small to moderate scale biomass systems
- Construction began July 2007 and was dedicated October 2008
- Builds on the current UMM district heating and cooling system across the campus (natural gas) and will provide 80% of thermal energy needs
- Provides fuel flexibility and choices (corn stover, wood, DDGS, straw, grass hay, etc)
- Gasification appears to be a clean and moderately priced method to provide heating and cooling. (~$5 per MM/BTU NG = $50 per ton biomass)
- “Wired” for research
UMM Biomass Gasification System

Courtesy of Hammel Green and Abrahamson, Inc
What do you do when gasoline is not available?

During the 2nd WW in Norway, there was 19,000 licensed vehicles running on wood chips. Making gas generators quickly became a major business.
People that remember this say 20 lbs of wood would take you as far as 1 gal of gas.
Pyrolysis

• Heating of biomass in the absence of air
• Anhydrous Pyrolysis
  – Flash pyrolysis – Bio-diesel
• Hydrous Pyrolysis
  – Thermal depolmerization -Bio-oil
• Vacuum Pyrolysis
  – Decreases boiling point
• UOP, LLC (Des Plaines, Illinois)
  – Honeywell and Ensyn
  – Rapid Thermal Processing (RTP)
  – Converts forest and ag residues to bio-oil for power and heat
Anaerobic Digestion - BioGas

- Primarily used in engine gensets but also can be feedstock for other biofuels

Composition:
- Methane
- Carbon Dioxide
- Hydrogen Sulfide
- Nitrogen
Community Biogas System

Feasibility study has been completed:

- Anaerobic Digester $10.59 MM BTU
- Biomass Gasification $10.44 MM BTU

Municipal financing improves economics
Large livestock producers near Morris
Large amounts of crop biomass
Large energy users including the ethanol plant
Inconsistent natural gas prices & supply
WCROC research and demonstration platform
Next step is underway!
Biodiesel

• Transesterification of lipids
  – Triglyceride is converted to methyl ester plus glycerol
  – Vegetable Oil, Methanol, and Sodium Hydroxide

• Glycerol is a by-product

• B2 mandate in Minnesota
Algae Biodiesel

• Algae grow rapidly and can have a high percentage of lipids, or oils.
• Can double their mass several times a day
• Produce at least 15 times more oil per acre than alternatives such as rapeseed, palms, and soybean
• Efforts to screen natural microalgae species to find the strains that produce the highest yields and the most oil.
• Combine with power plants – Algae uses CO2 then harvested for bio-diesel production
HR BioPetroleum

ALDUO™

PROPRIETARY PROCESS

Grow in Photo Bioreactors + Grow in Algae Ponds
DME (Dimethyl Ether)

- Produced by the dehydration of methanol
- BioDME – European Project to Produce Dimethyl Ether
- Low emissions
- Volvo Group
- Diesel replacement
- \( \text{CH}_3\text{OCH}_3 \)
- Colorless gas
Fischer Tropsch Fuels

- Conversion of carbon monoxide and hydrogen to liquid hydrocarbons using catalytic reactions (Co, Fe, Ru)
- Primarily Gasoline, Diesel, and Wax
- WWII
- Sasol
- Syntroleum and Tyson Foods – Bio-diesel and jet fuel from low grade animal fats
BioAlcohols

- Ethanol (10% mandate in MN)
  - C2 H6 O
- Methanol (wood alcohol)
  - CH3 OH
- Butanol
  - C4 H10 O
- Propanol
  - C3 H7 OH
Advanced Biomass R & D Timeline


* Advanced biofuels can include 2nd generation cellulosic ethanol, biobutanol, biodiesel, etc.
Major DOE Biofuels Project Locations
Geographic, Feedstock, and Technology Diversity

Nine Small-Scale Biorefinery Projects
Four Commercial-Scale Biorefinery Projects
Four Improved Enzyme Projects
Five Projects for Fermentation Organisms
Five Thermochemical Syngas Projects
Three Office of Science Bioenergy Centers
DOE Joint Solicitation Biomass Projects
Five Thermochemical Bio-Oil Projects
Six University Projects

Regional Partnerships
- South Dakota State Univ., Brookings, SD
- Cornell University, Ithaca, NY
- Univ. of Tennessee, Knoxville, TN
- Oklahoma State Univ., Stillwater, OK
- Oregon State Univ., Corvallis, OR

Modified 10/1/2008
Biomass Feedstocks

Corn for Grain, Harvested Acres: 2002

United States Total
68,230,523

02-M178
U.S. Department of Agriculture, National Agricultural Statistics Service
Harvest: Corn Stover

Raking Windrows

Round Baling

Cobs?
Biomass Nutrient Replacement

Cost of Nutrient Replacement Associated with Harvest:

<table>
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<tr>
<th></th>
<th>Nitrogen Replacement Cost ($/acre)</th>
<th>P2O5 Replacement Cost ($/acre)</th>
<th>K2O Replacement Cost ($/acre)</th>
<th>Total Nutrient Replacement Cost ($/acre)</th>
<th>Total Nutrient Replacement Cost ($/ton)</th>
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<tr>
<td>Grain Harvest</td>
<td>54.21</td>
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<td>Cob Harvest</td>
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<td>Stover Harvest</td>
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<td>26.55</td>
<td>68.74</td>
<td>127.12</td>
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Source: Iowa State University

*DOE target is $35 / dry ton of biomass by 2012
Wind Turbine:

1. 1.65 MW Vestas V-82
2. Installed March 2005
3. Produces 5.4 mil kWh / yr
4. Energy first used for research
5. Excess sold via direct line to University of Minnesota, Morris
6. Provides campus with over 50% of electrical energy needs
Hybrid Wind System

Phase I – Hydrogen & Electrical Energy Production

1. Electrolyzer
2. Compressor
3. Hydrogen Storage
4. ICE Engine Generator
5. Grid Interconnection
6. Web Enabled SCADA
First Wind to Hydrogen System in Utsira, Norway
Hybrid Wind System

Phase II: Value Added Wind Energy & Bridge Technologies

1. Production of Anhydrous Ammonia
   - Nitrogen fertilizer
   - Refrigeration and other uses

2. Transportation Fuel
   - Fleet vehicles
   - Service vehicles
   - Cars and pickups
Water \rightarrow \text{Oxygen and Heat} \rightarrow \text{H}_2 \rightarrow \text{Water} \rightarrow \text{N}_2 \rightarrow \text{REACTOR}
Nitrogen Fertilizer Production

Products

Ammonia

Am Nitrate

UAN Solutions

Urea

Ammoniated Phosphates

Phos Acid

“Ammonia is used directly as a fertilizer or used to produce other forms of fertilizers”

Source: Agriculture Energy Alliance, 2006
In 1928 – Hydro converted to make fertilizer via hydrogen and ammonia

Electrolysers installed at Rjukan 1930, 150 units, 30 000 Nm³/hr, 150 MW
Wind to Ammonia Drivers

1. Natural gas market drives ammonia production costs
2. Declining domestic ammonia production
3. Stranded wind resource due to low transmission capacity
4. High ammonia / nitrogen demand and robust infrastructure
5. Security for domestic bio-fuel, feed, and food production
6. Producer owned ethanol (Policy and Business Models)
7. Hydrogen economy bridge
Electrical Energy Use in the United States

NASA
Excellent Wind Resource
High Demand for Ammonia

& Excellent Wind Resource
Robust Ammonia Infrastructure
Road Map to Green Jobs (and Biofuels)

1. Identify cutting edge opportunities unique to Minnesota
2. Select a portfolio of technologies
3. Take technology risks
4. Make graduated steps
5. Be proactive and engaged
6. “Walk the walk”
7. Technology integration - Bio and renewable energy refineries
Contact Information:

Michael Reese
Director- Renewable Energy
West Central Research & Outreach Center
University of Minnesota
(320) 589-1711
reese@morris.umn.edu
http://renewables.morris.umn.edu

Upcoming Events:

Jan 15 – Advanced Biomass Wrkshp
Ammonia Fueled Vehicles

Rjukan 1933

Ann Arbor 2007