Challenges and Opportunities for Biomass Refining

Roger Ruan
Center for Biorefining and
Department of Bioproducts and Biosystems Engineering

University of Minnesota
St. Paul, Minnesota
Biomass Conversion

- Two major platforms
  - Sugar platform – corn and cellulosic ethanol
  - Thermochemical platform – gasification and pyrolysis
Large Scale Processes

- High capital investment
- High operation technicality
- High feedstock transportation and storage costs
- How to overcome these barriers?
Nature of Biomass Production

- Distributed production
- Transporting bulky biomass from scattering production sites to a central processing facility has been a key barrier to biomass utilization
Research has found that the financial advantage provided by large processing capacity may be offset by high delivered costs of feedstock, and suggests that biomass industry development should include smaller-scale facilities to be economically viable.

<table>
<thead>
<tr>
<th>Facility Capacity (dry ton/day)</th>
<th>Delivered Cost ($/dry ton)</th>
<th>Hauling Distance (one-way, miles)</th>
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</thead>
<tbody>
<tr>
<td>500</td>
<td>43</td>
<td>22</td>
</tr>
<tr>
<td>4000</td>
<td>52</td>
<td>62</td>
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Distributed Biomass Conversion Systems (DBCS) - A “Smaller” Solution
Bale to Barrel DBCS

One round hay bale
- diameter = 5ft
- length = 5ft

1,000lb, 100ft³
10lb/ft³
7,500,000BTU
75,000BTU/ft³

As fertilizer back to field for biomass production

Conversion

Power for conversion

Gas
- 2,250,000BTU

Char
- 1,500,000BTU

Biocrude
- 1.2 barrel
- 500lb, 6.7ft³
- 75lb/ft³
- 3,750,000BTU
- 562,500BTU/ft³

Implemented on average size farms
Distributed Biomass Processing Scheme
Benefits and Criteria for Successful DBCS

- Economic and social benefits for the rural community
- Have affordable capital cost
- Be easy to operate (turn-key) technology
Choose DBCS Technologies

- Cellulosic ethanol
- Gasification
- Pyrolysis
- Total liquefaction
Cellulosic Ethanol

- Cellulosic ethanol plants: 40-50 million gallons/year (~2,000 tons biomass per day), $300 million, technical and management challenges
- Furthermore, compared with corn ethanol production, additional processing costs are needed to convert cellulosic feedstock to fermentable sugars, which would raise feedstock-associated costs to as high as 70–80% of the final product cost.
Gasification

- Gasification plants: 100 tons biomass per day, $5.6 million, challenge bio-oil cleanup (Ensyn Technologies, Inc., DynaMotive Energy Systems Corp., and Renewable Oil International)

- Large biomass feedstock and user base required

- Small gasifiers have better potentials but not without challenges
Issues with Gasification

- Biomass uniformity for certain gasifiers
  - Ground and uniform

- Need to be equipped with gas cleanup facility
  - Particulate Formation
  - Tar Formation

- Unused syngas produced
  - Hard to transport
  - Fermentation is far from practical at this point
  - Syngas reforming
NTP-Assisted Catalytic Reforming

- Catalytic reforming has become a useful way to produce biofuels and other chemicals.
- Conventional catalytic reforming usually requires high temperature and high pressure.
- Catalysts can perform well at low temperature and pressure with assistance of Non-thermal Plasma (NTP).
Ionizations of Nitrogen and Hydrogen with NTP-Assisted Catalysis

- $N_2 \rightarrow 2N^+$
- $H_2 \rightarrow 2H^+$
- $N^+ + H^+ \rightarrow NH^+$
- $NH^+ + H^+ \rightarrow NH_2^+$
- $NH_2^+ + H^+ \rightarrow NH_3^+$
Products from Syngas

- Waxes
- Diesel
- Olefins
- Gasoline

Mixed Alcohols

Fischer-Tropsch

- Formaldehyde
- Cu/ZnO
- Ag

MTBE

Acetic Acid

- Isobutylene
- Acidification exchange

- Methanol

- CO + H₂

- Syngas

- i-C₄

- Alkaline-doped
  - ZnO/Cr₂O₃
  - Cu/ZnO
  - CuO/CoO/Al₂O₃

- Isosynthesis
- ThO₂ or ZrO₂

- WGS
- Purify

- Oxosynthesis
- HCO(CO)₄/Co(PPh₃)₃
- Rh(CO)₂(pPh₃)

- Ethanol

- Aldehydes
- Alcohol

- NH₃

- N₂ over Fe/FeO
  - (K₂O, Al₂O₃, CaO)

- H₂

- Direct Use

- MTBE
- MTO
- MTG

- Olefins
- Gasoline

- M100
- M85
- DMFC

NREL National Renewable Energy Laboratory
Microwave Assisted Pyrolysis (MAP) System
Pilot Scale MAP Reactor

- 4.5 kW power
- Computer central controlled process
- 10 kg/h through-put
- Various input materials

Key components
- Pyrolysis chamber
- Microwave generator
- Condensing column
Pilot Scale Continuous MAP System
Challenges and Counter Measures

- Bio-oil upgrading
  - Fractionation, purification, cracking
- Product development
  - Transportation fuels
  - Heating fuel
  - Biopolymers
  - Chemicals
- Pyrolytic syngas cleanup and utilization
  - Cleanup for gas turbine
  - NTP-assisted reforming to produce fuels and chemicals
- Market development
Total Liquefaction Process

- Atmospheric or low pressure
- Low temperature
- Use cheap bio-diesel glycerol (few cents/gallon) as liquefying agent
- Total utilization of biomass
- Easy to operate
Liquefaction Apparatus
Continuous Hydrothermal Biomass Pyrolysis System
Fossil Oil Like Bio-oil

Unlimited Possibilities

- Millions of years work in hours
- Can be implemented on or near farms to convert bulky biomass to easily managed pumpable liquids for transport to refineries
Biorefining of Biooils and Liquefied Biomass

- Polyester + DGG Composite
- Polyester film
- Polyester + fibers Composite
- Polyurethane foam
- Wood Adhesive
- Biofuel
Small Distributed Biomass Energy Production Systems

Summary

- Compared with current large-scale biomass energy systems, DBCS is more technologically feasible, economically viable, and sustainable. The DBCS offers a valid near-term solution to the realistic utilization of bulky biomass, and presents substantial opportunities for greater economic benefits with the biomass energy industry, and smaller-scaled distributed processing facilities.

- The DBCS should also be particularly attractive to developing countries where funds for large-scale plants are scarce, technical management skills are lacking, and the income generated is attractive to the rural community.
Summary of R&D Efforts to Overcome the Barriers in Thermochemical Processes

- **Biomass**
  - Scalable systems which can be implemented on farms
  - Robust systems which can process multiple feedstocks

- **Conversion process**
  - Optimized to produce bio-oils or syngas at high yield
  - Low capital and operation costs
  - Minimum requirement for water and fossil energy
  - Clean
  - Bring income to both biomass producers and processors

- **Product and market development and establishment**
  - Produce transportation fuels that meet industrial standards
  - Produce high value chemicals
  - Produce thermoset polymers
  - All is done within the biorefining approach (cleanup, fractionation and purification, upgrading, cracking, reforming, fermentation. ……)
  - Develop markets
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Thank You!
Comments and Questions?

Roger Ruan, Ph.D.

Director, Center for Biorefining
Professor, Bioproducts and Biosystems Engineering
University of Minnesota
1390 Eckles Ave., St. Paul, MN 55108, USA
http://biorefining.cfans.umn.edu
ruanx001@umn.edu
612-625-1710