BioEnergy in India

Balu Sarma
Praj Industries Limited
MAGEEP 2012 Symposium
Mumbai
Presentation Outline

- Why BioEnergy?
- Agricultural Residues in India
- Technologies for conversion of Biomass to BioFuels
- Background of Praj Industries Ltd.
- Overview of Praj Matrix – The Innovation Center
- Cellulosic Ethanol – The Praj Experience
- BioRefinery Considerations
Petroleum Consumption, Pricing, and Product Profile

Indexed Growth in Petroleum Consumption

Petrol Pump Prices in US

Petroleum Consumption (Mn Barrels per day)

Petroleum Product Profile in India


Source: PPAC
Key Issues with PetroFuels

- India’s oil import dependence has crossed 80%
- India’s oil import bill is in excess of $100 Bn
- India’s consumption of petroleum products is growing
- Public Sector OMC’s have large under-recoveries
  - PS OMC’s reimbursed by central government
- Private Sector OMC’s have shut down their retail marketing
- Kirit Parikh Committee Report Recommendations
  - Under-recoveries for Petrol and Diesel to be nil
  - Free market pricing for Petrol and Diesel
    - Will result in increased diesel price at current oil price
Mitigates Forex Outgo from Oil Imports

- India: > 2 Mn bpd imports @ >5% CAGR, >$50 Bn Forex
- US: ~ 12 Mn bpd imports, ~ $300 Bn Forex

Reduced GHG Emissions

Avoids Food versus Fuel Debate

- Use of available agro-residues: SugarCane Bagasse/Trash, Corn Cob and Corn Stover, Wood Chips/Sludge, Rice/Wheat Straws

Government Mandates

- US: RFS 2022 Mandate requires 21 Bn gallons of Advanced BioFuels to be blended with gasoline
- India: 20% ethanol blending by 2017

BioEnergy Technologies are past Pilot Plant stage

- Ready for Commercial Demonstration by Praj in India
## Agricultural Biomass Residues - India

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Biomass</th>
<th>Generation (MMT)</th>
<th>Surplus (MMT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rice Straw</td>
<td>112</td>
<td>8.5</td>
</tr>
<tr>
<td>2</td>
<td>Rice Husk</td>
<td>22.4</td>
<td>0.4</td>
</tr>
<tr>
<td>3</td>
<td>Wheat Straw</td>
<td>109.9</td>
<td>9.1</td>
</tr>
<tr>
<td>4</td>
<td>Sugar Cane Tops</td>
<td>97.8</td>
<td>79.5</td>
</tr>
<tr>
<td>5</td>
<td>Sugar Cane Bagasse</td>
<td>101.3</td>
<td>6.4</td>
</tr>
<tr>
<td>6</td>
<td>Maize Stover</td>
<td>22.7</td>
<td>1.1</td>
</tr>
<tr>
<td>7</td>
<td>Maize Cob</td>
<td>4.2</td>
<td>1.7</td>
</tr>
<tr>
<td>8</td>
<td>Maize Husk</td>
<td>2.7</td>
<td>1.1</td>
</tr>
<tr>
<td>9</td>
<td>Sorghum Stover</td>
<td>15.6</td>
<td>1.6</td>
</tr>
<tr>
<td>10</td>
<td>Bajra Stalk</td>
<td>12.2</td>
<td>1.2</td>
</tr>
<tr>
<td>11</td>
<td>Cotton Stalk</td>
<td>18.9</td>
<td>11.4</td>
</tr>
<tr>
<td>12</td>
<td>Chillies Stalk</td>
<td>0.6</td>
<td>0.5</td>
</tr>
<tr>
<td>13</td>
<td>Ragi Stalk</td>
<td>4.6</td>
<td>0.5</td>
</tr>
<tr>
<td>14</td>
<td>Pulses Wastes</td>
<td>18.9</td>
<td>5.7</td>
</tr>
<tr>
<td>15</td>
<td>Oil Seed Wastes</td>
<td>57.7</td>
<td>17.3</td>
</tr>
<tr>
<td>16</td>
<td>Bamboo (Top, Root and Leaves)</td>
<td>5.4</td>
<td>3.3</td>
</tr>
<tr>
<td>17</td>
<td>Pine needles</td>
<td>1.6</td>
<td>1.2</td>
</tr>
<tr>
<td>18</td>
<td>Water Hyacith (Whole)</td>
<td>15</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>623.4</td>
<td>164.5</td>
</tr>
</tbody>
</table>

**Source:** Ministry of Agriculture, Govt. of India

*Forest residues are not included*

130-200 Mn TPY range for various estimates from 125 Mn Ha land
Capacity-Area-Surplus Biomass Density Trade-Off

Biomass Processing Plant Size
(Based on Surplus Biomass Density)

- Plant Capacity (MT/Day)
- Area Coverage (KM²)

Legend:
- SBD=1
- SBD=2
- SBD=3
- SBD=4
- SBD=5
- SBD=6
Feed Stocks: Critical Issues

- Land Productivity
- Subsidies for Farmers
- Feedstock Supply Chain, Security, Pricing
- Multi-Feed Plants
- Quality Control
- Registry
- Material Handling, Storage and Transport

Societal and Governmental Engagement will be very important
Biomass Feedstock in India - Summary

- Feedstock – Diverse varieties, Seasonal, Regional
- Surplus Biomass Potential > 130-200 Mn tpy from 125 Mn ha agricultural land
  - Straws (rice and wheat), Corn Cob/Stover, Cotton Stalks, Oilseed residues, Pulse residues, Sugarcane tops/trash, Pulp/Paper Wood, Forest Wood
- Successful technology demonstration can enable
  - Several large (100-200 tpd) plants
- Local and attractive value propositions can be developed to benefit rural India – Energy and Economic Security
  - Biomass Suppliers (Farmers)
  - Biofuels Producers (Project Developers and Operators)
  - Biofuels Consumers (Industries, Farmers)
Biomass to Fuels Technologies

Biomass

Pyrolysis
  Bio-oil
    Fuels
    Chemicals
    Char

Gasification
  Syngas
    Catalytic/Microbial
      Fuels
      Chemicals
      Char
  Power
    Chemicals
    Fuels

Hydrolysis And Fermentation
  Chemicals
  Fuels

Ample scope for different technologies to co-exist
Key Issues with Biomass to Power

- Biomass based power is being promoted in India
- Energy Conversion in Biomass based power is less efficient than BioFuels
  - 1 ton of dry bagasse yields 800-1000 kWh of power
  - 1 ton of dry bagasse is expected to yield 1300 kWh of energy content in ethanol (30-60% higher)
- Biomass power is subsidized in several states
  - Power Purchase Price is Rs 6 per kWh in some states
  - At Rs 27 per liter of ethanol, equivalent price for ethanol is Rs 4.50 per kWh
- Biomass to Ethanol addresses a more important problem than Biomass to Power
  - India’s annual thermal coal imports are 60 Mn tons at $5 Bn
  - India’s Oil imports have crossed $100 Bn

Conversion of Biomass to BioFuels is more energy efficient and addresses a larger problem
Praj Industries Limited - Background

- Established in 1984
  - 1st Company to avail of VC funding in India through ICICI
  - Listed on Indian Stock Exchanges

- Business Lines
  - BioEthanol
  - Breweries
  - Water and Wastewater
  - Livestock, Health and Nutrition
  - Performance Enhancers
  - Energy Crops Services
  - Customized Engineering and Manufacturing

- Over 450 references in 60 countries
- Over 275,000 sq ft of manufacturing facilities of world class standards
- Team: >1000 People (80% Tech/Engg)
Praj Matrix – The Innovation Center

- Rs 130+ crore investment
  - 80,000 sq ft of Labs, Pilot Plants, and Offices
- 115 technologists and growing
  - 25 PhDs, 80 Masters
- 9 Tech Centers of Excellence
  - Biology, Chemistry, Engineering
- 16 Well Equipped Labs
- Pilot Plants
  - 2 tpd Cellulosic Ethanol pilot plant
  - Two 750 kg/d Chemical pilot plants
  - 500 sq ft Open Raceway Pond for Algal Cultivation

Bench and Pilot scale Facilities enable Validation of Scientific Assumptions and Rapid Commercialization
Cellulosic Ethanol at Praj - Chronology

- Literatur Review
- Bench Scale Facilities
- Bench Scale Experiments
- Pilot Plant Design and Engg
- Pilot Plant Erection
- Pilot Plant Trials
- Commercial Demo Plant

2005 2006 2007 2008 2009 2010 2011 2012

Copyright 2012 Praj Industries Ltd.
Integrated Process Flow Sheet

Renewable feedstocks

Material Handling & Sizing

Pre-Treatment

C6 Stream  C5 Stream

Hydrolysis and Fermentation

Distillation & Dehydration

Fuel Ethanol

Lignin

Recycle Water

Effluent Treatment

For Process Use

Power Steam

Copyright 2012 Praj Industries Ltd.
## Process Performance: Corn Cobs (1 metric ton basis)

<table>
<thead>
<tr>
<th>Process Step</th>
<th>C5</th>
<th>C6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material Handling Recovery (%)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Fractionation and separation (%)</td>
<td>70-75</td>
<td>96</td>
</tr>
<tr>
<td>C6 Hydrolysis Efficiency (%)</td>
<td>--</td>
<td>80</td>
</tr>
<tr>
<td>Fermentation</td>
<td>80</td>
<td>88</td>
</tr>
<tr>
<td>Distillation and Dehydration</td>
<td>99</td>
<td>99</td>
</tr>
<tr>
<td>Overall Yield (%)</td>
<td>60</td>
<td>67</td>
</tr>
<tr>
<td>Total Ethanol Yield</td>
<td>130-140</td>
<td>160-170</td>
</tr>
</tbody>
</table>

300-310 Lits / ton

Demo Plant expected to yield 300 liters of ethanol per bone dry ton biomass
Emerging Bio Refineries

1st Gen BioFuels & Biobased chemicals

Integrated BioRefining Technologies

Customized Advanced Biofuels & Bio Based Chemicals

Biofuels & Biobased Chemicals from Starch, Molasses

Large Integrated Plants for Advanced Biofuels & Biobased Chemicals from LC

High Performance Synthetic BioFuels & Functional Chemicals

Molasses, Starch

SUGARS

LignoCellulosic Biomass

Natural / Customised Micro-Organisms

Green Catalysts

Fermentations

Green Chemistry

Down Stream (Recovery & Purification)

Bio Ethanol & Advanced BioFuels

Bio Polymers

Bulk Chemicals

H & W Ingredients

Pharma Ingredients

Power

Globally, Multiproduct Biorefineries to produce Biofuels and Biobased Products Emerging Rapidly

Copyright 2012 Praj Industries Ltd.
BioRefineries – Key Considerations

- Feedstock
  - Price Volatility
  - Seasonality
  - Availability

- Process
  - Rate, Titer, Yield, Recovery
  - Capex, Opex
  - Scalability, Complexity, Flexibility

- Product
  - Price Volatility
  - Oil Price
  - Applications: Drop-In versus Replacement

- “Green”
  - Energy, CO2, Land, Water

Multi-Feed, Multi-Product Facility to offset Commodity Risks
Thank You