Biomass to Bioethanol - Second Generation Technology by Praj

Amol Sheth
18th and 19th Feb 2016
Agenda...

• Global Environment Concerns
• Indian Ethanol Scenario
• India Biomass Availability
• Enfinity - Praj Biomass to Ethanol Technology
• Innovative bolt on concept
• Business Opportunities
Global Environment concerns - GHG Emissions
The iconic India Gate in Delhi, shrouded in smog, is barely visible. Air pollution, caused by car emissions and industries, is rising rapidly.

Global Challenge: GHG Emission

Note: CO2 emission in million tons
Source: Global Carbon Project
Cellulosic ethanol: emission reduction potential

Use of cellulosic ethanol results in significant reduction in GHG emissions

DOE Bioenergy Technology Office
Cellulosic ethanol - Opportunity

- Government of India committed toward implementation of E5/E10 and E20 by 2017 - 2022
- Limited molasses availability & demand by industrial/potable sectors poses key challenge in implementing E5/E10 and E20
- MoPNG fixed reference price range for fuel ethanol at INR48.50 - INR49.50/Liter
- Government of India removed excise duty on ethanol for blending
- Oil ministry & cabinet approves production of bioethanol from cellulosic feedstock
- OMC includes ethanol made cellulosic feedstock in tender dated 29 Dec 2014
- Sugar Development Fund (SDF) to be available for ethanol capacity expansion
- GOI to announce policy for use of E85 & Flex fuel vehicles in India

COP 21, 2015 - Commitments by India-to reduce the intensity of its GHG emissions per unit of GDP by 33% to 35% by 2030 by the increased target of non-fossil fuel based energy to 40%.
Indian ethanol scenario

- Annual fuel ethanol demand (5%) blend = ~1.3 billion liters
- GOI plan of 20% ethanol blending by 2017 (EBP) will require ~5.9 billion liters
- Only 11 million MT molasses production for 2013-14 enabling production of 2.6 billion liters of ethanol
- Additional ethanol (~5.0 billion liters) demand cannot be fulfilled with existing raw material to achieve 20% EBP target

Biomass based ethanol has potential to help achieve ethanol blending mandate of 20%
Ethanol - Demand & Supply scenario in India

**Fig. in TKL**

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Petrol Sale Projection (8.38% CAGR)</td>
<td>27596</td>
<td>29909</td>
<td>32415</td>
<td>35131</td>
<td>38075</td>
<td>41266</td>
</tr>
<tr>
<td>Ethanol Requirement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(@ 5% blending)</td>
<td>1380</td>
<td>1495</td>
<td>1621</td>
<td>1757</td>
<td>1904</td>
<td>2063</td>
</tr>
<tr>
<td>(@ 10% blending)</td>
<td>2760</td>
<td>2991</td>
<td>3241</td>
<td>3513</td>
<td>3808</td>
<td>4127</td>
</tr>
<tr>
<td>(@ 20% blending)</td>
<td>5519</td>
<td>5982</td>
<td>6483</td>
<td>7026</td>
<td>7615</td>
<td>8253</td>
</tr>
</tbody>
</table>

Source: Bloomberg New Energy Finance, Ministry of Petroleum & Natural Gas, Planning Commission Government of India. Note: Gasoline demand is assumed to grow at 8.5% every year after FY 2011; 1 litre of ethanol assumed to replace 0.7 litres of gasoline.
## India - State wise Agricultural crop residue potential

<table>
<thead>
<tr>
<th>State</th>
<th>Agro-residues</th>
<th>Biomass Generation (MMT/Yr)</th>
<th>Biomass Surplus (MMT/Yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Punjab</td>
<td></td>
<td>50.8</td>
<td>24.8</td>
</tr>
<tr>
<td>Maharashtra</td>
<td></td>
<td>47.6</td>
<td>14.8</td>
</tr>
<tr>
<td>Uttar Pradesh</td>
<td></td>
<td>60.3</td>
<td>13.8</td>
</tr>
<tr>
<td>Haryana</td>
<td></td>
<td>29.0</td>
<td>11.3</td>
</tr>
<tr>
<td>Madhya Pradesh</td>
<td></td>
<td>33.3</td>
<td>10.3</td>
</tr>
<tr>
<td>Gujarat</td>
<td></td>
<td>29.0</td>
<td>9.1</td>
</tr>
<tr>
<td>Karnataka</td>
<td></td>
<td>34.2</td>
<td>9.0</td>
</tr>
<tr>
<td>Tamil Nadu</td>
<td></td>
<td>22.5</td>
<td>8.9</td>
</tr>
<tr>
<td>Rajasthan</td>
<td></td>
<td>29.9</td>
<td>8.6</td>
</tr>
<tr>
<td>Kerala</td>
<td></td>
<td>11.6</td>
<td>6.4</td>
</tr>
<tr>
<td>Bihar</td>
<td></td>
<td>25.8</td>
<td>5.1</td>
</tr>
<tr>
<td>West Bengal</td>
<td></td>
<td>36.0</td>
<td>4.3</td>
</tr>
<tr>
<td>Andhra Pradesh</td>
<td></td>
<td>24.9</td>
<td>4.3</td>
</tr>
<tr>
<td>Odisha</td>
<td></td>
<td>20.1</td>
<td>3.7</td>
</tr>
<tr>
<td>Telangana</td>
<td></td>
<td>19.0</td>
<td>2.7</td>
</tr>
<tr>
<td>Assam</td>
<td></td>
<td>11.4</td>
<td>2.4</td>
</tr>
<tr>
<td>Chhattisgarh</td>
<td></td>
<td>11.3</td>
<td>2.1</td>
</tr>
</tbody>
</table>
Potential Feedstock for production of bioethanol

- Can produce 3525 crore liters of bioethanol per annum from nearly 141MMT of biomass, which can not only meet nations fuel ethanol requirement, but also export to neighboring countries.

- 22 million MT of biomass can meet the demand of nation for 20% ethanol blending.

- Straws: 15 million tons of Rice straw is available (90% of it is now burnt in field).

- Can produce 300 crore liters of bioethanol per annum which can meet nations demand up to 70% fuel ethanol.
## EBP and overall benefits for India

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Unit</th>
<th>For 10% EBP</th>
<th>For 20% EBP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethanol required</td>
<td>Crore liters/ Annum</td>
<td>266</td>
<td>532</td>
</tr>
<tr>
<td>100 KLPD plants required</td>
<td>No.</td>
<td>80</td>
<td>160</td>
</tr>
<tr>
<td>Area covered for Biomass supply per 100 KLPD plant</td>
<td>Ha/ Annum/plant</td>
<td>~ 40000</td>
<td>~ 40000</td>
</tr>
<tr>
<td>Total crop area covered</td>
<td>Lakh Ha/Annum</td>
<td>32</td>
<td>64</td>
</tr>
<tr>
<td>Number of Farmers benefited</td>
<td>lakh</td>
<td>27</td>
<td>54</td>
</tr>
<tr>
<td>Additional income for farmers @ Rs 500/ MT raw material price</td>
<td>Rs Crore</td>
<td>500-530</td>
<td>1000 - 1100</td>
</tr>
<tr>
<td>Additional Job employment</td>
<td>No.</td>
<td>40000</td>
<td>80000</td>
</tr>
<tr>
<td>Approx. GHG savings</td>
<td>000`Tons of CO2 equivalent/ Year</td>
<td>2534</td>
<td>5069</td>
</tr>
<tr>
<td>Forest area equal to000`Tons of CO2 equivalent</td>
<td>Ha/ annum</td>
<td>9800</td>
<td>19700</td>
</tr>
<tr>
<td>Carbon Credits revenue@ Rs 152/MT of Carbon</td>
<td>Rs (Crore/ Annum)</td>
<td>39</td>
<td>78</td>
</tr>
<tr>
<td>FOREX savings ( 1 barrel @ 28 USD)</td>
<td>Rs (Crore)</td>
<td>3100</td>
<td>6200</td>
</tr>
</tbody>
</table>
Enfinity - Praj’s 2G Ethanol Technology
Our technology brings infinite possibilities to the environment and energy challenges confronting mankind... by making use of nature’s endless resources. That’s why we proudly call it.....enfinity.
Technology development journey

Biomass to ethanol - Pilot Plant

- Operational since - January 2009
- Raw material processing capability -
  - Corn Cobs + Corn Stover
  - Sugarcane Bagasse, Cane trash, Pith
  - Paddy (rice) straw
  - Wheat straw / cotton stalk
- Pilot plant trials validated work done at laboratory & bench scale
Ligno-cellulosic Feedstock Evaluation

Around 400 samples of feedstock from all parts of India and few samples from Europe and America analyzed

<table>
<thead>
<tr>
<th>Parameter (% w/w)</th>
<th>Corn Cob</th>
<th>Sugarcane Bagasse</th>
<th>Corn Stover + Corn Cob</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellulose</td>
<td>27-35</td>
<td>35-42</td>
<td>28-33</td>
</tr>
<tr>
<td>Xylan</td>
<td>25-33</td>
<td>17-25</td>
<td>19-25</td>
</tr>
<tr>
<td>Lignin</td>
<td>13-18</td>
<td>20-25</td>
<td>15-20</td>
</tr>
<tr>
<td>Arabinan</td>
<td>2-4</td>
<td>1.1-2.1</td>
<td>2-4</td>
</tr>
<tr>
<td>Ash</td>
<td>2.0-3.0</td>
<td>2.0-3.0</td>
<td>4.0-8.0</td>
</tr>
<tr>
<td>Protein</td>
<td>1.5-2.0</td>
<td>1.5-2.0</td>
<td>1.5-2.0</td>
</tr>
<tr>
<td>Extractives</td>
<td>1.6-5.0</td>
<td>1.6-3.0</td>
<td>8-18</td>
</tr>
<tr>
<td>Acetates</td>
<td>2.0-3.0</td>
<td>2.0-3.0</td>
<td>2.0-3.0</td>
</tr>
</tbody>
</table>

LAP & NREL methods employed

Consequences of Feedstock Composition variation

- Changed yield
- Enzymatic dosage
- Changed process parameters
- Lignin rich spent cake
Bio-Refinery

2G ethanol/bio-chemicals plant processing biomass

Addition of challenges
Addition of Challenges

- Wear and tear of the equipment
- Choking, corrosion & erosion in pre-treatment section
- Down time
- Loss of carbohydrates / byproduct formation
- Inhibitors and toxins formation
- Efficient enzymes needed
- Robust fermentation micro-organisms needed
- Handling and treatment of effluent streams
Praj has made significant performance improvements over the last three years.
Various Bolt-on models to make 2G Bio-ethanol technology viable
Many 1G ethanol plants operate 150 - 200 days / annum
- Additional 150-180 days operation using 2G bolt-on module
- Results in year round operations of bio-ethanol complex
- Higher asset utilization
- Fewer unit operations hence lower capEx
- Substantial increase in ethanol production at lower capEx
Biomass to bio-ethanol: Business model#1

- Biomass
- Pretreated slurry
- Enzymatic Hydrolysis
- S/L Separation
- Ethanol Storage
- Fermentation
- Distillation
- Dehydration
- Cooling tower
- COGEN
- Evaporators
- Waste Water treatment
- Lignin cake
- Existing production facility
Integrated approach to make bio-refinery a reality
‘enfinity’ - key technology highlights

**Proprietary end to end process design**
- Multi-feed capability
- Pre-treatment
  - Efficient degradation of biomass to sugars
  - Better biological processing ability
- Efficient enzymatic hydrolysis
- Thermally integrated process to achieve low net energy usage
- Water recycled; achieve zero process liquid discharge

**Enzyme Flexibility**
- Proven technology on multiple enzymes
- High yields with different enzyme strains

**Co-Fermentation**
- Yeast strain for efficient utilization of C5 (pentose) and C6 (hexose) sugars
  - Higher yield
  - Lower reaction time
  - Higher tolerance to solids

**Intellectual Property**
- Enfinity Technology -
  - Process patent filed and already granted in India, SA, Kenya; pending approval in other countries
  - Performance in spite of inhibitors
  - No detoxification steps leading to lower capex and opex
“enfinity” based potential second generation ethanol projects in India
Value maximization for biomass

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Praj innovative 2G ethanol technology provides higher returns

Biomass

PRAJ 2G SMART BIO-REFINERY

CO₂ 119 Kgs

Bio-CNG 49 KG

Bio-ethanol & bio-chemicals
220-325 Liters

Power 400 Kwh

Total Revenue potential  ~ ₹17,000 – 23,000

Note: 1) Liquid CO₂ market price of ₹8/Kg 2) Bio-CNG price ₹45/KG
3) Bioethanol price ₹46.50/Liter  4) Power price ₹ 4/Kwh
5) Carbohydrate content in biomass assumed at ~55%
6) Biomass price of INR 2000-6000 /MT

Praj innovative 2G ethanol technology provides higher returns
### "enfinity" 2G Ethanol Technology - Comparison with 1G

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>1G Ethanol</th>
<th>2G Ethanol</th>
<th>Conversion Cost</th>
<th>Feedstock Cost</th>
<th>Total Variable Cost of Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molasses</td>
<td>₹5-6/Liter</td>
<td>₹10-11/Liter</td>
<td>₹22-23/Liter</td>
<td>₹4500-6500/MT</td>
<td>₹28-34/Liter</td>
</tr>
<tr>
<td>Corn cobs</td>
<td>₹18-26/Liter</td>
<td>₹6-14/Liter</td>
<td>₹16-25/Liter</td>
<td>₹2000-4500/MT</td>
<td>₹30-34/Liter</td>
</tr>
<tr>
<td>Rice straw</td>
<td>₹23-32/Liter</td>
<td>₹16-25/Liter</td>
<td>₹28-34/Liter</td>
<td>₹1500-2500/MT</td>
<td>₹30-34/Liter</td>
</tr>
<tr>
<td>Bagasse</td>
<td>₹14-16/Liter</td>
<td>₹14-16/Liter</td>
<td>₹30-34/Liter</td>
<td>₹4000-4500/MT</td>
<td>₹30-34/Liter</td>
</tr>
</tbody>
</table>

- **Low Capex**
- **Limited operations ~ 180 days/year**
- **Limited feedstock availability**

- **Relatively higher Capex**
- **Operations ~ 330 days/year**
- **Availability of significant amount of feedstock at low cost**

**Basis of calculations:**
1. Molasses feedstock cost ₹4500-6500/MT
2. Corn cobs cost ₹2000-4500/MT (based on Praj estimates)
3. Rice straw cost ₹1500-2500/MT
4. Bagasse cost ₹4000-4500/MT
5. Biomass conversion cost are based on trials at Praj pilot facility
Addressing Key Challenges & Way forward
Key challenges for 2G ethanol projects in India

**Feedstock sourcing**
- Biomass aggregation
- Biomass supply chain
- Biomass transportation cost

- Low radius of biomass collection
- Biomass compaction to reduce transportation cost

**Economic viability**
- High capital cost
- Higher landed cost of feedstock
- High cost of debt

- Build small size plant - where biomass is available
- Praj’s innovative bolt-on model

**Risk management**
- Product off-take risk
- Technology risk

- Praj’s proven track record of building more than 600 plants across globe
- OMC’s to invest in 2G ethanol projects

Source: Feedback from various conferences and seminars
Rice straw supply chain

Grain Harvest

Residue Harvest

Transport

Increase bulk density if radius is above 40 Km

storage

Delivery

Bio-refinery

- Cut/ Windrow
- Bale
- Stack (20%)

- Load
- Transport

- Unload
- Stack (60%)

- Transport
- Unload

- Storage (20%)

45-50 days Harvesting window – baled straw can directly delivery to bio-refinery
Govt. of India emphasizing on achieving energy security of the country with a target of reducing import dependence by 10% by the year 2022

MoPNG* has formed ‘Working group of biofuels’ committee for effective implementation of EBP

MoPNG* instructed OMC’s to invest in biomass to ethanol projects in India

IOCL floated ‘Expression of Interest” (EOI) for setting up a biomass to ethanol projects in India

Other OMCs to follow

MNRE** is working on policy document for supporting investment in biomass to ethanol projects

BPCL R&D team visited Praj R&D center for evaluation of Praj’s cellulosic ethanol technology

*Note: Ministry of Petroleum & Natural Gas
**Ministry of New & Renewable Energy
Signed MOU’s with 4 prospects in North India

- One prospect is in business of biomass processing and already collecting and processing more than 500 MT of biomass per day. Established logistic and supply chain and infrastructure for biomass sourcing on sustainable basis.

- Second prospect has the existing infrastructure and connect with biomass suppliers which can be extended for aggregation of biomass required for 2G Plant.

- Other two are Praj’s existing Customers and distillery owners.

EOI received from NRI Investor: Interested in Multiple Projects in selected States in India

Opportunity for OMC’s to invest in second generation ethanol – using Indigenous technology
Points being discussed with MNRE for policy document

- Establishing economical and sustainable biomass supply chain logistic
  - Uniform & simple pricing mechanism for Biomass
  - Farmers friendly schemes for biomass collection machinery
  - Demarcated radius of operation for biomass to ethanol projects
- Viability Gap Funding (VGF) for biomass to ethanol projects (similar to solar/wind projects)
  - Viability Gap Funding on capital cost
  - Tax holidays
  - Availability of soft loans
- Risk mitigation
  - Differential pricing for cellulosic ethanol - MoPNG views sought
  - Fixation of ethanol pricing for period of up to 10 yrs
  - Renewable Energy (RE) Certificates for transportation fuels
Emerging business model..

PRAJ: “enfinity”
Biomass to Ethanol Technology

OMC’s:
1) Own Projects
2) Equity Participation in other projects
3) Ethanol long term buy-back agreements

Support from MoPNG – Working group, MNRE, MOEF, MOF & OTHERS

Investor/Project Promoter

Biomass Sustainable Supply Chain: GUJCOT, PEDA, HERDA, MEDA etc
Summary

- To Reduce GHG Emissions
- To Reduce Fuel Import Bill
- To Create Millions of rural Jobs
- To build multi-feed, multi-product bio refineries

Best in Class indigenous Technology is Ready for commercialization
Thank you

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