Lignocellulosic Ethanol Technology : Challenges

and

Praj Advanced Cellulosic Ethanol (PACE) Technology

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Outline

- Introductions
- Why Cellulosic Ethanol? : The Indian Context
- Challenges
- “PACE” Technology
- “PACE” Demonstration Plant
- Praj Biorefinery

Praj Industries Limited - Background

- Established in 1984
  - 1st Company to avail of VC
  - Listed on Indian Stock Exchanges
- Business Lines
  - BioEthanol
  - Breweries
  - Water and Wastewater
  - Sugar and Ethanol Performance Enhancers
  - Livestock Health and Nutrition
  - Energy Crops Services
  - Critical Process Equipment
- Over 500 references in 60 countries
- Over 275,000 sq ft of world class manufacturing facilities meeting global standards

The largest resource base for the BioEthanol Industry with global experience over diverse feedstock

The Innovation Center

- US$ 25+ Million investment
  - 80,000 sq ft of Labs, Pilot Plants, and Offices
- 115 technologists and growing
  - 30 PhDs, 80 Masters
- 4 Technology COEs
  - Biology, Chemistry, Engineering
- 16 Well Equipped Labs
- ISO-9001-2008 Analytical Lab
- Pilot Plants
  - 1 tpd Cellulosic Ethanol pilot plant

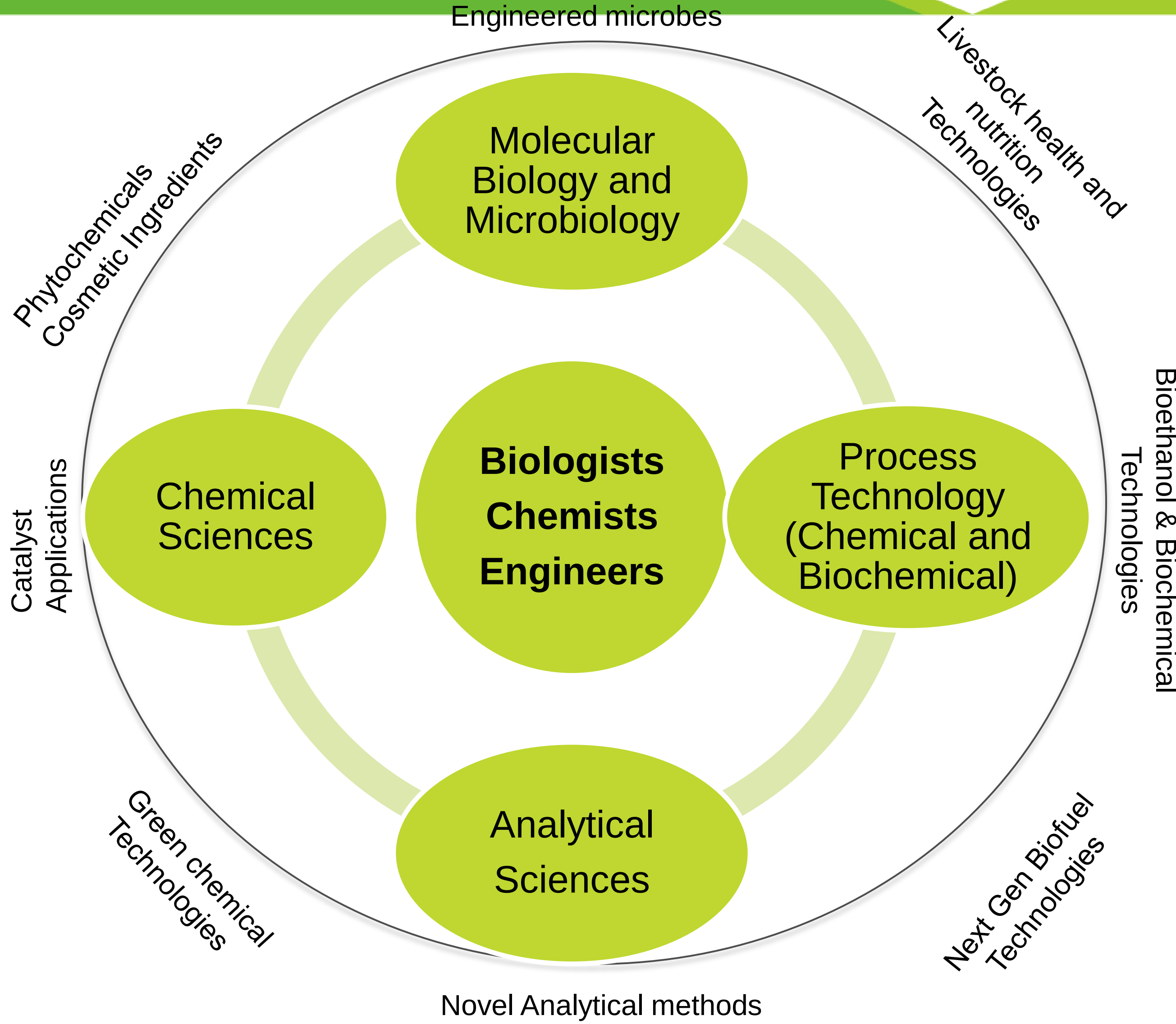
Bench and Pilot scale facilities enable validation of scientific assumptions and rapid commercialization

Praj Matrix – Infrastructure & Capabilities




Centers of Excellence

- Praj-Matrix employs a Centre of Excellence (COE) model as its operating mechanism.
- Each of the four COEs brings a particular technology specialization to the fore.
- Technology programs utilize resources from various COEs at any given time.

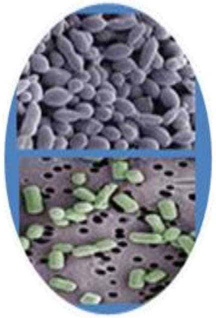


Our Focus – BioFuels, BioChemicals, Environment, Health & Wellness

Praj Matrix : Expertise

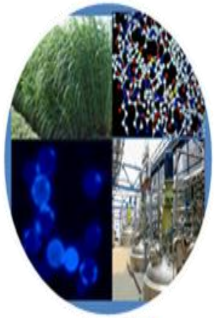
Agri-Feedstock Expertise

- Compositional database of over 2000 samples from different countries
- Proteins Typing
- Compositions of wet grains, solubles and DDGS along with variances
- Effect of unit processes on composition



Applied Microbiology Expertise

- Knowledge base on Fermentation Technologies using various Micro-Organisms
- Yeast Collection of over 100 industrial and feed cultures Select Bacterial Strains collection
- Growth / Fermentation kinetics
- Yeast derivative products and processes



Bio Process Expertise

- Fermentation Process development using yeast, bacteria and Fungi
- Expertise in Process Modeling, Simulation
- Enzyme applications for processing Feedstocks
- Development of downstream process for product recovery and purification
- Heat and Energy Integration with Effluent Management expertise

Why Cellulosic Ethanol? : The Indian Context

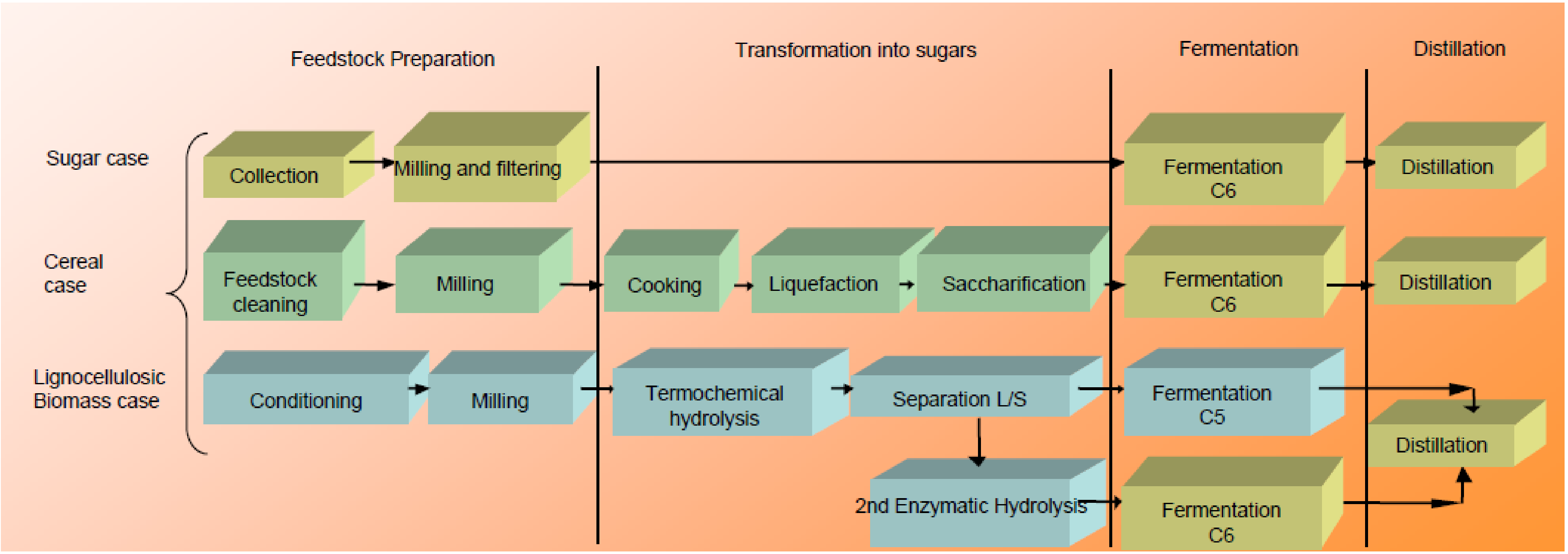
- India's oil import > 80%
  - ~ 3 million barrels per day
- India's annual oil import bill ~ $100 bn
  - Energy security at stake

- Abundant availability of Lignocellulosic feedstock (165 M MT)
  - Sugar Cane Bagasse, Corn Cob and Stover, Rice/Wheat Straw
- Avoids Food versus Fuel Debate
- Reduced GHG Emissions

Cellulosic ethanol is a potential solution to India's transportation fuel needs

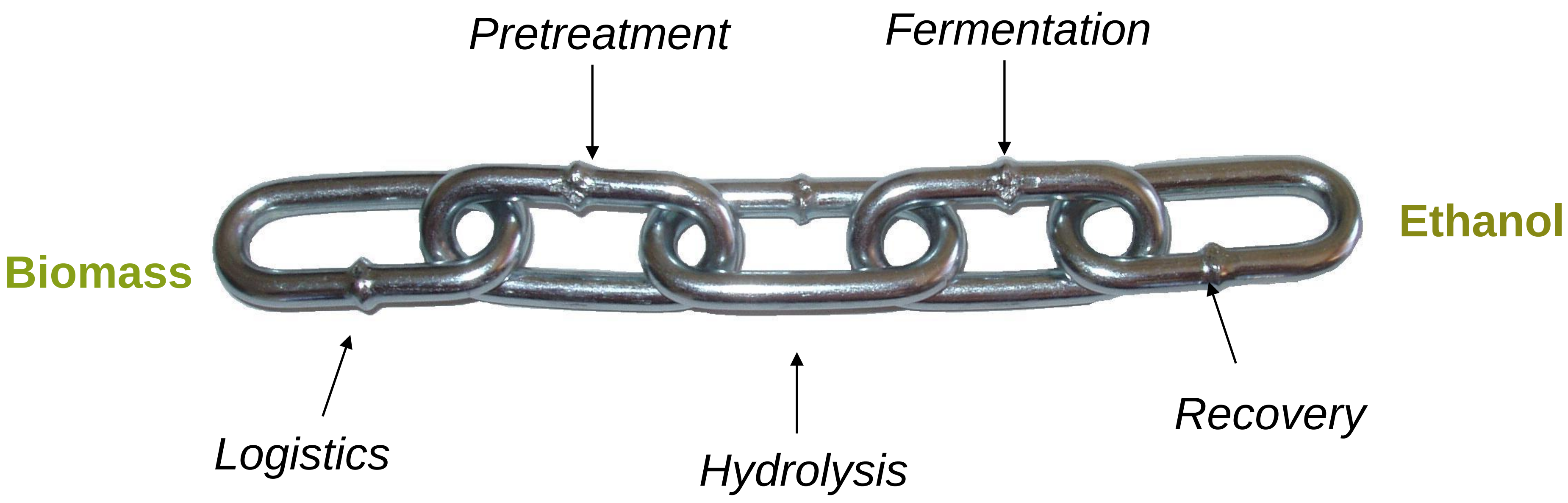
Cellulosic Ethanol : Challenges

LC Ethanol : Complexity



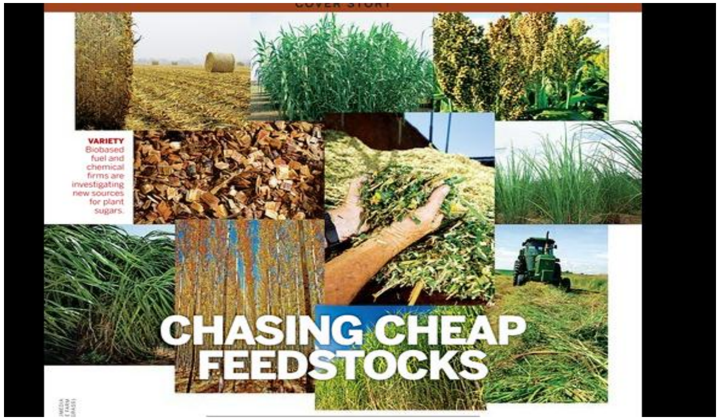
Cellulosic ethanol technology : Most difficult to master

LC Ethanol : Processing Chain



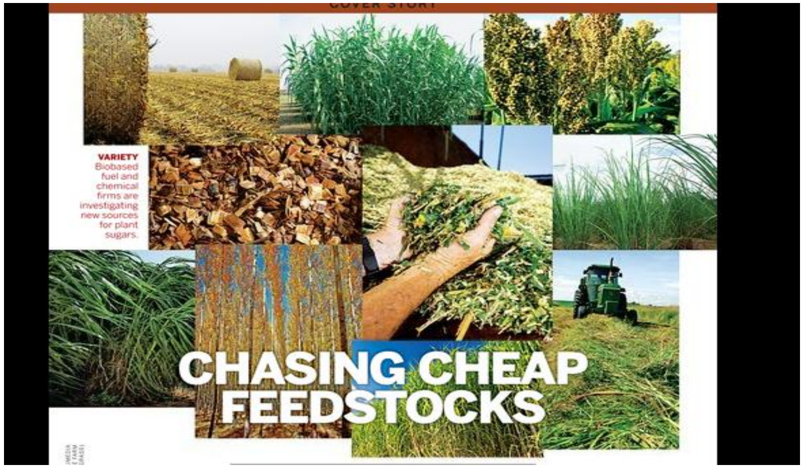
LC Ethanol : Challenges

- Feedstock
- Opex
- Capex
- Blending mandates



Feed stock

- Biomass residues :
  - Corn stover (stem, leaves and cobs):
    1-3 dry MT/acre
    Life cycle CO_2 emissions : 5 kg CO_2/mm btu
  - Bagasse : 8-9 dry MT/acre
- Energy crops :
  - Arundo donax :
    15 dry MT/acre
    Life cycle CO_2 emissions : 13 kg CO_2/mm btu
  - Napier grass
    14-18 dry MT/acre
    Life cycle CO_2 emissions : 19 kg CO_2/mm btu



All biomass is not created equal!
Structural and compositional differences exist

Feed Stock : Critical Issues

- Feed vs Fuel
- Land Productivity
- Feedstock Supply Chain
- Security and Pricing
- Material Handling,

  Storage and Transport
- Sustainability Considerations

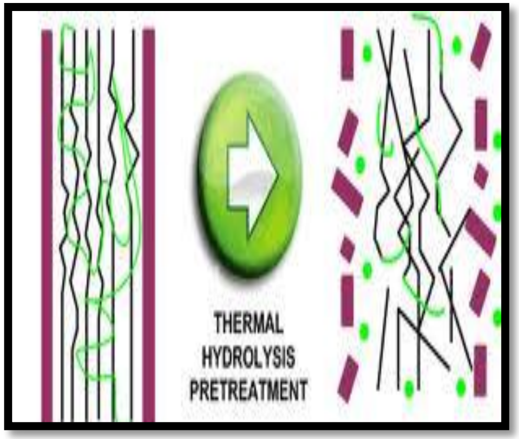
Societal and Governmental Support will be very important

Pre treatment and hydrolysis

- **Deconstruction of biomass to individual sugars**

➢ Acid (strong/dilute) + Enzyme : highly efficient (DSM, Praj, Abengoa)

Moderate on opex, High on capex



➢ Alkali +Enzyme : Moderately efficient (Dupont)

High on opex, moderate on capex

➢ Steam explosion +Enzyme : Moderately efficient (Chemtex)

High on opex, moderate on capex

- **Most of the operating cost from enzymes (dose and price)**
- **Need for low cost and better enzymes**

Fermentation

- **Separate C5/C6 fermentation**
- Need for S/L separation
- Non availability of efficient yeast (wild strains) for consuming C5 sugars in presence of inhibitors

- **Co-fermentation**
- GMO yeasts (Terranol, Fermentis, DSM, Taurus. GTA)
- Efficiency in presence of inhibitors is a challenge

- **Need to develop efficient co fermenting yeast**
- **Need to overcome regulatory hurdles for GMO**

Fermentation

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- **Low titres (< 5%)**
- **Need to develop efficient co fermenting yeast**
- **Need to overcome regulatory hurdles for GMO**

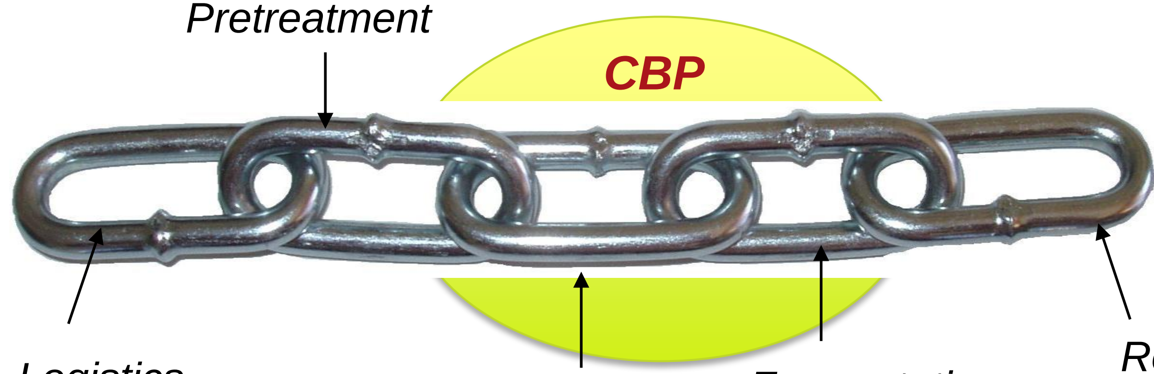
Economics : Comparison

Players	Yield	Conversion Cost	Capex
	(gal/MT)	($/gal)	($/gal)
Zeachem	135	1.00	8.0
Beta Renewables	80	0.80	5.6
DuPont	90	1.00	6.66
Clariant	70	0.90	5.0
POET DSM	90	1.12	10.0
Mascoma	83	0.89	9.5
Praj Ind	**75-85**	**0.81**	**5-7**

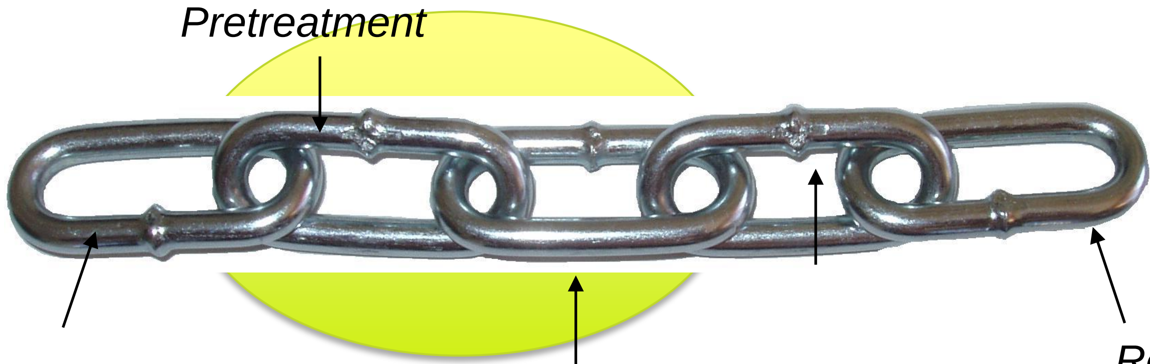
Source- Daily Biofuels Digest newsletter January 3, 2013

Processing Chain : Opportunities

Consolidated bioprocessing (CBP)



Hybrid process



Praj Advanced Cellulosic Ethanol (PACE) Technology : Journey to the demonstration plant

Let's
make it happen

PACE: Journey

Demo Plant - Operation

Demo Plant Design and Erection

Pilot Plant Trials

Pilot Plant Erection

Pilot Plant Design and Engg

Bench Scale Experiments

Bench Scale Facilities

2005 2006 2007 2008 2009 2010 2011 2012 2013 2014

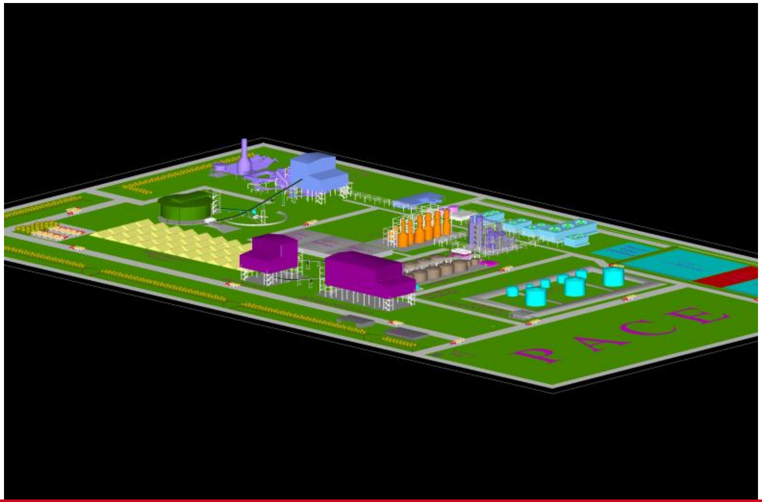
Summary

- Best in class Ethanol Yield
- Low capex and opex
- Economic feasibility from 100 TPD to 500 TPD of dry feed
- Highly Energy Integrated – Proprietary Low Energy Technology
- Effluent Management – *Zero Liquid Discharge (ZLD)* targeted
- In house Design, Engineering and Fabrication
- IP Status: 1 patent granted, 5 filed, Several additional applications in process

PACE technology backed up by scale-up experience and expertise of 30 years

Demonstration Plant:
Feedstock, Capacity, Location, Status

- Feedstock
  - Designed to handle multiple feedstock
    - Sugarcane Bagasse/Trash, Corn Cob/Stover,
- Capacity: 100 metric ton per day (dry basis)
  - Ethanol Production: 25,000 – 30,000 liters per day
- Location: At a Sugar Mill near Pune, India
  - Proximity to Praj Matrix
- Status: Engineering package ready,
  Permitting in-progress
- Target commissioning by 2nd half 2014



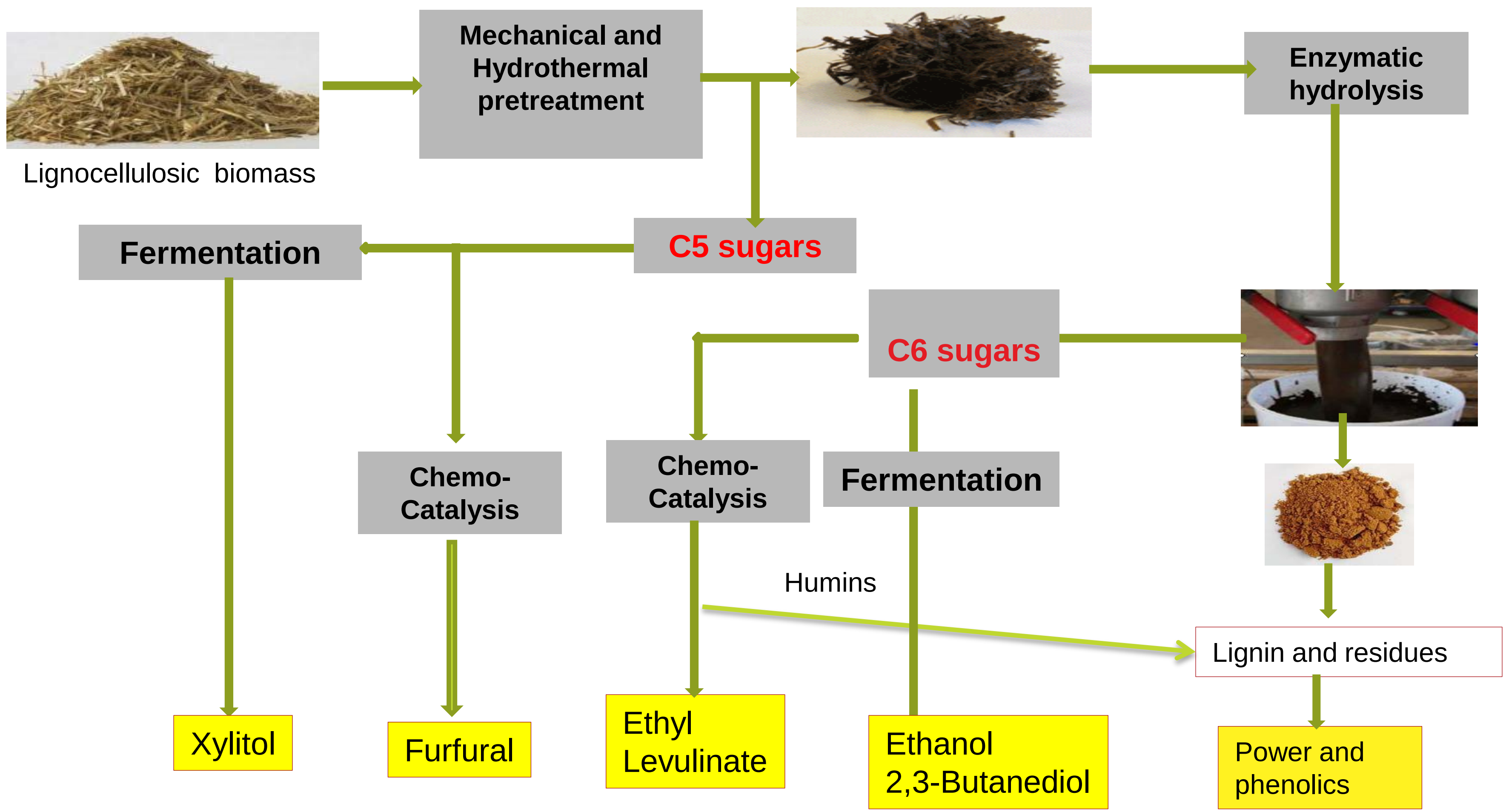
Comprehensive evaluation conducted to chose suitable Capacity and Location

Demonstration Plant : Objectives

- Demonstrate scale-up of the various unit operations
- Demonstrate suitability and reliability of equipment
- Demonstrate repeatability and reproduceability at larger scale
- Demonstrate energy integration
- Demonstrate effluent treatment, recycle and reuse (ZLD)
- Test multiple feed stocks
- Demonstrate Targeted conversion cost of Agro-residues to Ethanol
- Establish basic Cellulosic BioRefinery Concept

Critical Objectives are to Demonstrate and Validate Engineering Scale-Up and Targeted Conversion Cost

What next?



"Praj" Biorefinery : Bolt on to "PACE" plant

Collaboration Models

Input		Collaboration	Output	
Praj	**Partner**	**Model**	**Praj**	**Partner**
• Capabilities • Facilities • Cost • Dev Finance • Background IP/ • Knowhow	• Technology • Cost / • Finance / • IP • Customer Insight	**Joint Development** Partner Spends Praj Spends	• Technical Knowledge • Early Commercialization • Exclusive Rights • Non-Exclusive Rights • Preferred Supplier • License Income • Technology Fees • Sweat Equity in Mother Company	• Technical Knowledge • Accelerated Development • Early • Commercialization • Lower Devt. Cost • Exclusive/ Non exclusive Rights • Channel for Commercialization • License Income • Technology Fees
• Capabilities • Facilities • Cost • Technology	• Basic Technology • IP	**In-Kind Venture Capital** Praj Spends Praj Develops		

Public / Private R&D (SMEs, MNCs, Start Ups) (Joint Development)

Universities, Research Institutions, Government Agencies, Private Institutions, MNCs (In-Kind Venture Capital)

Flexible Win –Win Models for Partnerships

Thanks for your patience

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