



Current Status of Biofuels & Biochemicals

Bipin Shroff – Principal, AdvanceBio Systems LLC, Milford, OH, USA

S1041 Symposium: Stakeholder Perspectives on the Bioeconomy

August 11, 2015 OARDC/OSU, Wooster, Ohio

- Company Introduction
- What are Biofuels & Biochemicals
- Feedstocks
- Processes
- Current Players & Projects
- Conclusion



Introduction



- Formed in 2007
- Provide technology, engineering and process design services for
- **Conventional Ethanol**
 - starch and sugar
 - plant capacities up to 100 mm gpy
- **Advanced**
 - lignocellulosic
- Application of process simulation modeling of ethanol plants to support efficiency and technology upgrades and capacity expansion.



- Formed in 2009
- Exclusive rights to IP related to the mechanical design of biomass processing equipment used in the pulp & paper and biomass to chemicals at capacities to 700 dry tpd
- Scaled the process down to meet the immediate needs of the current market.
- Design, engineer, fabricate and supply biomass pretreatment reactors and ancillary equipment.
- Provide design and fabrication of small scale skid-mounted process equipment based on non-ABS IP.

What is a Biofuel

- Biofuel is any fuel derived from Renewable Biomass. An **Advanced** Biofuel is one derived from Renewable Biomass other than **corn kernel starch**. This definition includes:
 1. Biofuels derived from:
 - a. cellulose, hemicellulose or lignin
 - b. **sugar** and starch (other than ethanol from corn)
 - c. crop residue, vegetative waste material, animal waste, food waste and yard waste
 2. Diesel-equivalent fuel
 3. Biogas produced through conversion of organic matter
 4. Butanol or other alcohols from Renewable Biomass
 5. Other fuels derived from cellulosic biomass

Source: 7 C.F.R. § 4279.202

Types of Biofuels



- **First Generation**

- . Made from corn, wheat, sugar cane, rapeseed, sunflower seeds or oil palm.

- Examples – bioethanol, biodiesel, biogas

- **Second Generation**

- . Produced from waste biomass and energy crops.

- Examples – biodiesel, cellulosic ethanol, biohydrogen, biomethanol

- **Third Generation**

- . Produced from algae

- Examples – biodiesel (also includes bio-propanol, bio-butanol)

Source: UNEP Assessing Biofuels Report

What is a Biochemical

- Biochemical is a monomer, polymer, plastic, formulated product or chemical substance produced from Renewable Biomass
- Summary
 - Both are chemicals. Biofuels are used for energy content. Biochemicals are used as raw materials
 - Anything made from hydrocarbon can also be made from carbohydrate

Examples



Bio-based Feedstocks

- Starch Crops (corn and wheat)
- Sugar Crops (cane and beet)
- Dedicated Energy Crops
- Lignocellulosic (stover, straw, empty fruit bunches, bagasse)
- Oil Crops (palm, rapeseed)
- Aquatic Biomass (algae, seaweeds)
- Waste (industrial, post-consumer)



Lignocellulose

- Cellulose – glucose polymer
 - Readily fermentable but difficult to break polymer
- Hemicellulose – xylose polymer
 - Not readily fermentable and moderately difficult to break polymer
- Lignin – phenolic polymer
 - Tremendous potential but challenging to monetize (can make almost anything from lignin but money).



Conversion Technologies

- Biofuels and Biochemicals can be produced using various platforms:

1. Thermochemical

Syngas

Pyrolysis

2. Plant Base

Agriculture

Aquaculture

3. Sugar

4. Biogas

5. Lignin



Syngas Platform

- A mixture of carbon dioxide, carbon monoxide and hydrogen (Gasification of waste, industrial gases)
 - Ethanol (fermentation or catalytic)
 - Acetic acid, Butanol, Propanol, Isoprene (fermentation)
 - Methanol
 - Diesel (Fischer-Tropsch)

Pyrolysis

- Wood, agricultural residues
 - Bio-oil (Jet Fuel, Diesel)
 - Bio-char



Agriculture Plant Base

- Vegetable Oils (palm, coconut, soybean, sunflower, linseed, castor, canola etc)
 - Resins
 - Lubricants
 - Biodiesel
 - Bio-based Plastics
 - Polymers

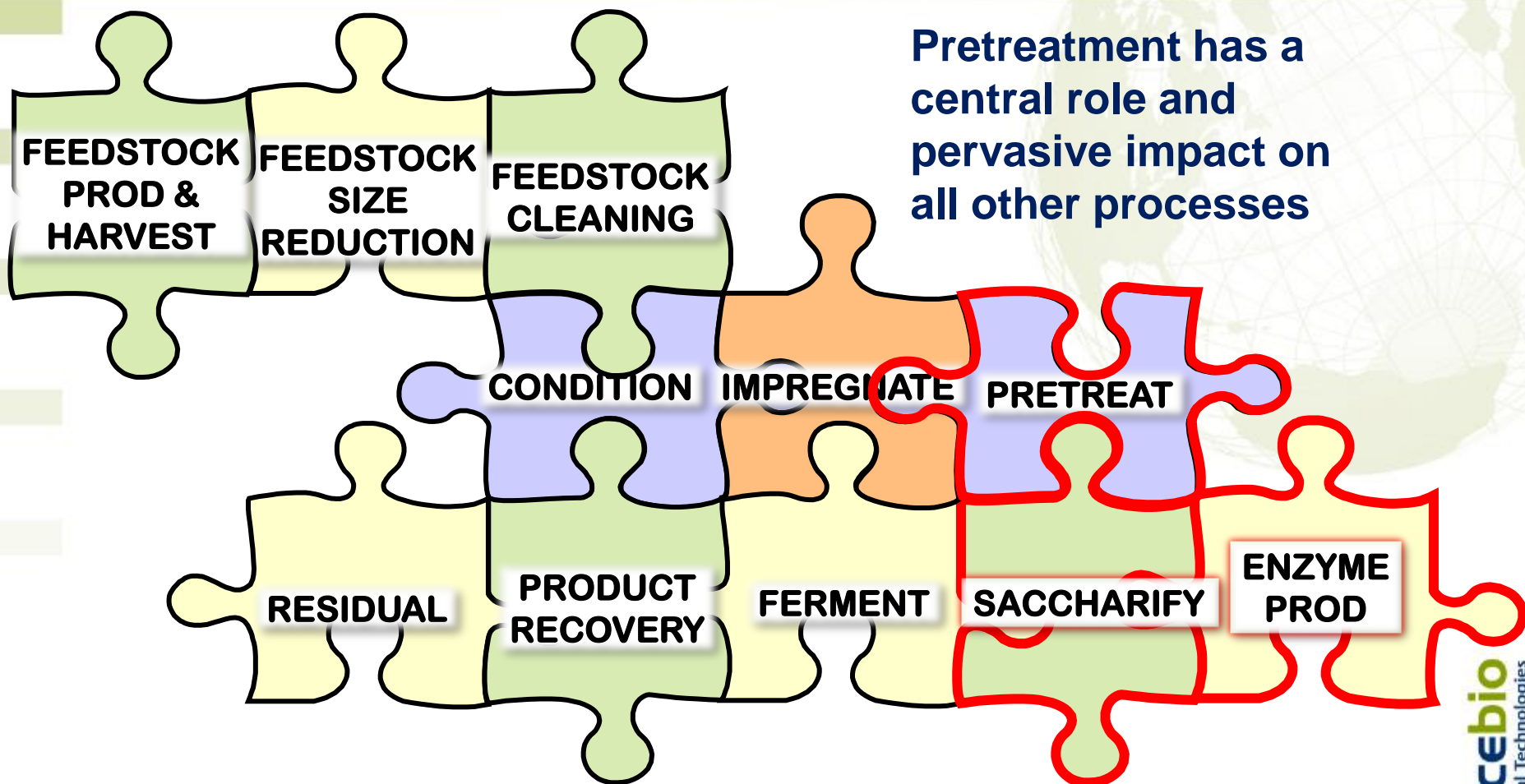
Aquaculture Plant Base

- Microalgae

- Personal Care
- Functional Fluids
- Food Ingredients
- Biodiesel
- Jet Fuel



Sugar Platform



Generation 2 Bench Reactor



Lab Scale Reactor



Lab Scale Reactor

Vertical Pretreatment Reactor System

Two-vessel system for primary and secondary pretreatment at different temperatures

- Biomass is heated by steam injection to temperatures of 120°C to 210°C in the pressurized mixing tube
- Preheated, premixed biomass is retained for set residence time in vertical holding vessel; gravity continuously moves material from top to bottom discharger in plug-flow fashion
- Residence time is adjusted by changing the amount of material held in the vertical vessel relative to continuous flow of material entering and exiting this vessel
- An optional second holding vessel allows for secondary pretreatment at lower temperatures—120°C to 180°C—with potential to add other chemical catalysts
- First vessel can operate from 10 to 60 minute residence times, or down to 5 minutes with volume-reducing insert; second vessel can operate from 10 to 40 minute residence times
- Reactor system is constructed of corrosion-resistant Hastelloy C-2000 to enable use of sulfuric acid, ammonia, and other chemical catalysts

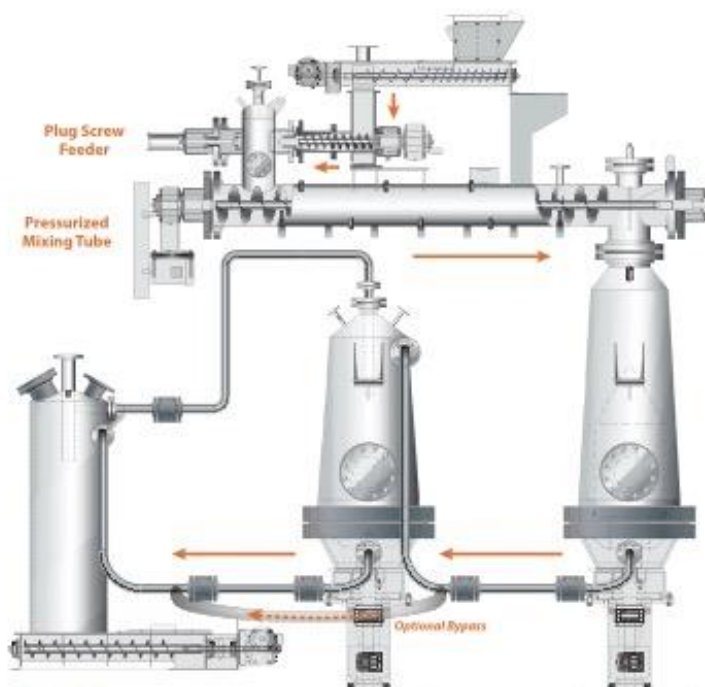
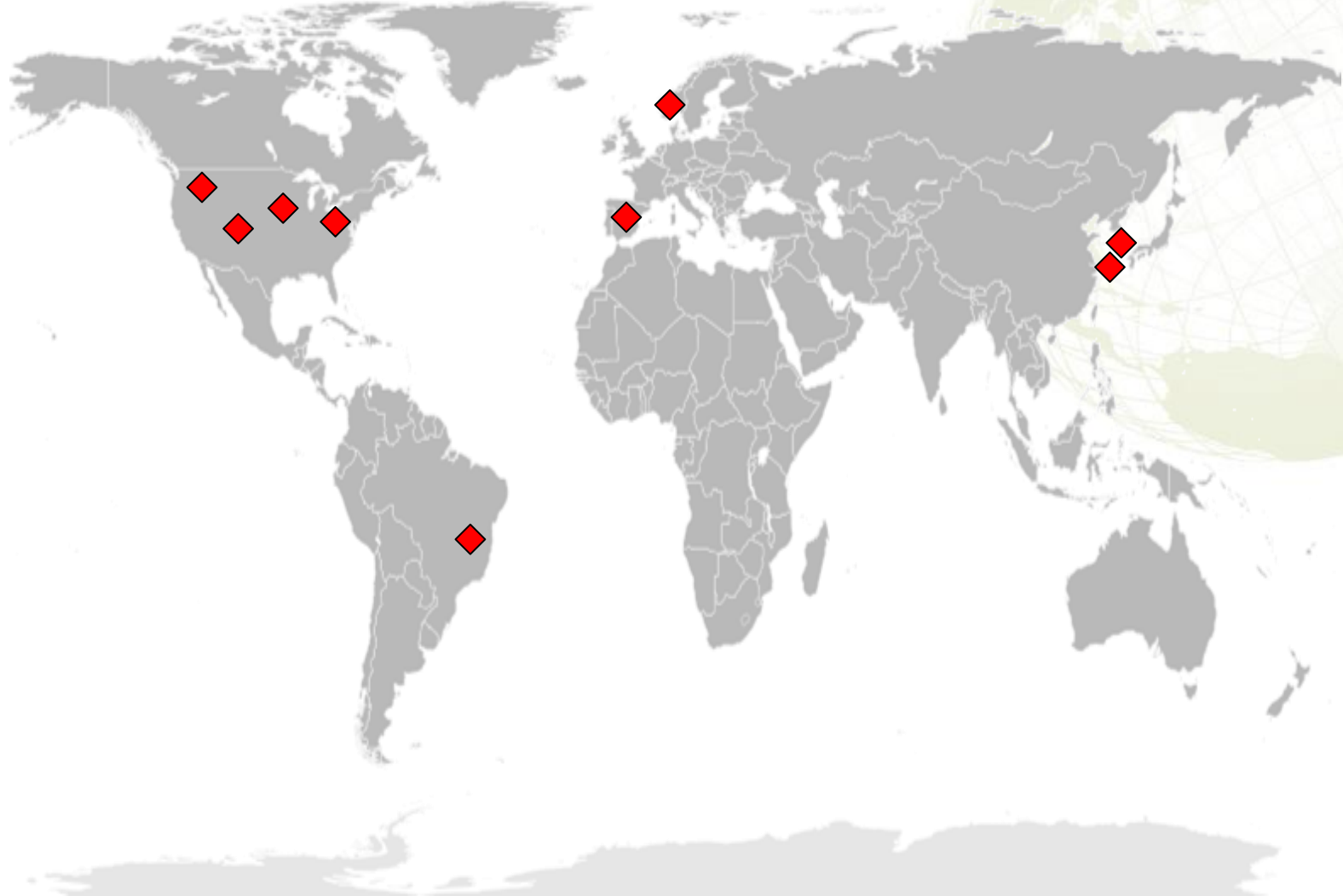


Photo by Cindy Gerk, MUEL-POL 19528





Commercial Scale(Furfural)



Sugar Platform

Feedstocks

- Sucrose
- Glucose
- Xylose

Products

Chemical Process

- Furfural, Levulinic Acid

Fermentation Process

- Succinic Acid
- Adipic Acid
- Glutamic Acid
- Acetone
- Butanol
- Butanediol
- Glucaric Acid

Biogas Platform

- Manure, food waste, municipal waste
 - Methane (fuel and raw material via reforming)



Lignin Platform

- Syngas Products – Methanol, Mixed Alcohols
- Phenols – Resorcinols, Cresols
- Hydrocarbons – Toluenes, Xylene
- Oxidized Products – Vanilin, DMSO
- Macromolecules - Composites, Binders, Adhesives



Cellulosic Biofuel (Ethanol)

Selected Active Companies

- Abengoa (Corn Stover, Wheat Straw)
- DuPont (Corn Stover, Switchgrass)
- Iogen (Wheat Straw)
- Poet/DSM (Corn Stover)
- Ineos Bio (Syngas)
- LanzaTech (Syngas)
- Beta Renewables (Chemtex) (Bagasse, Straw)
- Dong Energy (Inbicon) (Straw)
- Clariant (Multiple) (Sunliquid Process)
- Blue Fire Renewables (Agricultural)

Cellulosic Biofuel (Ethanol)

Inactive Companies

- Gulf Oil (Chevron)
- BEI (Quadrex) → Bionol → BCI → Celunol → Verenium → BP Biofuels
- Shell Oil
- Mascoma (acquired by Renmatix & Lallemand)
- Cobalt
- Range Fuels

Biochemicals

Selected Active Companies

- Multiple Products (Cargill)
- Multiple Products (ADM)
- Polylactic Acid (Natureworks)
- 1,3- Propanediol (DuPont/Tate & Lyle)
- 1,4 Butanediol (Genomatica & BioAmber)
- Isobutanol (Gevo)
- Butanol (Green Biologics, Butamax, WDL)
- Succinic Acid (Myriant, BioAmber)
- Multiple Products (DSM)
- Multiple Products (BASF)



Biochemicals

Selected Active Companies

- Glucaric Acid (Rivertop)
- Acetone (WDL)
- Multiple (Solazyme)
- Glucaric, Adipic (Rennovia)
- Levulinic Acid (GF Biochemicals)
- Lactic Acid (Plaxica)



Commercial Stage

Logos of companies involved in the commercial stage:

- Genencor
- Ajinomoto
- Evonik Industrie
- Jindan
- PCC Chem
- Cargill
- NatureWorks



A Roadmap to Accelerate the Advanced Manufacturing of Chemicals (2015)
http://www.nap.edu/download.php?record_id=19001

Bioplastics



35+ Billion Bottles Worldwide
distributed across water, sparkling, juice and tea beverage brands

By 2020

PlantBottle™ Packaging

will be used for all new PET plastic bottles

Bioplastics

- PlantBottle started in 2009
- Using 30% plant material
- Partnerships with Gevo, Virent, Avantium
- Technology licensed to Heinz & Ford
- Announced in June 100% PlantBottles by 2020



Bioplastics



Conclusions

- Industrial Biotechnology (IB) is here to stay
- Biofuels cannot be an economic driver at crude below \$ 80-100 range
- Biochemicals will have larger value than biofuels
- Food sugars will be a dominant feedstock till 2020
- Use of cellulosic sugars will continue to rise
- IB will be used to produce high-value products replacing chemical synthesis
- Buzzword is PARTNERING