Accelerating Production of Advanced Biofuels with Industrial Biotech Breakthroughs

BIOMASS 2008
Conference

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BIOTECHNOLOGY
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Some Industrial and Environmental Section Members

Can Biotechnology Save Ethanol?
Wrong question

Can biotechnology breakthroughs help us meet the Renewable Fuel Standard on schedule and in a sustainable manner while helping us produce more food for the world? Answer: YES

Why We Can't Afford for Biofuels to Fail: Rising Global Energy Demand

Biotechnology Breakthroughs Improving Biofuels

- AGRICULTURAL BIOTECHNOLOGY
  - Improving crop yields per unit of land
  - Increasing ethanol production efficiency
  - Increasing hardiness and survival of crops
  - Developing new dedicated energy crops

Biotechnology Breakthroughs Improving Biofuels

- INDUSTRIAL BIOTECHNOLOGY
  - Improving conventional ethanol production
  - Enabling commercial scale cellulosic ethanol
  - Developing bio-butanol
  - Researching and developing renewable hydrocarbons

Microbes and Fungi Found in Nature--Used to Make New Biotech Enzymes

Source: NOVOZYMES

One source of new cellulase enzymes

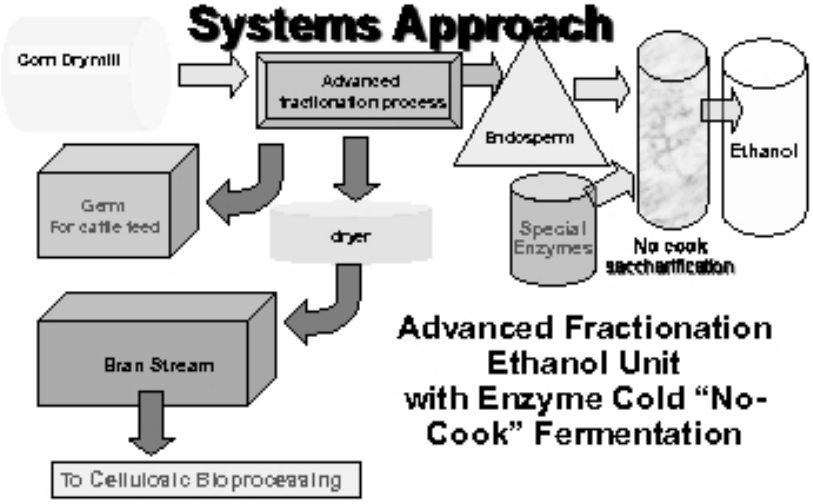
The Pacific Damp wood Termite
Zootermopsis angusticollis

Courtesy of Jared Leadbeater, CalTech, Pasadena, CA

Conventional Ethanol Improvements

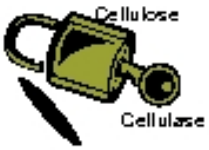
- More efficient **grain fractionation** increases efficiency and creates a new cellulosic feedstock stream
- New **biotech enzymes for "no cook"** saccharification—increase efficiency and reduce energy inputs and CO_2 outputs
- **Increases ethanol yield by 6%** per bushel of corn

POET Advanced Fractionation Systems Approach

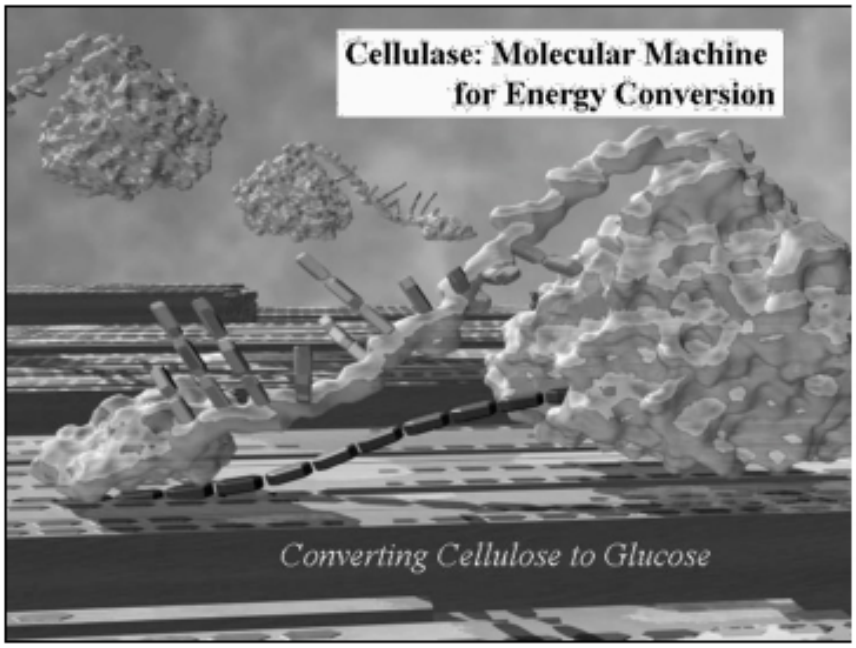


Advanced Fractionation Ethanol Unit with Enzyme Cold "No-Cook" Fermentation

Enabling Cellulosic Ethanol



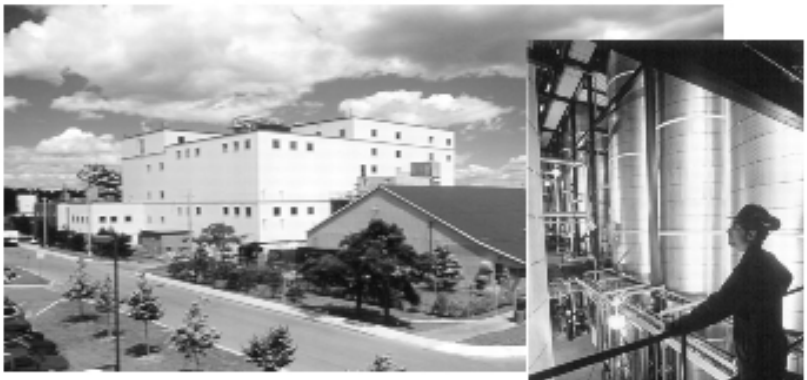
- Cellulase enzymes are the key to cellulosic ethanol
- These enzymes are produced by genetically enhanced microbes or GEMs and they convert the tightly bonded sugars in cellulosic plant matter into individual 5 carbon and 6 carbon sugars.
- These sugars (glucose and xylose) are then available for fermentation to ethanol or other products by other microorganisms.



Fermentation of Cellulosic Sugars

- Xylose (a 5 carbon sugar) is not readily fermentable by common industrial yeasts
- NREL and others developing new organisms that can efficiently ferment 5 carbon sugars to ethanol or convert them to other fuels
- Organisms also being developed to co-ferment 5 and 6 carbon sugars in one step

Iogen's Pilot Plant in Canada



Wheat Straw Feedstock

Iogen
Planned Commercial Scale Unit
2008-2009

- Will use wheat straw as cellulosic feedstock
- Plants to be located in Idaho & Canada
- Scale of 50 to 100 million gallons/yr

Abengoa Bioenergy Facility in Spain

Currently under construction to be completed in mid-2008

Salamanca cellulosic biomass-to-ethanol plant
wheat straw feedstock

Abengoa Bioenergy Salamanca, Spain

- Will produce 5 million liters per year (1.3 million gallons per year)
- Wheat straw feedstock
- Construction complete by mid-2008
- Biotech process not thermochemical

Abengoa Bioenergy
Planned Facility in Kansas
2007-2008

- 100 million gallon capacity
- 90 million gallons from corn starch
- 10 million gallons form wheat straw
- Will have energy island that utilizes corn stover for boiler fuel

Beyond Ethanol--3rd Generation Biofuels
Longer Chain Alcohols and Hydrocarbons

- Involves using microbes and synthetic biology to build new microorganisms that can produce higher value compounds for use as transportation fuels

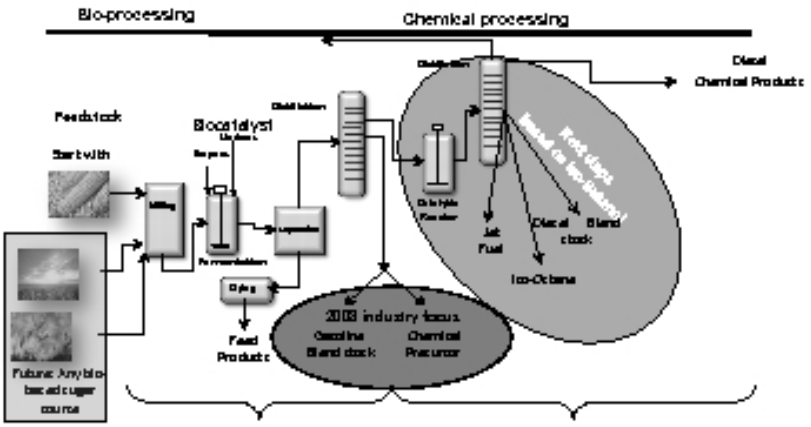
Examples

- Amyris--modular design of metabolic pathways
- LS9-combing genomics, proteomics and synthetic biology
- Gevo-butanol and other molecules

Process Overview

Gevo Process

Fuel and Chemical Biorefinery



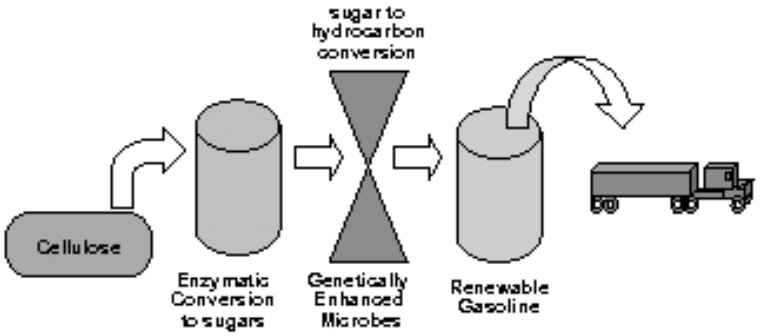
Renewable Gasoline

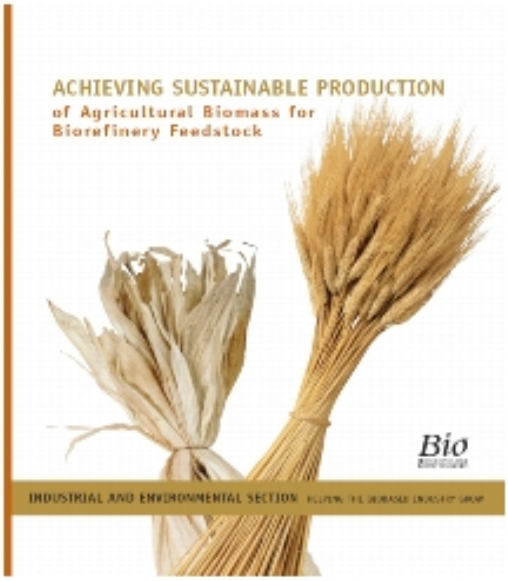
- Involves using microbes and rapid enzymatic pathway construction techniques to build new microorganisms that can of produce higher value compounds (hydrocarbons) for use as transportation fuels

Examples

- Amyris--modular design of metabolic pathways
- LS9-combing genomics, proteomics and synthetic biology

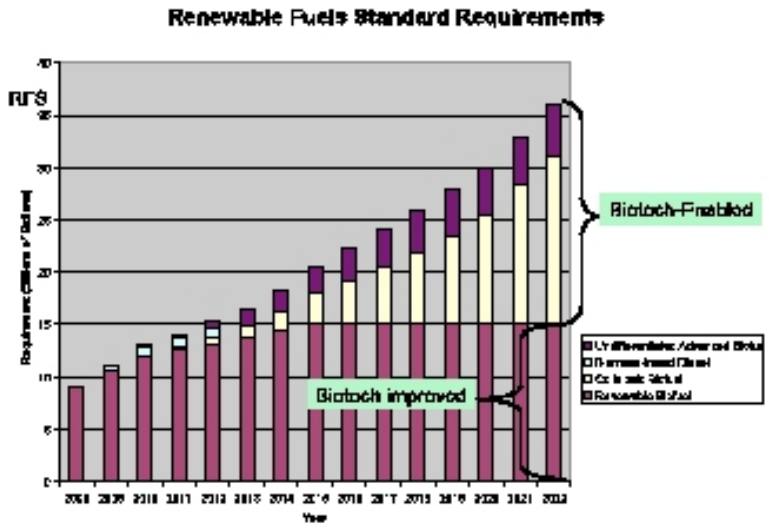
Renewable Gasoline





Achieving Sustainable Production of Agricultural Biomass for Biorefinery feedstock

- Some findings:
- Corn stover and cereal straw are most likely cellulosic feedstock in the near term due to high per acre yields
- Corn farmers could supply over 200 million dry tons annually within three to five years
- Collection of 30% of current annual stover production would yield 5 billion gallons of ethanol
- No-till may be required on some farms to preserve soil fertility and allow for sustainable harvesting

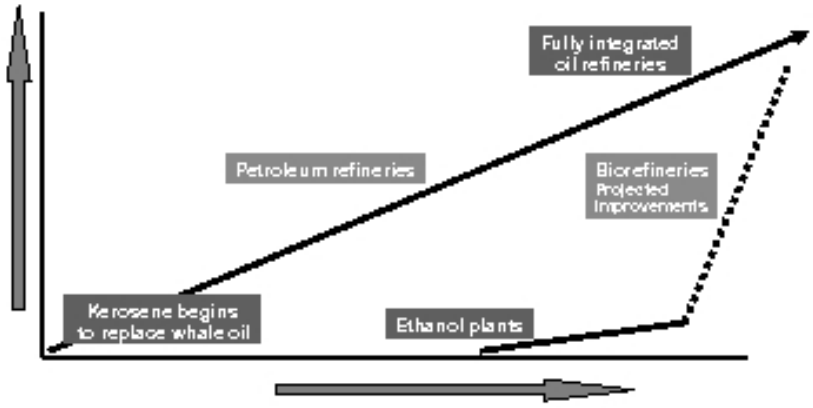


History of Oil Refineries
Instructive for Biorefinery Development

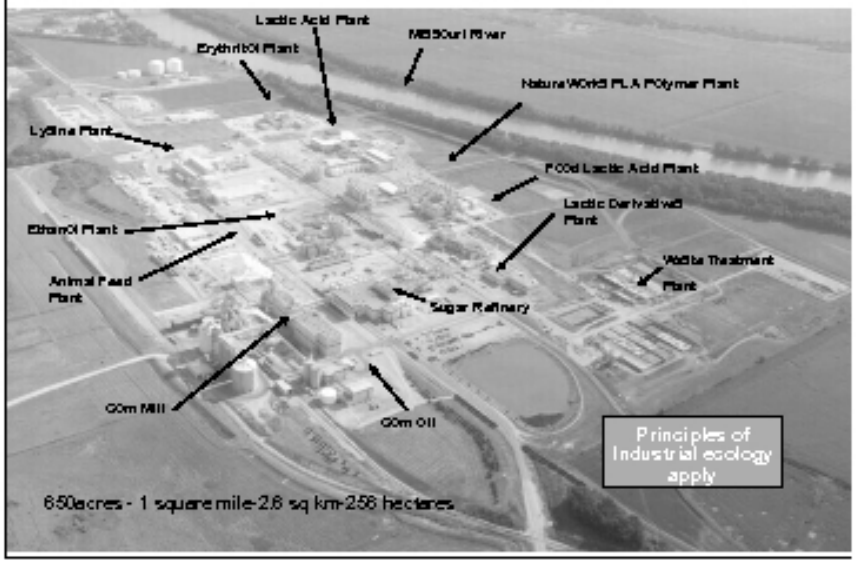
1853– Lukasiewicz was the first to distill kerosene from seep oil

1. 1859 –Principal refined product from petroleum was kerosene which quickly replaced whale oil in the United States. (disruptive technology)
2. 1908— "horseless carriages" needed fuel. Distillation refining did not produce enough of it—only about 20 percent gasoline from a unit amount of crude oil.
3. 1913--Thermal cracking then doubled the efficiency of refining, to produce 40 percent gasoline per unit of oil. The refiners could then keep pace with automobile demand.
4. 1930's—Catalytic cracking added to refining efficiency
5. Today—coking, steam cracking, alkylation, catalytic reforming, hydrocracking are used to maximize refinery outputs
6. Modern oil refinery was over 125 years in development

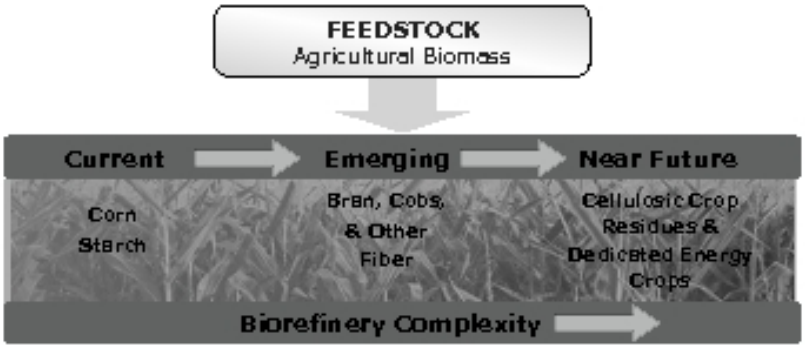
We Are Just at the Beginning of the Biorefinery Journey



Example of a Biorefinery--Blair,NE (Cargill Site)



Biorefineries and Feedstocks Will Evolve Over Time



Biotech Innovation is Accelerating Evolution in Biofuels Development

- Improving **starch to ethanol** processes
- Enabling **cellulosic ethanol** processes
- Enabling **new fuels—like butanol** to be produced from carbohydrate feedstocks
- Enabling radical new technology to produce **renewable hydrocarbons** from ag feedstocks through the application of synthetic genomics
- Producing crop **yield improvements**
- Developing new **dedicated energy crops**

Biotechnology Addresses Biofuels Concerns

- **Energy Balance**
  - 1970s – Ethanol at best: not energy neutral
  - Today – Corn ethanol produces 1.4 units energy for every unit fossil input
  - No cook technology will improve
  - Tomorrow – Cellulosic > 5:1 return on fossil investment
- **Food & Fuel**
  - Biotech varieties have helped increase yields 30% since 1996
  - McKinsey & Co estimate that at this rate the first 15 billion gallons RFS would require no additional corn acres
- **Sustainability**
  - The only actual field study of cellulosic ethanol from switchgrass (PNAS, Jan08) found 93% reduction in GHG vs. gasoline
  - Biomass utilization enhances GHG profile
- **RFS**
  - Biotech is rapidly improving conventional ethanol production
  - Cellulosic and other second generation biofuels are moving to market much faster than predicted
  - Third generation biofuels coming soon

New Blog

http://biofuelsandclimate.wordpress.com/

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Thank you