An Overview of Processing Options and Considerations

Ed Clausen

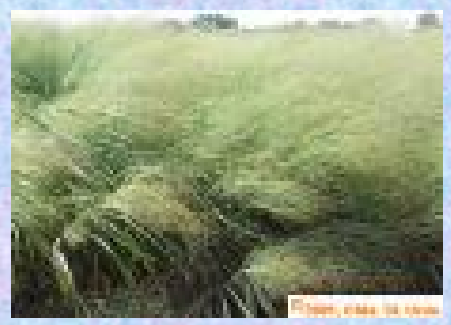
University of Arkansas

Ralph E. Martin Department of Chemical Engineering

Fayetteville, AR

Heat
Electricity

Liquid Fuels



Biomass

Compost

Agricultural
Uses

Value-Added
Products

Value-Added Products

- Value-added products are the other products that can be made from biomass in addition to energy
- These products range from steam and power to plastics to high value pharmaceuticals
- Tommy Smith (Potlatch) will cover value-added products in biorefineries, and Jerry King (U of A) will further address value-added products this afternoon

Liquid Fuels from Biomass

Near Term

- Biodiesel
- Ethanol from corn

Longer Term

- Ethanol from lignocellulosics
- Other liquid fuels

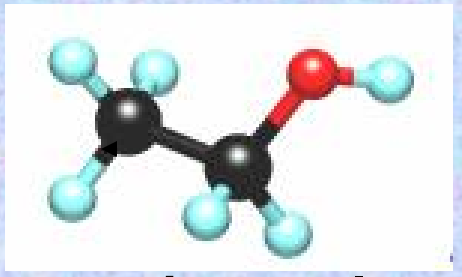
Cal McCastlain (Patriot BioFuels) and Gary McChesney (Viceroy) will cover biodiesel production

Ethanol (Grain Alcohol) from Corn

Corn

Starch

Hydrolysis/
Fermentation



Ethanol

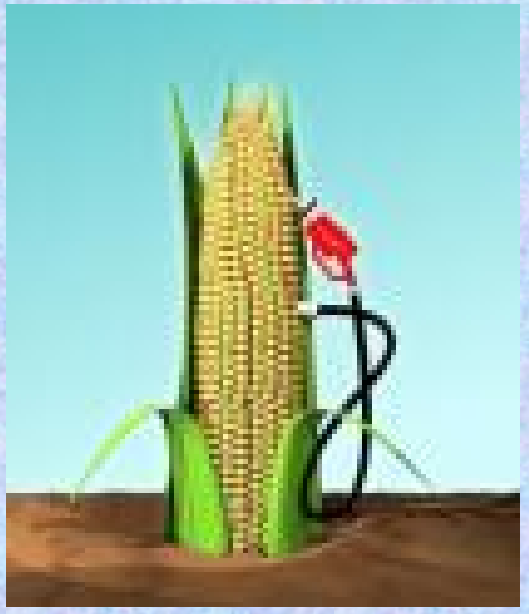
Blending

Fuel

Ethanol from Corn

- 1 bushel (56 lb) of corn yields about 2.7 gallons of ethanol and 18 lb of DDGS
- In 2005, about 14% of the corn crop (1.6 billion bushels) went to ethanol
- A typical modern ethanol plant produces 50 million gallons of ethanol annually, and uses 18 million bushels of corn, grown on about 128,500 acres

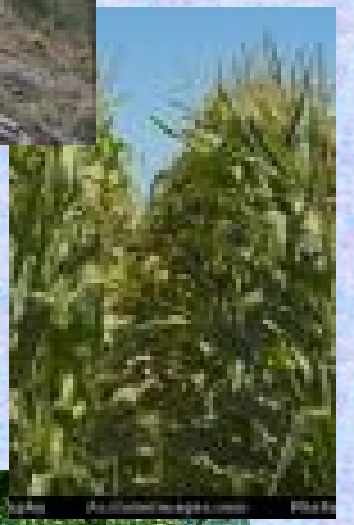
A few ethanol facts . . .

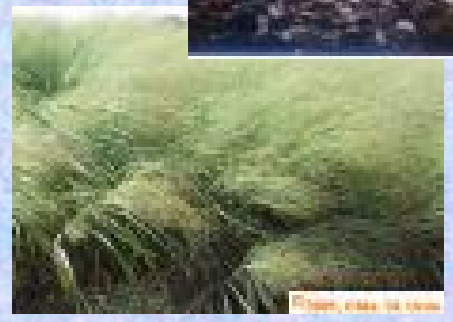
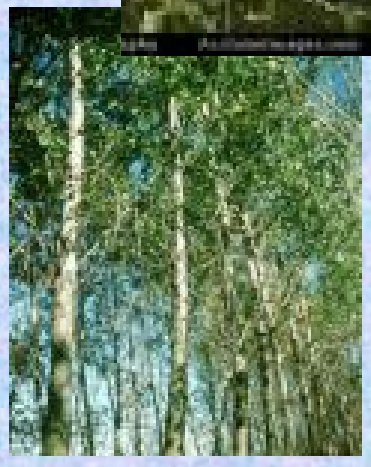


- In 2005, the U.S. produced a record 4.3 billion gallons of ethanol from corn
- There is potential to produce perhaps 13 billion gallons of ethanol from corn (only 7% of our liquid fuel needs) without negatively affecting the food supply

The Key is Lignocellulosic Feedstocks . . .

- Agricultural Wastes:
  Corn stalks, wheat straw
- Forestry Wastes:
  IFR, bark, paper fines
- MSW (Garbage)
- Energy Crops:
  Switchgrass,
  Hybrid poplar

Liquid Fuels Products from Lignocellulosics . . .

- Cellulosic Ethanol
- Mixed Hydrocarbons

- Bio-crude (pyrolysis oil or bio-oil)

Lignocellulosics may be converted to ethanol by two routes . . .

- Sugar Platform—convert biomass to sugar as an intermediate
- Thermochemical Platform—convert biomass to syngas as an intermediate
- The selection of a route depends on many factors

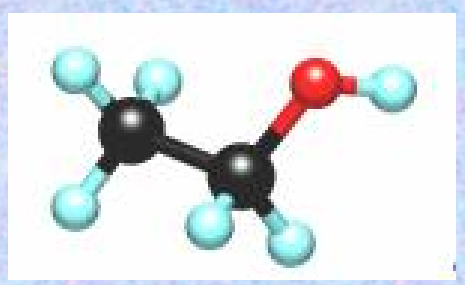
Sugar Platform . . .

Biomass

Hydrolysis

Sugars

Fermentation



Ethanol

Blending

Fuel

Sugar Platform . . .

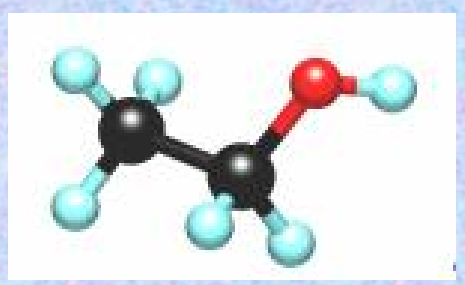
Biomass

Enzymatic

Hydrolysis

Sugars

Fermentation



Ethanol

Blending

Fuel

Enzymatic Hydrolysis Process

Advantages

- Clean sugar solution that is easily fermented to a number of products

Disadvantages

- High pretreatment and enzyme costs
- Lignin not converted
- Five carbon sugars are not easily fermented

IOGEN CORPORATION

Sugar Platform . . .

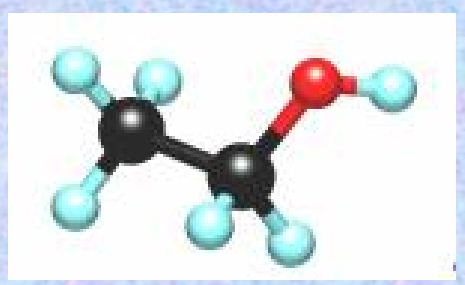
Biomass

Dilute Acid

Hydrolysis

Sugars

Fermentation



Ethanol

Blending

Fuel

Dilute Acid Hydrolysis Process

Advantages

- Very simple process
- No acid recovery

ABENGOA

BC International Corporation

Disadvantages

- Low sugar yields
- Degradation products
- Lignin not converted
- Five carbon sugars are not easily fermented
- Gypsum produced as by-product

Sugar Platform . . .

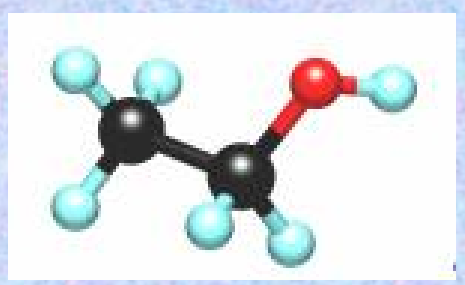
Biomass

Concentrated Acid

Hydrolysis

Sugars

Fermentation



Ethanol

Blending

Fuel

Conc. Acid Hydrolysis Process

Advantages

- Clean sugar solution that is easily fermented

Disadvantages

- Acid recovery required, expensive
- Lignin not converted
- Five carbon sugars are not easily fermented

MASADA RESOURCE GROUP

ARKENOL

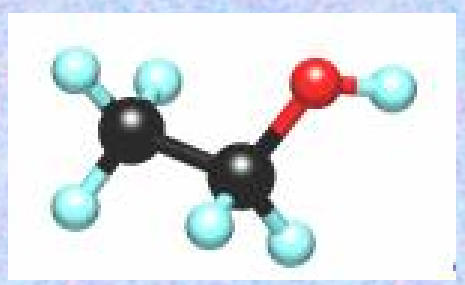
Thermochemical Platform . . .

Biomass

Gasification

Syngas

Fermentation



Ethanol

Blending

Fuel

Gasification/Fermentation Process

Advantages

- Utilizes lignin—high yields
- Can be used on any carbonaceous feedstock
- Significant waste heat generated

Disadvantages

- Gasification and fermentation of syngas is relatively new
- Has been only one pilot demonstration plant

BRI ENERGY
Clean Technology for Renewable Energy

Yields/Economics . . .

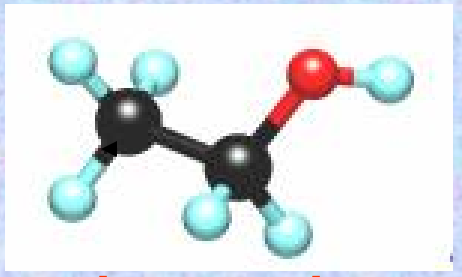
- Ethanol yields from biomass are 40-100 gallons per ton, depending on the conversion technology
- Ethanol from cellulosic biomass is projected to cost between 60¢ and $1.20 per gallon, depending on feedstock cost and conversion technology

Thermochemical Platform . . .

Biomass

Syngas

Catalysis



Hydrocarbons

Processing

Fuel

Biocrude Production

- Biomass is thermally degraded at high temperatures and pressures (pyrolysis)
- A crude bio-oil is produced, along with other products
- The biocrude is refined to produce liquid fuel(s) or used directly for thermal or electrical energy

btg
biomass technology group

When will we be ready to convert lignocellulosics to liquid fuels?

- Depends on the technology and the interest and development of the private sector