Fuel Grade Ethanol Bio-refining

C Merritt  Plant Engineer
Sunoco Inc.
Presentation Objectives

- Bio-refining and Bio-fuels
- Ethanol as a bio-fuel
- Look at how ethanol fits in the USA’s energy portfolio.
- Fuel grade ethanol production- the technical processes from sugar, starch and cellulosic material.
- Industry challenges going forward
Why the interest in bio-fuels/ bio-refining?

• After 9/11 we realized that we need to invest in our own transportation fuel production. **The Pentagon is a big supporter**

• The USA has a lot of usable land and lots of waste that could be used for bio-fuel production

• Job creation for industries that support bio-refining
  • Farmers
  • Mills
  • Trucking and rail transportation
  • Refining equipment manufactures

• The supply of oil is finite........
Bio-Refining - The basics

• Bio-refining is simply the biological, chemical and mechanical methods of converting some renewable feed stock into a useful product.

• Bio-refining is associated with renewable fuels (bio-fuel)
  • Direct biomass use for fuel (combustion)
  • Methanol, Ethanol, Butanol production
  • Biodiesel production - including algae derived fuel
  • Digester gas – methane production
  • Syngas (gasification) and pyrolysis oils (Pyrolysis)

• Generally will involve valuable co-products
Alternatives to Bio-refining

- Off shore drilling....and Canadian tar sands
- Hydro-fracking
- More nuclear power
- Solar and wind power development
- Clean coal
- Energy Conservation

• None of these alone will compensate for our current use of oil........especially long term
Bio-Fuels Policy

• **EISA- 2007 Energy Independence and Security Act**- intent of moving our nation forward towards greater energy independence. It created RFS

• **Renewable Fuel Standard – RFS** called for the increase in renewable fuels like ethanol and biodiesel production by 2022. This lead to 10% ethanol in our gasoline.

• RFS provides R&D money, subsidies to growers and producers

• **RFS2 effective 2010**- a revision to the original standard....to include more advanced feed stocks.... like cellulosics. Puts limit of 15 billion gallons/ year on “starch based fuels”

• Some subsidies may go away. Without RFS the bio-refining industry would not have developed.
Ethanol: The Good, Bad and the Ugly

• It is easy to make ethanol from corn- established feed stock, a little harder from wood/grasses (cellulosics)
• It adds oxygen to the gasoline – lowers emissions.
• It has about 75% of the BTU’s of gasoline, but higher octane
• It readily absorbs water up to 6% weight.
• It contains carbon dioxide gas as an impurity.....when this combines with water you get dilute acid.....not good for an internal combustion engine.
• Inhibitors and additives are used to neutralize the carbon dioxide....but also have negative consequences if over used
Ethanol Chemistry

- Methanol - CH₂OH
- Ethanol – CH₃CH₂OH
- Isopropyl alcohol or (dry gas) – (CH₃)₂CHOH
- Butanol- CH₃CH₂CH₂CH₂OH
- Gas is CH₃-(CH₂)ₙ-

- C-C bonds have more energy than C-O bonds and are more hydrophobic. The O-H bonds help oxygenate and lower emissions.
History of Ethanol Use

- Ethanol was used as a lamp oil prior to the Civil War.
- Original Ford Model T automobiles ran on ethanol.
- Prohibition in 1920 forced ethanol based fuel into disuse until late 20th century.
- Brazil mandated renewable fuel after 1970’s energy crisis. Their sugar cane crop became a major feed stock for ethanol based fuel.
- In 1990 the USA produced 900 million gallon/year. In 2010 we produced 13 billion gallons of fuel ethanol, mostly from corn.
- In 2010 ethanol fuel displaced 455 million barrels of imported oil.
World Ethanol Production

• 2010
  – North and Central America 13.7 billion gal/yr
  – South America (Brazil) 7.1 billion gal/yr
  – Europe 1.2 billion gal/yr
  – Asia 0.8 billion gal/yr
  – Australia 0.06 billion gal/yr
  – Oceania 0.06 billion gal/yr
  – Africa 0.04 billion gal/yr

*Data from the RFA 2010 annual report
The Current Industry Facts

• Over 200 operating corn to ethanol plants in the US
  — Enough plants to meet the 15 billion GPY limit set by RFS2
  — They currently use about 40% of the corn grown in the US
  — They compete with world food market, both human and animal feed

• About 35 cellulosic to ethanol plants, all are small < 500,000 GPY
  — Two large plants in construction, both using corn stover as the primary feed stock.
  — Not enough capacity to meet the RFS2 requirements
  — Technology is quickly closing in on profitability.
  — Feed stock supply chain is major issue
Ethanol to Market Pathway

Farmers

Grain Brokers

Ethanol Plants

Blenders

Retailers

Gas

Consumers
Making Ethanol via Fermentation
Ethanol Bio-refining Feed Stocks

- Corn, Sugar Cane, Sorghum
- Cellulosic
  - Wood/plant material
- Other Crops
  - Sugar Beets, Sweet Potatoes, Grains, Waste Food Stuffs...anything that has sugar, starches or cellulose
- The ideal feed stock would be a waste product or easy to grow and not compete with the world food supply.
Ethanol Production Flowchart

Cellulose Process

Sugar Cane Process

Corn Process

Sugar
Fermentation
Distillation
Drying
Ethanol

Starch Conversion (Cook or Enzymatic Hydrolysis)

Co-Product Recovery
Animal Feed Chemicals

Thermochemical Conversion

- Heat and Power
- Fuels and Chemicals

- Corn Stover
- Switchgrass
- MSW
- Forest Residues
- Ag Residues
- Wood Chips

www.msue.edu (2011)
The Corn Challenge

• For a 85 million gallon per year plant
  – 85,000,000 gal/ 2.8gal per bushel = 30,357,143 bushels corn per year
  – And each acre of corn can produce about 150 bushels.......then
  – 30,357,143/ 150 = 202,381 acres per year or
  – 202,381 ac/yr/ 365 days/yr = 554ac/day

– 85million gal/yr is .085/14 = 0.6% of US ethanol supply
Corn conversion to Ethanol Process Description

Ethanol, CO2, High Protein Animal Feed and Corn Oil

56 lbs (1 bushel) + 19 lbs (2.8 gallons) + 18 lbs = 18 lbs Dried Distillers Grain + .8 lbs
The Requirements for Making Ethanol

- Constant and consistent Logistics
- Technical Processes
  - Mash Preparation
  - Fermentation
  - Distillation and dehydration
  - Liquid and solids separation
- Good process quality program- prevent bacterial infections, and maintain fuel standards
- Good water and energy conservation program
Logistics

Annualized feed stock, utilities and product flow for our 85 million gallon per year corn based ethanol plant

1. Corn – 83,200 bushels of corn/day
2. Ethanol- 233,000 gallons / day
3. Dried Distillers grain – 748 tons /day
4. CO₂ food grade – 748 tons / day
5. Corn oil – 7,500 gallons /day
6. Natural Gas- 49,300 dekatherms/ day
7. Water- 630,000 gallons/ day
8. Electricity- 8.3 megawatts per hour
Logistics
Technical Processes
Kernel Corn

Dry grind with hammer mills

Steam

Recycled water

Slurry blending

enzyme

Liquefaction 8 hours @ 180F

Mash for fermentation

heat
Mash Preparation
Conversion of corn sugars to alcohol

- **LIQUEFACTION**
  - Sulfuric Acid

- **YEAST HYDRATION**
  - More Amylase Enzyme

- **YEAST PROPAGATION**
  - Urea
  - CO$_2$

- **FERMENTATION**

- Purified and bottled
Fermentation tanks
Yeast Management
Carbon Dioxide Capture

Linde
DISTILLATION and DEHYDRATION

FERMENTATION

BEER WELL, 15% ETOH

DISTILLATION COLUMNS

Whole stillage (Corn mash w/o alcohol)

MOLECULAR SIEVES

Denaturant (gas)

200 PROOF Ethanol

FINAL PRODUCT TANKS

Denatured Ethanol
Distillation, Dehydration and Evaporation (DDE)
LIQUIDS AND SOLIDS SEPARATION

Whole Stillage → CENTRIFUGES → THIN STILLAGE → EVAPORATORS → ATM

Whole Stillage → DRYERS → WETCAKE

Whole Stillage → DRYERS → DISTILLERS

Backset → WETCAKE

Thin Stillage → SYRUP

Thin Stillage → EVAPORATORS → SYRUP

Thin Stillage → ATM

Thin Stillage → EVAPORATORS → SYRUP

Thin Stillage → ATM

Thin Stillage → ATM

Dry Distillers Grains → Corn Oil Centrifuge

Dry Distillers Grains → Corn Oil Centrifuge

Dry Distillers Grains → Corn Oil Centrifuge

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifuge → Corn Oil

Corn Oil Centrifage
Dryers
Energy and Water Conservation

• Most corn ethanol plants use ATM’s (anaerobic digestion) to clean up recycled water and Reverse Osmosis to treat boiler make up water.

• Steam usage is very high. Cleanliness of heat exchangers and evaporators is paramount.

• Boilers and dryers are high natural gas users. Efficiency of both are important.
Challenges for Ethanol Bio-Refining

• What is the long term transportation fuel strategy for the USA?
• When will the oil actually run out?
• We do not have enough corn based ethanol production to meet the proposed E-15 (15% ethanol in gasoline)
• How do we regulate ourselves?
Future of Ethanol Production

• Corn based Ethanol industry has made itself profitable- marginally
• Availability of corn is issue
• Cellulosic derived ethanol is still about 2 years away from production viability. Feed stock supply issues
• The role of butanol and other pyrolysis derived oils is unknown
• USA petroleum refineries are moving overseas
• We are in a transition period
• Government regulation will strongly influence this industry
Questions?
The major questions about cellulose based ethanol

• How do you handle massive amounts of wood chips or corn stover or willow or......
  – How do we procure the feed stock supply

• The pre-treatment step make us nervous
  – What separation technology is best to isolate the C6 sugars.....and maybe the C5 sugars

• How do we market the co-products

• How much is the initial capital investment?

• If we could integrate, what is the best way
How much Forest Residue to replace 50% of the corn

• If we were to use a process that yielded 70 gallons of ethanol per ton of forest residue....

• 85 million gal / 2 = 42.5 million gal, and

• At 70 gal/ton we would need 42,500,000/70 = 607,140 tons per year or 1,663 tons per day

• This equates to about 55 trucks per day

• The supply network would be a limiting factor
Summary

• Conversion of our corn plant would require front and back end changes
• Use the cost of sugar as a means to evaluate feed stocks for fermentation
• Small incremental changes can lead to big savings
• Use the cost of steam as a means to evaluate biomass combustion for steam production
• Never forget the intangibles........