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Biomass as a Source of Renewable Energy and its Impact on the Air Quality

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Biomass is a great source of renewable liquid fuel

- New manufacturing processes are producing Ethanol from cellulosic feedstocks, also called biomass feedstocks.

Sugar cane bagasse. Photo by Warren Gretz, DOE/NREL.

Ethanol as Fuel

- Cellulosic Ethanol is generally blended in gasoline to reduce emissions, increase octane, and extend gasoline stocks

Photo by Warren Gretz, DOE/NREL.

Cellulosic Ethanol

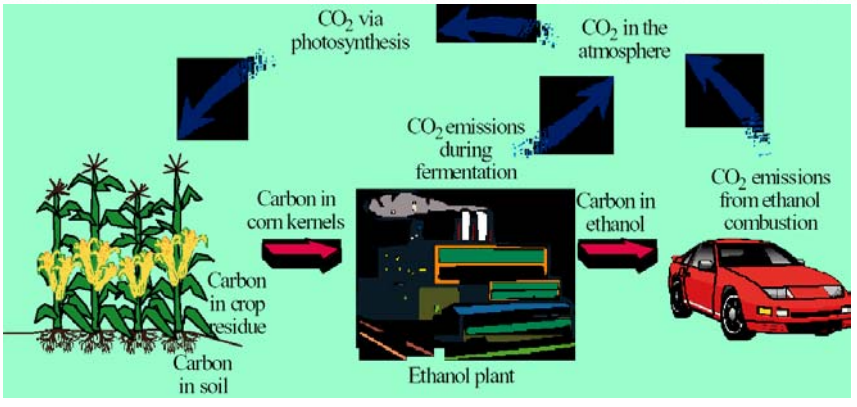
- Ethanol is a liquid transportation fuel made from renewable resources or plant biomasses such as:
  - Agricultural wastes: corn, grain, grasses, sugar cane, straw
  - Wood based waste: newsprint, woodchips,& manufacturing waste materials.

Wood chips. Photo by Warren Gretz, DOE/NREL.

Cellulosic Ethanol Helps lower GHGs

- Ethanol is a clean burning fuel that lowers overall Green House Gas Emissions
- Emits nearly 60% less greenhouse gases than reformulated gasoline
- The biomass absorbs the Carbon Dioxide as it grows
- Ethanol contains a high percentage of oxygen (35%) producing more complete fuel combustion. Oxygen acts as oxygenating agent during combustion in the IC engine preventing formation of CO and reducing air emissions.

Overview of CO2 life cycle in biomass ethanol



Benefits of Cellulosic Ethanol

- **Relies on non-food and waste resources.**
- Cellulosic materials that can be made into ethanol are classified under 4 headings
  - Agricultural waste: forest residue, municipal solid waste, and energy crops. wheat straw, corn stover (leaves, stalks and cobs), rice straw, and bagasse (sugar cane waste).
  - Forestry residue: wood and logging residues, rotten and dead wood, and small trees.
  - Municipal solid waste: paper, wood, and other organic materials that can be converted into ethanol.

Benefits of Cellulosic Ethanol Cont.

- Energy crops: grown specifically for fuel, include fast-growing trees and shrubs, such as hybrid poplars, willows, and grasses such as switchgrass.

Poplar harvest. Photo by Warren Gretz, DOE/NREL.

Switchgrass. Photo by Warren Gretz, DOE/NREL.

Benefits of Cellulosic Ethanol Cont.

- 1999 study by Argonne National Laboratory found that substituting Cellulosic ethanol for gasoline would result in a net greenhouse gas reduction of 86 percent
- Cellulosic ethanol plants can dispose of a wide variety of organic wastes
- A few small-scale cellulosic ethanol plants are operating in the U.S. and Canada, using sugar cane residue, municipal solid wastes, rice straw, and timber residue as feedstocks.

Benefits of Cellulosic Ethanol Cont.

- Ethanol has been used as a transportation fuel in the U.S. since about 1908. Henry Ford designed the Model T to run on either gasoline or ethanol, and ethanol continued to be widely available as an automobile fuel through the 1930s.
- New Flexible Fuel Vehicles currently available, operate on E85 ethanol based fuels with a content of 85% ethanol and 15 % petroleum.

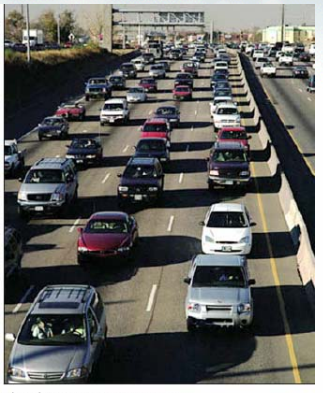


Photo by Warren Gretz, DOE/NREL.

Conversion of Cellulose to Ethanol

- Cellulosic materials are generally less expensive than corn but also harder to convert to sugar.
- Using sulfuric acid, through either *dilute acid hydrolysis* or *concentrated acid hydrolysis*
- Process called *enzymatic hydrolysis where by cellulase is used, instead of sulfuric acid, to convert cellulose to sugar* (*thermal gasification* and *pyrolysis*)

Cost of conversion

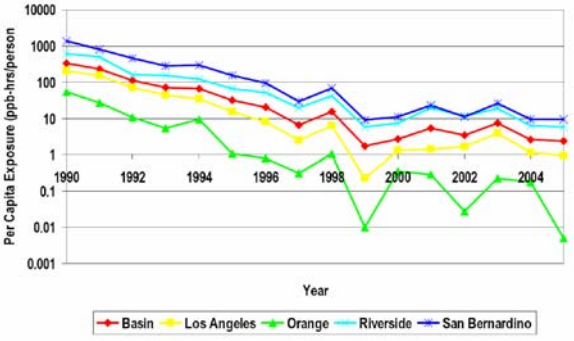
- Until recently, the cellulase enzymes used for enzymatic hydrolysis were prohibitively expensive, costing five or six dollars per gallon of ethanol.
- In 2005, two companies— Novozymes Biotech and Genencor International reported achieving costs as low as 10 to 20 cents per gallon of ethanol.

Ethanol in the US

- Over 30 percent of all gasoline sold in the U.S. is blended with ethanol.
- Many states require gasoline to contain ethanol Minnesota, New York, and Connecticut require gasoline to include a 10 percent ethanol blend, known as E10.

Cellulosic Ethanol in California

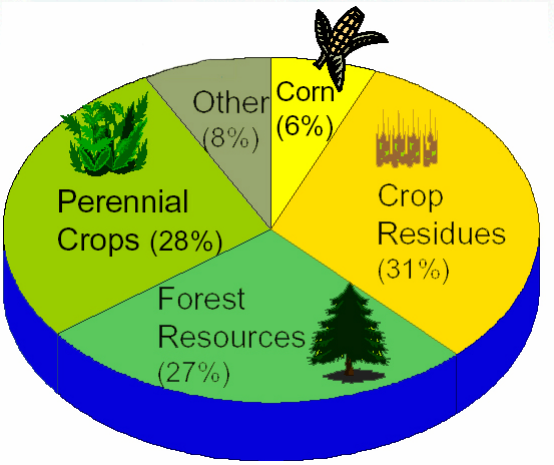
- CA uses ~1 billion gal/yr of ethanol - 25% of US production.
- Per CARB Ozone Levels dropped significantly after E6 was implemented statewide January 2004. Exceedance days for the states one-hour ozone standard dropped from 125 in 2003 to 97 in 2005, a 22% reduction in the SCAQMD one of the most polluted areas in the US.



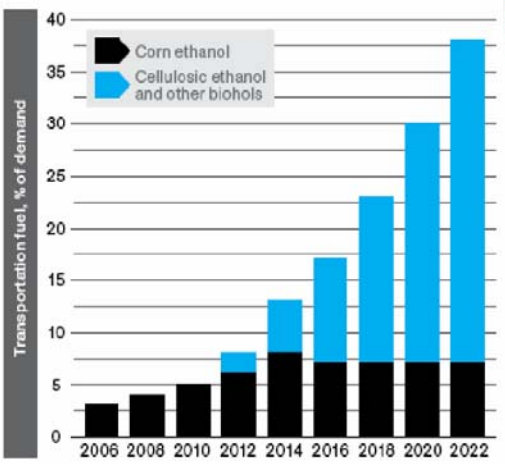
Cellulosic Ethanol in California

- Gov. Schwarzenegger's Executive Order S-06-06
- Established targets to increase production and use of bioenergy, including ethanol and bio-diesel fuels made from renewable resources:
  - For biofuels, the state shall produce a minimum of
    - 20 percent of its biofuels within California by 2010,
    - 40 percent by 2020, and
    - 75 percent by 2050.

Current US Ethanol Production by source



US Ethanol Production Projection



E10 Ethanol

- Significant reductions from THC, CO, PM
  - – Current Predictive Model 3% less HC exhaust with attention to higher emitters: 5% less
  - – Non-road reductions in CO, THC (22%CO) No other fuel formulation can do this!
  - – Colorado, UK studies show up to 50% less fine organic particulates (PM0.5)

E85 Major NOx Reductions

- NOx reductions of 40% are typical, explained by lower combustion temperature of ethanol relative to gasoline.
- E85 extends overall transportation fuel volume

Advantages of Ethanol

- Octane enhancer
- Partially renewable, some homegrown
- Reduction in CO, debatable reductions in GHGs
- No vehicle modifications needed for E10 and Standards well established for low level blends
- Compared to gasoline, use of E85 can result in a significant reduction in ozone-forming vehicle emissions in urban areas.

Disadvantages of Ethanol

- Lower volumetric energy content than gasoline.
- Decreased fuel economy: E10 by 2-5%, E85 by 20-30 %
- Emissions increases with low level blends: acetaldehyde, evaporative emissions, NOx
- Weather or other factors can limit feedstocks and reduce ethanol production
- Not conducive to pipeline transport: needs other forms of transport.

Conclusion

- Energy problems are profound and require dramatic changes in our way of life within the next decade or two.
- It is unrealistic to hope that ethanol will replace petroleum or allow us to continue using energy as we have for the past 75 years.
- The first and most urgent priority of any sensible national energy strategy will be efficiency and conservation, reducing our energy usage to more sustainable levels.

Conclusion
(cont.)

- Cellulosic ethanol is our most promising biofuel option right now from the standpoint of reducing our reliance on oil and making the transition to a more sustainable transportation system.
- Ethanol has many clear tailpipe emission benefits and is generally far more environmentally benign than the gasoline.
- The more important questions about ethanol concern its possible impacts on air, water, and soils. As the cost of Cellulosic ethanol continues to drop, the ethanol industry will start to look far different from what it is today.