Ethanol – The Primary Renewable Liquid Fuel

Perspective paper by Rathin Datta, Mark Maher, Coleman Jones, and Richard Brinker

J. Chemical Technology and Biotechnology, 2011,
86: 473-480, Society of Chemical Industry

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The Major Findings

The paper establishes that the conversion of biomass-to-ethanol is the most efficient and productive use of biomass to create a high octane, environmentally friendly transportation fuel.

1) The conversion of biomass-to-ethanol enjoys **NATURAL EFFICIENCES** which lead to the highest yields

2) Ethanol has a long history of **SUPERIOR PERFORMANCE**

3) Ethanol is **READY FOR TODAY'S CARS**

4) There is **ABUNDANT BIOMASS** to displace foreign oil

Natural Efficiencies: Utilizes Oxygen

- Biomass feedstocks that are abundantly available in the U.S. and worldwide, contain a high quantity of oxygen. To utilize this biomass most efficiently, conversion must include the entire feedstock, including the oxygen.

- Cellulosic ethanol is the alternative t ransportation fuel which retains most of the oxygen portion of the feedstock.

Biomass feedstock	Oxygen mass (%)
Hybrid Poplar	41.5
Black Locust	41.6
Eucalyptus	42.5
Monterey Pine	42.1
Corn Stover	40.6
Sugarcane Bagasse	41.4
Switchgrass	40.0

- Ethanol's compatibility with the oxygen in biomass and lower carbon requirements lead ethanol to have a higher yield and more BTUs of output per ton of incoming biomass than "drop in" alternatives such as butanol or hydrocarbons

Natural Efficiencies: Half the Carbon

- The biofuel option is most naturally compatible with biomass and has the highest yield from the least amount of feedstock, leading to greater efficiency, lower costs, and less greenhouse gas emissions.
- Requiring at least half as much carbon as other biofuels, biomass-to-ethanol gets the highest yields

Product	Conversion equation	Theoretical Yield	Typical Yields Achieved
Ethanol	3"CH_2O" → $C_2H_5OH + CO_2$	51%	46 to 50% (90 to 98% of theoretical achieved in industrial carbohydrate fermentations)
n-Butanol or iso-Butanol	6"CH_2O" → $C_4H_9OH + 2CO_2 + H_2O$	41%	23 to 25% (55 to 60% of theoretical yields achieved in industrial scale ABE fermentations)
Octane C8-Hydrocarbon	13"CH_2O" → $C_8H_{20} + 5CO_2 + 3H_2O$	29.7%	Not practiced industrially – wide mix of hydrocarbons and oxygenates produced

Long History Of Superior Performance

Ethanol is well-suited to help displace oil due to its long history of superior performance, and a rapidly expanding infrastructure for its deployment

- Ethanol has a long history of use, since Henry Ford's original Model T in 1908
- Blended with gasoline (from 3% to 85%) in many countries for decades
- Ethanol is suitable for spark ignition "Otto" cycle engines
    - 80% of vehicles run on this type of engine
    - About 650 million worldwide
- Automobile manufacturers have successfully adapted their technology to handle ethanol gasoline blends

Long History Of Superior Performance

Ethanol's performance characteristics versus gasoline offset a lower BTU value, allowing E85 cars to achieve 75-80% of standard vehicles' mileage

- With a high performance – 108 Octane – ethanol is used in Indy Car and Nascar
  - In the future, turbo charged and higher compression ratio engines will be able to take full advantage of the higher octane ethanol fuel
- Compared to gasoline, ethanol's lower boiling point and higher heat of vaporization are beneficial in existing and high performance engines
- Ethanol is clean burning, adding oxygen into the fuel
- Flex Fuel Vehicles running on cellulosic ethanol will have lower lifecycle emissions than butanol or gasoline

Ready for Today's Cars

Biomass derived ethanol is ready for widespread commercialization and distribution today, while the commercial timeline for other fuel technologies is still unknown

- 9 million Flex Fuel Vehicles are on the road today, able to use up to 85% ethanol
- In 2012, half of the cars U.S. automakers sell will be flex fuel capable
    - Currently ALL new vehicles sold are approved for E15, or 15% ethanol

Advanced ethanol is ready today while other technologies, including electric vehicles, are still developing

- National Research Council report found electric vehicles will have little impact on oil consumption before 2030
- Renewable fuels can be the primary source of clean energy for transportation for decades while this transition takes place

Abundant Supply of Biomass

Sufficient supply of non-grain biomass to displace oil swiftly and sustainably

- A joint 2005 DOE/USDA study and Sandia National Labs study in 2009 both found that there is over 1 billion tons of sustainable biomass in this country, which could create approximately 90 billion gallons of ethanol and replace one third of petroleum by 2030
- Sources include forest biomass, crop residues, sorted waste and new energy crops
- Purpose grown energy crops will prevent water runoff, add nutrients into the soil, and are able to grow on marginal lands

History shows that an efficient and sustainable biomass supply can be developed and maintained to support increased usage

- In the Southeastern U.S., pulpwood production quadrupled from 1953 to 2006, while the total area of forest land remained stable since the 1970s, at about 214 million acres
- Land ownership has also remained stable – 89% privately owned

Major Conclusions

1) **Biomass-to-ethanol has natural efficiencies.** On a molecular level, ethanol is the fuel that is most compatible with biomass:
   - Ethanol requires at least half as much carbon as other biofuels.
   - Cellulosic ethanol is the fuel that best utilizes the oxygen in the biomass.
   - A ton of biomass converted to ethanol will have higher yields than other alternative biofuels, resulting in the lowest cost to the consumer, and less greenhouse gas emissions to the environment.

2) **Ethanol has a history of superior performance.** A fabric of American transportation for over a century, ethanol has the proven longevity other fuels do not.

3) **Today's cars are ready for ethanol.** America's cars are rapidly being developed to run on higher ethanol blends. The transition to electric vehicles will take decades; ethanol is ready today.

4) **Sufficient biomass exists to make an impact.** America has sufficient biomass to supplant our dependence on foreign oil by 30%.

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