CELLULOSIC ETHANOL FACT SHEET

National Commission on Energy Policy Forum:
The Future of Biomass and Transportation Fuels

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I. RAW MATERIALS (FEEDSTOCKS)

Biomass. Plant matter of recent (non geologic) origin or materials derived therefrom.

Cellulosic biomass. Biomass composed primarily of plant fibers that are inedible by humans and have cellulose as a prominent component. These fibers may be hydrolyzed to yield a variety of sugars that can be fermented by microorganisms. Examples of cellulosic biomass include grass, wood, and cellulose-rich residues resulting from agriculture or the forest products industry. At a representative price of $40/dry ton, cellulosic biomass costs the same per BTU asoil at $13/barrel.

Cellulosic biomass may be available as either:

Residues - biomass resulting from activities or processes undertaken for some purpose other than ethanol production. Examples of such residues include corn stalks and other non-edible parts of plants used to produce food, municipal solid waste, and pulp and paper industry wastes.

Dedicated crops – crops grown for the primary purpose of energy production. Examples of potential dedicated crops for producing cellulosic biomass include grass and short rotation trees.

Comparison of ethanol production from corn and cellulosic biomass. Corn* is easier, and currently less expensive, to process into ethanol than is cellulosic biomass. However, cellulosic biomass is less expensive to produce than corn by a factor of roughly 2 on a per ton basis, and the amount of ethanol that can be produced per acre of land of a given quality is

* The discussion of "corn" here concerns corn kernels, which are currently used for ethanol production and represent about half the above-ground dry matter of a corn plant at harvest time.

higher for cellulosic biomass than for to corn. Relative to corn, production of a perennial cellulosic biomass crop such as switchgrass requires lower inputs of energy, fertilizer, pesticide, and herbicide, and is accompanied by less erosion and improved soil fertility. Finally, cellulosic biomass differs from corn kernels in that it contains substantial amounts of non-fermentable, energy-rich components that can be used to provide energy for the conversion process as well as to produce electricity (see discussion of energy balance below). Process energy for corn ethanol production is typically provided by coal or natural gas, although it would be possible for process energy to be provided by biomass in the future.

The chemical composition of ethanol produced from corn and lignocellulose is identical. However, ethanol production and utilization cycles are different when cellulosic biomass is used as the raw material as a direct result of the features mentioned in the preceding paragraph. Key aggregate characteristics impacted by these features in addition to feedstock cost include process energy balance and greenhouse gas emissions. For ethanol production from corn based on current practice, fossil energy inputs into the production cycle represent about 2/3 of the energy content of the ethanol produced, and greenhouse gas emissions on a per mile basis are about 2/3 of a gasoline base case, representing an approximately 33% reduction. For ethanol produced from cellulosic biomass, the energy balance and greenhouse gas emissions are more favorable, as considered below (Section III).

II. PRODUCTS & PROCESSES

Ethanol and fuel utility. Ethanol is a two-carbon alcohol (C_2H_6O), which is a high performance fuel for use in spark-ignited internal combustions engines. The warrantees of all new cars sold in the United States cover use of 10% ethanol/90% gasoline blends. In addition, the capability to utilize ethanol and gasoline in any ratio up to 85% ethanol is established in over 2 million "fuel-flexible vehicles" on the road today at no incremental cost to consumers. Since a gallon of ethanol contains about 2/3 the energy of a gallon of gasoline, a larger fuel tank is required to achieve a given travel radius when using ethanol-rich fuels. Ethanol can be reformed to hydrogen, either at the point of fuel delivery or on-board the vehicle, which can subsequently be used in a fuel cell. Both reformers and fuel cells are not now commercially available.

Current commercial status and cost of production. About 2.1 billion gallons of ethanol are produced annually from corn in the United States today. This may be compared to current yearly gasoline consumption of 131 billion gallons, which is equivalent to 164 to 196 billion gallons of ethanol (depending on how it used). Consumption of liquid fuels for heavy duty vehicles is about a third of gasoline consumption with air travel accounting for a smaller additional fraction. Fuel ethanol sells in the United States for about $1.20/gallon ($1.50 to $1.80 on a gasoline-equivalent basis), which may be compared to wholesale gasoline prices of about $0.75/gallon.

About half of current ethanol production capacity is associated with wet mills, which are integrated facilities producing a range of products in addition to ethanol such as sweeteners, corn gluten meal, gluten feed, starch, and, increasingly, additional biologically-produced products such as feed supplements. The remainder of production capacity, and most of recently-added capacity, is in dry mills. Dry mills are typically smaller than wet mills, and produce ethanol and a single animal feed coproduct (distiller's dried grains).

There are no commercial plants producing ethanol from cellulosic biomass in the world, although celllulosic ethanol has been produced during war time by processes featuring acid hydrolysis. Several commercial ventures have been proposed involving selling ethanol produced from cellulosic biomass into existing chemical or fuels markets, suggesting that cost-competitive production of ethanol from cellulosic biomass in these markets, although not bulk fuel markets, is within reach today. Funding for such ventures has however not been secured to date.

Conversion technology. Steps involved in producing ethanol from cellulosic biomass involve an activation step, biological conversion, product recovery (typically via distillation), and residue processing and utilities. Activation involves converting recalcitrant cellulosic biomass into reactive intermediates, and may be accomplished via either pretreatment & enzymatic hydrolysis, acid hydrolysis, or gasification. Of these alternatives, the lowest future costs have been projected pretreatment and enzymatic hydrolysis. Process design studies consistently indicate that steps associated with overcoming the recalcitrance of cellulosic biomass are the most costly, involve the greatest technical risk, and have the largest potential for R&D-driven cost reduction. A considerable literature exists in which specific R&D advances are analyzed with respect to potential for cost reductions and probability of success.

III. EVALUATION & IMPLICATIONS

Energy balance considerations. The ratio of energy output to fossil energy input is favorable (> 4) for production of cellulosic ethanol, and can be expected to improve further as the technology matures. Fossil energy inputs for production and delivery of cellulosic energy crops are modest, e.g. estimated at about 5% of the energy content of the feedstock for switchgrass production, and inputs for waste cellulosic feedstocks are potentially lower still. The energy content of unfermentable process residues is greater than the energy than required for conversion to ethanol in the current designs, with the excess representing an attractive source of electrical power. The combined energy yield of ethanol and power is over 50% of the energy content of cellulosic biomass for current designs.

Greenhouse gas emissions. The photosynthetic production of biomass removes from the atmosphere the same amount of CO_2 that is returned upon conversion and utilization. The extent to which the ideal of a sustainable carbon cycle (zero net greenhouse gas emissions) is approached depends on the fossil energy inputs required used in the feedstock production/conversion/utilization cycle. Since such inputs are very low in the case of cellulosic ethanol (above), net greenhouse gas emissions are also very low. Several detailed life cycle studies have concluded that greenhouse gas emissions accompanying use of cellulosic ethanol are less than 10% accompanying use of gasoline, and zero or negative net greenhouse gas emissions have been estimated for some scenarios.

Additional environmental implications. Agricultural production of cellulosic biomass is widely thought to entail decreased environmental impacts and some significant environmental benefits as compared to production of row crops. Rates of erosion are exceedingly low for perennial grasses, and field data and models indicate that soil organic matter and fertility increase over time under grass cultivation even with regular harvest. Nutrient capture rates are very high due to the extensive root system of perennial grasses, with loss of nutrients to water sources corresponding low. Anticipated rates of pesticide and herbicide application are much lower for energy crops than for row crops. Elements removed from the soil as part of harvesting biomass must be replenished by additives to the soil, but there is potential to recycle such elements from the processing facility back to the field. Several studies associate conversion of cropland from row crops to perennial grasses with improved water quality, fertility, and wildlife habitat. Effluents from biomass processing facilities are amenable to conventional treatment technologies and are not expected to present a significant burden on the environment if managed responsibly.

Land availability. There are 1.9 billion acres of land in the contiguous United States, of which about 450 million acres is categorized as cropland and an additional 580 million acres is categorized as range or pasture. These categories exclude forestland used for commercial forestry or parks/nature preserves. Most agricultural, pasture, and range land is in use today for food production today, with about 90% of agricultural output going to feed animals and 10% going to feed humans directly. About 30 million acres of cropland has been placed into the Conservation Reserve Program, primarily motivated by a desire to prevent erosion due to row crop production on sensitive sites. Most of the land in the CRP is planted in perennial grasses. Widely-divergent estimates have been made as to the potential availability of biomass on a scale sufficient to provide for large-scale energy needs.

IV. GOVERNMENTAL SUPPORT & INCENTIVES

Current support for research and development. Federal funding for bioenergy (fuels and power) has been estimated at $150 million annually. Of this, about $48 million is spent on biomass-based fuels, including but not restricted to ethanol, with the largest expenditures by the DOE followed by the USDA. The annual renewable energy appropriation is among the most heavily earmarked of all appropriation bills, with net DOE funding after earmarks for biomass-derived fuels and power having decreased annually since 2000. In the area of bioenergy and biobased industrial products, which includes a variety of raw materials not limited to cellulosic feedstocks and a variety of products not limited to fuels, the combined DOE and USDA funding request for FY04 is 36% smaller than the FY03 appropriation.

Tax incentives and other legislation. The effective price of ethanol for use in low-level gasoline blends is lowered by 54 cents per gallon by federal tax incentives, with additional state incentives available in some locations. The Senate recently voted to incorporate a Renewable Fuels Standard (RFS) into the Senate Energy Bill (S.14). Among other provisions, the RFS would require renewable fuel production at the level of 5 billion gallons by 2012. Amendments to S.14 that would provide extra credit for production of ethanol produced from cellulosic materials have been proposed.