Agricultural Biofuels: Technology, Sustainability and Profitability

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NABC's nineteenth annual meeting—hosted by South Dakota State University—convened in Brookings, SD, May 22–24, 2007. Delegates were welcomed by Kevin Kephart (vice president for research and dean of the Graduate School, SDSU), Gary Lemme (dean of the College of Agriculture and Biological Sciences, SDSU), Tony Shelton (NABC chair, 2006–2007) and Ralph Hardy (NABC president). The conference attracted 110 delegates from twenty-two US states and two Canadian provinces, and from Egypt, Niger and Taiwan. Plenary sessions were held on the afternoon of May 22 and the mornings of May 23 and 24. Excursions—laid on for the afternoon of May 23 to a biodigestor at Milbank, to the VeraSun ethanol plant at Aurora, and to the USDA National Resources Conservation Service Laboratory at Brookings—were informative and much enjoyed, and provided practical backdrops to the discussions. As well as an excellent banquet on May 22, attendees were treated to prime South Dakota beef at a barbecue at the State Agricultural Heritage Museum, Brookings, on the evening of May 23.

Ex-Senate majority leader Tom Daschle was the banquet speaker (*Breaking America's Addiction to Oil through Agriculture*) and luncheon addresses were delivered by South Dakota Governor Mike Rounds (S*outh Dakota's Leadership in Production and Adoption of Agricultural Biofuels*) and Jim Fischer (US Department of Agriculture, *Building a Prosperous Future in which Agriculture Uses and Produces Energy Efficiently and Effectively*).

Session #1—*Sustainability: Impacts and Issues*—comprised presentations by Bill Richards (25×'25 National Steering Committee, *Food, Feed, Fiber and Fuel: A New World for American Agriculture and Environmental Sustainability*; Brendan Jordan (Great Plains Institute, Minneapolis, MN, *Ushering in a Sustainable Bio-Economy*); Suzanne Hunt

(Worldwatch Institute, Washington, DC, *Biofuels For Transportation Sustainability*); and Steve Bantz (Union of Concerned Scientists, Washington, DC, *Biofuels: An Important Part of a Low-Carb Diet*).

In session #2—*Technology: Biomass, Fuels and Co-Products*—presentations were made by Dick Flavell (Ceres, Inc., Thousand Oaks, CA, *Turning Biomass Crops For Biofuels Into Commercial Reality*); Larry Smart (SUNY College of Environmental Science & Forestry, Syracuse, NY, *Breeding, Selection and Testing of Shrub Willow as a Dedicated Energy Crop*); Bill Gibbons, (South Dakota State University, Brookings, SD, *Challenges on the Road to Biofuels*); Kurt Rosentrater (USDA/ARS North Central Agricultural Research Laboratory, Brookings, SD, *Ethanol Processing Co-Products: Economics, Impacts, Sustainability*); Mark Bricka (Mississippi State University, Mississippi State, MS, *Energy-Crop Gasification*); and David Ramey[1] (ButylFuel, LLC, Blacklick, OH, *Butanol: The Other Alternative Fuel*).

The speakers in session #3—*Economics and Sustainability*—were Wally Tyner (Purdue University, West Lafayette, IN, *Biofuels, Energy-Security and Global-Warming Policy Interactions*); Roger Wyse (Burrill & Company, San Francisco, CA, *Capital and Sustainability*); Mark "Bump" Kraeger (PRIME BioSolutions, Omaha, NE, *Food vs. Fuel? An Integrated Approach to Producing Both*); Danny Le Roy (University of Lethbridge, Lethbridge, AB, *Development and Sustainability of the Biofuel Industry in Canada*); and Maria Wellisch (Natural Resources Canada, Ottawa, ON, *Biofuels and Biorefinery Development in Canada: The Question of Sustainability*).

The conference theme—agricultural biofuels—was comprehensively covered, with high-quality presentations that stimulated lively Q&A sessions[2] with audience participation and active discussions within three breakout workshops[3].

A selection of key points made by speakers and which emerged from the Q&A sessions is provided below to enable the reader to obtain an overview of the biofuels topic. The presentations in the following chapters provide expanded discussion.

United States/Global Issues

- The world consumes about two barrels of oil for every barrel discovered. (p. 28)
- Worldwide, 98% of transportation relies on petroleum-based fuels; the transportation sector is responsible for about 25% of the world's greenhouse gasses. (p. 56)
- Increasing demands from China and other countries have stretched oil-production capacity and played a significant role in higher prices. (p. 28)
- Promoters of biofuels, coal and oil should not become mutual enemies. All three will be needed plus natural gas, solar and other new technologies. (p. 25)
- Breaking the US addiction to oil will require the whole country—farmers, scientists, businesses, and government—working together. (p. 18)

[1]Mr. Ramey drove from Ohio to Brookings in his unmodified 1992 Buick Park Avenue, powered by butanol to demonstrate its utility as a biofuel.

[2]Q&A transcriptions are on pages 69–75, 149–152, and 195–200.

[3]A summary of the breakout workshop discussions is on pages 203–210.

- A recent estimate of the hidden cost of oil dependence amounts to about $3 per gallon of liquid fuel excluding multiplier effects. This estimate includes incremental military costs, supply-disruption costs and direct economic costs. (p. 155)
- The United States uses 21 million barrels of oil a day, *i.e.* 5% of the world's population uses 25% of its oil. (p. 15)
- The United States is borrowing money from its economic competitors to pay for foreign oil, thus subsidizing people whom we are asking our soldiers to fight. (p. 16)
- The United States is the largest producer of CO_2, with transportation accounting for ~33%, *i.e.* what comes out of the tailpipe. (p. 59)

Alternative Fuels

- The objective of the 25×'25 Committee is to steer the United States towards producing 25% of its energy from the land by 2025—through biofuels, wind, hydropower and solar technology. (p. 44)
- About 500 organizations have signed on to the 25×'25 vision, including the major farm organizations, auto companies, farm-equipment manufacturers, and conservation and environmental groups. Governors have signed on, as have many state legislatures. (p. 44)
- Domestically produced biofuels have the potential to provide long-lasting solutions to national security, economic competitiveness and oil-price and supply problems. (p. 24)
- Domestically produced biofuels create jobs, keep dollars in the country and lessen adverse environmental impacts. (p. 24)
- Significant supplies of renewable energy will not become available overnight, nor will they totally replace petroleum in the foreseeable future. (p. 24)
- The United States will continue to need coal and new coal technologies for cost-effective, stable energy production. (p. 25)
- The entire biofuel life cycle—all of the issues that are involved with feedstock production, including planting, processing, transportation and storage—should be quantified and compared with the fossil-fuel life cycle. (p. 55)
- The production of biofuels from cellulosic biomass requires a new industry to be born—many factors have to be put in place ranging from the technical to the political. (p. 79)
- Most estimates indicate a maximum production of 15–18 billion gallons of ethanol from corn starch with 42 billion gallons from cellulosic sources by 2030. (p. 62)
- A comprehensive approach is needed for rapid development of alternative fuels, involving plant breeders, agronomists, bioprocess engineers, biotechnologists and microbiologists. (p. 215)

- Adoption of new alternative fuels will require the development of adequate infrastructure including vehicle systems, vehicle-refueling facilities, distribution and storage facilities, refineries and conversion facilities. (p. 24)
- Butanol can be used as an automobile fuel without engine-retrofitting and with mileage better than from gasoline. (p. 142)

Environmental Considerations

- Over the long term, the United States must displace petroleum—old biomass—with new biomass, with practices that preserve wildlife habitats, soil quality, water quality, maintain or increase farm income, encourage rural development and reduce greenhouse-gas emissions. (p. 51)
- Renewable energy from our land is the most socially acceptable, environmentally friendly and economically feasible of all the choices. (p. 44)
- A combination of harvested and unharvested grasslands—as cellulosic feedstock—offers the best opportunity for maximizing wildlife habitat. (p. 53)
- Low-carbon-fuel policies need to focus on minimizing greenhouse-gas emissions. (p. 63)
- The two largest developing economies, China and India, will be the future world leaders in emissions. (p. 29)
- An international consensus is building that a certification system is needed to enable consumers to buy sustainably produced biofuels. Sustainability standards are being developed in the Netherlands in association with the United Kingdom. (p. 57)
- Public awareness/education is needed on biofuels. (p. 73)
- Water quantity is also a source of concern in terms of needs to grow more corn, starch processing and ethanol purification. (p. 56)
- Production of one liter of ethanol requires between four and eight liters of water, depending on the process. (p. 183)
- The economic incentive to import biofuels—especially biodiesel—from tropical countries, threatens the rain forests that provide enormous climate-moderating and habitat resources for all citizens in the world. (p. 183)
- It is anticipated that growers will use more fertilizers and chemicals to increase yields in response to the much higher prices for cereals and oilseeds. (p. 183)
- Much more work is needed to produce reliable data on emissions from biofuels and biofuel blends. (p. 56)
- A cyclic process has been developed whereby corn kernels are converted to ethanol and distillers grains; the distillers grains are fed to cattle in an adjacent feedlot; manure from the cattle goes to an adjacent anaerobic digester along with thin stillage from the ethanol plant, generating biogas; biogas from the digester is

burned in the boilers to create heat to cook the corn entering the ethanol plant; cellulosic solids from the digester are converted to generate more ethanol. (p. 174)

Food vs. Fuel

- The food vs. fuel issue is emotional and complex. Interactions between food and fuel markets will be increasingly problematic. People are concerned and their concerns need to be addressed. (p. 57)
- An inevitable and undesirable result of rapidly expanding ethanol production is that livestock producers incur much higher costs of their major input: feed grain. Beef, hogs and poultry have been hardest hit. (p. 181)
- Assuming that economic production of ethanol from cellulosic biomass is achievable, bioenergy production will bring the greatest land-use changes since widespread adoption of agricultural technology began in the 1930s. (p. 45)

Co-/By-Products

- As the ethanol market segment continues to grow, so do the quantities of processing residues, or co-products, that are generated. (p. 107)
- The sale of distillers grains contributes substantially to the economic viability of ethanol manufacturing. (p. 109)
- Opportunities to increase economic returns from ethanol production from corn starch include processing distillers dry grains into high-value animal feeds, human foods and industrial composites. (p. 110)
- For utilization as feed, distillers dry grains are being transported greater distances via truck and rail, and stored in bins, silos, *etc.*, until final use. (p. 110)
- Distillers grains may have potential as a fish-feed substitute for fish meal. (p. 112)
- Because distillers grains are high in fiber and low in starch, they have potential as a food ingredient for diabetics. (p. 113)
- Preliminary studies indicate that distillers grains can be utilized to produce biodegradable films, foams and composites. (p. 116)

Biomass/Feedstocks

- Perennial crops will be a major component of overall cellulosic biomass resources, but there has been little breeding to improve their bioenergy traits. (p. 85)
- A potential of more than one billion dry tons per year of cellulosic feedstock, available on a sustainable basis, has been established. (p. 32)
- The utility of various biomass feedstocks should be investigated while awaiting economically viable cellulosic ethanol. (p. 52)
- One of the major bottlenecks to widespread commercial deployment of new perennial energy crops is the scale-up of high-quality planting stock. (p. 90)

- Although the economics of production of ethanol from switchgrass and miscanthus critically depend on biomass yield and efficiency of conversion of cell-wall materials to biofuels, these factors have received little attention from breeders and are not optimized for large-scale agriculture. (p. 80)
- New varieties of energy crops/trees/shrubs have to be developed with higher productivity, greater bulk density and less lignin content with low inputs of water and fertilizers. (p. 215)
- One estimate suggests that switchgrass with a farmgate price of $40/ton would produce ethanol equivalent to gasoline from oil at $15/barrel, and at $50/ton the oil equivalent would be only $18/barrel. (p. 51)
- Growing perennial crops for biomass provides opportunities for increased carbon sequestration. (p. 54)
- We need to partner with energy producers so that we are not just growing, collecting and storing. Feedstocks need to have markets that will probably need supports at first. (p. 52)
- Biomass yield, tons per unit of land, is the number-one trait to be increased. (p. 81)
- In the case of shrub willow, life-cycle assessment indicates that net energy ratios for the production of power by combustion or gasification are in the range of 1:10–15. (p. 86)
- Shrub willows can be planted on otherwise marginal agricultural soils that do not support high yields of corn or soybean. (p. 86)
- All the fats and oils in the United States would displace only about 10% of the diesel usage. (p. 62)

Process

- Biochemical conversion involves pre-treatment processes and enzymatic hydrolysis to break down biomass into sugars that are subsequently fermented to ethanol by microbes (usually yeast). Alternatively, thermochemical conversion processes use gasification or liquefaction to degrade biomass into a mixture of one- and two-carbon molecules (syngas) which is catalytically converted into more complex products, including ethanol, gasoline or diesel. (p. 97)
- Although gasification is a well developed "sledgehammer" adaptable to many types of feedstock, problems remain to be solved. (p. 135)
- A resource directory of all of the research projects on various feedstocks and conversion technologies, both regionally and nationwide, and a comprehensive list of demonstration projects in each state would be beneficial. (p. 54)
- A number of plans and goals have been initiated by the federal government and other groups in recent years. One of the most prominent is the Advanced Energy

Initiative (AEI). Key components of the AEI include "chang[ing] how we power our automobiles" and "chang[ing] how we power our homes and offices," emphasizing advanced battery technologies to improve hybrid vehicles and reducing the cost of producing ethanol from cellulose. (p. 34)

- We lose about three-fifths of available energy resources in the process of conversion to useable forms, whether for mechanical work as in an automobile engine, or in burning fuel to make electricity. (p. 30)

US Policy/Economic Issues

- Ethanol has been produced for fuel in the United States for almost 30 years. Between 1978 and today, the ethanol subsidy has ranged between $0.40 and $0.60/gallon. The federal subsidy today is $0.51/gallon, paid to the blender. (p. 156)
- Long-term extensions are needed of the federal tax credits that did so much to start the current alternative energy revolution. (p. 23
- Studies at the University of Tennessee and at the Rand Corporation, indicate that 25 by '25 is possible, if:
  - society and Congress have the commitment to fund the R&D,
  - the cellulose conversion to ethanol is economically viable,
  - the US Forest Service is involved,
  - a hundred million acres more land are brought into energy-crop production. (p. 45)
- The toughest consideration relates to political and social dynamics; no textbook exists on whether an approach will be accepted by society. (p. 49)
- When the US blending requirements for ethanol are met, the price of ethanol is likely to decrease. (p. 72)
- The oil industry is going to fight biofuels on one side, and quietly invest in it. (p. 74)
- Harvesting and transport constitute ~50% of the cost of the feedstock at the biorefinery gate. (p. 80)
- The United States must either put an additional, substantially higher, tax on petroleum fuels, subsidize alternatives to petroleum, or create fuel standards. (p. 156)
- With crude oil at $60 per barrel, the break-even corn price is $4.72 per bushel including both the additive premium and the fixed federal subsidy. (p. 157)
- For either a fixed or variable subsidy, the cost of the incentive is paid through the government budget. For a standard, consumers do not pay through taxes but pay directly at the pump. (p. 162)
- If we want to achieve both energy security and global-warming objectives through

a standard, then it would be appropriate to partition the standard with a higher fraction being cellulose-based fuels. (p. 163)

- One of the unknowns in this area is the regulatory/policy environment and if that uncertainty persists, money that has been flowing into this industry will begin to flow elsewhere. (p. 167)
- in a couple of years, revenues from industrial biotechnology will exceed those from traditional biotech, which have been related chiefly to drug development and healthcare. (p. 170)
- A global response to climate change will spur a business revolution larger than did the internet. (p. 171)

Canada

- Canada is a net exporter of all kinds of energy: oil, coal, natural gas, uranium, hydro-electricity and others. Its policy objectives from expanding the biofuel industry in Canada are: to reduce greenhouse gas emissions; to increase and stabilize farm incomes by increasing the demand for farm commodities; and to promote rural development and diversification by encouraging biofuel plants in rural communities. (p. 178)
- Renewable energy policies in the United States will likely have greater economic impacts on Canadian agriculture than will domestic biofuel policies. (p. 183)
- Ethanol development in Canada has been much slower than in the United States for reasons of grain supply and government policy. (p. 178)

South Dakota

- South Dakota is the first state to produce more ethanol than gasoline consumed. (p. 22)
- South Dakota has led the country in reaping economic benefits from growing fuel. Ethanol plants have produced returns of 33% for their investors and have drawn $400 million in new capital investment into the state. (p. 17)
- South Dakota is first in the percentage of corn used for ethanol and fourth in total production in the United States: >550 million gallons in 2006. In 2007, projected production was 843 million gallons. (p. 21)
- South Dakota alone has enough agricultural land to produce more energy than all but one member of OPEC. (p. 17)

Breakout Sessions

At the breakout workshops, which were convened at the conclusion of each plenary session, delegates in small groups had further opportunity to discuss issues raised in the presentations and Q&A sessions and to voice other related matters. Three 1-hour workshops were held with specific questions addressed as follows:

- Workshop I—*Sustainability: Impacts and Issues* (pp. 203–205)
  - Question 1: What are the chief food/feed/fuel competition concerns? What actions are recommended to minimize these concerns?
  - What incentives and technologies are needed to induce farmers to grow cellulosic crops?
  - What measures and policies should be adopted to address environmental concerns over cellulosic biofuel crops?
  - What is the likelihood—and potential impact—of deploying genetically modified (GM) perennial energy crops?
- II—*Technology: Biomass, Fuels, and Co-Products* (pp. 206–207)
  - What technologies and agronomic practices need to be applied or developed to improve the quality and quantity of biomass crops?
  - What are the priorities for processing technology improvements and how can we encourage development of these technologies? (Or, are market forces sufficient drivers?)
  - How do we evaluate the overall sustainability of various renewable energy systems—biofuels, biopower, or hybrids of the two?
  - What issues underpin present and future production and use of co-products (such as DDGS, cellulosic ethanol byproducts, glycerol from biodiesel)? For example, conversion of corn fiber to ethanol will alter the composition and supply of DDGS.
- III—*Economics and Sustainability* (pp. 208–210)
  - What policies will maximize investment in processing plants, distribution infrastructure and consumer adoption of biofuels?
  - What policies to stimulate renewable fuels production seem reasonable?
  - What is the role of the public sector (USDA and universities) in assisting agriculture in its response to the energy situation?
  - How critical is it that processing facilities generate their power from renewable sources (lignin, wind-power, co-generation, *etc.*) instead of petroleum? Also, how important is net water usage in processing technology?

Many diverse viewpoints emerged from the workshops[4]; the discussions did not produce consensus on the issues. This was not unexpected since biofuels are in a dynamic, but still early stage of development. The questions raised have long-term significance whereas the state of the science is analogous to that on genetically engineered crops in the late 1980s and early 1990s.

[4]The workshops summary is on pp. 203–210.