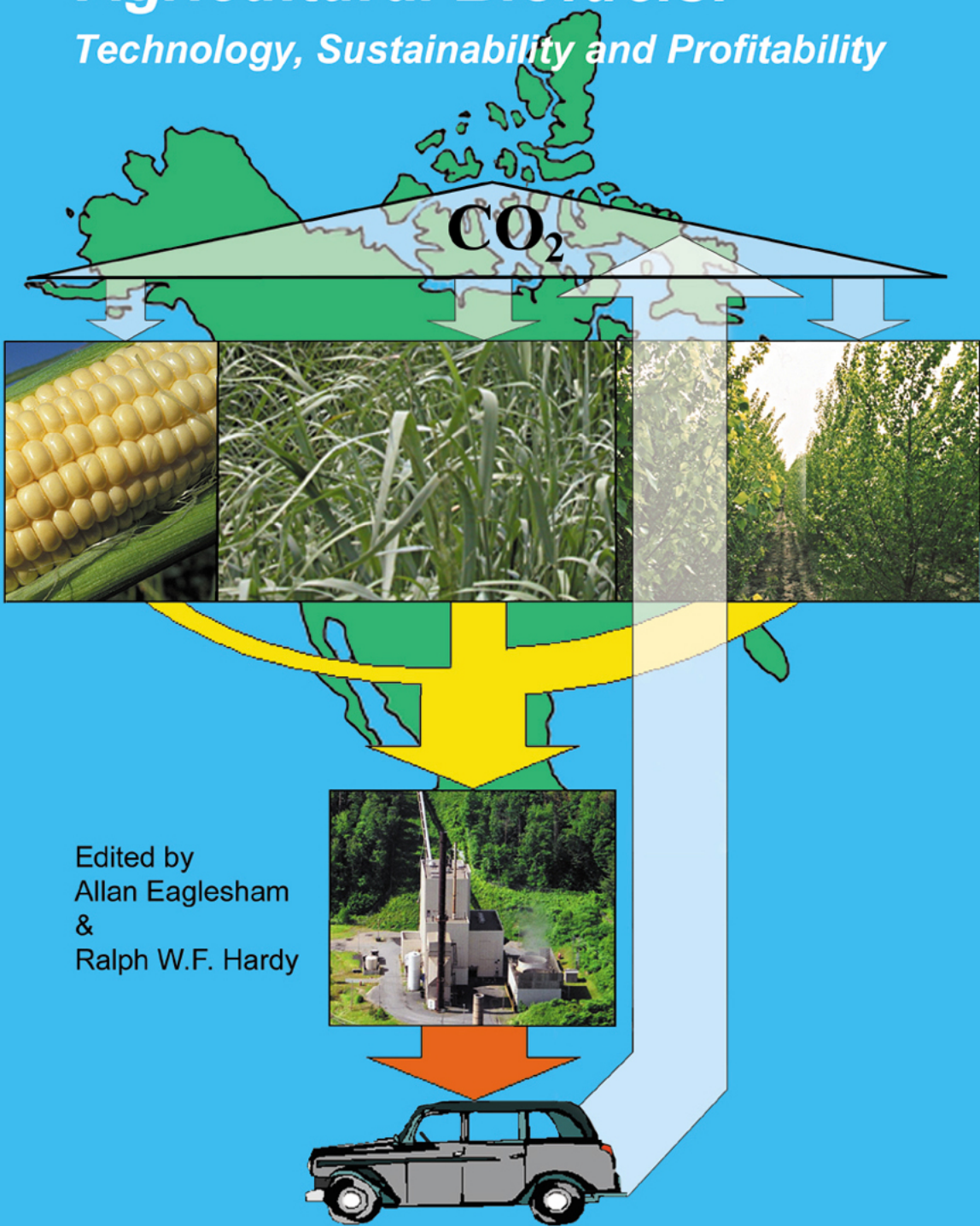


NABC Report 19

Agricultural Biofuels:

Technology, Sustainability and Profitability





NATIONAL AGRICULTURAL BIOTECHNOLOGY COUNCIL REPORT

THE COVER illustrates US and Canadian biosources—corn, perennial grasses and woody crops—for conversion to liquid transportation fuel in rurally located biorefineries. The relative sizes of the photographs of the crops, corn at 25% and biomass crops at 75%, depict their expected relative future importance when commercial technology is fully operational for biomass feedstocks. All of the biofuel sources recycle carbon, but, as indicated by arrow size, the perennial low-input biomass crops are more efficient than is high-input corn. The CO₂ “roof” represents the greenhouse-gas effect.

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The Biorefinery in New York, Lyonsdale Biomass LLC, Lyons Falls, NY. Photograph courtesy of Catalyst Renewables Corp.

NABC REPORT 19

*Agricultural Biofuels:
Technology, Sustainability and Profitability*

Proceedings of the nineteenth annual conference of the
National Agricultural Biotechnology Council, hosted
by South Dakota State University, Brookings, SD,
May 22–24, 2007

Edited by
Allan Eaglesham and Ralph W.F. Hardy

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NABC REPORT 19

Agricultural Biofuels: Technology, Sustainability and Profitability

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NATIONAL AGRICULTURAL BIOTECHNOLOGY COUNCIL

*Providing an open forum
for exploring issues in
agricultural biotechnology*

NABC, established in 1988, is a consortium of not-for-profit agricultural research, extension and educational institutions.

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NABC Report 18, *Agricultural Biotechnology: Economic Growth Through New Products, Partnerships and Workforce Development* (2006)

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NABC's nineteenth annual meeting—*Agricultural Biofuels: Technology, Sustainability and Profitability*—was hosted by John Kirby at South Dakota State University (SDSU), Brookings, SD, with administrative assistance from Kevin Kephart and Gary Lemme, to all of whom we are most grateful for a highly successful conference.

Thanks are due to the members of the organizing committee¹ for an excellent agenda and first-rate choice of speakers: Janean Caugherty, Ken Daschiell, Jim Doolittle, Bill Gibbons, Van Kelley, John Kirby Padu Krishnan, Kasiviswamanathan Muthukumarappan, Jennifer Pickard, Kurt Rosentrater, Sandy Rusten and Emery Tschetter.

Seamless operation of the proceedings resulted from the excellent efforts of the following:

Banquet and Luncheon Master of Ceremonies Gary Lemme.

Moderators Ken Daschiell, Van Kelly and John Kirby.

Workshop Facilitators Tom Cheesbrough, Jeremy Freking, Wade French, Darrell Grandbois, Doug Raynie, Craig Russow, Evert VanderSluis and C.Y. Wang.

Workshop Recorders Theron Cooper, Basil Dalaly, José Gonzalez, Jim Julson, Joan Kreitlow, Tyler Remund, Lisa Tenlep and Tom West.

Drivers Abby Bartosh, Vyku Ganesan, Derek Hereen, Brett Hofer, Chenchiah Marella, Josh McCarthick, Nick Michael, Louis Muench, Tim Nath, Sri Pasikanti and Seth Swanson.

Agricultural Heritage Museum/Auditorium and Audio-Visual Support/Photography/Program and Signage/Registration Janean Caugherty, Smita Chandraa, Liz Christianson, Wendy Craddock, Barb Hartinger, Bill Lee, Jay Meyers, Paul Mobley, Terry Molengraaf, Andrea Olson and Emery Tschetter.

Tours Jena Carsrud, Ken Dashiell, Wade French, Darrell Grandbois, Mike Hoiium, Kraig Kruger, Mike Lockrem, Jeff Loutsch, Ryan McMillan, Sharon Nichols, Chad Nielson, Deb Patterson, Joe Pikul, Max Pravecck, Annette Redepenning, Walter Riedel, Angela Rohweder, Kurt Rosentrater, Rylene Telkamp and Meredith Thompson.

Barbecue Amanda Knorr, Tanner Machado, Josh McCarthick, Louis Muench, Tim Nath and Jenny Thurlow.

Thanks go to ICM, the North Central Sun Grant, South Dakota Certified Beef, the South Dakota Corn Council, the South Dakota Pork Producers Council, POET and VeraSun for defraying costs of meals and refreshments, and to USDA-ARS for programmatic support. And we owe a debt of gratitude to Susanne Lipari for guidance and assistance behind the scenes.

On behalf of NABC, we thank Tony Shelton for exemplary leadership as NABC's chair for 2006–2007.

Ralph W.F. Hardy
President
NABC

Allan Eaglesham
Executive Director
NABC

December 2007

¹RWFH and AE also served on the organizing committee.

PREFACE

When the National Agricultural Biotechnology Council was established in 1988, its goals were the early identification of agricultural biotechnology issues and their discussion in an open forum; the safe efficacious and equitable development of the products and processes of agricultural biotechnology; and the development of public-policy recommendations. Today, with a membership (page v) that includes most of the leading not-for-profit agricultural research and educational institutions in Canada and the United States, NABC continues to strive to identify and consider in open forum the major issues, and provide all stakeholders—including representatives from academia, government, industry, public-interest groups and farming—the opportunity to speak, to listen, and to learn. Through its meetings, NABC has addressed topics of major current concern (see page v): sustainable agriculture in 1989; food safety and nutritional quality (1990); social issues (1991); animal biotechnology (1992); risk (1993); public good (1994); gene ownership (1995); novel products and partnerships (1996); challenged environments (1997); gene escape and pest resistance (1998); food security (1999); the future biobased economy (2000); genetically modified food (2001); integration of agriculture, medicine and food for human health (2002); societal acceptance of biotechnology (2003); international issues (2004); human and environmental health (2005); and economic growth (2006).

In 1998, the NABC council issued a *Vision Statement*¹ for agriculture and agricultural research in the twenty-first century. It envisions improved food, feed, and fiber, but most importantly sees agriculture expanding into energy, chemicals, and materials. This bio-based economy, balanced with a reduced fossil-based economy, is projected to contribute to national security, sustainability, minimization of global climate change, expanded farmer-market opportunities, and rural development. In 2000, the NABC's twelfth annual meeting, hosted by the University of Florida, Gainesville, in Orlando, FL, focused on these opportunities. It was the first discussion to explore benefits from, and concerns about, the biobased economy. From that meeting grew the annual *World Congress on Industrial Biotechnology and Bioprocessing: Linking Biotechnology, Chemistry and Agriculture to Create New Value Chains*, the fourth of which convened also in Orlando, March 21–24, 2007², co-organized and sponsored by the Biotechnology Industry Organization, the American Chemical Society and NABC. And in 2007, NABC issued *Agriculture and Forestry for Energy, Chemicals and Materials: The Road Forward*³, an updated and expanded version of the *Vision Statement* that describes opportunities for agriculture and forestry to be the basis for a hybrid bio-/petro-based economy with 100+ billion gallons of transportation fuel and value-added chemicals and materials produced from domestic biomass, and a structure for attainment.

Biofuels—currently a hot media topic—provided the focus for NABC's nineteenth annual meeting. Hosted by South Dakota State University, *Agricultural Biofuels: Tech-*

¹*Vision for Agricultural Research and Development in the 21st Century: Biobased Products Will Provide Security and Sustainability in Food, Health, Environment, and Economy.* <http://nabc.cals.cornell.edu/pubs/vision.cfm>.

²The 2007 *Summary Proceedings* is available at http://nabc.cals.cornell.edu/pubs/WCIBB2007_proc.pdf.

³http://nabc.cals.cornell.edu/pubs/The_Road_Forward.pdf; Hardy, R.W.F., Eaglesham, A., Shelton, A. (2007) Agriculture and forestry for energy, chemicals, and materials: The road forward. *Industrial Biotechnology* 3 133–137.

nology, Sustainability and Profitability convened in Brookings, SD, May 22–24, 2007. The NABC-19 plenary presentations—eighteen in all—addressed underpinning and ancillary issues of the production of transportation fuels from agricultural and forestry biomass nationally and internationally, including agronomic sustainability, impact on food production, technological constraints, co-products, and economic and policy issues. The modules were titled as follows.

- *Sustainability: Impacts and Issues*
- *Technology: Biomass, Fuels and Co-Products*
- *Economics and Sustainability*

Leaders from academia, industry, dairy farming, federal agencies, and public-activist groups shared their views with an even more diverse group of attendees. In all, 110 delegates participated. As is traditional for NABC meetings, participants convened also in smaller breakout groups to discuss issues raised in the foregoing plenary sessions and to make recommendations to policymakers.

Plenary and breakout sessions were held on the afternoon of May 22 and on the mornings of May 23 and 24, and the afternoon of May 23 was devoted to excursions by bus. Participants had the opportunity to visit a 2,000-head dairy-farm biodigester in Milbank, the VeraSun ethanol plant in Aurora, the USDA-ARS North Central Agricultural Research Laboratory in Brookings, or the Farm Service Agency's Natural Resources Conservation Service Farm in Brookings. There was strong consensus that the tours were enjoyable as well as instructive, demonstrating the 2007 reality of biofuels and related activities.

To increase graduate-student participation at NABC conferences, the *Student Voice at NABC* initiative was launched in Brookings. NABC offered \$500 grants to one graduate student delegate (GSD) from each member institution to assist with travel and lodging expenses, with the registration fee waived. The GSDs were expected to attend all NABC-19 sessions and workshops and meet as a group on the evening of May 23 to identify current and emerging issues in agricultural biotechnology, including biofuels.

This volume contains summaries of the plenary/banquet/luncheon presentations and of the workshop discussions, provides full transcripts of Q&A exchanges involving the speakers and audience members and the *Student Voice* report.

In 2008, NABC 20—*Reshaping American Agriculture to Meet Its Biofuel and Biomaterial Roles*—will be hosted by the Ohio State University in downtown Columbus, OH, June 3–5. This conference will further explore the “agricultural biofuels” theme of NABC 19 with examination of trends and policies; impact of using crops as renewable energy resources; and how to derive value from generated co-products. Keynote speakers will address four sessions followed by response panels presenting contrasting viewpoints:

- *Megatrends Reshaping American Agriculture*
- *Optimizing the Value of Co-Products/By-Products*
- *Enhancing Productivity of Biofeedstocks*
- *Policy Issues Impacting Agriculture and Bioenergy*

More information on NABC 20 may be obtained in the spring 2008 issue of *NABC News* (http://nabc.cals.cornell.edu/newsletter/NABCnews_current.pdf).

Allan Eaglesham
Executive Director
NABC

Ralph W.H Hardy
President
NABC

CONTENTS

- 1 PART I—CONFERENCE OVERVIEW
 - 3 Agricultural Biofuels: Technology, Sustainability and Profitability
Allan Eaglesham & Ralph W.F. Hardy
- 13 PART II—BANQUET AND LUNCHEON PRESENTATIONS
 - 15 Breaking America's Addiction to Oil through Agriculture
Thomas A. Daschle
 - 21 South Dakota's Leadership in Production and Adoption of Agricultural Biofuels
Mike Rounds
 - 27 Building a Prosperous Future in which Agriculture Uses and Produces Energy Efficiently and Effectively
James R. Fischer
- 41 PART III—PLENARY SESSIONS
 - 41 **SUSTAINABILITY: IMPACTS AND ISSUES**
 - 43 Food, Feed, Fiber and Fuel: A New World for American Agriculture and Environmental Sustainability
William Richards
 - 49 Ushering in a Sustainable Bio-Economy
Brendan Jordan
 - 55 Biofuels For Transportation Sustainability
Suzanne Hunt
 - 59 Biofuels: An Important Part of a Low-Carb Diet
Steven Bantz
 - 69 Q&A

77 **TECHNOLOGY: BIOMASS, FUELS AND CO-PRODUCTS**

79 Turning Biomass Crops For Biofuels Into Commercial Reality
Richard B. Flavell

85 Breeding, Selection and Testing of Shrub Willow as a Dedicated Energy Crop
Lawrence B. Smart, Kimberly D. Cameron, Timothy A. Volk & Lawrence P. Abrahamson

93 Challenges on the Road to Biofuels
William R. Gibbons

105 Ethanol Processing Co-Products: Economics, Impacts, Sustainability
Kurt A. Rosentrater

127 Energy-Crop Gasification
R. Mark Bricka

137 Butanol: The Other Alternative Fuel
David E. Ramey

149 Q&A

153 ECONOMICS AND SUSTAINABILITY

155 Biofuels, Energy-Security and Global-Warming Policy Interactions
Wallace E. Tyner

167 Capital and Sustainability
Roger Wyse

173 Food vs. Fuel? An Integrated Approach to Producing Both
Mark Kraeger

177 Development and Sustainability of the Biofuel Industry in Canada
Danny G. Le Roy & K.K. Klein

187 Biofuels and Biorefinery Development in Canada: The Question of Sustainability
Maria Wellisch

195 Q&A

201 **PART IV–BREAKOUT SESSIONS**

203 Workshops Summary
Kenton E. Daschiell & Van C. Kelley

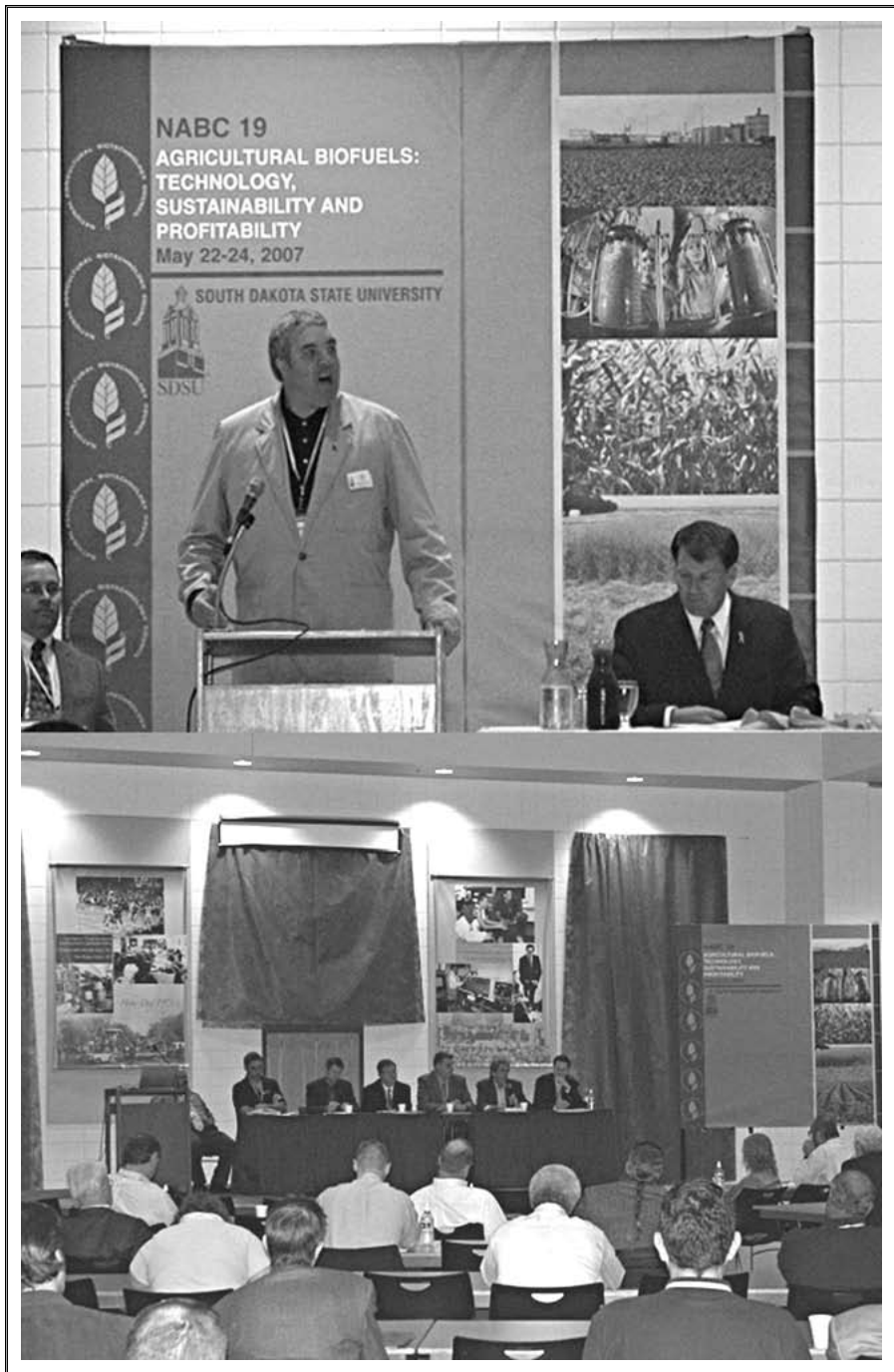
211 **PART V–THE STUDENT VOICE**

213 Student Voice at NABC: The Concept

215 Student Voice at NABC 19
Clairmont Clementson, Sarah Collier, Haluk Gedikoglu, Chinnadurai Karunanithy, Alissa Meyer, Arijit Mukherjee, Thomas Niehaus, Kari Perez & Buck Wilson

217 PART VI—PARTICIPANTS

249 PART VIII—INDEX



PART I—CONFERENCE OVERVIEW

Agricultural Biofuels: Technology, Sustainability and Profitability <i>Allan Eaglesham & Ralph W.F. Hardy</i>	3
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Agricultural Biofuels: Technology, Sustainability and Profitability

ALLAN EAGLESHAM & RALPH W.F. HARDY
*National Agricultural Biotechnology Council
Ithaca, NY*

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 biodigester 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 (*South 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 (25x'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 Ramey¹ (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 sessions² with audience participation and active discussions within three breakout workshops³.

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)

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

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

³A 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 CO₂, 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 feed-stock—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 workshops⁴; 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.

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



NABC 19
AGRICULTURAL BIOFUELS:
TECHNOLOGY,
SUSTAINABILITY AND
PROFITABILITY
May 22-24, 2007



SOUTH DAKOTA
STATE UNIVERSITY



PART II—BANQUET AND LUNCHEON PRESENTATIONS

Breaking America's Addiction to Oil through Agriculture <i>Thomas A. Daschle</i>	15
South Dakota's Leadership in Production and Adoption of Agricultural Biofuels <i>Mike Rounds</i>	21
Building a Prosperous Future in which Agriculture Uses and Produces Energy Efficiently and Effectively <i>James R. Fischer</i>	27

Breaking America's Addiction to Oil through Agriculture

THOMAS A. DASCHLE
Alston & Bird
Washington, DC

It's particularly nice to be back here at South Dakota State University, my *alma mater*. In Washington, I sometimes come across people who haven't heard of our school. I tell them it's the Harvard of South Dakota—but with a better animal husbandry program. That line usually gets a laugh, but today it's no joke. Agriculture programs like the one here at South Dakota State—and it's one of the best in the country—have never been more relevant. In coming years, we're going to rely on our farmers not just for food, but also for fuel. And that puts the work here at South Dakota State not just at the center of our farming policy, but also at the center of our environmental policy, our national security policy, and our economic policy.

CLIMATE CHANGE

Today, Americans use 21 million barrels of oil a day. We're a twentieth of the world's population, and we use a quarter of its oil. Our consumption will keep growing, to an estimated 40% by 2025. That wouldn't be a problem except that when we burn oil, we're also burning up our planet.

There's no doubt any more that global warming is happening. 2006 was the hottest year in recorded history. The second hottest year? 2005. When 99% of scientists say something is happening, it's happening. But we're only just beginning to see its effects.

A couple of weeks ago, I spent a few days in Aberdeen, SD, helping my mother dry out from terrible flooding caused by a torrential rainstorm. The local meteorologists call it a 5,000-year flood. Although nobody can say that global warming caused that flood, we do know that global warming is going to make events like these more frequent. And more intense.

It won't just be big storms now and then. Climate change is also going to affect day-to-day life. One recent estimate said that if global warming continues unchecked, it will push land suitable for wheat cultivation deep into Canada and Alaska by 2050. I'm all for promoting our state's farmers. But the minute they start having to grow tropical fruit, we're all in trouble.

And we'll actually have it better here in South Dakota than on the coasts. Rising temperatures mean melting ice caps, and melting ice caps mean rising ocean levels, which is a big deal when more than half of Americans live within 50 miles of the ocean.

So that's one consequence of our appetite for oil: we're wrecking our climate with no idea whether we'll ever be able to fix the damage. But our dependence on oil doesn't just threaten the survival of our planet; it also threatens our national security.

NATIONAL SECURITY

We saw last summer just how vulnerable we are to fluctuations in the price of oil. We depend on oil to run our factories, to get to work, to fuel our military. The countries that control its price are the countries that have it. And that's not us, at least not any more.

Today, the United States has just 3% of the world's oil reserves, compared to 60% for the Middle East. Nearly 80% of the world's reserves are held by state-controlled companies. We spend \$50 billion per year to protect these oil supply lines, but that's no guarantee. All a country like Iran or Saudi Arabia or Venezuela has to do is turn off the tap to send prices skyrocketing. Many of these countries do not like us, and they are more than likely to express their dislike by squeezing us with the power they have: the power over our energy. When they do, the cost can be enormous. Economists say these fluctuations in the price of oil have cost our economy \$7 trillion over the last 30 years. And today, oil imports account for \$260 billion a year – half our trade deficit.

Here's what these numbers mean in simple terms. We are borrowing money from our economic competitors in order to burn up our planet and indirectly subsidize some of the very people who we are asking our soldiers to fight. By any measure, our addiction to oil is a huge and growing problem. It threatens our climate, our economy, and our place in the world. It is related to every other big problem we face. And it is not getting better.

ONE REALISTIC SOLUTION

There are two possible solutions. One is to use less oil—for Americans to drastically cut down on their driving, for businesses to use less heavy machinery, for our military to ration itself. This is not going to happen in a significant way.

The second solution is to replace oil with an alternative fuel. Thankfully, we have a substitute at hand. Ethanol is clean, renewable, and can be grown right here by American farmers. It represents the obvious next step in human evolution. Thousands of years ago, we went from hunting for our food to growing it; today we're doing the same for energy. It's so obvious that you'd think politicians would be pushing each other out of the way to embrace it. But 7 years ago, when Senator Lugar and I introduced the first Renewable Fuels Standards (RFS) bill, we faced great skepticism about our initial goal of producing 5 billion gallons of ethanol by 2012.

You don't hear much from those skeptics any more. This year, it looks like we will exceed the new RFS requirement of 7.5 billion gallons by almost 1.5 billion gallons, 5 years ahead of schedule.

One hundred and fifteen ethanol plants have been built in the United States since the late 1970s. Today, seventy-nine more are under construction. In the last 5 years, new demand for biofuels has led South Dakota farmers to plant 300,000 acres that had never been farmed before. South Dakota leads the United States in farmer-owned ethanol plants, leads the country in percentage of corn used for biofuels, and is fourth in total ethanol production.

South Dakota has also led the country in reaping the economic benefits that can come from growing fuel. Ethanol plants in South Dakota have produced returns of 33% for their investors and have drawn \$400 million in new capital investment into the state. More than 14,000 South Dakotans have some stake in ethanol production.

And there's plenty of room to grow. South Dakota alone has enough agricultural land to produce more energy than all but one member of OPEC. It used to be a political punch line when people said the Midwest could replace the Middle East as the world's energy supplier in the twenty-first century. It's not any more.

We've made great progress over the last 20 years. But today, ethanol makes up just 3% of American auto fuel. We have a long way to go.

PROMOTING ETHANOL WITH GOOD POLICY

It starts with smart policy. That means, first, raising the RFS to reflect the increasing output of America's farmers and the increasing urgency of climate change and our dependence on oil. We need to keep boosting production of domestic, corn-based ethanol.

But we also need to start moving towards the next generation of biofuels. That's why we need a Low Carbon Fuels Standard like the one being advocated for by Governor Schwarzenegger and Senator Obama.

Today, the only guaranteed consumption of ethanol is from the E10 standard blend market, or about 15 billion gallons annually. But ethanol will truly succeed when it's not a petroleum additive, but a petroleum substitute. That means exploring variations like cellulosic ethanol. In particular, that means more of the great research being done here at South Dakota State on potential sources of energy like switchgrass and big bluestem. And if the government sets incentives, our businesses and best minds will rush to claim them.

We need to work steadily towards these goals when the price of oil is high, but also when the price of oil is low. In the past, oil-producing companies have been able to temporarily drop prices, destroy investments in oil alternatives, and then raise prices even higher than they were initially. We can't let other countries dictate our energy policy. That's why it is time to make the tax credit for blenders of ethanol variable, meaning producers get more help when the price of oil is low, and less when it is high.

Together, these three policy changes will allow America to start shrinking its oil addiction and growing its stake in the fuels of the future.

BLASPHEMY BECOMES TRUTH

The Irish playwright George Bernard Shaw once wrote that, “All great truths begin as blasphemies.” That’s how it was for ethanol. In the late 1980s, the oil companies tried to stamp it out. In 1990, during the debate over the Clean Air Act, the first President Bush called it “Daschle gasoline.” Back then, it was a put down. Today, it’s a badge of pride.

We know that we’re addicted to oil. Even President Bush has admitted it. And we know that addiction is bad for us. But we have a solution. Ethanol and other biofuels come from American farmers and producers, pass through American refiners, and fulfill American energy needs. No soldier will have to fight overseas to protect them. And no international cartel can turn off the spigot on us. By making smart investments, we can turn America’s farms and fields into the victory gardens of the twenty-first century.

It won’t be easy. It will take smart research like the kind discussed at NABC 19. And it will take smart government policies that unleash the innovation and productivity of the private sector.

But we’ve met huge challenges before. When Sputnik first shot across the sky in 1958, we worried that we had fallen behind the Soviet Union forever. Eleven years later, we had a man on the moon. Breaking our addiction to oil will require the whole country—farmers, scientists, businesses, and government—working together. But working together, there is nothing we cannot achieve.

And South Dakota can lead the way.



TOM DASCHLE represented South Dakota for eight years in Congress and eighteen years in the Senate. Today, as an advisor to the law firm of Alston & Bird, he provides strategic advice on public-policy issues such as energy, healthcare and agriculture. He is also a distinguished fellow at the Center for American Progress.

Senator Daschle serves on the boards of InterMedia Partners, the Freedom Forum, CB Richard Ellis, the Mayo Clinic, the National Democratic Institute for International Affairs, and Caro-Links, Inc., and is a member of the Council on Foreign Relations. He is also a visiting professor at Georgetown University's Public Policy Institute.

From 1978, he served four terms in the House of Representatives then four terms in the Senate. He was appointed to the powerful Senate Finance Committee and in 1994 was appointed minority leader, and after Democrats gained control of the Senate in 2001 he held the position of majority leader until 2003. During that period, he worked with members of both parties in Congress and the administration in crafting the response to the attacks of 9/11/2001. He also served as a member of the Agriculture, Veterans Affairs, Indian Affairs, Finance and Ethics Committees.

South Dakota's Leadership in Production and Adoption of Agricultural Biofuels

MIKE ROUNDS
Office of the Governor
Pierre, SD

In South Dakota we are doing all that we can to support biofuels technology and to commercialize and promote their use. Since 2002, ethanol production has tripled within our state and we have no intention of stopping there. South Dakota is ranked first in the nation in farmer-owned ethanol plants, which is important because it means that the profits stay in the local area.

RAPID EXPANSIONS

We are first in the percentage of corn used and fourth in total ethanol production in the United States. South Dakota's ethanol plants produced more than 550 million gallons of fuel in 2006, a new record for our state. In 2007, South Dakota is expected to develop the capacity to produce 843 million gallons. Altogether, with state incentives, federal incentives and private hard work, we will boost ethanol production from 165 million gallons in 2002 to over a billion gallons by the end of 2008, including facilities operating now, those under construction and those that have been announced or are on the drawing board.

To encourage people to use ethanol, we have reduced state taxes on ethanol-blended gasoline at the pump since 1979. We provide a \$0.02 per gallon tax break for the 10% blend and a \$0.12 per gallon tax break for E85. In the past 27 years, \$75 million in taxes were not collected from gasoline users. Since 1989 we've provided production incentives to ethanol plants. In 17 years those payments have totaled over \$43 million. But we've done more than that because we've also supported opportunities to transport the ethanol. We've put together over \$6 million in rail-line work and in loans for improvements for ethanol plants in the eastern part of the state. Last November I implemented a new flex-fuel-vehicle (FFV) purchase policy for our state fleet. We now buy FFVs for all models on which the option is currently available. That was about 82% of the state's order of new vehicles in 2006, bringing the FFV total in the state fleet to 562 units or about 17%. Within the next 2 years, 57% of our fleet will comprise FFVs. It will be hard to go much

higher than that until the industry produces three-quarter-ton and larger trucks with flex-fuel engines. But when they make them, we will buy them. Our state transportation shops, where you would normally find a state employee filling up a vehicle, don't carry E85. In order to generate an interest in the private sector in putting in E85 pumps, we make our state employees purchase E85 fuel from convenience stores and other private-sector pumps. It's a little more expensive, but we're moving in the right direction with our policy of utilizing products from within our state. I have had only a handful of complaints from taxpayers recognizing that the dollars are staying locally for the purchase of gasoline, even if it costs a little more than buying in bulk at our state shops.

I've proposed and won approval of a state excise-tax exemption to promote ethanol-plant expansion. We used to have an exemption for new construction, but discovered that plants can become more efficient with expansion in an existing location.

CENTERS OF EXCELLENCE

I am pleased to relate that, in 2006, university researchers and industry partners in South Dakota and throughout the nation collaborated to develop South Dakota's fifth 2010 research center. The term "2010" denotes a long-term plan for economic development for educational purposes and for promoting a knowledge-based economy within our state. This fifth center is for bioprocessing R&D. It will focus on research that leads to new technologies for processing crop-derived materials in an effort to reduce the nation's dependence on foreign oil.

During our 2007 legislative session, we won approval for our sixth 2010 research center: the Center of Excellence for Drought-Tolerance Technology, at South Dakota State University. The primary focus will be to identify genes associated with resistance of drought, extreme temperatures and disease, and improved crop quality. It will emphasize research that leads to emerging technologies and drought-tolerant crops and partnerships with the private sector so that we will have crops and feedstocks for our animals and energy production in the future. Climate change may mean less rainfall within our state along with the rest of the Great Plains, and we want to have available the types of crops to continue to be the breadbasket for America.

SUN GRANT INITIATIVE

South Dakota State University, a leader in the \$192 million Sun Grant Initiative to develop the bioeconomy, hosts the North Central Sun Grant Center for Indiana, Illinois, Iowa, Minnesota, Montana, Nebraska, North Dakota, Wisconsin and Wyoming as well as South Dakota. The Sun Grant Initiative was established by Congress for the purposes of researching and developing sustainable and environmentally friendly biobased energy alternatives in cooperation with the Departments of Transportation, Energy and Agriculture.

In the private sector, South Dakota-based ethanol-industry leaders POET and Vera-Sun, are at the forefront in research and the building of integrated biorefinery facilities to produce starch and cellulosic ethanol and other biobased products. Because of all of these efforts, South Dakota is now the first state to produce more ethanol than gasoline consumed; in 2006, our citizens purchased 438 million gallons of unleaded vehicle fuel

and in November of that year our state recorded over 440 million gallons of ethanol production. Therefore, for private passenger vehicles, South Dakota has become virtually energy-independent. For biodiesel, I've issued an executive order directing the use of a minimum of 2% biodiesel in all state diesel vehicles whenever it is available. We've changed our laws to provide incentives for the expansion of plants producing ethanol and other alternatives from a variety of biomass products such as wood chips, corn stalks, corncobs, wheat straw, and, I hope, switchgrass. We will produce ethanol from as many different sources of biomass as possible; we must diversify if we are to meet the goals that most people in America would like to see.

ACHIEVING GOALS

More research is needed. I'm proud that South Dakota and NABC are playing key roles in our nation's efforts to replace 25% of our petroleum needs with renewable energy resources by the year 2025¹. The goal is to have America's farms, ranches and forests provide 25% of the total energy consumed in the United States while continuing to provide safe, abundant and affordable food, feed and fiber.

It's one thing to make a goal, it's another thing to do the planning and then the hard work that makes the goal become a reality. As a member of the Midwest Governors Association, I'm proud that we've adopted the 25x'25 goal along with over 500 other organizations and businesses. States like South Dakota must continue their individual efforts to promote production and encourage use of alternative fuels and alternative energy so that we can become truly energy independent as a country. The national government has a very significant role to play as well. In addition to the Midwest Governors Association, South Dakota is also a member of Western Governors Association and that organization has also made energy independence a top priority. Three years ago, we asked a distinguished and diverse group of more than 250 high-level stakeholders from throughout the west to craft a series of policy recommendations to develop an additional 30,000 megawatts of clean energy by 2015; to achieve a 20% increase in energy efficiency by 2020; and to create incentives for a reliable and secure transmission grid for the next 25 years. To meet these and the 25x'25 goal, we must have some long-term federal commitments to creating alternative energy and energy independence. In a nutshell, for any of us to significantly move forward we need long-term extensions of the federal tax credits that did so much to start the current alternative energy revolution. We need:

- a 10-year extension of the existing production tax credit for renewable electricity technologies, a 10-year extension of the investment tax credit for solar technologies,
- a 10-year extension of tax incentives for all innovative energy-efficient technologies,
- a significant increase in the current integrated gasification combined cycle (IGCC) tax credit, and
- need significant extension and increase of the cap on clean energy bonding authority for public power and for the tribes.

¹See pages 43–46.

Those are the key points that our western governors and lobbyists are making to the Senate Finance and House Ways and Means committee members this week. We cannot continue with 2- and 3-year extensions of these important tax credits. We need long-term extensions so that many of the commercial projects that will come from research can be built and produce more homegrown American energy.

NATIONAL PRIORITIES

Another way that we can work together with our Congressional delegations is to make sure that they truly understand the importance of biofuels and renewable energy in their writing of the new 2007 Farm Bill. A national commitment to renewable energy was initiated 5 years ago with the 2002 Farm Bill; the energy title focused on renewable energy, energy efficiency and biobased products, creating several excellent programs that need to be continued, such as the Renewable Energy and Energy Efficiency Improvements Program and the Biomass Research and Development Program, the Energy Audit and Renewable Energy Program, the Biorefinery Development Grants Program, the Cellulosic Bioenergy Program, the Conservation Biomass Pilot Project, the Bioenergy and Products Research Initiative and the Forest Wood to Energy Program.

A few years ago electric outages were in the headlines. Today it's high gas prices. Both electrical generation and transportation fuels are critically important to the future of the United States. Of the 20 million barrels of oil consumed each day in the United States, 68% is used in the transportation sector; however, currently, biofuels produce only 2% to 3% of those transportation fuels. It's imperative that we develop long-term uninterrupted flows of transportation fuels and that means developing alternative replacement fuels including ethanol and biodiesel. As we get smiles from people throughout our state every time we say it, I'd much rather be doing business with a farmer in South Dakota, Nebraska or Iowa than a sheik in the Middle East. It doesn't mean that we don't have friends there, but I'd much rather have the dollars staying locally.

Using new alternative fuels will require the development of adequate infrastructure including vehicle systems, vehicle-refueling facilities, distribution and storage facilities, refineries and conversion facilities. Domestically produced biofuels give us both immediate and potentially long-term and long-lasting solutions to national security, economic competitiveness and price and supply problems that plague us today. Domestically produced biofuels obviously also create jobs, keep dollars in the United States and lessen adverse environmental impacts. This is so important to western governors that we have created a regional taskforce to develop a policy roadmap for alternative fuels. The roadmap will describe the potential resources, technologies and capabilities in the western states and create possible scenarios for sustainable feedstock development, conversion technologies and environmental impacts that can be influenced by public policy.

ENERGY-SOURCE INTEGRATION

Huge supplies of renewable energy will not become available overnight, nor will they totally replace petroleum in the foreseeable future. Our national goals are to increase domestic energy production and trade with energy producers who are our friends. We must

start using more Canadian crude oil. TransCanada is building a pipeline from Hardisty, Alberta, through the Dakotas down to Oklahoma then east to Illinois that will carry 435,000 barrels/day of tar-sands crude to US refineries. That's 435,000 barrels that we won't need to get from the Middle East or Venezuela. There's talk of other new pipelines to bring more, needed tar-sands crude to the United States.

The same is true of coal that is right here in the United States. Again, ways of generating electricity without fossil fuels will not happen overnight. We will continue to need coal and new coal technologies for cost-effective energy production, stable energy production, and a transition to a future that will continue to include both alternative energy and cleaner burning coal. Promoters of biofuels, coal and oil should not become mutual enemies. We will need all three plus natural gas, solar and other new technologies. No single solution exists for our energy problems. There are many solutions and the providers of those solutions should not waste their time and resources in conflict with each other.

RURAL REVITALIZATION AND RESOURCE PRESERVATION

Much of what will happen in the future and on the bridge to the future will be market-driven. Most of the users of electricity and fuels—and that's all of us—are not going to pay more for fuel just so that we can be politically correct. Our choices will be determined by price, quality and reliability, as with any other product in the marketplace. And all who do the research to create biofuels production processes will play roles in determining price, quality and reliability; the energy future of America is truly in your hands. Today, many millions of rural Americans have a dream of new energy independence and new prosperity. They are beginning to see that dream come true, which is where hard work comes into play. Each of us has a role in the creation of cost-effective energy alternatives for the future.

One of the great things about the future is that it's not determined yet. We are not the victims of destiny. We are the creators of our own destiny. We create the future for ourselves, our children and all of the future generations with every decision that we make. That's why conferences like this are so important. A farmer once told me that all real wealth comes from the land. He was right. The oxygen we breathe, the food we eat and almost all of the fuel that we use to run our machines and create the electricity that we use come from the land. Our task is to make sure that we use that land wisely for those human purposes so that it will always be there for the generations that come after us.



MIKE ROUNDS was sworn in as South Dakota's thirty-first governor in 2003. From 1990 to 2000, he served five terms in the state senate, representing District 24, including Pierre and the surrounding areas. In 1994, he was chosen by his peers to serve as senate majority leader, a post he held for six years.

The oldest of eleven children, he was born in Huron, SD, and is a lifelong resident of Pierre. He earned a BS in political science from South Dakota State University. He is part owner of Fischer, Rounds & Associates Inc., an insurance and real estate agency with offices in Pierre, Mitchell, Rapid City and Brandon. He previously served as board president of the Oahe YMCA and vice president of the Home and School Association of St. Joseph School. He is married with four children.

Governor Rounds has proposed a plan to create a coalition of ethanol-producing states to ensure a sound national ethanol policy in order to maximize promotion of renewable fuels. Ethanol-producing states sometimes compete with their neighbors in the marketplace. In addition, potentially huge ethanol markets (*e.g.* California) have not been tapped due to perceived obstacles. A coalition can address issues such as reliability of supply during drought years and transportation costs.

Building a Prosperous Future in which Agriculture Uses and Produces Energy Efficiently and Effectively

JAMES R. FISCHER

*US Department of Agriculture
Washington, DC*

The current energy situation presents the United States and the world with challenges and opportunities. In moving forward with renewable energy and energy efficiency, in meeting the challenges of oil dependence, national security, and global warming, we should remember that the greatness of the United States has always been its ability to cultivate human talents and apply them in developing new technologies. The history of American agriculture is an excellent example of this. Advances in crop and animal sciences have led to ever-increasing yields, lower energy intensities, and more abundant, affordable food. Blessed with substantial agricultural lands, the United States has made the most of our opportunities and fed a large and growing country, and the world as well.

Our new challenge, and our new opportunity, is energy. Science and education will develop and sustain the bio-economy. Cooperative, interdisciplinary efforts will be required to address technical and market issues in the physical, biological, and social sciences, and efforts will be needed at all levels of the development continuum, from basic research to commercialization. Education will be required to introduce youth to agricultural-energy issues, to train the workforce of the bio-economy, to develop the next generation of professionals and researchers, and to inform consumers about new types of energy sources and products. The US Department of Agriculture (USDA) is undertaking numerous efforts in these areas of science and education. Others should make a point of directing their talents and technologies to support this. This is the path forward for us. This is how we can move beyond a petroleum economy to make oil dependence a thing of the past, and safeguard our environment for future generations. We can achieve our goals through scientific research and development (R&D), and by educating the next generation to create the bio-economy.

THE ENERGY SITUATION: CHALLENGES

Oil Dependence

Many American adults have memories of the two oil price shocks of the 1970s, which contributed to high inflation and unemployment. Fears of similar supply-related disturbances have led to a new correlate to national security called “energy security.” Generally speaking, this is the ability of the nation to obtain energy reliably and affordably. In practice, the term is most often used in connection with oil imports. While the economy is less vulnerable to oil-supply disruptions or price spikes than it was three decades ago, geopolitical and oil-market concerns are strong.

In 2006, the United States imported about 60% (on a net basis) of the crude oil and petroleum products it used. Concerns are heightened because a significant share of current imports comes from the Middle East. Most of the world’s long-term supplies of less expensive crude oil deposits are in that region, so the share is expected to increase. Since the terrorist attacks of 2001, concerns have grown. The war in Iraq, additional terrorist attacks around the globe, and specific attempts to attack oil facilities in the Middle East make markets and governments insecure about supply disruptions.

This is an even greater danger when markets are tight. Increasing demand from China and other countries has stretched production capacity and played a significant role in higher oil prices. With little spare capacity, supply disruptions could have more dramatic effects, and the risk of oil-price volatility is greater than ever.

Oil is a finite resource. It was deposited in geologic processes over millions of years. There may still be a large volume of it left, but it is certain that it is running out. The term “peak oil” refers to a kind of tipping point in world supply. The peak is the point where the maximum production is reached. After that, exploration to find new sources and new technologies to produce more from existing wells are insufficient to continue to increase production. The decline may be steep or gradual, but it is inevitable. Production in the United States reached its peak in 1970, but the world as a whole has not yet reached that watershed.

Human use of oil has been outstripping our ability to extract it. The world consumes about two barrels for every barrel discovered. It took approximately 125 years to use the first trillion barrels of oil, and we are on pace to use the second trillion barrels in about 30 years. Production has exceeded new finds for the last two decades. Many experts are bearish on oil’s future. For example, oil magnate T. Boone Pickens is not optimistic about continued increases in mankind’s oil use. He thinks that global oil production cannot be increased much above its current level, that we are at or near peak oil. He believes that changes resulting from decreasing oil supply are not likely to be abrupt, but that changes will play out over time.

Climate Change

Global climate change is also a growing concern with the use of fossil fuels, including oil. In recent years the scientific consensus regarding anthropogenic warming of the earth’s climate has solidified. A growing body of evidence demonstrates that human activities are

warming the earth, and that there are serious resulting impacts. Recent working group reports of the Intergovernmental Panel on Climate Change (IPCC) conclude that there is “very high confidence” that human activities have resulted in warming (IPCC, 2007a) and there is “high confidence” that these effects are taking place (IPCC, 2007b).

Projections of possible effects are uncertain, but many governments have initiated activities to limit, and eventually halt, growth in concentrations of greenhouse gases in the atmosphere. The Kyoto Protocol, ratified by 166 countries and other governmental entities, took effect on February 16, 2005. Although criticized widely, the Protocol is a significant step in global action to mitigate emissions. The United States never ratified it, and has not enacted mandatory emissions controls at the federal level, but instead has emphasized the importance of scientific and technological advances in achieving similar goals.

State and local governments have taken steps to mitigate emissions. California has passed legislation that requires a 25% cut in carbon emissions by 2020 to reduce emissions to 1990 levels. California and four other western states also agreed, in February 2007, to set a cap for carbon emissions for their region before the end of 2007 and to set up an emissions-trading system by August 2008. Seven northeastern states have agreed to mandatory limits on carbon dioxide emissions from power plants. This action aims at a target of stopping the increase in emissions by 2009, and reducing them by 10% from 2005 levels by 2019. Other states and cities have also taken action, and there is movement for federal leadership in this area.

A lawsuit filed by several states and environmental groups seeking to compel the Environmental Protection Agency (EPA) to regulate greenhouse gas (GHG) emissions from motor vehicles reached the US Supreme Court. The Court decided on April 2, 2007, that EPA did have authority under the Clean Air Act, and ordered EPA to reconsider regulation of GHG emissions from new cars and trucks. This bolsters activity already underway for federal regulation. Many legislative initiatives have been introduced to Congress, and companies including Shell Oil have called for federal action to ensure consistent nationwide regulatory treatment of GHG emissions.

Energy Use and Economic Development

Energy consumption is fundamental to modern economies and to daily life in developed countries. Energy consumption and affluence are tightly linked. Some developed countries use energy more efficiently than others, but these two variables track very closely in a regression analysis. Developed economies will use more energy as their economies continue to grow, and, over the next several decades, developing countries are expected to exponentially increase their energy use as their economies modernize. The two largest developing economies, China and India, will be the future world leaders in emissions. As the world’s population grows toward 10 billion or more this century, greater energy use and its resulting GHG emissions will be an inevitable result.

How Well We Use Energy

Where we get energy now and how well we use it is an indication of our current energy

status and what direction we need to move in. Non-renewable energy sources supplied about 94% of US energy in 2001. Petroleum, natural gas, and coal each supply about a quarter to a third of the total, and nuclear energy supplies under 10%. We use renewable energy for only about 6% of our energy needs. More than half of this is biomass—mostly in the form of wood chips and other wastes and residues used in the forest products industries, like paper-making. Hydroelectricity represents another large segment of the renewable share, with other sources like wind, solar, and geothermal contributing smaller shares. Renewable energy, with its many positive attributes, could make up a significantly larger share of the total.

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. We could reduce demand considerably if we used energy more efficiently. Perhaps our best energy resource is the energy we waste.

THE ENERGY SITUATION: OPPORTUNITY AND RESPONSIBILITY

A number of areas show promise for the use of renewable energy and energy efficiency—both non-biological and biological. Renewable energy sources, including wind, solar, and geothermal, are likely to play an increasing role in our energy mix. Wind power in the United States has grown to more than 11,600 megawatts, and its costs have fallen to a few cents per kilowatt-hour, in a competitive range with fossil-fired electric generation. Technological development may increase output and decrease costs for smaller wind turbines operating in lower wind-speed environments, opening more potential markets. Solar power costs are higher, but have also fallen dramatically over the years. The worldwide solar industry has been booming, to the extent that prices for inputs such as silicon have increased with high demand. Geothermal energy, for electricity generation and direct supply of heat, has also increased, especially in the western United States.

Similarly, energy efficiency will be more important, with technologies such as improved engines and zero-energy buildings coming to market. Hybrid electric drive, already commonplace, can enhance vehicle power and performance while decreasing fuel use significantly. “Plug-in” hybrids could extend the use of electricity in vehicles. With enhanced batteries, cars and trucks could run solely on electricity or fuels, or a combination of both. Further in the future, fuel cells powered by hydrogen could replace the internal combustion engine altogether. Zero-energy buildings are structures that integrate energy efficiency technologies and on-site renewable electricity generation to produce at least as much energy as they use, selling power into the electricity grid at times. Such buildings might have highly insulating coated windows, light-emitting diode (LED) lighting systems, and other efficiency measures, along with solar panels integrated into roofing tiles and connected to the electrical system.

The food system includes numerous opportunities to employ these renewable generation and efficiency opportunities. For example, wind turbines are now present on many farms and ranches, with more potential to supply land and wind resources from agriculture. Efficiency advances in buildings and vehicles would also benefit many parts of the agricultural value chain, both pre- and post-harvest.

There are also opportunities unique to agriculture. For example, genomics could produce a greater array of nitrogen-fixing crops, reducing the need for fertilizer. This can be understood as an energy efficiency technology, saving natural gas through agricultural science.

Biomass is already being used for energy and other products, but there is great potential for more. Trends are upward. Table 1 shows the markets available to current biomass resources. Grains and oilseeds are the primary biomass resources being used to produce transportation fuels—ethanol and biodiesel—as well as other biobased products.

On the other-hand, wood is the primary biomass feedstock used to generate electricity. Non-hydro renewables currently generate only 2% of US electricity, and of that 2%, most (71%) is generated by woody biomass; 13% wind; and 16% geothermal.

TABLE 1. CURRENT BIOMASS RESOURCES AND MARKETS.

Feedstock source	Product markets		
	Transportation fuel	Chemicals & materials	Electricity
Grains	Ethanol	Starches, sugars, animal feeds, organic chemicals	
Oilseeds	Biodiesel	Industrial oils, animal feeds, organic chemicals	
Wood		Paper, pulp, wood products	Steam cycle C-firing with coal; anaerobic digestions; landfill gas; combustion with steam cycle

Biofuel use, although still a small fraction of US consumption, is growing rapidly; 131 ethanol plants are now operating¹, with eighty-two under construction or expansion. The industry has a production capacity of more than 7 billion gallons per year (BGY). The United States produced nearly 5 billion gallons of ethanol in 2006. Biodiesel production has surpassed 200 million gallons per year, with more potential to expand. Biodiesel potential is not considered to be nearly as large as ethanol potential, however.

The demand for biofuels is so large that effects are already being felt in the agriculture industry, such as higher corn prices. Ethanol consumption was small relative to the size of the gasoline market, about 3.5%, but it represented a larger and growing share of corn production, about 14%, in the 05/06 marketing year (Fig. 1).

¹November 2007 figures.

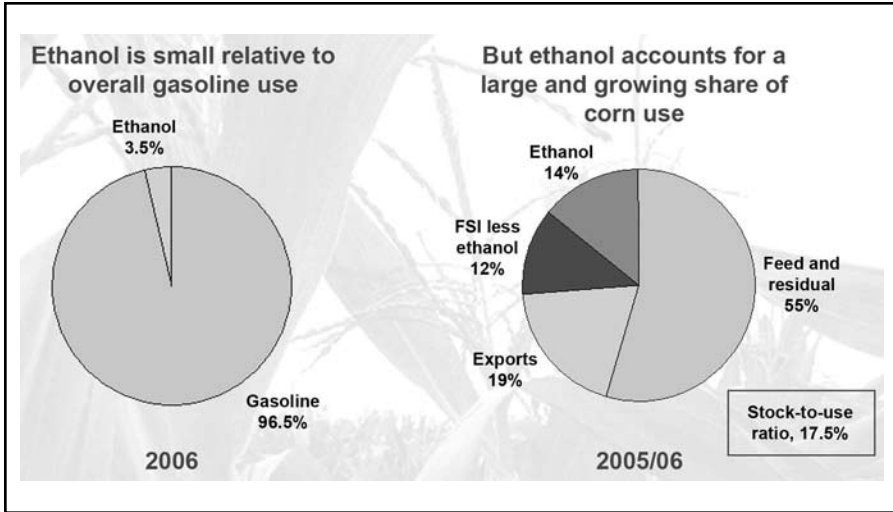


Figure 1. Ethanol in gasoline and corn markets.

Corn's use for ethanol has more than tripled in 6 years, and continued strong growth is likely. A share of 20% of the corn crop is expected for 2006/07. Projections for 2010 indicated that 2.6 billion bushels will be required for ethanol—1.2 billion bushels more than in 2005. Demand has caused corn prices to spike to over \$4.00 per bushel, and the outlook is for continued high prices. Concerns have been raised over the availability and cost of corn grain for livestock feed globally.

The size and speed of the increase in corn demand for ethanol production is unprecedented in its effect on the US feed-grain market and its implications for other agricultural markets. The question of sustainability must be addressed. How markets adapt to this increased demand is likely to be one of the major developments of the early twenty-first century in US agriculture.

While a target of 35 billion gallons of alternative fuel has been set for 2017, it is worth noting that the entire current US corn crop would produce only about 27 billion gallons. If the United States commercializes other feedstocks, notably cellulosic feedstocks, corn would become one of several crops or wastes used to make ethanol, and pressure on agricultural markets might ease. The raw material is potentially available: a potential of more than one billion dry tons per year of cellulosic feedstock, available on a sustainable basis, has been established (Fig. 2) (USDA and DOE, 2005).

The utilization of cellulosic feedstocks to manufacture fuel, electricity, heat and valuable co-products is now taking a high priority in agricultural and energy circles. This is a tremendous opportunity for agriculture to usher in a bioenergy future that can help address energy security and environmental challenges, and to profit in doing so. This opportunity is also an important responsibility. The challenges we face are daunting, and agriculture can contribute significantly in meeting them. It is our duty to do so.

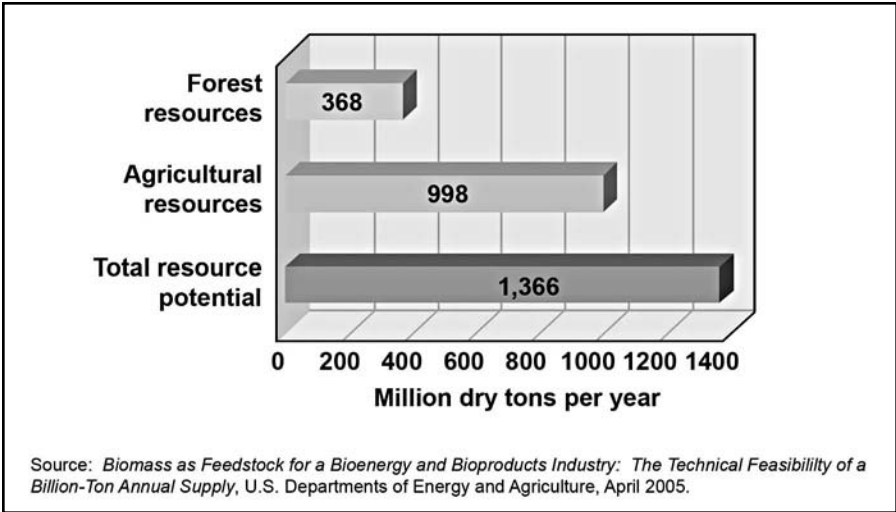


Figure 2. Annual biomass resource potential from forest and agricultural resources.

INITIATIVES AND GOALS

Over several decades, energy policy has been enacted to develop renewable sources and promote efficiency. In recent years, there has been a renewed push for transformation of the energy sector, as evidenced by several initiatives and goals that have been established.

Federal Activity

Federal legislation and other developments have been directed at energy challenges over the past three decades. Significant federal legislation beginning in the 1970s focused on energy directly or environmental issues that impacted energy. Tables 2 and 3 list some of the major energy-related legislation in this period.

1978	Public Utility Regulatory Policies Act (PURPA) Energy Tax Act (ethanol blends \$0.40/gallon tax exemption)
1992	Energy Policy Act (tax credit for renewable energy production)
1998	Energy Conservation Reauthorization Act (included biodiesel credit) Alternative Motor Fuels Act (encouraged cars fueled by alternative fuels)
2000	Biomass R&D Act (DOE/USDA joint R&D biobased industrial products)
2002	Farm Bill (First energy title in Farm Bill history)
2004	Job Bill (included biodiesel fuel tax credit)
2005	Energy Policy Act of 2005 (RFS, production tax incentive through 2007)
2006	State of the union—"addicted to oil" Advanced Energy Initiative
2007	State of the union—"20 in 10" Biweekly energy briefings to USDA secretary Farm Bill—increase budgets for bioenergy R&D

TABLE 3. FEDERAL ENVIRONMENTAL POLICIES IMPACTING ENERGY.

1990	Clean Air Act (CAA) (first major environmental policy to have an impact on renewable energy)
2006	EPA requires the use of ultra low sulfur diesel fuel (15 parts per million sulfur)
2010	Non-road diesel fuel regulations will take effect

One example illustrates the effect of well-constructed public policies to help achieve energy goals. A production tax credit (PTC), applicable to electricity generated by wind turbines, was set at a level—\$0.15 per kilowatt-hour, with subsequent upward adjustments for inflation—that provided just the incremental economic incentive to cause state-of-the-art wind technology to compete with alternatives. The evidence of its influence is the dropoff in wind farm construction during lapses that occurred between expiration and renewal of this policy in 2000, 2002, and 2004 (Fig. 3).

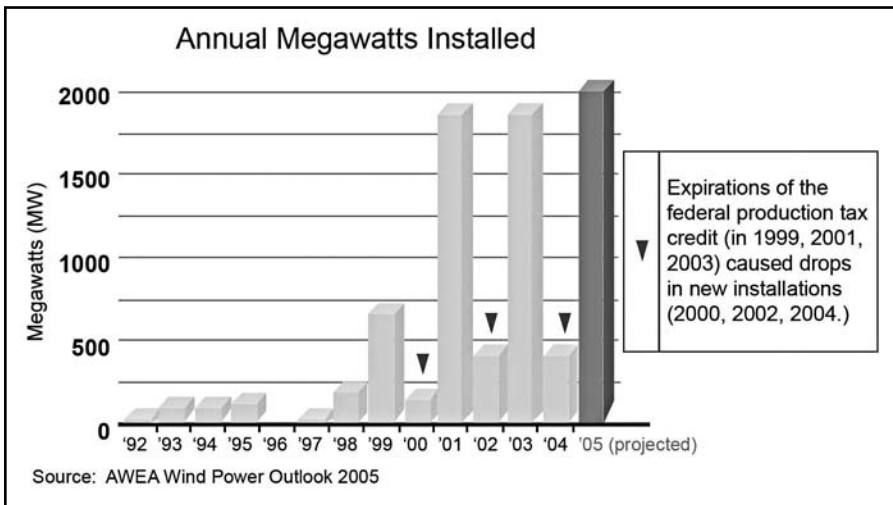


Figure 3. Effect of production tax credit (PTC) on the US market.

Initiatives

In addition to the legislation, regulation, speeches, and other notable activities listed in the tables, 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.” One focus is on advanced battery technologies to improve hybrid vehicles, including plug-in hybrids that could both draw from and contribute to the electric power grid. Another focus is reducing the cost of producing ethanol from cellulose. With lower costs for conversion, developments in feedstocks, and in infrastructure and vehicles, there is the potential for tens of billions of gallons of cellulosic ethanol in

the next decade or decades. A third area in transportation is the development of hydrogen fuel cells. Practical, safe, powerful, and cost-effective hydrogen fuel cell-powered vehicles—especially if hydrogen is generated from renewable sources—could be the future of transportation. The AEI also targets residential and commercial building energy use, focusing on clean coal, nuclear and renewable energy.

The Biofuels Initiative was developed to target a goal the president set in his 2006 state of the union speech—to replace more than 75% of our oil imports from the Middle East by 2025. This initiative has been accompanied by a proposed near doubling (from \$89.8 to \$179.3 million) of the budget of DOE's Biomass Program, in the FY 2008 budget request, compared to the FY 2006 appropriation, to accelerate cellulosic ethanol development and related technologies. The budget for USDA also includes a proposed increase of \$50 million per year for 10 years for energy in the Research, Education, and Economics mission area.

The Biomass Research and Development Act of 2000 created the Biomass Research and Development Initiative. Its vision is that by 2030, "a well established, economically viable, bioenergy and biobased products industry will continue new economic opportunities for the United States, protect and enhance our environment, strengthen US energy security, provide economic opportunity, and deliver improved products to consumers." By 2030, this initiative's ambitious goals are that there will be 68 billions gallons of biofuels, constituting 20% of the market for liquid vehicle fuels, 10 quadrillion BTUs (quads) of electricity generated from biomass sources, and 55 billion pounds per year of bioproducts.

The most recent of these initiatives is the National Biomass Action Plan. This is an inter-agency effort of the federal government, led by USDA and DOE to coordinate R&D activities across the government related to biofuels. Representatives met in a workshop in November 2006 to define agency roles and activities, identify gaps in R&D and synergies across agencies, and to assess budgets. A report of the conclusions from the workshop is forthcoming.

Goals

Many goals have been set to motivate public- and private-sector efforts in developing biomass energy. Goals have been set by both governmental and non-governmental groups.

DOE set a goal, in response to the president's 2006 state of the union address, to displace 30% of 2005 gasoline usage with biofuels by 2030. This has been called the "30 by 30" goal, and envisions 60 billion gallons annually of biomass fuels in 23 years.

In his 2007 state of the union message, the president articulated a nearer-term goal related to transportation fuel. Called the "20 in 10" goal, it calls for reducing US gasoline usage by 20% by 2017. Three-quarters of this amount (15 percentage points of the 20%) would come from substituting biofuels and other alternative fuels, with the remainder from vehicle efficiency.

A non-governmental group has issued a call for "25x'25"—the use of energy from the agricultural sector, plus wind and solar power, to provide 25% of US energy needs by 2025, representing an estimated 32 quads of bioenergy in 18 years.

The Aspen Institute, a non-partisan, non-profit organization, has set a very ambitious goal of 100 billion gallons of ethanol produced in the United States annually by 2025.

NABC has also set several goals. For liquid transportation fuels, it targets biofuels for 50 billion gallons by 2025, and 100 billion gallons or more by 2035. For organic chemicals, the aim is for glucose produced at \$0.04 per pound and competitively priced ethylene, most likely produced with genetically modified organisms. In the area of organic materials, NABC envisions new fiber crops with functional improvements and higher yields, produced with genetically modified organisms (NABC, 2007).

CREATING THE BIO-ECONOMY

NABC has recognized what is needed in agricultural biotechnology through its history. The organization has been at the forefront in creating a bio-economy. Earlier visioning documents have contributed significantly to the national biomass conversation. Policy suggestions from NABC documents have been incorporated into national policy, as in the Biomass R&D Act of 2000.

The latest in a series of visioning documents, the recently released “Road Forward” strategic planning document, sets out a roadmap for the required technical progress (NABC, 2007). New feedstocks will be required, including residues, dedicated energy crops, and others, to provide a large, sustainable supply. New technologies to convert feedstocks into fuels and other products will also be needed. Both biochemical and thermochemical conversion are under study. Finally, demand for bioenergy and bioproducts will need to match growing production capacity. Markets include transportation fuels, electricity and heat, and industrial chemicals and materials.

Meeting ambitious policy goals and realizing the bio-economy will require many technological advances. It is a large task and we must identify the Road Forward to accomplish it. The Road Forward for the energy future is *Science and Education*. Our country has been defined by its talent and its technology. The history of American agriculture is an excellent example of this. Advances in crop and animal sciences have led to ever-increasing yields, lower energy intensities, and more abundant affordable food. Blessed with substantial agricultural lands, the United States has made the most of its opportunities and fed a large and growing country, and the world as well. Now we are turning to agricultural technology’s new challenge: energy.

The USDA is engaged in programs in science and education in an effort to lead the agricultural community in meeting this challenge. The focus of energy science and education programs include both renewable energy (biobased and other renewable energy) and energy efficiency—both pre-harvest or traditional agricultural, and post-harvest, or including the rest of the food system. The three goals to be accomplished are:

- Develop comprehensive *research* programs that effectively explore the role of agriculture as both a user and producer of energy.
- Establish energy science *education and extension* activities related to agriculture with university and industry partners as well as federal and state agencies.
- Initiate comprehensive *technology-transfer* programs for agriculture energy research for agriculture producers, suppliers, and users.

Traveling in the HOV Lane

Going down the road quickly toward a bright energy future will take a lot of cooperation. It's as if different scientific disciplines are driving in separate cars and in separate lanes down a highway. With so many cars, there is a lot of traffic, and the going can be slow at times. But if the different disciplines ride together in the same vehicle, they can take the HOV lane and move faster. In creating the energy future, many approaches will be necessary. Varied research will be required. A unified, interdisciplinary approach will be necessary to address the multi-faceted challenges we face, drawing on expertise in physical, biological, and social sciences. In the physical sciences, research questions include the lower energy density of biomass compared to fossil fuels, the emissions characteristics of fuel combustion, and gasification or pyrolysis of a variety of biomass feedstocks, to name a few examples.

In the biological sciences, research will address issues such as the need to increase feedstock yields, the requirement for regionally specific, environmentally sustainable, and cost-effective feedstocks; the cell wall problem, *i.e.* the recalcitrance of cellulose to break down into the sugars needed; and the development of microorganisms, enzymes, and biochemical pathways for conversion of feedstocks to fuels and products.

Research needs exist also in the social sciences. For example, policymakers and others need assessments of the economic impacts of bioenergy and bioproduct expansion on agricultural, energy, and other markets, in North America and globally. Consumer acceptance of new fuels and new bioproducts, such as 1,3 propanediol (PDO), used to make DuPont's Sorona® polymer, must be gauged, with understanding developed of the most efficient ways to educate consumers to accelerate market acceptance.

In addition, many of the problems that need to be addressed are multi-faceted, and need even more cooperation than the coordination of different fields. The interactions necessary will require the building and nurturing of inter-disciplinary teams.

In another scenario, the cars traveling in separate lanes are government, industry, and academia. These different groups, also, need to get into the same vehicle and travel in the HOV lane. Government can make policies to help speed the development and adoption of new technologies, in areas like tax and financial incentives to public education. Government can also play a pivotal role in coordinating the efforts of different sectors. Industry can be a key player in developing technologies, and is absolutely central in determining how technologies will come together and flourish in the marketplace. Academia is very good at doing research in the physical, biological, and social sciences. With all of these key players moving together, they can make much better progress than if each were traveling alone.

R&D Continuum

Developing new technologies to the point of commercialization requires a continuum of activities, from the initial idea to the mass market. Activities are required in basic research, development, demonstration, deployment, and commercialization to move new ways of providing energy services, chemicals and materials along a development pipeline. For example, while research on the fundamental character of cell-wall structures is ongoing,

industrial, academic, and government interests must work in concert to set up demonstration plants to prove the feasibility of continuous processing of a new conversion technique, while elsewhere market researchers work to define consumers' requirements for committing to biofuels in their vehicles.

Education

Educational activities will ensure that the next generation of researchers, workers, and consumers are prepared to carry on running and expanding the bioeconomy. Education should begin with youth. For example, teacher-training and instructional materials can be developed for classroom use. USDA and others can reach out to youth groups already active in agriculture. The National Association of State Universities and Land Grant Colleges (NASULGC) and DOE have worked with 4-H clubs. Youth educators in seven states were trained in Washington, DC on curricula pertaining to energy and lighting to be taught in a 4-H after-school program. These partners are also working with the Future Farmers of America (FFA) to introduce energy science into high-school curricula.

Higher education activities are also needed. The Department of Labor has predicted that the retirement of scientists will soon leave the country about five million scientists below recent levels. Technical schools can train young people to be the technicians of the bioeconomy—for example, to operate collection and storage facilities for energy crops, or to run testing procedures to ensure biofuels have the right chemical specifications.

Undergraduate courses and majors will help train future professionals. In the same way that large numbers of students began earning certificates or even majoring in environmental studies in the last one or two decades, the bioeconomy will need courses with titles such as “bioenergy engineering” or “energy crop agronomy.”

Graduate programs will train professional practitioners and researchers. For example, a few years ago Iowa State University (ISU) introduced a Biorenewable Resources and Technology graduate program, with the cooperative work of several science and engineering departments. ISU grants MS and PhD degrees in this area.

Student competitions at all levels can motivate young people and harness their creativity. Models for these kinds of learning programs in renewable energy include the Solar Decathlon for college students and fuel cell model car racing competitions for high-school students.

Technical schools will have to train people who will make up a lot of the workforce of the bio-economy. For example, we'll need people who know how to operate collection and storage facilities for energy crops, or run test procedures to ensure biofuels have the right chemical specs.

Consumer and business education can increase market awareness and acceptance of bioenergy and bioproducts and better prepare businesses and their employees to participate in the bioeconomy. These could take the form of workshops, seminars, workforce-development classes, and consumer brochures or television programs. For example, a training session could be held for builders and their employees who want to incorporate energy efficiency and renewable energy into new homes and commercial buildings. Or a class could be held to teach fleet operators how to manage supply of renewable fuels and

operate and maintain fleets of flex-fuel vehicles. Consumer education can make a big difference. This is evident with programs like the joint EPA-DOE Energy Star program's "Change a Light, Change the World" campaign. If every American changed out just five high-use light fixtures or the bulbs in them with ones that have earned the ENERGY STAR label, each family would save about \$60 per year in energy costs and prevent the emission of greenhouse gases—totaling the same amount as the emissions from more than 8 million cars.

Science and Education for the Energy Challenge

Our new challenge, our opportunity, and our responsibility, is energy. The USDA is determined to apply the talent and technology of agriculture to bioenergy, and others should make a point of directing their energies to support this. The road forward toward our energy future is *Science and Education*. This is how we can move beyond a petroleum economy to make oil dependence a thing of the past, and safeguard our environment for future generations. We have to do this together—riding together in the same car and moving quickly along in the HOV lane.

The USDA has started the process of getting researchers together for a large, long-term cooperative effort. In September of 2007, USDA convened a workshop of government and academic people to plan its approach to energy science and education. Participants worked to identify a vision and goals for the effort, identify program areas of focus and crosscutting issues, establish agencies' responsibilities, and suggest a process to achieve goals.

Participants and others interested in NABC 19 should also become engaged in the cooperative effort to move quickly toward the bio-economy and the energy future. They should do things to promote the concept of the HOV, multi-lane science and education highway—create interdisciplinary teams, or even new academic departments; keep working on R&D, but also take actions to make sure lab results get moved toward the market, with technology transfer partnerships with industry or university spin-off startups, for example. Other actions that readers can take include promoting education to create a sustainable pool of talent in individual fields and crosscutting groups, oriented toward bio-energy and bioproducts. These are actions like creating new curricula, new undergraduate majors, graduate programs, or even creating an endowed chair in bioenergy. The central, critical idea is for us all to be cooperating and coordinating in an almost unprecedented way—driving together in the same car, moving in the HOV lane.

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JAMES FISCHER has spoken nationally and internationally to diverse audiences on renewable energy production (wind, solar, geothermal, biomass) as well as on improving energy efficiency in agriculture.

In 2003, he was appointed to the Board of Directors for the Energy Efficiency and Renewable Energy Programs of the US Department of Energy. As senior technical advisor (academe) he developed innovative partnerships and models of collaboration, especially with land-grant universities, the US Department of Agriculture, foundations and the agricultural, industrial and business communities. In January 2007 with his wife, Sharon, he formed James R. Fischer and Associates LLC, a company focused on technology and management issues at the nexus of agriculture and energy, assisting the USDA Undersecretary for Research, Education and Economics to coordinate energy science and education programs for the Research, Education and Economics mission area of the USDA.

Fischer, who holds a PhD in agricultural engineering from the University of Missouri-Columbia, served as a USDA research engineer in the 1970s and as a faculty member and dean at three universities: Missouri, Michigan State, and Clemson. He has published more than a hundred papers, contributed book chapters, testified before Congress, and served on peer review panels and advisory boards.

PART III—PLENARY SESSIONS

SUSTAINABILITY: IMPACT AND ISSUES

Food, Feed, Fiber and Fuel: A New World for American Agriculture and Environmental Sustainability <i>William Richards</i>	43
Ushering in a Sustainable Bio-Economy <i>Brendan Jordan</i>	49
Biofuels For Transportation Sustainability <i>Suzanne Hunt</i>	55
Biofuels: An Important Part of a Low-Carb Diet <i>Steven Bantz</i>	59
Q&A	69

Food, Feed, Fiber and Fuel: A New World for American Agriculture and Environmental Sustainability

WILLIAM RICHARDS¹

Richards Farms, Inc.

Circleville, OH

Sustainability isn't good enough. We have the technology in corn—and hopefully we'll have the technology for dedicated energy crops—to go beyond sustainability to resource enhancement. Biofuel production offers opportunities to improve soil, water and air quality, not just to conserve and sustain.

CONSERVATION TILLAGE

My family farm is about 30 miles south of Columbus. Three sons are there, operating about 2,800 acres of corn and soybean. I've spent my career in the development and practice of conservation tillage—no-till, direct seeding, whatever we call it. We have land that hasn't been turned by a moldboard plow in more than 45 years. We have 30 years of continuous no-till. In addition, we've developed a controlled traffic system that keeps the wheel tracks in the same spots to avoid compaction. We have developed and modified equipment from those early days, some of which is still in use.

We've seen soil improvements beyond our dreams: increased organic matter content (carbon sequestration is working), and erosion essentially eliminated. Planting gets easier and easier each year. Stands get easier to obtain each year. Yields are increasing. Fuel, labor and machine costs and herbicide use are decreasing. No-till has helped keep our family farm competitive, profitable and, really, beyond sustainability these past 40 years. It also helped send me to Washington when Secretary Yeutter and Assistant Secretary Moseley needed a farmer with some conservation experience to guide other farmers in conservation requirements in the '85 and the '90 Farm Bills. Conservation compliance became a condition for eligibility for federal program benefits, albeit not a legal require-

¹Co-chair of the 25x'25 National Steering Committee.

ment. At the Soil Conservation Service, we were very frustrated. Producers were hostile, so we initiated a campaign to market opportunities and advantages and the economics of conservation, and we had good success. When considering sustainability in biomass production, take a look at that model because it could work again. Again, this is a farmer talking, not necessarily espousing member organizations' policy.

25×'25

The objective is to produce 25% of US energy from the land by 2025. That's not just biomass, that's wind, hydropower and solar. I co-chair the national steering committee with J. Read Smith, a no-till wheat farmer from Washington State. We started with about ten on that committee—many of whom are colleagues of attendees at this meeting—and expanded to about twenty-five members.

The committee meets several times a year, funded by the Energy Futures Coalition, a non-politically-partisan group of DC leaders—members of previous administrations or of Congress—who came together shortly after 9/11. It was sparked by President Clinton's CIA director, Ambassador James Woolsey and includes John Podesta, Clinton's chief of staff, and Boyden Gray from the President George H.W. Bush's administration.

After issuing several extensive reports, the Energy Futures Coalition concluded that the US must find ways to reduce dependence on fuel from its enemies. Former Director Woolsey believes that the US is involved in a war that could be longer than the Cold War. It's the first war America has fought in which it is funding both sides, with \$250 billion/year for importation of oil. When you add the problems that the Iraq conflict brings—the injuries, fatalities, *etc.*—it's probably costing us a billion dollars a day for oil imports. Woolsey maintains that this war will continue until we find some sort of energy independence.

A speaker at this conference made the statement that we have to be careful of our choices. I only hope that we have choices because we may be just one attack away from serious problems. The Coalition examined alternatives—clean coal, oil shales, drill more US oil, and nuclear—and found that each has negative social implications. Renewable energy from our land is the most socially acceptable, environmentally friendly and economically feasible of all the choices, therefore the Energy Futures Coalition reached out to agriculture. Ernie Shae is the full-time coordinator of the 25×'25 effort, assisted by several staff members.

MORE THAN A DREAM

Our mission is to facilitate, to bring together agricultural, environmental, commercial and scientific organizations around energy policy. Our slogan "25 by '25" is catchy and it resonates. About 3 years back we started with a vision and developed a goal that has generated interest beyond our greatest expectations. Twenty-five percent of our energy from our land by 2025 may be more than a dream. It may well be a necessity. About 500 organizations have signed on to our vision, including the major general farm organizations, the big three audit companies, John Deere, Case and other equipment manufacturers, and conservation and environmental groups around the country. Twenty-five governors

have signed on, as have many state legislatures. Resolutions have been introduced in both houses of Congress. Last week it passed the Agriculture Committee and it's now before the Senate. We've held three national renewable energy summits, all well attended. Our Ohio summit convened in November 2006; we had about 200 registered and 300 showed up. We've organized 25x25 alliances in nine states.

The steering committee has visited the DOE labs in Colorado twice. We met with the State Board of Agriculture in California where we heard from Steven Chu, Nobel Laureate director of the Berkeley Laboratories. He called for an effort equivalent to the Manhattan or Apollo Project if the US is to solve this problem. We have facilitated two policy sessions where our participating organizations put forth policy positions which our steering committee compiled into an action plan that's available on the internet². We've been able to work under the "yes if" principle with these organizations: Yes we'll agree, yes we'll continue around the table but we reserve certain other requirements. This seems to be working considering that we've brought so many agricultural and environmental organizations together in the same room.

We've sponsored two studies, one at the University of Tennessee and the other at the Rand Corporation, both of which showed that, yes, 25 by '25 is possible, if:

- society and Congress have the commitment to fund the R&D,
- we solve the economics of cellulose conversion to ethanol,
- we utilize our forest resources,
- we're willing to bring a hundred million acres more land into energy-crop production.

The Tennessee study is also available on the internet³.

CELLULOSICS: PROBLEMS AND POTENTIAL

I predict that energy production will bring the greatest land-use changes since widespread adoption of agricultural technology began in the 1930s. That's assuming that we can achieve economic production of ethanol from cellulosic biomass. I do not think that corn stover will be the solution or *a* solution. I think that residue will continue to be more valuable when left on the soil, which, of course, is the key to no-till. Also, the harvest window is too narrow. Most of the Corn Belt has very few days between the end of harvest and the beginning of bad weather. And even if John Deere comes up with a wonderful machine that puts the corn in one bin and the corn stalks in another tank, farmers have a culture of fast harvest: harvest to avoid risk. It will take some real prices to get farmers to slow that harvest down and collect those corn stalks. Compaction will also be a factor.

It's going to take big dollars to really collect the cellulose that we are dreaming about.

²http://www.25x25.org/storage/25x25/documents/IP%20Documents/actionplanfinalweb_08-27-07.pdf

³<http://www.agpolicy.org/ppap/REPORT%2025x25.pdf>

I think we'll use a dedicated energy crop. I have experience with switchgrass which we planted for the pheasants on CRP land. The pheasants are safe because that stuff grows well over my head and productivity must be tremendous. We need research on those feedstock grasses. We must find ways to concentrate those feedstocks. We're not going to be hauling fluffy material very many miles. We're going to need technology that locates those processing plants or some kind of gasification or other new technology that gets those feedstocks into a transportable mode much different from what we are looking at now.

Let's assume that we find solutions to cellulosic production. Think what that will do to our land. Think of millions of acres of underutilized brush and pastureland. Solving erosion problems, improving soil, water and air quality and providing wildlife habitat. Think of millions of acres of undervalued forest that can be used for cellulosic ethanol. When these forests are thinned and improved, they are very much more valuable for timber. And think of the opportunity we have to get conservation policies and programs in place that we've only dreamed of in the past.

A WHOLE NEW WORLD

As a farmer I'm excited. I've maintained for many years that expensive energy would be bullish for agriculture. In my 50 years as a producer we've almost always had excess production. Our productive capacity in this country has almost always exceeded demand for food and fiber. In crop agriculture, we have survived through export markets and with support programs from the public. When you add renewable energy from our land we are in a whole new world. I believe we can produce 25% of our energy while continuing to produce safe, abundant and affordable food, feed and fiber, and we can do it by 2025 while enhancing the environment. Not only can we do it, I believe that we *must* do it.

I'll close with a quote from a famous, but sometimes forgotten, American. In the early years of the twentieth century, this great scientist at Tuskegee University made this statement:

I believe that the Great Creator has put ores and oil on this earth to give us a breathing spell. As we exhaust them we must be prepared to fall back on our farms, which is God's true storehouse and can never be exhausted. We can learn to synthesize material for every human need from the things that we grow.

—George Washington Carver



WILLIAM RICHARDS served as chief of USDA's Soil and Conservation Service (Now Natural Resources Conservation Service) from 1990 to 1993. During his tenure, he initiated the highly successful National Alliance for Crop Residue Management and spearheaded a formal partnership agreement among SCS, the National Association of Conservation Districts and the National Association of

State Conservation Agencies. Richards' commitment to conservation extends to his family in Circleville, OH, one of the first in the United States on which conservation tillage was adopted on the entire acreage.

Mr. Richards is a senior advisor on Farm Bill and agricultural policy. He is an Ohio Agriculture Hall of Fame inductee and recipient of distinguished service awards from Ohio State and Purdue Universities, the National Association of Conservation districts, and the National Association of Farm Managers and Rural Appraisers.

A graduate of Ohio State with a degree in agricultural economics, he currently serves as co-chair of the 25x'25 national steering committee.

Ushering in a Sustainable Bio-Economy

BRENDAN JORDAN

*Great Plains Institute & North Central Bio-Economy Consortium
Minneapolis, MN*

The Great Plains Institute, formed in 1997, is a small non-profit operation focused primarily on policy related to energy and climate. A comprehensive strategy that uses a variety of energy technologies will be needed to deal with the challenges ahead—everything

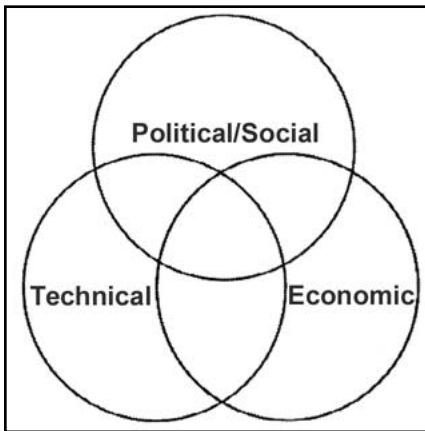


Figure 1. Test for feasibility of climate/energy solutions.

from biomass, wind, improved energy efficiency, hydrogen and other delivery systems, advanced coal technology with capture and storage, to hydroelectricity.

This conference is framing energy solutions in terms of technology, sustainability and profitability. I use a Venn diagram (Fig. 1) to think through things when evaluating a particular approach. The first issue is whether a scheme is technically feasible; engineers assist with that. The second issue is to evaluate the economics relative to other schemes proposed, for which methodologies are available. The toughest consideration relates to political and social dynamics; no textbook exists on whether an approach will be accepted by society.

STAKEHOLDER CONSENSUS AS A TOOL

We try to address social and political issues through stakeholder consensus. We have used this approach with a number of projects. Powering the Plains, a regional project in the Dakotas, Iowa, Manitoba, Minnesota and Wisconsin looking at the electricity sector, was created at the initiation of the conversation about climate change and energy security. The best approach was to bring the right people together for discussions in an environment in which they would not be quoted. Times have changed since then, and many of the leaders in that group are now very public about issues of energy security and climate

change, and we hope that we played some small role in that; but obviously, the political dynamic has shifted. We have worked also with the Upper Midwest Hydrogen Initiative, a public/private effort to advance hydrogen and fuel-cell technologies. The Coal Gasification Work Group is focused on advanced technologies that allow capture of carbon dioxide. I've been involved also with the Biomass Working Group, a regional stakeholder group working on state policy related to biomass. And the Midwest Renewable Energy Tracking System (M-RETS) is a group of utilities, regulators and environmentalists that has worked to create a system that should be implemented in 2007 to allow regional trading in renewable energy credits.

We've also done some research on native grasses as feedstocks. The North Central Bio-Economy Consortium is a collaborative effort involving land-grant experiment stations, cooperative extension and state departments of agriculture. The idea was generated in July of 2006 at the Midwest Association of State Departments of Agriculture meeting. We launched the Consortium in April, 2007.

BIO-BELT

In the north-central states we are getting organized in this way because we are, in a real sense, the bio-belt. We have the bulk of the existing biorefineries as well as those under construction. As we move to advanced biofuels from cellulosic materials, it's been said that those materials will be spread more evenly across the country—which is certainly true—but it looks as though the north-central region has a great deal of that material as well, as indicated by studies by the National Renewable Energy and Oakridge National Laboratories.

One of the efforts that we have participated in—which I am pleased that I can finally talk about in public as it's been behind the scenes for a long time—is an energy summit for Fall 2007 as a key part of the 2007 agenda of the Midwest Governors Association, chaired this year by Governor Doyle of Wisconsin; the North Central Consortium has been invited to provide input.

Figure 2 contrasts CO₂ emissions in 1960 and 2005, by sector and fuel, for eight states in the Midwest. Clearly we should focus little attention on natural gas in the transportation sector—coal in the electricity sector and oil in the transportation sector are the main producers of CO₂. While there is technology that allows us to produce electricity from feedstocks other than coal with less CO₂ emission, there are fewer options for the transportation sector. Biofuels hold great promise for transportation, but not without possible adverse aspects:

- Competing land uses (food vs. fuel);
- Possible economic failure of ethanol plants;
- Loss of acreage in permanent cover;
- Loss of soil carbon;
- Loss of wildlife habitat;
- Diminished water quality.

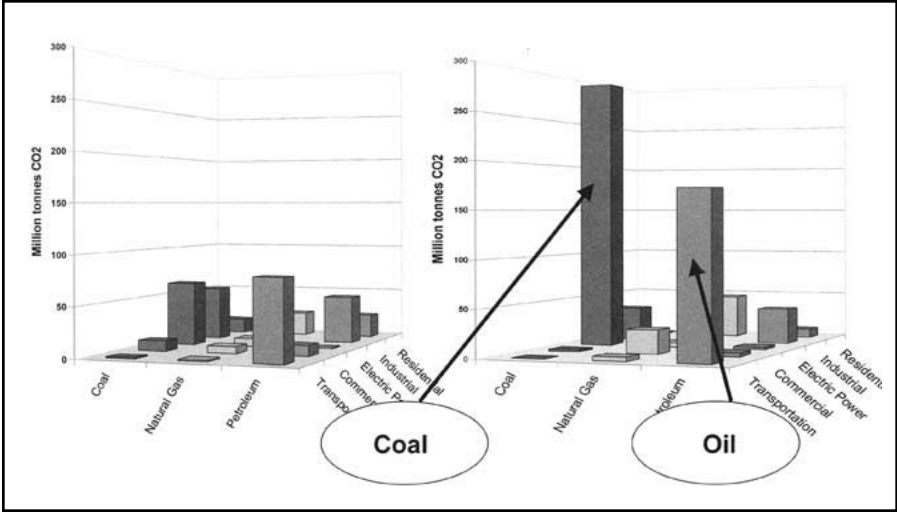


Figure 2. CO₂ emissions for eight Midwest states, from coal, natural gas and petroleum, in the transportation, commercial, electric-power, industrial and residential sectors.

Furthermore, although corn ethanol, soy biodiesel, canola biodiesel and other fuels from commodity crops will play increasingly important roles, other sources of bioenergy will be needed to realize the goals laid out in the president's 2006 state-of-the-union speech and by the 25x'25 committee¹. Over the long term, we must displace petroleum—old biomass—with several types of new biomass, using approaches that preserve wildlife habitats, soil quality, water quality, maintain or increase farm income, encourage rural development and reduce greenhouse-gas emissions. The different types of biomass will variously impinge on soil quality, water quality, wildlife, *etc.* The so-called “billion-ton study” suggested that a total yearly production of 1.3 billion tons of biomass is feasible in the United States. I feel that this is a conservative estimate, in view of, for example, the seven-fold increase in corn yields since the 1930s; breeding, selection, hybrid and molecular technologies, *etc.*, are likely to have similar effects on the yields of energy crops.

BIOMASS DEVELOPMENT

The economics of ethanol production from biomass indicates a variety of opportunities. 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. The comparisons are less favorable against energy from coal and natural gas, but these calculations fail to take account of downstream costs of CO₂ release to the atmosphere. The economics of the cellulose-conversion technology is the major stumbling block.

¹See pages 43–46.

How many years away are we from commercial cost-competitive cellulosic ethanol? At least 5? Another technology at the demonstration stage and close to commercially viable is pyrolysis²—a thermochemical process that converts any kind of biomass material to bio oil, a mixture of chemicals similar to crude oil. Ensyn, a company in Wisconsin, converts about 10% of the bio oil it produces to liquid smoke, a flavoring for bacon, etc., and the rest is burned off as boiler fuel. At least twenty companies are exploiting gasification processes in the United States, with many applications. This is a way to demonstrate the utility of biomass feedstocks while awaiting economically viable cellulosic ethanol. Two companies in Minnesota—the Chippewa Valley Ethanol Company and the Central Minnesota Ethanol Cooperative—are gasifying biomass to replace natural gas. The managers of ethanol plants don't particularly like spending \$15 million a year on natural gas; fortunately they can often buy biomass from the people supplying them with corn, thus this is an incremental step towards cellulosic ethanol: a proven technology can be used to demonstrate a feedstock. They don't have to manage multiple risks. Once the utility of a feedstock has been demonstrated, they may consider producing liquid fuels through an enzymatic or thermochemical process.

In the Cheritan Valley biomass project in southern Iowa, an 800-megawatt coal-fired powerplant uses switchgrass (at 2%) along with coal. It consumes up to 14 tons/h of switchgrass grown on CRP land. Much is being learned regarding the logistics of biomass supply, transportation and storage, directly applicable to other switchgrass-based technologies. Similarly, we have the opportunity to appraise the utility of a variety of biomass feedstocks—with specific state/locale relevance—while cellulose-conversion technology is being optimized. Accordingly the following feedstocks are under study in the indicated states:

- Corn stover: IA, IL, MN, IN, OH
- Switchgrass/grass polycultures: IA, ND, SD, KS, NE, MN, IN
- Wheat straw: ND, SD, NE, KS
- Sorghum: IA, KS, MO
- Wood residues: MI, MN, WI, MO
- Dedicated woody crops: MN, MI, WI, MO, OH, IN
- Miscanthus: IL

WIN-WIN OPPORTUNITIES

Agronomic and forestry research on productivity will remain important, but we're at a point where research alone is not going to take us where we need to go. We do need to learn how to deploy. 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; but the best way to understand the logistics involved is to actually

²See pages 127–135.

deliver them to processors. We cannot expect farmers and producers to take on all the risk, therefore we need to partner with them at least until we figure out how this is going to work. Incentives need to be in place.

While feedstock logistics will be a challenge it's also the area where we have the greatest opportunity for cost reduction. We need to partner with equipment producers, custom harvesters, manufacturers, and a variety of other commercial entities with relevant experience. And involvement of state departments of agriculture and land-grant research and extension experience will be necessary. Many "win-win" opportunities exist with a variety of feedstocks; much may be learned as we produce and deploy them in demonstration projects, for example:

- Corn-stover removal can increase no-till and conservation tillage;
- Cover crops can create biomass supply while improving soil carbon, water quality;
- Forest residue removal can decrease fire risk, improve lumber quality, and potentially improve habitat;
- Tree crops can be managed as mixtures.

For example in Minnesota and the northern region in general, removal of some, but not all, stover may open the soil to a small extent, favoring seed germination, allowing the soil to reach higher temperatures more quickly in the spring and could allow no-till and other conservation tillage practices to move further north. There's a variety of different cover-cropping approaches that add soil carbon and improve soil quality and could be paid for by biomass markets.

Forest-residue removal offers a number of opportunities. Removal of some smaller diameter trees can increase the eventual size and value of other trees. In some instances, management practices are already employed, so the price of the biomass doesn't have to cover the cost. Wildlife habitats may also be improved. None of these things are automatic, but there are opportunities.

In DOE-funded research that we helped conduct at South Dakota State University, the University of North Dakota Environmental Research Center and the University of Minnesota, we looked at simple mixtures of two to three species of native grasses—switchgrass, big blue stem and Indian grass. The switchgrass mixtures produced only slightly lower yields than did the monoculture. It's noteworthy that switchgrass is the only crop of the three to have been bred for yield; big blue and Indian have been bred as high-protein forages. Not surprisingly, the grasslands with greater plant-species diversity had higher bird-species richness and density. Diversity was similar in harvested and unharvested plots, but the species differed, suggesting that some combination in harvested and unharvested grasslands will offer the best opportunity for maximizing wildlife habitat.

Data from other switchgrass projects indicate that ash content peaks in July and August and steadily decreases through the winter. This is relevant to industrial processing because ash causes slagging with pyrolysis and related technologies. Harvesting in the fall or through the winter also will provide the opportunity to maximize bird habitat and avoid harvesting during the primary nesting season.

Growing perennial crops for biomass provides opportunities for increased carbon sequestration. There may be further opportunities for sequestration enhancement through breeding, conservation tillage and increased rotation length in forestry systems.

IMPROVING COMMUNICATION

In traveling around the region, I get the sense that one hand doesn't always talk to the other hand. Iowa needs to know what Nebraska is doing, for example; we are all learning as we go and there's no need to reinvent the wheel every time we want to get a corn-stover gasification project up and running. Everyone can benefit from better sharing of information, from regulators to project developers. It would be beneficial to all to have 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. NABC might take the lead in these endeavors—much sharing of information and collaboration would likely follow.

The North Central Bioeconomy Consortium website is at www.ncbioconsortium.org. Information on our native-grass research is available at nativegrassenergy.org and the Great Plains Institute website is at www.gpisd.net.



BRENDAN JORDAN joined the Great Plains Institute, Minneapolis, MN, in 2004, where he manages the cellulose initiative. His work emphasizes the development of biomass as a resource for creating value-added energy and other products in order to displace fossil fuels, stimulate rural economic development, improve air, soil and water quality, and address global warming. Since August 2006, he has staffed the Biomass Working Group, a 55+-member stakeholder group in the upper Midwest developing state-policy recommendations for advanced biomass technologies.

With Sara Bergan, Mr. Jordan works on the Institute's US Department of Energy-funded native grass energy research—a collaborative project involving South Dakota State University, the University of North Dakota Energy and Environmental Research Center and the University of Minnesota.

Jordan, a graduate of Carleton College in Northfield, MN, has an MS in science, technology, and environmental policy from the University of Minnesota's Humphrey Institute of Public Affairs. His international experience includes a Judd Fellowship at the Center for Environmental Studies in Budapest, Hungary.

Biofuels For Transportation Sustainability

SUZANNE HUNT
Worldwatch Institute¹
Washington, DC

For the past couple of years, we at the Worldwatch Institute have been examining key sustainability issues and how to deal with them. Initially, our aim was to engender interest in biofuels, to have them taken seriously. With the focus then firmly on fossil fuels, renewable forms of energy were not seen as likely to make significant contributions. But, the more we looked at them, the more we saw their potential, with the possibility of farmers being paid decent prices for new crops in new markets.

Now there's almost too much attention, with many rushing to get in on the action. We want to offer a word of caution—let's develop biofuels wisely. I will discuss key sustainability issues and provide examples of use of renewable energy in Guatemala and Honduras.

NOT NECESSARILY GREEN

I stress to policymakers that biofuels are not guaranteed to be green or sustainable. Some see biofuels as a panacea that will help address everything from energy-security to poverty to climate change. But we have to be deliberate in how we develop them. Possibly the most important issue is land use, especially in terms of conversion of natural habitats and effects on climate. As an extreme example, conversion of virgin forest to row crops for bioenergy results in net increases in greenhouse gasses (GHGs), even in the long term.

Also important is feedstock choice. In our environmental analyses, we examine the entire biofuel life cycle—all of the steps that are involved in biofuel-production chains, including feedstock production, processing, distribution and storage—and compare it with the fossil-fuel life cycle. It is a mistake to examine biofuels in terms of an ideal standard.

¹Ms. Hunt is now an independent consultant.

Worldwide, 98% of transportation relies on petroleum-based fuels and the transportation sector is responsible for about 25% of the world's greenhouse gasses. Climate change is one of the drivers pushing the biofuels boom, albeit less so in the United States than elsewhere. In the European Union for example, they've made progress with greenhouse-gas emissions with the exception of the transportation sector, which constitutes a major challenge.

Figure 1 provides a representation of ranges of CO₂-emission benefits for various feedstocks. Much more work is needed to produce reliable data on emissions from biofuels and biofuel blends, but this figure provides food for discussion. From left to right are switchgrass, poplar and willow, wastes and then sugar (with a broad range as it includes beet and cane), vegetable oils, and then starch sources, which are least beneficial.

In terms of environmental risks, expansion of cropland into sensitive areas is a source of concern, as are soil degradation and water issues. Expansion of corn planting in the Midwest may lead to increased fertilizer and pesticide runoff, exacerbating the dead zone in the Gulf of Mexico. Similar concerns relate to farming changes in the watershed serving the Chesapeake Bay. Water quantity is also a source of concern related to water needs to grow and process feedstocks.

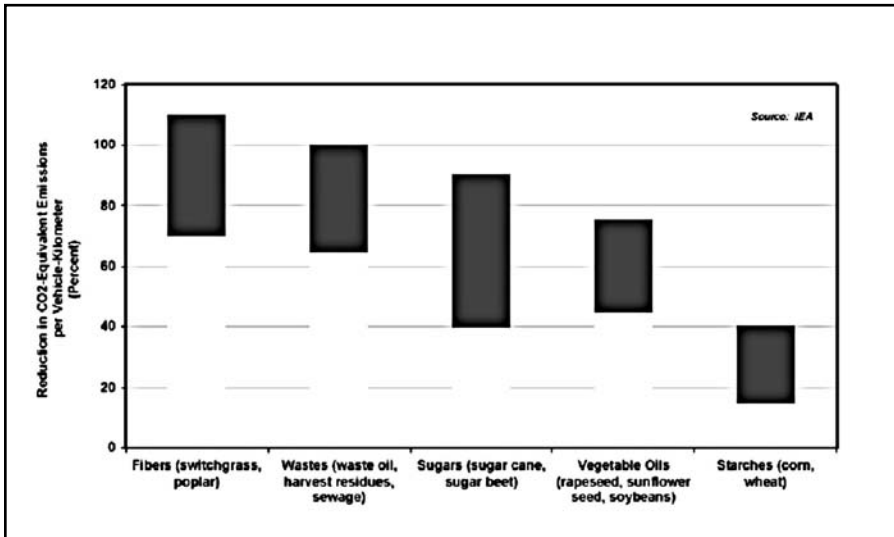


Figure 1. Feedstock impacts on vehicle CO₂ emissions.

SOCIAL RISKS

We adopt a global perspective at the World Watch Institute. Violent conflicts over land, water and other resources are not pressing issues in the United States, but they did occur in Brazil when they started ramping up their ethanol industry, so these concerns are not unfounded.

It is encouraging that there is strong farmer control of the ethanol industry in South Dakota. However, trends towards ownership concentration are apparent in the United States, Brazil and in some other major producing countries. Hopefully there will be conversations on counteracting this development to retain space for family farmers and smaller producers.

The food vs. fuel issue—how increasing prices of food may affect the poor—is one of the issues I am asked about most. It's emotional and complex. The interactions between food markets and fuel markets will be increasingly problematic. No matter where you come down on this issue, people are concerned and it needs to be addressed.

In 2007, the world's population is expected to change from a majority rural population to a majority urban. However, many developing countries will remain agriculturally based. Considering that biofuels are possibly the most powerful force to affect the agricultural sector in many decades, impacts on developing countries will require close monitoring.

ENSURING SUSTAINABILITY

How do we ensure that this industry will be developed responsibly and sustainably? In Germany they are tying tax incentives for biofuel development and adoption to sustainability criteria, and soon biofuels will be required to meet sustainability standards by law. Preferential federal purchasing has been used successfully. In parts of Canada, for example, the government has purchased ethanol from smaller producers in preference to purchasing from larger entities. Governments can focus their R&D on sustainable production methods.

Since 2006, there have been efforts not to put brakes on this industry, but to erect guard rails. An international consensus is building that a certification system is needed to enable consumers to buy sustainably produced fuels. Sustainability standards are being developed in the Netherlands in association with the United Kingdom. The European Union recently passed a 10% biofuels-blending mandate, but they are realizing that sustainability standards must be added.

The Sustainable Biodiesel Alliance—a new nonprofit entity—was recently formed in the United State by Willie Nelson's wife and celebrities involved in the biodiesel industry who wish to ensure that their efforts are causing no environmental harm.

There is an interesting program in Brazil in which incentives are provided to small producers; biodiesel production has become a poverty-alleviation tool. Small families are given a house and a piece of land and if they produce castor bean for a certain period of years and meet quotas, they then assume ownership of the land. And in California they have the low carbon-fuel standard.

The Roundtable on Sustainable Biofuels is an international academic and NGO-led initiative with industry partners, formed as a multi-stakeholder transparent process to develop standards.

EXAMPLES OF PROJECTS IN LATIN AMERICA

Jatropha is a tropical oilseed crop being examined as a feedstock for biodiesel production. It is non-edible and, as it grows well in poor soils, has potential to help with soil reclama-

tion. In Guatemala, small-holder farmers are planting jatropha cuttings on abandoned land and it is used to provide living fencing around rubber plantations.

Empacador Toledo is a large company in Guatemala City that utilizes chicken and pork fat from fast-food producers for biodiesel. They are producing 30,000 gallons/month, to run 200 of their delivery trucks. Rather than having to pay to have the waste disposed of, they are reducing their fuel costs. Aquafinca Saint Peter Fish, SA, Honduras, is the world's largest producer of tilapia. The fatty portion of the fish waste is converted into biodiesel, which supplies their considerable transportation needs.



As an independent consultant, **SUZANNE HUNT** divides her time among the US Department of Energy, the Inter-American Development Bank (IDB) and private sectors clients. She meets regularly with government, industry, and civil society leaders and with members of the media, appearing on CNN International, CNN en Español, MTV, Voice of America and public radio. She speaks frequently before diverse audiences ranging from European Parliamentarians to farm associations. She also gets out into the field as much as possible, and in the spring of 2007 drove an old truck on biodiesel and waste grease from Washington, DC, to Costa Rica—visiting producers and policymakers along the way—as part of the “Greaseball Challenge.” Science magazine featured her as a “Pioneer” in August 2007.

Ms. Hunt has extensive environmental research, policy, education and planning experience. She directed the Worldwatch Institute’s bioenergy program for two years where she coordinated the landmark study, *Biofuels for Transportation: Global Potential and Implications for Energy and Agriculture*. Under her leadership, a team of international experts assessed opportunities and risks of large-scale international development of biofuels. Before joining Worldwatch, she worked at Environmental Defense on social and environmental safeguard policy reform at the International Finance Institutes.

She has a BS in environmental science from Penn State and a dual master’s degree in international affairs and natural resource management from American University and the UN’s University for Peace in Costa Rica.

Biofuels: An Important Part of a Low-Carb Diet

STEVEN BANTZ
Union of Concerned Scientists
Washington, DC

The Union of Concerned Scientists is a science-based organization in DC, Berkeley, CA, and Cambridge, MA, involved in energy and environmental issues. By “low-carb diet” in my title, I mean reducing the carbon intensity of the fuels that we use to address climate change.

Future energy solutions will have to address three main challenges:

- strategic, *e.g.* increasing energy security,
- economic, *i.e.* they will have to be economically feasible and sustainable and promote economic development, and
- be environmentally sound, *i.e.* reducing all forms of energy-related pollution.

I will concentrate on the last, mainly in terms of global-warming pollution.

TRANSPORTATION AND CLIMATE CHANGE

Climate change and global warming are much in the news. The United States is the largest global-warming polluter. Figure 1 shows the carbon emissions due to fossil-fuel combustion for 2003; transportation accounts for about a third, counting only what comes out of the tailpipe. If upstream emissions are included—production of fuel, *etc.*—it’s about 40% of the US global warming pollution. Cars and trucks in the United States, including the upstream emissions, account for about 25% of the total global warming pollution, approximately the same as the entire economies of all other countries combined, except China and Russia.

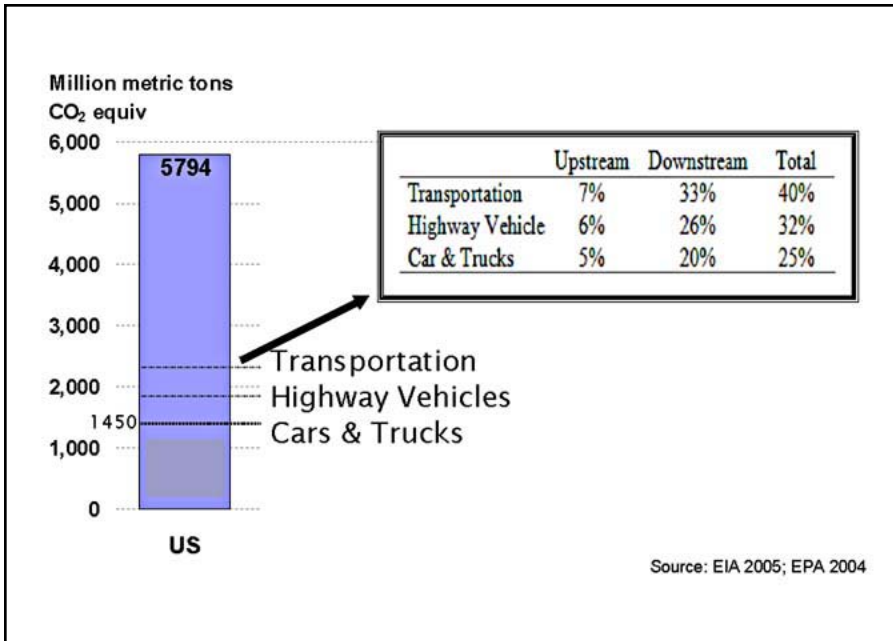


Figure 1. Global-warming pollution from the United States, 2003.

Consumption of petroleum in the United States is expected to increase by about 30% by 2030 and the import gap is growing because domestic production is staying constant (Fig. 2). So, people are looking for opportunities for petroleum replacement, such as extraction of tar sands from Alberta, gasification of coal, and biofuels. More use of electricity for transportation is likely, and possibly, eventually, hydrogen for fuel cells. In examining replacement choices, we need to look at the entire life cycles, including upstream emissions involved in feedstock production.

LIFE-CYCLE CONSIDERATIONS

Figure 3 shows various fuels relative to gasoline in terms of lifecycle global-warming pollution. Broad ranges are shown because aspects of the calculations are uncertain. There is much we need to understand before making choices for the long term. The values for coal liquification (“coal-to-liquid,” CTL) do not include sequestration of carbon; if carbon dioxide is sequestered, then the global-warming pollution will be similar to that for gasoline. Currently there is debate in Congress regarding CTL vs. biofuels relative to the Renewable Fuel Standard. Senators from coal states are pushing to include CTL in the discussion. And in his 2007 state-of-the-union speech, President Bush said that he wants to increase the use of renewable and alternative fuels up to 35 billion gallons by 2017. The term “alternative” includes CTL. Therefore, as we move down this road to

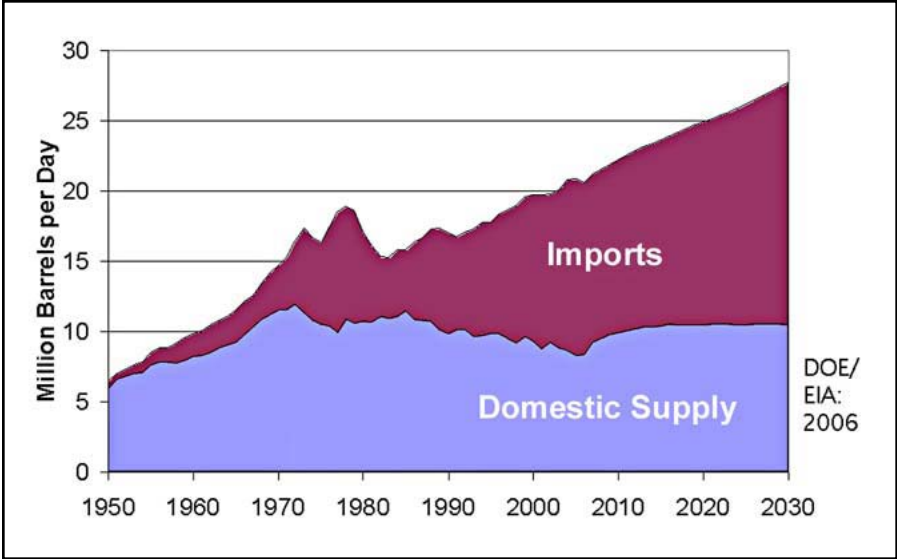


Figure 2. US sources of petroleum

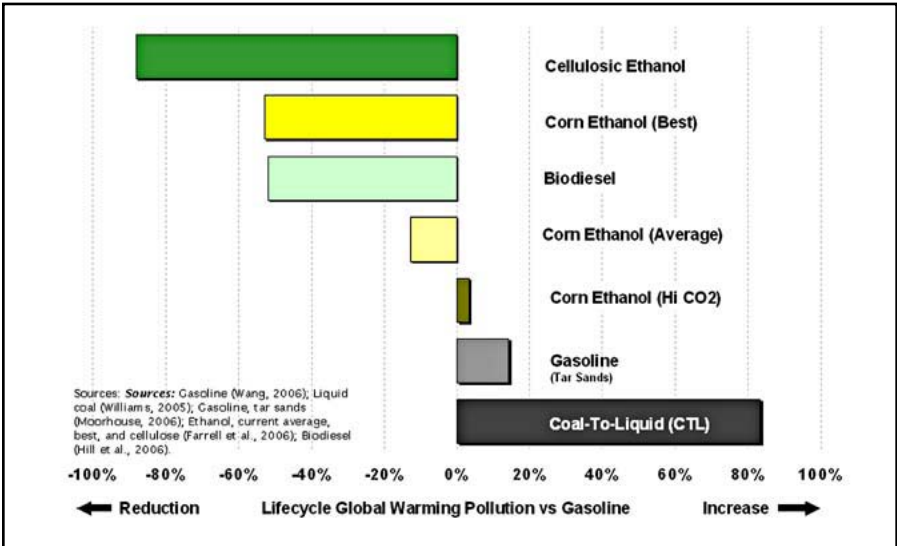


Figure 3. Global warming pollution: renewable and alternative fuels relative to gasoline.

renewable and alternative fuels, we need to evaluate each in terms of the full life cycle, including global-warming impact, because the solutions to our energy needs must meet all three of the highlighted criteria.

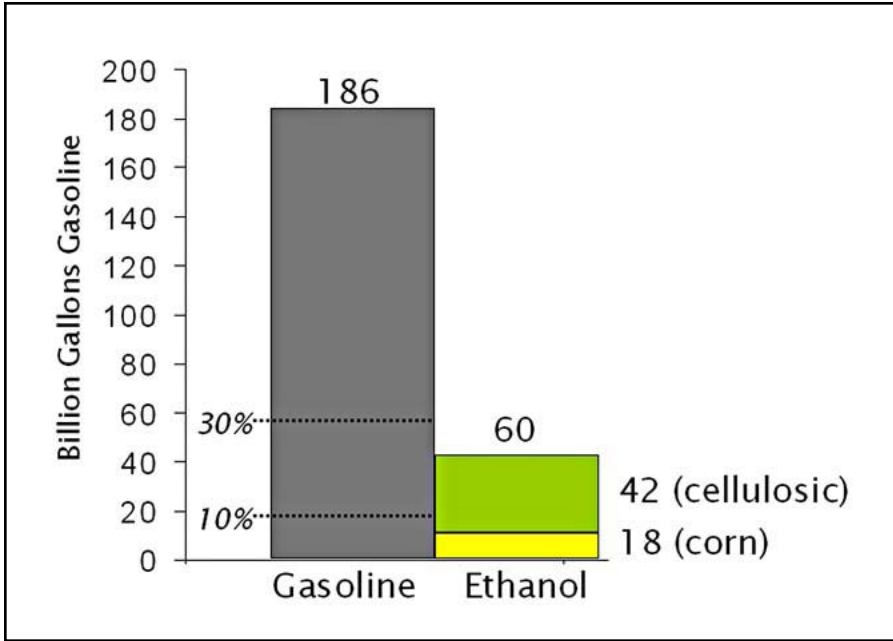


Figure 4. Ethanol production by 2030?

BIOFUEL LIMITATIONS

The amount of petroleum that we can displace with ethanol is limited, as it is for diesel and biodiesel. Right now, the United States is producing about 5 billion gallons of ethanol and consuming about 136 billion gallons of gasoline per year. If we max out ethanol production from corn today, it accounts for about 15% of total crop production. So, complete replacement of gasoline with starch ethanol is not doable. The same is true for biodiesel; all the fats and oils in the United States would displace only about 10% of the diesel usage. Consequently, there is increasing interest in nonfood—non-corn, non-soy—biofuels, including cellulosic ethanol.

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 (Fig. 4). At 60 billion gallons/year, the United States would still be shy of 30% of its projected petroleum needs. Clearly, renewable fuels are not a silver bullet and we have to address our transportation needs comprehensively, including miles per gallon and vehicle miles traveled per year. Figure 5 provides a scenario analysis for business as usual and possible contributions from the three legs of the transportation stool by 2030. If there is a 4%/year mpg improvement, taking into account vehicle-stock turnover, it will provide 35% of the reduction. A reduction of 0.5%/year in vehicle miles traveled amounts to a 6% reduction, and starch and cellulosic ethanol combined may contribute 12%.

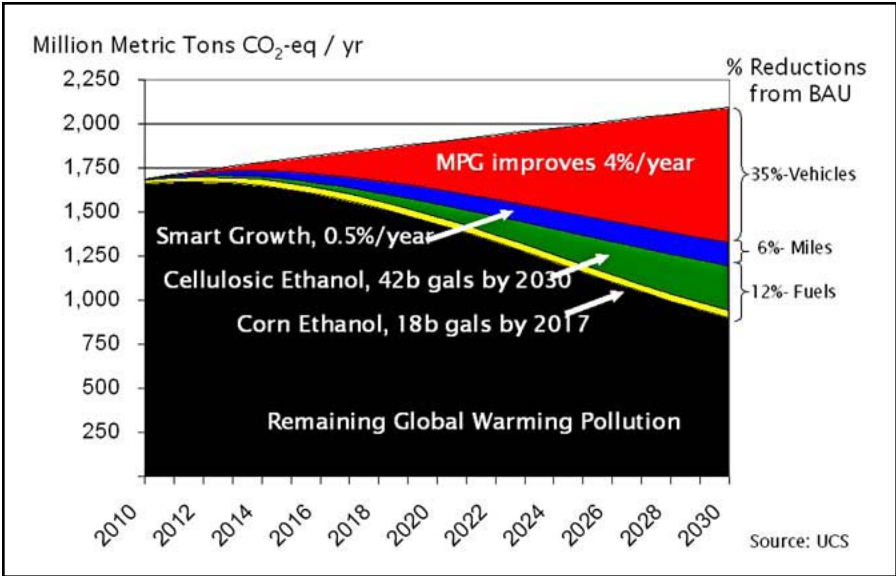


Figure 5. Potential reductions in global-warming pollution (US cars and trucks).

POLICY ISSUES

Congress is considering policy to mandate improvements in corporate average fuel economy (CAFE) standards. California has some bills on the table to provide “febrates,” *i.e.* incentives to purchase fuel-efficient vehicles. Also, California is leading the way in minimizing greenhouse-gas emissions from vehicles, and twelve other states are following suit. From a policy standpoint influencing miles traveled is mostly a local issue, achievable mainly by encouraging mass transit. Tax credits have done much to build the ethanol and biodiesel industries.

The renewable fuel standard, enacted in the 2005 Energy Policy Act, is now somewhat obsolete because it has been overshot by the growth in the renewable fuels industry. California announced in January 2007 that, by 2010, it would set carbon-intensity standards for all of the transportation fuels used in that state. With respect to R&D funding and grants and loan guarantees for deployment of new technologies, in 2007 the DOE announced \$385 million for six cellulosic plants in various parts of the United States as the vanguard for cellulosic ethanol development.

Low-carbon-fuel policies need to focus on minimizing greenhouse-gas emissions, because renewable fuels are not necessarily beneficial for the environment. Such policies will drive the transition towards new and value-added markets. They will provide safeguards against higher carbon alternatives like CTL, and promote diversity of feedstocks and address some of the feedstock-limitation issues. They will minimize other unintended consequences of large-scale production of renewable fuels—*e.g.* by encouraging perennial biomass-crop production—and increase the market size for renewable fuels, which will support the domestic economy and spur global competition.

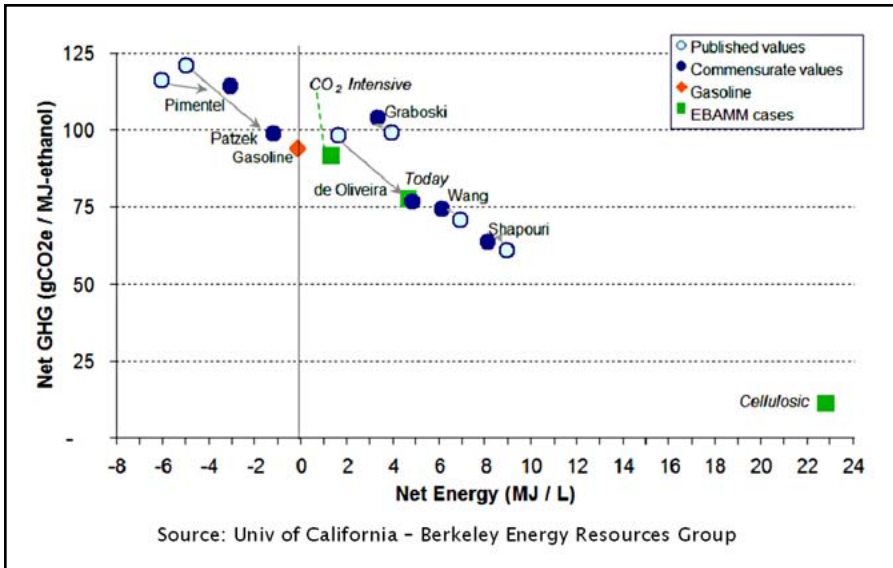


Figure 6. Disagreement on how to count “carbs.”

Life-cycle analyses over the past 10 years have revealed much uncertainty in the data. In 2006, research at UC Berkeley examined six “well to wheel” life-cycle analyses for corn-starch ethanol and revealed contrasting numbers (Figure 6). On the X-axis is the energy loss or gain per unit volume and on the Y-axis is global-warming pollution as grams of CO₂ per unit of energy. Numbers determined by Pimentel and Patzek were on the negative side whereas more recent studies were more positive, but varied widely.

Energy-policy-related decisions are being made based on greenhouse-gas-emission reduction; having sound data is fundamentally important. In May 2007, the EPA announced the launching of a cost-benefit life-cycle analysis of biofuels for the upper Midwest. The best data available relate to the ethanol-production plants. Upstream from that, the numbers are less certain. Corn is being grown in various locations under a range of conditions and farm-management practices. A system is needed whereby these variables are accounted for.

The second bar in Fig. 7 denotes ethanol produced from corn starch at a plant that burns coal; there is no CO₂ advantage over burning gasoline. The third bar represents the current industry average—wet-mill and dry-mill plants using various sources of energy. The fourth bar represents plants now being installed, mostly dry-mill facilities powered by natural gas with a ~30% reduction to gasoline. The energy and emissions profiles are improved if the distillers grains are not dried (Fig. 7, fifth bar); some companies gain this advantage by placing feedlots next to the ethanol plant. With biomass used to power the boilers, the savings may be in excess of 50%.

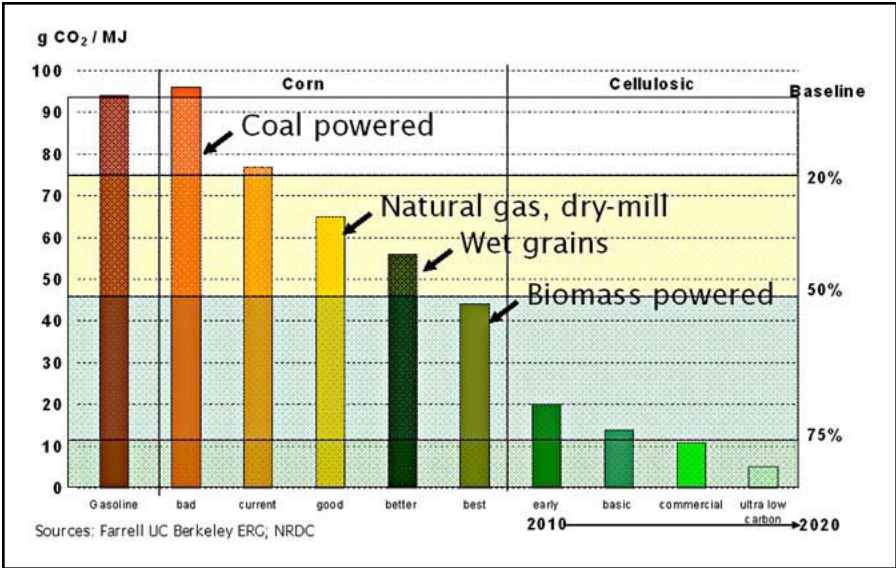


Figure 7. Global-warming impacts of ethanol produced under various conditions.

The reductions vs. the baseline projected for cellulosic ethanol (Fig. 7) are those being considered in Congress with reference to the renewable fuel standard (RFS). In the Bingaman bill, to be “renewable,” the requirement is for 20% below the emissions baseline. The Bingaman bill ramps up from the current RFS, which caps out around 15 billion gallons per year (Fig. 8) from conventional biofuels (from corn starch), and then advanced biofuels (from biomass) make up the difference from ~2016. It is projected to rise to 36 billion gallons by 2022 with 21 billion from what’s classified as advanced biofuels.

National low-carbon-fuel standard bills (from Boxer and Obama-Harkin) are under consideration, fashioned after the California bills. They have two phases for advanced biofuels (Fig. 9). Phase II represents 50% to 75% reduction and phase III is greater than 75% reduction vs. baseline. Therefore, over time, they are ramped up to obtain greater reductions in greenhouse-gas emissions. The line represents the low-carbon fuel standard, considering the total amount of transport fuels used, with an average for greenhouse gas emissions through 2010; the requirements are for a 5% reduction by 2015 and a 10% reduction by 2020. Similarly, the California fuel standard is for a 10% reduction by 2020. This is an aggressive production goal in view of the data presented in Fig. 4.

These bills take into account all forms of energy, not just biofuels. If plug-in hybrid vehicles become available soon, electricity will probably start to play in the mix for lower-carbon transport fuels within 5–10 years. This will complicate the situation in view of the fact that fuel standards today are implemented at the blender level. When a consumer plugs in a vehicle, where is the point of regulation? Despite this complication, this needs to be part of the mix for low-carbon transport energies.

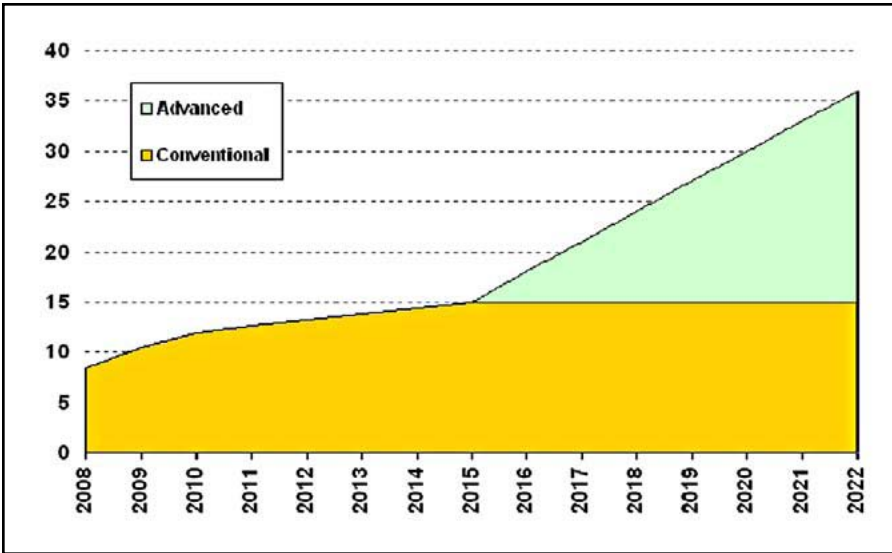


Figure 8. National renewable fuel standard (billions of gallons).

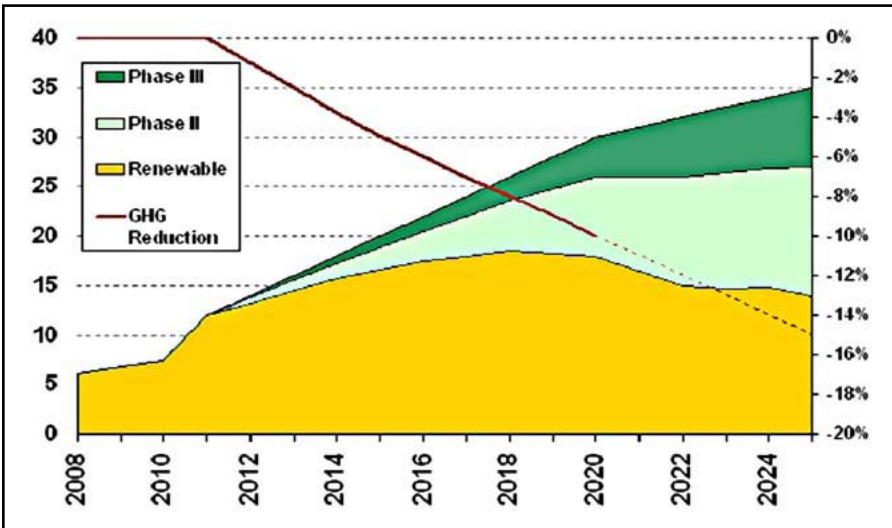


Figure 9. National low-carbon standard bills (billions of gallons).

IN SUMMARY

I've discussed minimizing the global-warming impact of the fuels that we use, their carbon intensity. As I demonstrated, we need to combine expansion of biofuel consumption with improvements in fuel economy and conservation and smart growth to reduce our demand for petroleum. Also, we need to make sure that expansion of biofuel consumption has no adverse effects on public health. We must not backslide on air-quality gains achieved in recent years, and we must promote ecologically sound bio-energy systems. Bio-energy developments will expand economic opportunity, hopefully not just for the ADMs and the Cargills, but for everyone along the supply chain who participates, including farmers in South Dakota as well as in India and Guatemala.



As a senior engineer in the Clean Vehicles Program of the Union of Concerned Scientists (UCS), **STEVEN BANTZ** analyzes and assesses transportation issues with a focus on biomass-based fuels and energy. He advocates for sustainable production and use of bioenergy in conjunction with aggressive increases in energy efficiency, reduced demand through conservation, and reforms in transportation and land-use policies (smart growth) to achieve timely reductions in greenhouse-gas emissions and dependence on fossil fuels.

Before joining UCS in August 2006, Mr. Bantz worked as a process control engineer for eighteen years with DuPont, and later Koch Industries, serving in various roles in operations support, R&D, project development in plant startups in Singapore, Brazil, China, Mexico, and the United States

He holds a bachelor's degrees in electrical engineering from the University of Illinois and in engineering and physics from Illinois College, and is finishing a master's degree in integrated science and technology at James Madison University. For his thesis, Bantz has developed a system-dynamics model to help understand the impacts of limited feedstock availability on the rapid expansion of the biodiesel industry.

Sustainability: Impacts and Issues

Q&A

MODERATOR: JOHN KIRBY
*South Dakota State University
Brookings, SD*

Art Zimiga (Rapid City School District): Throughout America, corn is grown as a staple. If we use it for ethanol, what impact will it have on people who continue to need it as a staple? I ask because this very land that we are on right here was tall grass. To some people that was a burden, but to the Lakota people it had its proper place in a relationship. Western civilization came in and plowed up the land and planted pastures, and pretty soon they overgrazed it and then made farmland. Here we are in the twenty-first century, and my question is: How are you going to include the native peoples' knowledge, not just of the land but of the relationship of the plant kingdom with mankind?

Suzanne Hunt: All of our choices from the energy matrix now in place are highly dependent on policies. The future 10, 20, 30 years depends on the path we choose. If our vision of the future for this area is a return to prairie grasses, with energy from wind and the sun and from biomass, that may be different from the vision that other people have. You could go to policymakers and share your vision and the wisdom of the native people and, thus, influence policy. This next decade is going to be extremely important. We've hit a tipping point in terms of realization that the global climate issue is, indeed, very serious. The gases that, for decades, we've been dumping into the atmosphere in huge quantities are having effects. Combined with oil-security issues and need for rural development in many parts of the world, a perfect storm is in the making. But it takes time to develop new technologies and we are finally seeing significant investment towards achievement of renewable energy systems. The next 10 years will be critical and I am glad that you wish to contribute to the decision-making process.

Brendan Jordan: Native cultures probably have much knowledge of possible value-added medicinal products from plants and how to manage complex agricultural systems like polycultures and prairie ecosystems. There's widespread management of a variety of ecological systems with fire, and we're just starting to understand now how to manage them with a different type of disturbance—biomass removal. I think there is great opportunity to learn from fire-disturbance management to figure out what the differences are from harvest removal. I think there are huge opportunities. Thank you for bringing it up.

William Richards: Renewable energy presents the opportunity to return these prairies to grasses. Our 25×25 study shows that the two most profitable crops by 2025 will be corn and switchgrass, or some other variety of biomass, which are two of the best soil-building crops. With the appropriate technology and policy, we have the opportunity to return these prairies to close to their original condition.

Richard Flavell (Ceres, Inc.): Each of you has been associated with the production of analyses and reports and you've referred to many other reports. Each of you has also talked about what is going on in Congress, so my question is: Are you confident that the decision makers have the right vision? Have they got the right detail? Do they have the right understanding to make the right legislation in the Farm Bill and so on—to make sure this gets off the ground and everybody in the value chain wins?

Hunt: My first reaction would be “no,” just to answer it simply. A few have good staff who are doing their homework, but that's probably the exception rather than the rule. The biofuels industry needs to work with the research community to improve environmental practices and also improve the environmental image because there is a growing backlash. Along with public education there is need for education of decision makers. An election is coming up with Iowa an important state. Everyone will be paying attention. But, do they have the right and the best information on biofuels? A number of groups are starting to realize that in DC, but it definitely needs more effort.

Steven Bantz: I agree that the short answer to the question is “no.” We need more information and we need to learn a lot. Some of the bills before Congress propose that—as we go down this path—impact studies are done to provide the option to, for instance, change the renewable fuels goal. The Environmental Protection Agency announced that they are planning a detailed analysis in the upper Midwest on the impacts of biofuels, which will help. A lot of the reports and studies that we reference come out of academia, and we need federal agencies to step up and work together—the USDA, Environmental Protection Agency and Department of Energy—to develop sustainability criteria, and quantify greenhouse gas impacts of fuels. There are holes in the current data—big holes—for instance, impacts of land-use changes on climate. A lot of the life-cycle analyses of biofuels don't incorporate land-use changes, and we need to figure out the best way to do that. Many people are working with policymakers to put language into legislation to deal with some of these sustainability issues and put a carbon framework in place so we can quantify greenhouse-gas impacts from the choices we make.

Richards: I would be a little more positive. My answer to your question is “not yet.” Congress is a product of the public. Until the public sees the problem, how do we expect Congress to see it? There has been much hype on high prices at the pump and danger of high food prices, but until the lights go dim or there are lines at the gas pump, we probably won't get change. I hope we get it before that.

Jordan: I echo the sentiment that the politicians writing the Farm Bill cannot have better information about this than the society they work for. Probably we all have some kind of Farm Bill position each differing in certain respects, and that's what the politicians are getting. In any case, our elected officials will not let lack of knowledge stop them from doing something. There's going to be a lot in this bill about energy. I think that Bill Richards is right. As a society, we need to figure out what the path forward is and once we achieve a consensus it will be relatively easy for politicians to figure out the right path forward.

Flavell: There's the information dimension, but there's also the time dimension. What can we do to help Congress make decisions in accordance with their own timescales of expectation?

Jordan: There are two ways to look at that issue. There's the actual writing of the Farm Bill but there's also the follow-up, and I'm pretty confident that this bill will have the tools necessary to start getting projects up and running. The best way to respond may be by pooling projects together—using whatever tools are available—to find the answers we need. Anyone else have a better idea?

Hunt: Yes, also give input on timeframes. Politicians love to have bold sound-bite goals like “twenty-five by twenty-five.” But are these realistic, and if they are and if that's where we are going we should put a line in the sand, and at some point we may have to admit that we have serious problems—we need to get to “X” by “Y”—which may require policy changes. Improving information sharing was mentioned. A bio-energy wiki has been created, and is available at www.bioenergywiki.net with information on research in Minnesota, South Dakota, *etc.*, with potential to interact with counterparts at Cornell, Syracuse, *etc.* We have a lot to do to ensure that the right information goes to politicians. It seems that we are talking a lot to ourselves and less to politicians or the public in ways they can understand.

Ralph Hardy (NABC): Mr. Richards, can you expand on your comments on switchgrass and provide targets on tons/acre, cost to produce per ton, *et cetera*?

Richards: That came out of the Tennessee study, projecting corn out to 2025. It was a 198-bushel US average from the technology we have. The slope of the last few years might get us there before 2025. Switchgrass was at \$60/ton and 10 tons/acre, figuring we are going to get some improvement in yield. We need good data on what it will cost to get switchgrass to a client. It didn't assume any breakthrough in gasification or other technology.

Hardy: So, you are projecting a gross of \$600–700/acre from corn and a gross of \$600 from switchgrass. Can you give figures on the cost side?

Richards: We don't really know what the cost of that corn will be. It depends on cost of nitrogen and seed technologies. That was assuming increase in fuel needs over the country. You'll have to read the study as to where they were pegging oil at that time, but I do remember that those two crops stuck out because soybean had dropped off and wheat had dropped way back—cotton was just about holding its own—so those figures were exciting to me as a corn farmer and a conservationist.

Jordan: This isn't directly answering your question and I hesitate to throw too many numbers out there without having my spreadsheets in front of me, but on the perennial side I think a number of potential drivers could improve the economics of those systems. As Bill mentioned, one is inputs. Growing switchgrass or a native grass polyculture requires much less nitrogen. The other potential driver is a climate policy. Already the North Dakota and Minnesota Farmers' Union and Iowa Farm Bureau are starting to aggregate carbon credits and sell them into the Chicago Climate Exchange. As the price of those credits increases—presuming it does—it will tip the scales towards perennial systems that have the capacity to sequester more carbon. I'd be happy to point out specific numbers to you when I have them in front of me and to share with you costs of production, baling, harvesting and transportation.

Audience Member: We've talked about policy as a strong driver and the current political coalition for biofuels is strong, but what looming threats do you see to that coalition 5 or 10 years down the road, and what should we be doing today to ensure that the coalition remains strong for as long as possible?

Richards: Well the threats on our 25×'25 vision are coming real fast from the livestock community. They are quite upset about the corn prices and the feed costs that they now have. I remember way back in school that they taught us that cheap corn brings cheap hogs and *vice-versa*, and if you look at what's happened there's nothing that will cure high prices like high prices. So, these prices will adjust. The best thing that could happen to us is to have a great corn yield this year. We would be a whole lot better off as farmers with \$3–3.20 corn and a good crop than—God forbid—\$5 corn and lose a whole bunch of a market and our future. We're beginning to get quite a push back on our 25×'25 goals because of feed costs and a lot of talk of food costs. However, I'm surprised—the figures that I'm getting from economists indicate that food costs are not going up as much as you might think. So it's going to be an interesting summer, both for production and in terms of what the public learns and feels and does about renewable energy.

Jordan: One potential obstacle—once we've satisfied the nation's blending requirements for ethanol, the price of ethanol is likely to decrease. An analysis from the Center for Agricultural and Rural Development at Iowa State University indicates risk of some plant

failures in the coming years as we satisfy the national blending requirement unless we come up with policy to increase the requirement. Did I get that right?

Richards: As I understand the arithmetic, it takes 7 to 8 billion gallons to satisfy the octane needs—it's almost an automatic market there for us. If we get the 10% blend over the country that will take 15 billion gallons, about 15 billion bushels of corn. We'll probably reach that 15 billion bushel corn crop by 2015. In fact, as a corn farmer, I look at the improvements in yield and our crops even in problem years and wonder what we would do without ethanol. The potential—it's so exciting. In the Iowa study, they used base numbers of \$3, \$3.20 for corn, and assumed the price of oil at about where it is. Hey—raise the price of oil and everything goes up, including the energy that it takes to haul food to our tables. I don't want to say the study was unfair, but the reporting of it really bothered us.

Bantz: It addresses the supply side—renewable energy from biofuels and other types of energy—and seriously addresses the demand side: vehicle efficiency, and efficiency of our homes and businesses. We won't dig ourselves out of this hole unless we seriously address the demand side.

Hunt: Part of the push back could come from public opinion. The media want things that are simple, and they want things that are dramatic. They love negative stories too. I've been getting more and more calls on negative aspects of biofuels: are they going to make people starve? We don't want to see Bono doing charity concerts for the starving in Africa because of biofuels. I don't think I can stress this enough. We need to make sure that we don't lose people who might be supportive. Renewable energy, including sustainable biofuels, needs to become part of our culture. Much like smoking was the sexiest thing to do in the 1950s, whereas now you're basically a social outcast if you smoke—I'm hoping that the current energy system will go the same way, that 20 years from now no one will think of putting gasoline in their car. It has to be a cultural shift.

Carol Hanley (University of Kentucky): One of the things I've heard a lot of you talk about is changing public opinion and public awareness and your media events and getting information transfer. I'm here because we do a lot of professional development for teachers and we work directly with students, and that is an effective way to get information to the places where it can do the most good. In my profession, I don't see a lot with biofuels programs for teachers or students yet. We see little tiny pieces. In Lexington, KY, we are trying to initiate a program of community-based science for students and teachers, and you've given me so many ideas. If anybody would like to help me write or fund a proposal, or go in together on a proposal—I'm serious. You all know how effective it is to increase public awareness and knowledge via the legislature, but going through teachers and children is also effective way to do it, and I'm willing to work with anybody who is willing to work with me.

William Gibbons (South Dakota State University): I'll just add to that—one of the things that we are trying to do is get students involved in this industry because the industry needs the workers.

Audience Member: If the biofuels industry takes off, does it mean the end of the petroleum industry? Will they compete or work in synchrony? Can the biofuels industry reach everyone who is accessible to the petroleum industry?

Hunt: Never underestimate the power and resources of the oil industry. Exxon is now the most profitable company in history. BP just invested \$500 million in research on advanced biofuels. Shell has invested quite a bit of money. We are starting to see huge investments. And they can hire the best talent and they have the best resources, including the best lobbying resources. I think you will see them do what the car industry did with electric vehicles, for example, when California passed its no emission vehicle law they took a two-pronged approach. They developed an electric vehicle, in case they would need it, and they fought the law. The oil industry is going to fight biofuels on one side, and quietly invest in it. When it becomes more beneficial financially to make money from biofuels they can switch over. I think they are going to win no matter what.

Jordan: The oil companies will be fine. Don't worry.

Bantz: They won't go away soon. We will be blending biofuels with petroleum products for quite a while. But I do want to add to an earlier question. Al Gore and others have helped to educate people, influencing the discourse on climate change. States like California are establishing comprehensive climate-change policies, which is needed at the federal level. And people are now working on this at the federal level. Whether new policies will be enacted this session or not, nobody knows. But this will drive a lot of what happens in the energy industry in the next decade.

Haluk Gedikoglu (University of Missouri): Gasoline prices in the United States are still much lower than in other countries. I don't see any incentive for consumers to decrease their fuel consumption or for automakers to create more efficient cars. In Europe, taxes are based on the size of the engine, so there is a demand for more-efficient vehicles. Do you think we will see policies that encourage consumer awareness?

Bantz: No politician wants to suggest a carbon tax or a tax on fossil-fuel usage because increasing taxes is so unpopular in this country. You are exactly right: as gas prices increase, eventually consumption decreases, but not nearly enough. Fuel-efficiency mandates will be needed to obtain improved fuel economy in a timely manner.

Richards: Until the public starts backing away at the gas pump, they are not getting the economic signal that it's a problem. Are the automakers getting the signal? Well, we hear that they are not doing so well. I traded my 2001 car for the 2006 equivalent—same

make, same everything—and the mileage went down by 5 mpg. We've got to change this. Detroit has to get the message that mileage and efficiency matter. But will they? We are using more fuel than when prices were cheaper, so the economic signal isn't there.

Bantz: The big three like to say that they are participating in helping to lower greenhouse-gas emissions by producing more flex-fuel vehicles, but if you look at the flex-fuel vehicles that are on the market, most of them are large fuel-guzzlers. Also, they are getting a CAFE credit for producing those flex-fuel vehicles, which ends up making us consume more petroleum over all. The automakers need to stop pointing fingers at other people because they are a big part of the solution. However, they are also very strong in Washington as are the oil companies. It's not an easy battle, but we as consumers need to demand more choices when we walk into the showroom, for example a flex-fuel vehicle that gets 40 mpg.

Hunt: The 1981 Volkswagen Rabbit pick-up that I drove on a recent trip through Central America got 40 mpg from biodiesel. Henry Ford would say, "Well, this looks about the same as when I left." If you consider advances in sound technology and medicine, if this were really a priority we could get there. We could double the efficiency of the American fleet if we just had the average mpg in Europe. On one hand we need to use our consumer pressure and on the other hand policymakers need to put the policies in place. The car companies are always saying, "Consumers aren't asking for this. They want sexier, faster cars." Henry Ford is quoted as saying, "If I had asked consumers what they wanted they would have said 'faster horses.'" We need to be smarter, and we should be thinking more about what we need and less about what consumers want.

Turning Biomass Crops for Biofuels into Commercial Reality <i>Richard B. Flavell</i>	79
Breeding, Selection and Testing of Shrub Willow as a Dedicated Energy Crop <i>Lawrence B. Smart, Kimberly D. Cameron, Timothy A. Volk & Lawrence P. Abrahamson</i>	85
Challenges on the Road to Biofuels <i>William R. Gibbons</i>	93
Ethanol Processing Co-Products: Economics, Impacts, Sustainability <i>Kurt A. Rosentrater</i>	105
Energy-Crop Gasification <i>R. Mark Bricka</i>	127
Butanol: The Other Alternative Fuel <i>David E. Ramey</i>	137
Q&A	149

Turning Biomass Crops for Biofuels into Commercial Reality

RICHARD B. FLAVELL

Ceres, Inc.

Thousand Oaks, CA

It is now becoming recognized that, in spite of the huge success of converting corn starch into ethanol by its cleavage to sugars followed by fermentation to ethanol, this cannot satisfy the challenges set by the US government to produce 35 billion gallons of biofuels per year by 2017. Instead, the growing of dedicated energy crops and converting their cellulose and hemicellulose to ethanol, or the equivalent, is a more attractive and essential approach. It can produce a much higher ratio of energy output to input than making ethanol from corn. It also avoids the fuel versus food and feed arguments that are being debated at present. Cellulose-derived biofuels are essential to meet the targets set by the US government and aid in the reduction of the rate of increase of CO₂ production in the atmosphere.

The production of biofuels from cellulosic biomass requires a new industry to be born. It requires the production of feedstocks of high-yielding plants, their harvesting, storage and transport to biorefineries. Here they are subjected to thermochemical conversion or treatment to make the cellulose and hemicellulose accessible to degradative enzyme cocktails, incubation with the enzymes or organisms capable of breaking down the polymers to sugars and then fermentation to ethanol or some similar molecule. These industrial chains have to be integrated in specific localities under conditions where each industrial contributor gets enough reward out of the value chain. Because of the complexities in achieving this, many factors have to be put in place ranging from the technical to the political. My contribution to this meeting focuses on what is needed for dedicated energy crops to be developed and available for biofuels production. This is also the focus of Ceres, “The Energy Crop Company” dedicated to energy-crop production.

DEDICATED ENERGY CROPS

There is much discussion about which crop species are likely to be the most efficient at producing large quantities of biomass sustainably with minimal inputs. These crops need to be capable of generating high biomass on a sustainable basis, have a high ratio of

energy output to input, and high proportions of constituent materials that are suited to the downstream processes of conversion to biofuels. Amongst the favorites in the United States are perennials such as switchgrass, miscanthus and sugar cane because their biomass can be harvested year on year from the same root stock; it is not necessary to use fuel to plant them each year. Switchgrass is a native grass that has covered the US prairies. Many different forms are readily available and the US Departments of Energy and Agriculture (DOE and USDA) have had small research programs to evaluate it for biomass production for many years. Miscanthus, on the other hand, is native to Asia, covering temperate to tropical areas. Sugar cane is adapted to the tropics and over-winters only in the extreme south of the United States. All these species, like corn, are C4 grasses; they make higher biomass per unit of light energy absorbed than most flowering plants. They also have a higher water-use efficiency than most plants. The perennial species also have the valuable property of moving their excess nitrogen and other nutrients back down into the roots upon senescence at the end of the growing season, ready for use again in the spring when growth is reinitiated. This means that valuable nutrients like nitrogen fertilizers, which are very energy expensive to make, are conserved in comparison with annual crop-production systems.

Switchgrass and miscanthus have not received much or any attention from breeders and thus are not optimized for large-scale agriculture and the needs for efficient-energy production. Yet the economics of biofuels production from them is critically dependent on the biomass yield and the efficiency of conversion of the cell-wall materials in the biomass to biofuels. This is because the harvesting and transport costs are some 50% of the cost of the feedstock at the biorefinery gate and these costs are heavily influenced by the distances tractors have to go to harvest the fields and the trucks have to go to transport the harvested materials to the biorefinery. Furthermore, current varieties of these species have not been optimized to achieve the required high biomass under the range of environments that will be necessary for such extensive production of biofuels. Therefore plant breeding is essential to realize the government's goals.

PLANT BREEDING TO IMPROVE DEDICATED ENERGY CROPS

What does it take to breed improved varieties of the key biomass crops such that farmers and biorefinery owners can have confidence that the economics of the feedstock production make sense, given the price of oil, *etc.*?

First, there is the need to assemble a comprehensive collection of germplasm that has a large number of variants of the genes in the species and combinations of the variants that program the ability of the species to survive and produce high yields under a range of conditions. These genes and combinations of genes have been assembled by natural selection. In switchgrass there are two broad types—lowland and upland—that are adapted to southerly and more northerly conditions. These, for the most part, have different numbers of chromosomes and so are relatively distinct. Having a selection of the gene variants in both types is essential to be able to make new combinations via breeding that result in the crops being adapted to the range of environments required. For miscanthus it means getting the germplasm from foreign parts such as Asia. Here one must allow

for the conditions laid down by the Convention of Biological Diversity, which ensures that host countries agree to the commercial exploitation of the germplasm and get some return if it is used commercially elsewhere.

Second, one needs an aggressive plant-breeding program. Plant breeding—making new combinations of genes by combining pollen and eggs from different parents and selecting improved plants—is usually a time-consuming process and requires screening of a large number of progeny and sometimes many generations of further crossing and selection. The selection necessarily needs to be done in the diverse environments relevant to where optimized production is required. This is why plant breeding, while brilliantly successful over long time periods, is usually a slow process when judged against the urgent needs of the farmer and processor for rapid improvements. Faster genetic gains can often be obtained by making hybrids between distantly related parents because the genetic deficiencies of one parent can be made up for by the other parent and the combinations of the dissimilar genes often results in improved vigor where the hybrid is better than either parent. Sugar cane and the highest yielding miscanthus are such hybrids. Switchgrass is a natural hybrid.

What traits commonly need to be optimized?

Biomass yield, tons per unit of land, is the number-one trait to be increased for the reasons described above. To gain the most biomass, plants need to grow as long as possible. This means an early start and growing well until frost or harvest time. If seeds need to be got from the crop, then flowering should be late but not too late for good seed set and ripening. If seed is not required, such as in the biomass production fields, then flowering can be as late as possible to allow more biomass to accumulate. Flowering is often conditioned by daylength/latitude and/or temperature. There are well known genes that determine flowering time so there is the opportunity to select plants that have the right combinations of genes to program flowering for different regions.

Other agronomic traits to be optimized are likely to be drought tolerance, nutrient use efficiency, root growth, disease tolerance, as well as all the architectural features that determine the features of the plant that result in high biomass and ease of harvesting.

Another key trait to provide the maximum yield of gallons of biofuel per unit of land is average cell-wall composition and structure. Cellulose and hemicellulose reside in cell-wall complexes that often prevent easy degradation in the biochemical conversion processes. Lignin complexes have evolved in certain cell walls to provide strength and other properties. Lignin provides more energy upon burning, but inhibits biochemical degradation of cellulose and thus it is desirable to optimize both the amounts and structure of lignin in cell walls to optimize the yield of biofuel per ton harvested.

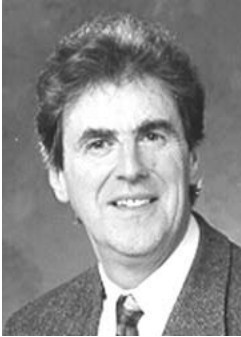
The inhibitory effects of lignin increase the costs of the biochemical process considerably and demand more complex biorefinery construction. Thus assays for energy release and ease of sugar production and fermentation need to be coupled to the plant-breeding and selection processes.

The challenge to produce rapidly high biomass crops with optimum composition to cover the range of environments required is huge. Plant improvement and testing is a relatively slow process. However, today the use of molecular markers of short chromo-

some segments carrying genes of known function offers the opportunity to speed up the selection of improved types. To achieve this requires knowledge of the DNA sequences in the chromosomes of the species, the positions of genes that program desirable traits, and the genetic linkage between variant DNA sequences and preferred versions of genes. Then the DNA markers that signify the preferred genes and gene combinations can be used to monitor the presence of the preferred genes and select the preferred types, without needing to assay the properties of the growing plant so intensively. This can save time and money. Without exploitation of this approach on a large scale, the development of improved plants will be delayed, with substantial consequences for achieving the government's goals. Certain genes conferring valuable properties can be added to a crop as transgenes to speed up plant improvement in ways that are difficult to achieve otherwise. Ceres has amassed a large number of such genes ready for application in dedicated energy crops as breeding programs evolve.

CERES: "THE ENERGY CROP COMPANY"

Ceres is a specialist biotechnology and plant-breeding company committed to providing dedicated energy crops for the biofuels industry, across a range of environments where biorefineries will be built. It is assembling large collections of germplasm for the relevant crops and has established partnerships with other major plant-breeding organizations to develop better crops rapidly. It has in-licensed improved varieties and is bulking up high-quality seed ready for sale to the industry in 2009. This will coincide with the building of the first biorefineries and will provide crops for them to start producing biofuels in 2010. To establish which varieties best suit which environments, Ceres and partners have established many field trials in strategic locations, the results from which will emerge and continue over the coming years. Ceres has established the means of measuring and genetically changing optimum cell-wall composition for dedicated energy crops. It is also linking with biorefineries and other laboratories to evaluate the efficiency of various genetic strains of harvested materials in the various industrial conversion processes. It is deploying molecular markers to build the most efficient breeding processes for these dedicated energy crops and so meet the challenges to supply high-yielding biomass crops where and when they are required.



RICHARD FLAVELL joined Ceres in 1998. From 1987 to 1998, he was the director of the John Innes Centre in Norwich, England, a premier plant and microbial research institute. He has published over 190 scientific articles, lectured widely and contributed significantly to the development of modern biotechnology in agriculture. His research group in the United Kingdom was among the very first worldwide to successfully clone plant DNA, isolate and sequence plant genes, and produce transgenic plants.

Dr. Flavell is an expert in cereal plant genomics, having produced the first molecular maps of plant chromosomes to reveal the constituent sequences. He has been a leader in European plant biotechnology initiating and guiding a pan-European organization to manage large EU plant biotechnology research programs more effectively. In 1999, he was named a Commander of the British Empire for his contributions to plant and microbial sciences.

Flavell received his PhD from the University of East Anglia and is a fellow of EMBO and of the Royal Society of London. He is an adjunct professor in the Department of Molecular, Cellular and Developmental Biology at the University of California-Los Angeles.

Breeding, Selection and Testing of Shrub Willow as a Dedicated Energy Crop

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Multiple national imperatives are driving a switch from fossil-based energy sources to renewable energy, including:

- efforts to reduce carbon emissions and slow climate change,
- a push to improve homeland security by reducing reliance on foreign sources of petroleum,
- a desire to stimulate the rural agricultural and forest-based economies, and
- the need to transition from limited fossil fuel resources to sustainable and environmentally benign sources of energy.

Two important components of the portfolio of renewable energy solutions are the conversion of plant biomass to liquid transportation fuels and the production of combined heat and power (CHP) from sustainably produced biomass. Both of these can address the major national imperatives if the production, consolidation and conversion of biomass to either liquid fuel or combined heat and power are accomplished in ways that have highly favorable net returns on energy investment. The production of liquid transportation fuels, such as ethanol, from biomass will provide a transition fuel compatible with much of the current infrastructure and personal vehicle fleet in North America. The use of biomass to produce renewable power can also contribute to reducing reliance on petroleum-based transportation fuels, once plug-in hybrid and electric cars become widely commercially available.

Perennial energy crops will be a major component of overall biomass resources, but there has been little breeding to improve bioenergy traits.

BIOMASS FEEDSTOCKS FROM PERENNIAL ENERGY CROPS

In considering available and possible biomass feedstocks that could be utilized for the production of biofuels or CHP, there is the potential to collect large amounts of residues

from agricultural and forestry sources, as well as low-value biomass from forests (Perlack *et al.*, 2005). However, in order to ensure a long-term and sustainable supply of biomass, there is a need to develop and deploy perennial energy crops on marginal agricultural land specifically to produce biomass for renewable energy projects. These systems would generate multiple societal benefits in addition to producing biomass as a feedstock for fuels and power. Initial research has identified several perennial crops with potential for regional deployment as an energy crop, including a number of perennial grasses, hybrid poplar and shrub willows. Once established, perennial grasses or woody crops can be harvested multiple times over the life of a planting, with relatively low inputs on an annual basis. These plants also tend to accumulate carbon belowground over time and can provide valuable wildlife habitat, while diversifying the agricultural landscape (Volk *et al.*, 2004). 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 (Mann and Spath, 1997; Heller *et al.*, 2004).

SHRUB WILLOW AS A DEDICATED ENERGY CROP

Shrub willow has been developed as a dedicated energy crop since the mid-1970s, when researchers in Sweden (Christersson *et al.*, 1993), and not long after in Canada and the United Kingdom, recognized the potential of this fast-growing plant that vigorously re-sprouts the spring after the stem biomass is harvested (coppiced). Willow typically breaks bud very early in the season and can have a high leaf-area index, thus can be very efficient in capturing available seasonal irradiation. Although willow species are often found in wetlands, along creeks, and in other flooded habitats and can tolerate poorly drained soils, they can also thrive in upland fields and grow very fast in moderately well drained soils that receive regular rainfall (Newsholme, 1992). In this respect, shrub willows can be planted on otherwise marginal agricultural soils that do not support high yields of corn or soybean due to poor drainage conditions, limited fertility, or regular spring flooding.

Willow is planted by pushing a section of dormant 1-year-old stem into the soil of a properly tilled field, after which it will produce roots and the dormant buds will emerge to form new stems. Willow fields are planted in a double-row arrangement at ~15,000 plants per hectare (ha^{-1}), with 0.76 m between rows, 0.61 m between plants in a row, and 1.52 m spacing between double rows to allow clearance for cultivation and harvesting machinery. Planting can be accomplished using a four- or six-row planter attachment to a tractor, which accepts >2 m-long whips and cuts them into 20-cm sections (cuttings). Pre-emergent herbicides are applied soon after planting to control weeds (Kopp *et al.*, 1992), which is critical for successful plantation establishment. Fall site preparation and planting of a winter cover crop are advisable on soils with a higher soil erosion potential (Volk, 2002). If weeds do become problematic, especially in the first 2 years, mechanical cultivation can be applied between the rows. At the end of the establishment year, plants are typically coppiced, which stimulates new growth the following spring. From that point on, the plants are harvested every 3 or 4 years for seven or more rotations. Harvesting can be accomplished using a self-propelled forage harvester equipped with a specialized or modified cutter head capable of sawing the stems just above the soil and

feeding them into the harvester, which delivers wood chips—uniformly 5 cm or less in size—to a wagon or truck. The window for harvesting opens immediately after senescence and leaf fall, and continues until bud break in the spring, which allows nutrients to be recycled to the root system and may be done when the ground is frozen to reduce soil compaction and rutting. Chips are trucked to the fuel yard of the power plant and are piled for storage and moderate drying before conversion by combustion or gasification. Typically, a modest amount of slow-release fertilizer (100 kg N ha⁻¹) is added in the spring after each harvest (Adegbidi *et al.*, 2003).

GENETIC IMPROVEMENT OF SHRUB WILLOW AND SELECTION OF VARIETIES FOR BIOENERGY TRAITS

Early commercial-scale demonstration of shrub willow bioenergy crops in the United States relied on varieties developed in the breeding program of Louis Zsuffa at the University of Toronto that had been tested in trials at SUNY-ESF. Many of these varieties were F₁ progeny of crosses of *Salix eriocephala*, and a number of these were moderately or severely susceptible to *Melampsora* spp. rust. Varieties developed in Sweden (Larsson, 2001), and deployed commercially by Svalöf Weibull AB (now Lantmännen Agroenergi), were tested in New York and quickly found to be susceptible to damage by potato leaf hopper (R.F. Kopp and L.P. Abrahamson, unpublished). Thus, in order to develop new varieties with improved yield and to support the long-term deployment of shrub willow crops in North America, SUNY-ESF initiated a willow-breeding program in the mid-1990s. Since 1994, a diverse collection of more than 700 willow accessions, representing over twenty species and hybrids, has been assembled through collection of naturally established plants in the wild or disturbed environments, contributions of naturally collected or bred germplasm from United States and overseas collaborators, and from the purchase of varieties available from commercial nurseries (Smart *et al.*, 2005). Techniques for the collection of pollen and for mechanical pollination were developed and adapted for the species in the breeding program (Kopp *et al.*, 2002). Since 1998, researchers at SUNY-ESF have produced approximately 200 families from more than 575 attempted controlled pollinations.

Selection and testing of clones has been accomplished through three levels of field trials:

- family screening trials,
- selection trials, and
- regional yield trials.

Crosses were completed in 1998 and a family screening trial was established in the field at LaFayette Road Experiment Station in Syracuse, NY, but due to a facilities-management decision, this trial was removed in 1999 and selections were made based only on preliminary growth evaluations. Thirty individuals were selected and propagated in nursery beds for 2 years to generate sufficient cuttings to establish a replicated selection trial in 2001 consisting of sixteen of those clones, as well as four individuals collected from natural stands, and five reference varieties, some of which were used as parents in the 1998 crosses. Crosses completed in 1999 produced forty-six families that were evaluated in a

family screening trial in the field at LaFayette Road Experiment Station. More than 2,000 seedlings were planted in linear plots by family with 0.3-m spacing between plants and 1 m between rows. The seedlings were coppiced after the first season and then stem height, number of stems, and diameters were measured after two seasons of growth. Based on those measurements, four families were chosen as having superior overall family performance and the top fifteen individuals were selected from each family. A total of twenty-two other exceptional individuals were selected from eight other families. Cuttings were made from these plants for the establishment of a replicated selection trial in 2002.

The 2001 selection trial was planted at the Tully Genetics Field Station in Tully, NY, using dormant 25-cm cuttings in typical production spacing. Each plot contained forty plants (twenty plants per row with one double-row per plot) and was replicated in three completely randomized blocks. These plants were coppiced at the end of the first growing season, then were subsequently harvested after three growing seasons post-coppice (end of 2004). The innermost twenty plants per plot were weighed and subsamples were collected and dried to determine moisture content, so that total dry biomass could be calculated per plot. Based on these first-rotation harvests, nine of sixteen clones produced through breeding yielded greater mean biomass than the reference variety *S. dasyclados* 'SV1', which had a mean yield of 7.4 oven-dry tons (odt) ha⁻¹ yr⁻¹ (Fig. 1). The top variety in this trial after one harvest rotation was *S. miyabeana* 'SX64', with mean yield of 11.3 odt ha⁻¹ yr⁻¹, 53% higher than that of 'SV1'.

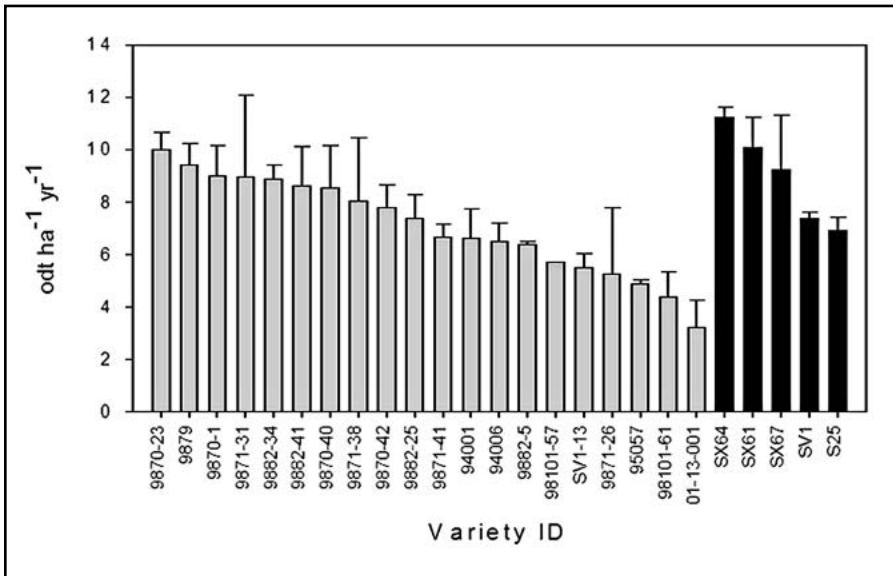


Figure 1. Mean first-rotation production of varieties tested in the 2001 genetic selection trial at Tully, NY. Grey bars (\pm standard error) represent varieties produced through controlled breeding or collected from naturally established stands. Black bars represent current production varieties for reference.

The 2002 selection trial was planted at the Tully Genetics Field Station using rooted 12- to 17-cm cuttings in four-plant row plots with 0.6 m between plants in a row and 0.9 m between rows ($\sim 18,500$ plants ha^{-1}). Each four-plant plot was replicated in eight completely randomized blocks, each of which contained eighty-two new clones and four reference varieties. Some plots suffered mortality soon after planting, most likely due to exposure and sensitivity of the roots to herbicide that had been applied at planting time, since there has been little further mortality after year 1. These plants were coppiced at the end of the first growing season, then stem height, number, and diameters of the inner two plants per plot were measured at the end of the first growing season post-coppice (end of 2003). Based on calculations of total stem area per plant after one growing season, sixty-nine of eighty-two new varieties produced greater total stem area per plant than the reference variety 'SV1' (Fig. 2). The mean total stem area of the top clone (99202-011) was 114% greater than that of 'SV1'. Based on these measurements, cuttings were made from 1-year-old stems of forty-two of the original family screening trial plants and planted in nursery beds to scale-up for future trials. First-rotation harvest of the 2002 selection trial was completed after the second growing season post-coppice (end of 2004) and a second harvest was done 2 years later (end of 2006). To obtain an estimate of growth potential and account for the anomalous establishment mortality, measurements of plots with less than three living plants were removed from the data set. A modest amount of fertilizer (100 kg N ha^{-1}) was applied in the spring after the first harvest. Based on yields from each harvest, twenty-four of the new clones and variety 'SX64' produced greater dry biomass than reference variety 'SV1', which produced $11.9 \text{ odt ha}^{-1} \text{ yr}^{-1}$ in the second

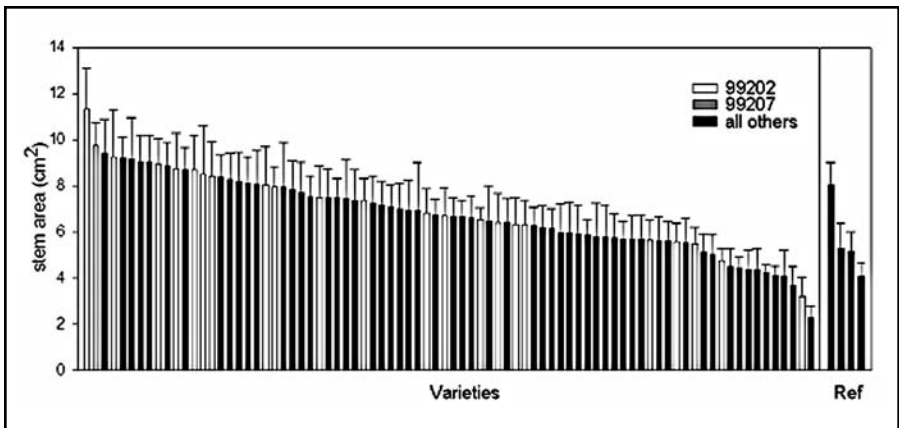


Figure 2. Mean stem area per plant (\pm standard error) of varieties tested in the 2002 genetic selection trial, Tully, NY. Stems larger than 3 mm were measured at a height of 30 cm at the end of the first growing season post-coppice. The four bars on the right represent current production varieties for reference. Open bars represent siblings in family 99202, grey bars siblings in family 99207, and black bars members of several other families.

2-year harvest rotation of this trial. The top clone (99202-011) produced a mean biomass yield of 21.9 odt ha⁻¹ yr⁻¹ in these small experimental plots. Overall mean yields increased 6.2% from first harvest to second, and sixty of the eighty-six clones in the trial produced greater yields in the second rotation. Although these yields are impressive, they were produced in very small plots on a single site. To test the potential yield in commercial-style plantings and plasticity to varying site conditions, it is necessary to test these clones at many varied sites in larger plantings.

Prior to large-scale commercial deployment, the best estimate of variety responses to regional environmental differences and soil types is determined through replicated yield trials with multiple varieties planted in commercial-style spacing. Based on measurements and harvest yields from the 2001 and 2002 selection trials, varieties were selected to be planted in yield trials that were established in Belleville and Tully, NY, in 2005. These trials contain fourteen new varieties and four reference varieties planted by hand with 25-cm dormant cuttings in seventy-eight-plant plots arranged in three double-rows that each have thirteen plants per row. Each trial contains four complete randomized blocks, for a total of 312 plants per variety and 5,616 plants overall. These trials were coppiced at the end of the establishment-year growing season (end of 2005). At the end of the 2006 growing season (first-year post-coppice), stem diameters, number, and height of the tallest stem were measured for the inner eighteen plants of the middle double-row. Together, stem diameter and stem number are reliable predictors of biomass yield, but they do not account for differential biomass density and second- and third-season differences in growth among varieties (Tharakan *et al.*, 2001, 2005). Comparisons of the first-year post-coppice stem-area measurements of these two trials highlight the potential for genotype-by-site interactions. Among the reference varieties, *S. sachalinensis* 'SX61' produced the greatest mean stem area per plot and *S. miyabeana* 'SX64' was ranked 4th at Tully, while 'SX61' was ranked 13th and 'SX64' was 18th in the Belleville trial. In contrast, reference variety *S. eriocephala* 'S25' was ranked 14th and *S. dasyclados* 'SV1' was 16th at Tully, but 'S25' was 4th and 'SV1' was 2nd at Belleville. Among the new varieties, the mean stem area per plant for 99239-015 and 9871-31 were significantly greater than that of reference variety 'SV1' over both sites combined. At least with respect to total stem area per plant measured in these trials, the current production varieties 'SV1,' 'S25,' 'SX61,' and 'SX64' display site-specific patterns of growth productivity. A positive outcome of this testing will be to identify new varieties that display high yield and greater plasticity to site and environment conditions, so that growers need not be overly concerned about matching specific varieties to particular combinations of site characteristics.

One of the major bottlenecks to widespread commercial deployment of new perennial energy crops is the scale-up of high-quality planting stock, whether it is seed lots of switchgrass, rhizomes of *Miscanthus x giganteus*, or whips of shrub willow. Considering the urgency of the need to dramatically expand acreage planted with energy crops to meet national goals, the selection and propagation of improved varieties must occur as soon as possible. To begin to break this bottleneck, SUNY-ESF and the Research Foundation of SUNY have licensed shrub-willow varieties developed through research at the College to Double A Vineyards dba Double A Willow (www.DoubleAWillow.com) for production

and commercial sale of willow planting stock (whips, stakes and cuttings). Since willow stems have very weak maintenance of bud dormancy, it is critical to store dormant stems frozen at -2 to -4°C , which requires capital investment in large volumes of storage freezer capacity at any shrub willow nursery. With funding from the New York State Energy Research and Development Authority, Double A Willow has installed storage freezers capable of holding approximately 10 million cutting equivalents. They have also established nursery beds with over 100,000 plants currently representing sixteen biomass varieties, with plans to dramatically expand those this year and in the future. With this type of commercial development and investment, there is good possibility that cultivation of shrub willow crops will expand to help meet the needs of society for renewable and sustainable sources of energy.

ACKNOWLEDGMENTS

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LAWRENCE SMART (associate professor in Environmental and Forest Biology, State University of New York College of Environmental Science and Forestry, Syracuse, NY) is a plant geneticist and physiologist and has been a leader of efforts in genetic improvement of willow at SUNY-ESF since 1998. He has assembled a large and diverse collection of willows, produced hybrid families through controlled pollination, selected high-yielding individuals, patented a number of those varieties, and transferred those to a commercial nursery for production of planting stock.

Smart received his PhD in genetics at Michigan State University in 1992 and was an NSF postdoctoral fellow at the University of California-Davis. Since 1996, he has taught courses in cell physiology, plant physiology, techniques in plant physiology, and a senior synthesis in biotechnology at SUNY-ESF. In addition to *Salix* genetics, Dr. Smart's research includes studies of cuticular wax biochemistry, stomatal physiology, and drought tolerance.

Challenges on the Road to Biofuels

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Lignocellulose-based ethanol offers a renewable, sustainable and expandable resource to meet the growing demand for transportation fuels. The main hurdles to be overcome include feedstock-supply logistics, conversion technology and workforce availability. Agronomists, agricultural engineers, and implement-manufacturing companies are addressing feedstock production, harvest, storage and transportation. Several universities, especially those in the Midwest, are developing new curricula and programs to bolster the workforce pipeline in bioprocessing. Therefore, the focus of this presentation will be on issues related to conversion technology.

The US ethanol industry is primarily based on processing of corn grain (*i.e.* starch) through either dry-grind or wet-milling processes. Development of the dry-grind industry began in the mid-1970s, and South Dakota State University (SDSU) was a leader in that effort. SDSU was the site of the nation's first on-campus ethanol production facility, and Figure 1 shows the distillation columns. Work at SDSU established initial costs (Dobbs *et al.*, 1984) and energy-balance data (Stampe, 1982) for farm-scale ethanol plants, as well as technology innovations such as thin-stillage recycling (Gibbons and Westby, 1982) that are still in use today.

Based on the pioneering work at SDSU, the fledgling industry expanded as multi-million gallon, farmer-owned plants sprung up across the Midwest. Figure 2 shows the basic process flow in modern ethanol plants, while Figure 3 shows the current status of US ethanol production. The current (mid-2007) US production capacity exceeds 6 billion gallons per year, with another 6 billion gallons of plant capacity under construction



Figure 1. Distillation column of the SDSU farm-scale ethanol plant.

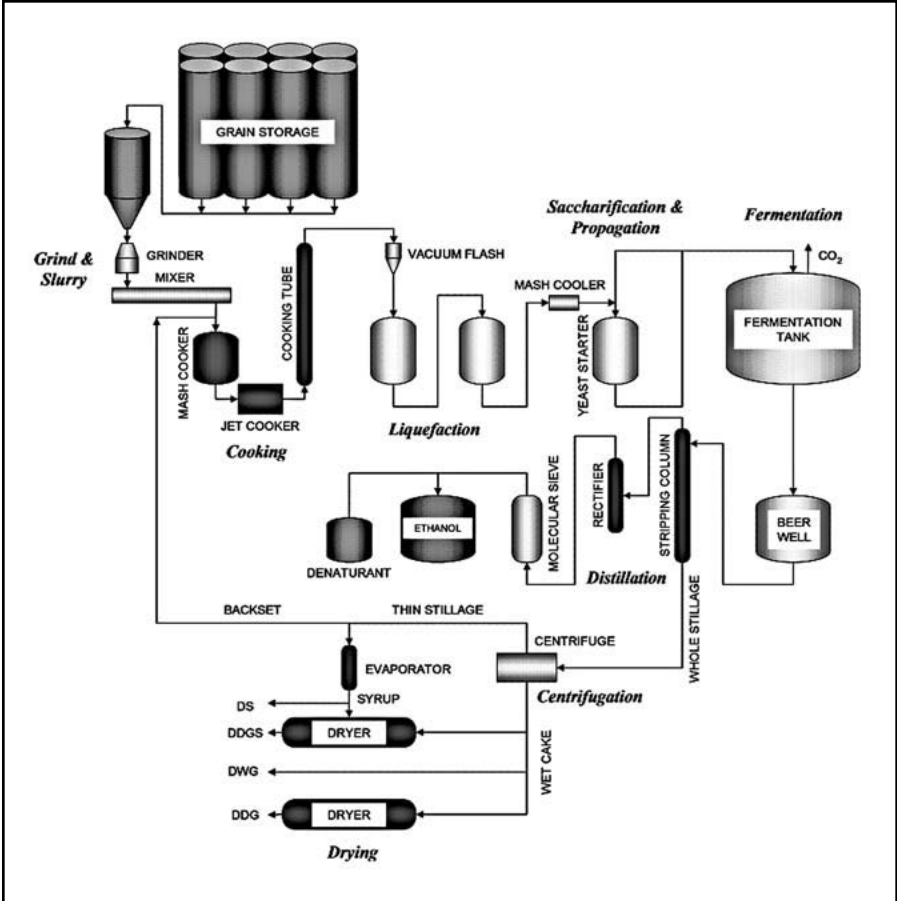


Figure 2. Corn dry-grind process (courtesy of Kurt Rosentrater¹).

(<http://www.ethanolrfa.org>). However, based on projected corn-grain availability, there is a general consensus that the upper limit for corn ethanol will be in the 14–15 billion gallons per year range.

LIGNOCELLULOSIC ETHANOL

Due to the large demand for transportation fuels and the fact that corn-based ethanol can, at most, account for 10–15% of this need, there is widespread interest in producing ethanol from lignocellulosic biomass. However, for this next step to be taken, several significant processing challenges must be overcome. As shown in Figure 4, the National

¹Contributor to this volume, pages 105–125.

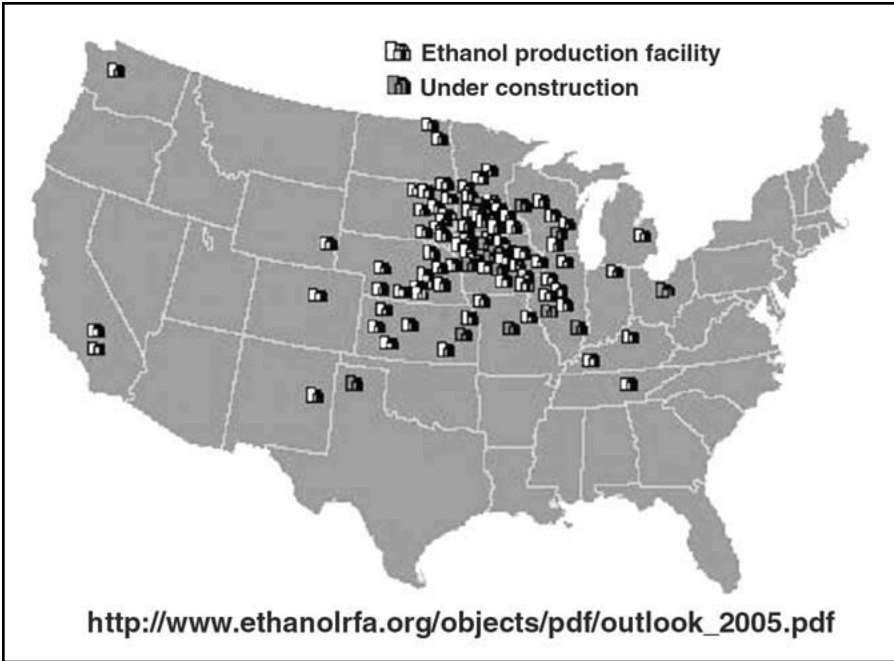


Figure 3. Current and planned ethanol biorefineries (courtesy Renewable Fuels Association).

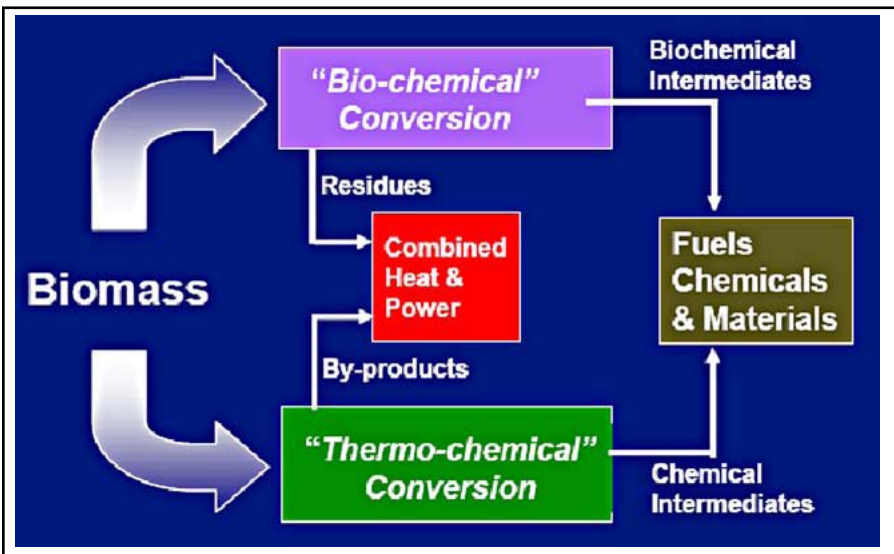


Figure 4. NREL biomass conversion platforms (courtesy National Renewable Energy Laboratory).

Renewable Energy Laboratory (NREL) has categorized the various processing options into two categories. Biochemical conversion processes use pretreatment processes and enzymatic hydrolysis to break down biomass into fermentable sugars that are subsequently fermented to ethanol by microbes (typically yeast). Alternatively, thermochemical conversion processes use gasification or liquefaction to degrade biomass into one- and two-carbon molecules that are catalytically converted into more complex products. Our focus at SDSU and the Center for Bioprocessing Research and Development (CBRD) has been on the biochemical conversion route, with work in the areas of pretreatment, hydrolysis and fermentation.

PRETREATMENT AND HYDROLYSIS

The goals of pretreatment and hydrolysis are to open the biomass structure and release the sugars in high yield and concentration, while producing minimal amounts of inhibitory byproducts such as furfurals. Most current chemical and physical pretreatment processes are limited by either not being intensive enough to release sugars in high yield, or are overly intensive, resulting in degradation of sugars (*e.g.* to furfural). A further disadvantage of most traditional processes is that the resulting hydrolysate streams contain a mixture of 5- and 6-carbon sugars. Commercial yeast strains cannot ferment 5-carbon sugars, and for microbes that can, the mixed sugars result in a diauxic fermentation in which 5-carbon sugars are metabolized only after the 6-carbon sugars are consumed. This two-stage process essentially doubles fermentation time, and, therefore, doubles required fermentation-tank capacity.

Our approach to overcoming these challenges is to develop a novel and economical reactor to fractionate and hydrolyze lignocellulose. The process is based on the clean-fractionation (CF) technology developed at the National Renewable Energy Laboratory (NREL) (Bozell *et al.*, 1997), which uses solvents (16% methyl isobutyl ketone, 34% ethanol, and 50% water) to fractionate the biomass. Lignin is dissolved in the solvent stream, hemicellulose in the aqueous stream, while cellulose is left behind in a moist pulp. One limitation is the cost of the solvents, and we are evaluating continuous high-shear extrusion to reduce solvent use. Clean fractionation extrusion should also improve efficiency and productivity of the process. Figure 5 shows our proposed process for incorporating clean fractionation extrusion into the lignocellulose conversion process.

Preliminary work on extrusion processing has evaluated both single- and twin-screw extruders. The single-screw extruder (Fig. 6) has a barrel length to diameter ratio of 20:1 and compression ratio of 3:1. We have investigated extrusion speeds of 80 and 120 RPM and temperatures of 120, 150, and 180°C. The twin-screw extruder (Fig. 7) has a barrel length to diameter ratio of 30:1 and compression ratio of 3:1. Conditions investigated included speeds of 200 and 400 rpm, temperatures of 25 and 100°C, and substrate-moisture levels of 15, 20, 25, 30, and 40%. Average results of extruding various warm-season grasses are shown in Table 1. In general, lower screw speeds (80 RPM) and higher temperatures (180°C) enhanced digestibility in the single-screw extruder, whereas in the twin-screw extruder the highest digestibility was found with 200 RPM, 25°C and 20% moisture content.

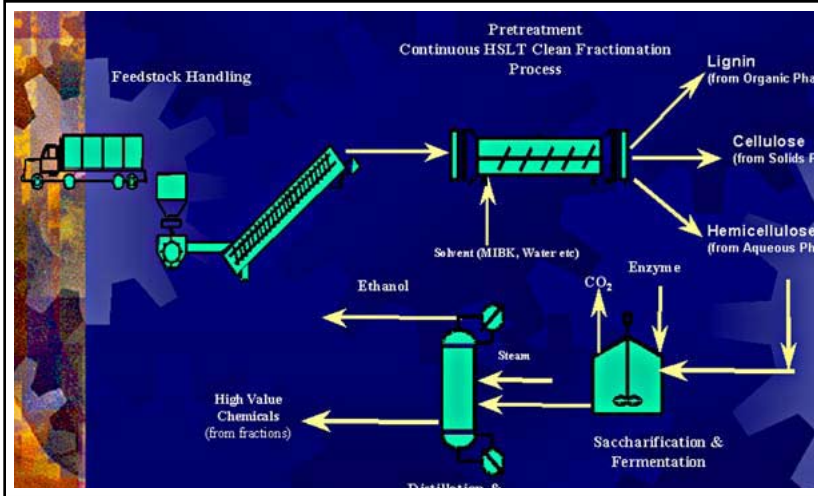


Figure 5. Clean fractionation extrusion processing system.

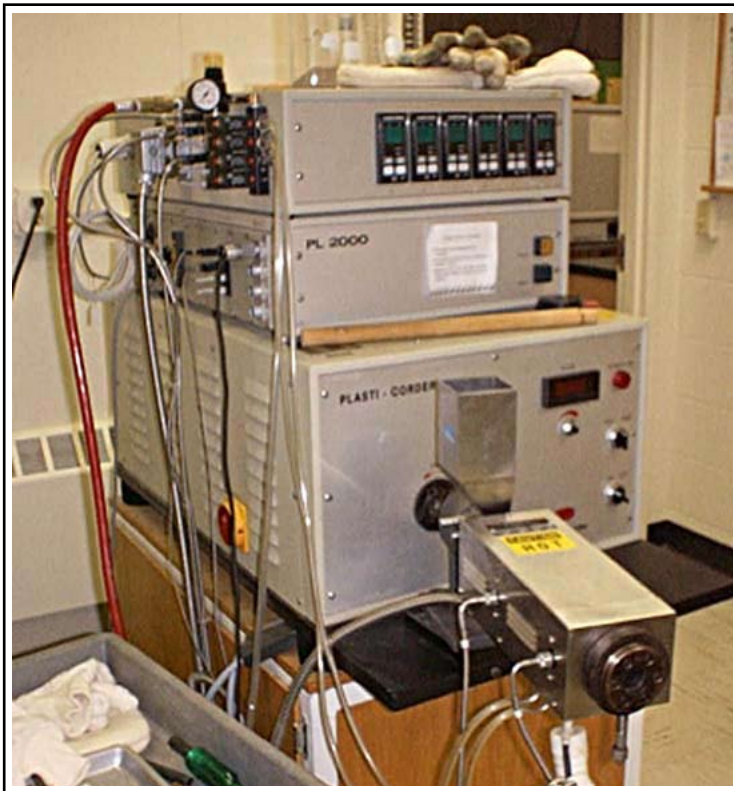


Figure 6. Single-screw extruder.

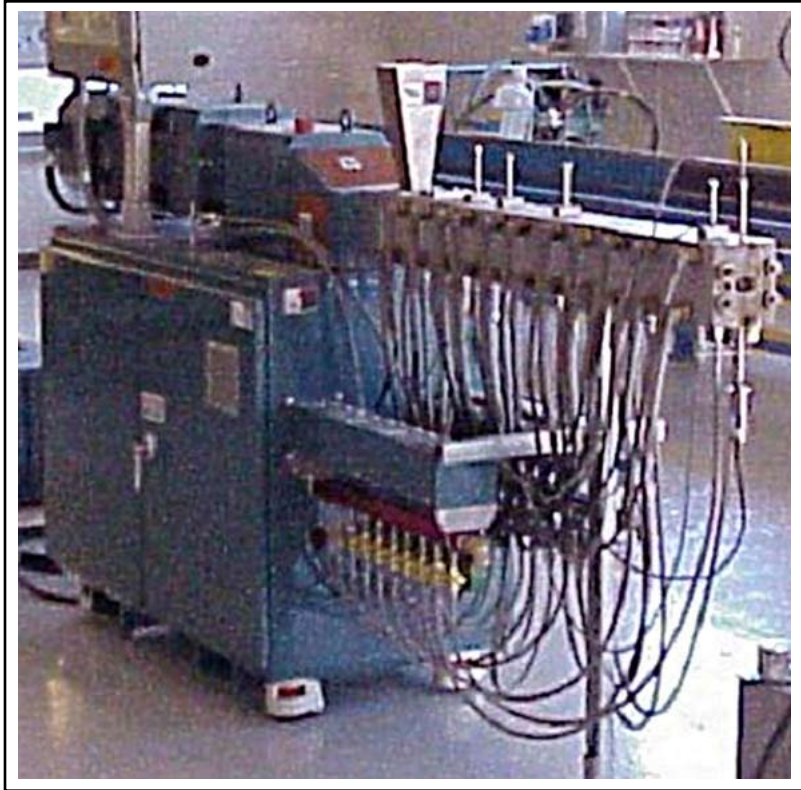


Figure 7. Twin-screw extruder.

TABLE 1. EFFECT OF EXTRUSION ON MAXIMUM GLUCOSE AVAILABILITY FROM THREE GRASSES.

Grass	Control Extruded (%)	
Big bluestem	21	36
Indian	23	32
Switch	21	25

CONVERSION

Another critical issue in production of ethanol from lignocellulose is low bulk density of biomass and presence of non-fermentable components such as lignin (Zaldivar *et al.*, 2001). The relatively light, fluffy nature of biomass requires that large volume of water be added to create a flowable slurry that can be processed through conventional reactors, piping, pumps, *etc.* Typically, slurries become too viscous to pump at 15–20% solids, restricting sugar concentrations, and subsequently ethanol titers to 3–5 wt % (Sedlak

and Ho, 2004; Hahn-Hägerdal *et al.*, 2005; Hamelinck *et al.*, 2005). In comparison, modern corn-ethanol facilities routinely achieve 15%+ ethanol in the fermented beer. Due to lower sugar and ethanol concentrations, biomass-ethanol plants would require substantially larger (2–4×) reactor capacities (increasing capital costs), would consume much more energy for distillation, and would have greater water and wastewater handling charges (increasing operating costs) (Hamelinck *et al.*, 2005). These higher process costs largely negate the feedstock cost advantages of biomass, and have impeded commercialization. Moreover, the increased demand for water may also affect the potential location of processing plants.

One approach to overcoming these limitations is to conduct saccharification and fermentation in a solid-state or high-solids environment, instead of traditional submerged bioreactors. Solid-state fermentation (SSF) is defined as a process in which microbes grow on moist solid substrate in the absence of free-flowing water. SSF has been evaluated for a number of applications, with reviews provided by Rimbault (1998), Pandey *et al.*, (2000) and Krishna (2005). Holker *et al.* (2004) note that microbes in nature typically grow on solid substrates, and that “cultivation of microorganisms in aqueous suspensions may rather impair their metabolic efficiency.” They list a number of biotechnological advantages of SSF, but also point out that the main obstructions to industrial use as relating to the development of gradients during cultivation.

To overcome the issue of gradient development in SSF, several reactor designs have been proposed to address the key factor of adequate mixing. These have ranged from static trays (Rajagopalan and Modak, 1995) and deep static beds (Chinn *et al.*, 2003) to rotating drums (Hardin *et al.*, 2001) and helical blade mixers (Schutyser *et al.*, 2003). Unfortunately, many of these designs are not amenable to scale-up or continuous material flow desired in industrial scale facilities (Mitchell *et al.*, 2000). We have developed two continuous-flow, solid-state or high-solid bioreactor designs that successfully overcome many of these performance issues. The plug-flow, rotating solid-phase bioreactor (Fig. 8) was used to ferment fodder beet pulp with *Saccharomyces cerevisiae* to 8–9 % ethanol in 36–48 h (Gibbons *et al.*, 1984; Gibbons and Westby, 1986a, b and c). This same reactor was subsequently used to ferment sweet sorghum pulp to 6% ethanol in 72 h (Gibbons *et al.*, 1986), while *Kluyveromyces marxianus* produced 7% ethanol in 48–72 h from Jerusalem artichoke pulp (Gibbons, 1989). The high-solids, diffusion fermentor (Fig. 9) was able to convert beet cubes to 9% ethanol with retention times of 264 h for liquid and 72 h for beets (Gibbons and Westby, 1986d; Gibbons and Westby, 1987 a and b; Gibbons *et al.*, 1988). Due to their design, construction, and continuous-flow operation, we believe that one or both of these designs will be scaleable for industrial production of ethanol from pretreated biomass, using a combination of cellulase enzymes and appropriate yeast.

To most effectively accomplish simultaneous saccharification and fermentation in the same vessel we will explore the use of thermotolerant yeast. This will allow enzymes to operate at closer to optimal temperatures, while reducing both enzyme repression and catabolite inhibition (Zaldivar *et al.*, 2001). Use of thermotolerant yeast would also provide the added benefits of reducing cooling costs and discouraging contamination (Banat *et al.*, 1998).

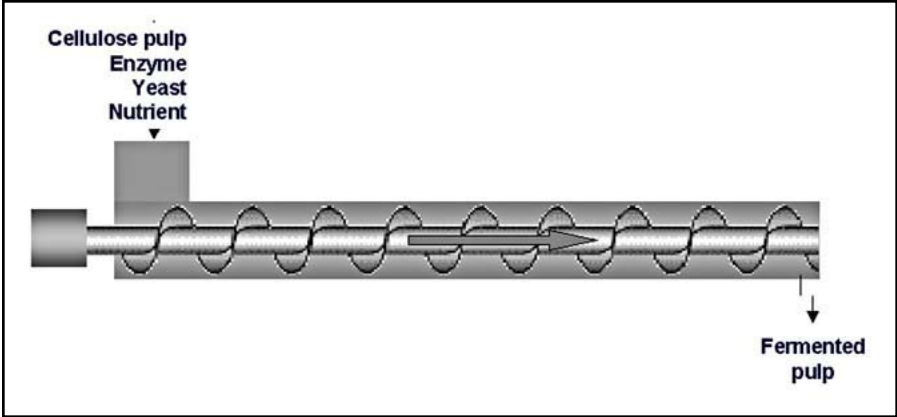


Figure 8. Solid-state bioreactor.

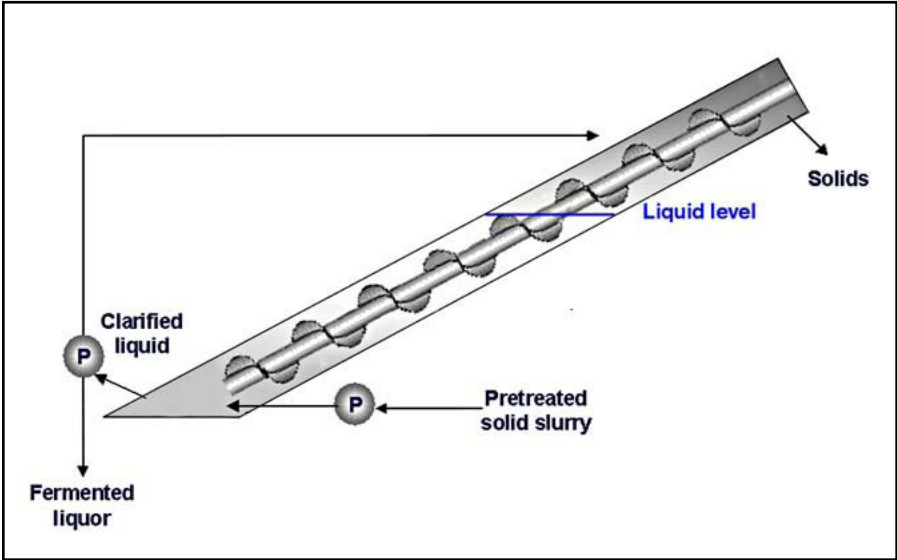


Figure 9. High-solids bioreactor.

ACKNOWLEDGMENTS

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WILLIAM GIBBONS' graduate research at South Dakota State University focused on production of ethanol from grains and dedicated biomass crops such as fodder beets and sweet sorghum. This work was an outgrowth of SDSU's groundbreaking research on farm-scale ethanol production conducted in the late 1970s.

Upon receiving his PhD in 1987, Gibbons joined the Biology / Microbiology Department as an industrial microbiologist, focusing on using microbial metabolism to develop value-added products from agricultural materials as replacements for petroleum-based products. These projects have included production of ethanol, organic acids (acetic, lactic, propionic), biopolymers (gellan, scleroglucan, and polyhydroxyalkanoate) and microbial protein, and have resulted in over thirty peer-reviewed publications. Support for this research has come from federal, state, and industrial sources.

Dr. Gibbons is also the associate director for the Center for Bioprocessing Research and Development (CBRD), a partnership of researchers at SDSU, South Dakota School of Mines & Technology, and several bioprocessing companies. The CBRD mission is to develop and commercialize novel bioprocessing technology, while supplying the science and engineering pipeline with the high-quality graduates needed to support this emerging industry. In addition to an aggressive research program, Gibbons teaches undergraduate and graduate courses.

Ethanol Processing Co-Products: Economics, Impacts, Sustainability

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The production of corn-based ethanol in the United States is dramatically increasing; as is the quantity of co-products generated from this processing sector. These streams are primarily utilized as livestock feed, which is a route that provides ethanol processors with a substantial revenue source and significantly increases the profitability of the production process. With the construction of many new plants in recent years, it is imperative to augment current uses and to find new outlets for these materials, in order to maintain the economic viability of this industry. Known collectively as distillers grains, these residuals have much potential for value-added processing and utilization in other sectors, but barriers currently exist. The goal of this article is to discuss five such constraints and opportunities: storability and handling, value-added livestock and other animal-feed use, human-food use, nontraditional processing into manufactured products, and potential use as sources of bioenergy. Addressing these issues will be essential to the growth of the industry, both in terms of developing new and refined methods for storing and handling these materials, and in identifying and developing new market opportunities for them. Ultimately, alleviating these constraints and pursuing these new possibilities will improve manufacturing economics and can augment the viability of the corn-based fuel-ethanol industry.

DDG CHALLENGES

Currently, the US fuel ethanol industry's only outlet for the nonfermentable residues resulting from the manufacturing process has been utilization as livestock feed. This approach to utilization is well established, but as the ethanol industry continues its rapid growth, and as the generated quantities of these distillers grains increase over time, this avenue needs to be augmented if it is to retain, or even increase, its current high-value economic returns.

Indeed, a host of issues surrounds the value and utilization of distillers grains, both from the ethanol production standpoint, and from a livestock-feeding perspective. Some of the most pressing include:

- the large quantities of energy required to remove water coupled with the high cost of energy; moving distillers dried grains with solubles (DDGS) to diverse and distant markets when there are fluctuations in supply and demand;
- how to avoid mycotoxin contamination;
- variability in nutrient content, quality, and associated quality-management programs, which ultimately impact end-users;
- lack of an industry-wide quality-grading system;
- inconsistent product identity and nomenclature;
- lack of standardized laboratory testing procedures;
- lack of education and technical support for the industry;
- international marketing and export challenges; and
- lack of a national byproduct organization to address these issues and spearhead marketing efforts for these co-products.

Indeed, a question that inevitably arises is, “What are we going to do with all of the DDGS?” These are discussed in more depth by Rausch and Belyea (2006), Rosentrater and Giglio (2005), Rosentrater (2006a) and UMN (2007).

A persistent barrier to effective distillers grains utilization is product storability and flowability—so much so that it has serious economic implications for ethanol plants. Opportunities to increase potential economic returns also include processing DDGS into high-value animal feeds, human foods and industrial composites. To date, however, very little has been published in the scientific literature addressing these four topics. These are all fertile areas for research, but a reference base from which to work is needed. They have tremendous implications for the successful growth of the industry.

STATUS OF THE US FUEL ETHANOL INDUSTRY—2007

With growing energy requirements, coupled with an increasing reliance on nonrenewable fossil fuels, markets for which have historically been quite volatile, the energy security needs of oil importing nations, including the United States, continue to escalate (EIA AEO, 2007). Biofuels—renewable sources of energy—can help meet these increasing needs, and can be produced from a variety of biomass materials including residue straw, corn stover, perennial grasses, legumes, and other agricultural and biological materials. At this time, however, the most heavily utilized substrate in the United States is corn starch. Although directly tied to the market value of the grain itself, fuel-ethanol production from corn is readily accomplished at a relatively low cost *vis-à-vis* other biomass sources. In fact, it is currently the only biological material that can be economically converted into ethanol on an industrial scale. The number of corn-ethanol plants, and their processing capacities, has been markedly increasing in recent years. At the beginning of 2007, for example, 110 manufacturing plants in the United States have an aggregate production

capacity of 5.5 billion gallons per year (20.8 billion liters per year). Moreover, seventy-six plants are currently under construction or expansion, and upon completion will contribute an additional 5.6 billion gallons per year (21.2 billion liters per year) (BBI, 2007; RFA, 2007a). As the ethanol market segment continues to grow, so do the quantities of processing residues, or co-products, that are generated.

In-depth details on ethanol manufacturing, which are beyond the scope of this discussion, can be found in Tibelius (1996), Dien *et al.* (2003), Jaques *et al.* (2003), Maisch (2003), Bothast and Schlicher (2005) and Weigel *et al.* (2005). Briefly, ethanol production from corn grain can be accomplished by wet-mill processing, which is very capital intensive, or dry-grind processing, which has substantially less capital and operational requirements, and thus has rapidly gained prevalence in the industry. The dry-grind production process (Fig. 1) consists of several key steps, including grinding, cooking, liquefying, saccharifying, fermenting, and distilling. Typically, there are three main products from a dry-grind facility:

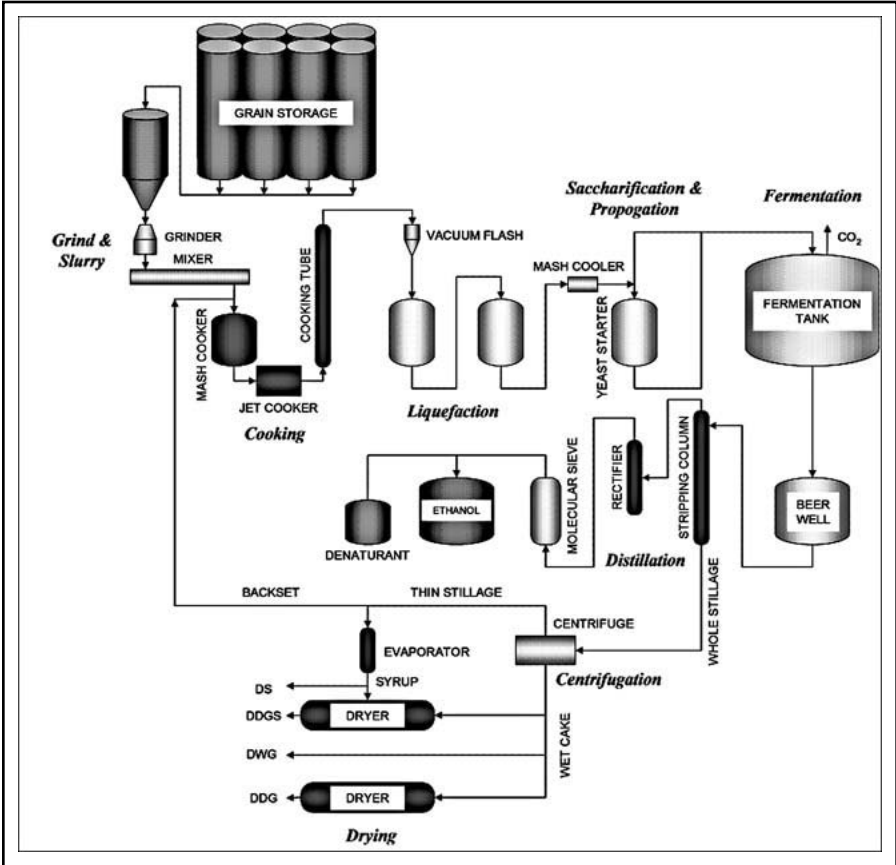


Figure 1. Process flow diagram of a typical dry grind corn-to-ethanol manufacturing plant.

- ethanol, the primary end product (approximately a third of the original corn mass);
- residual nonfermentable corn kernel components (approximately a third of the original corn mass), marketed primarily in the form of DDGS (Fig. 2), and to a lesser degree in the form of distillers dried grains (DDG), which do not contain added solubles, distillers wet grains (DWG; Fig. 3), and condensed distillers solubles (CDS; Fig. 4) (hereafter “distillers grains” will be used in a generic sense to refer to all of these residual materials); and
- carbon dioxide (approximately a third of the original corn mass).

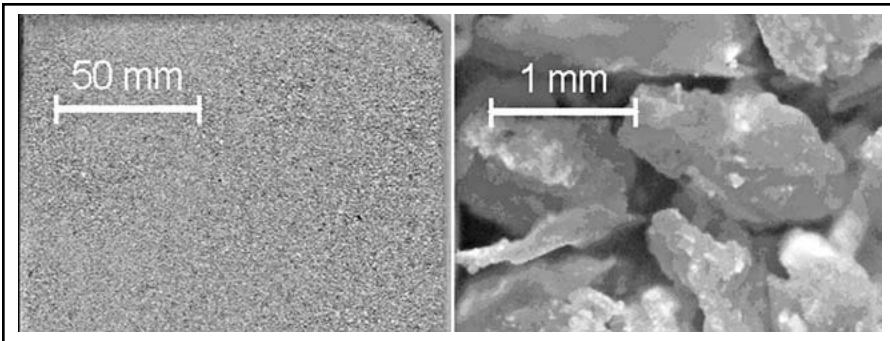


Figure 2. Solid non-fermentable residues—distillers dried grains with solubles (DDGS).



Figure 3. Solid non-fermentable residues—distillers wet grains (DWG).



Figure 4. Liquid non-fermentable residues—condensed distillers solubles (CDS).

Residue streams are separated from the ethanol during distillation. They are often dried to approximately 10% moisture content, to ensure a substantial shelf life, and then sold as distillers grains (generally DDG or DDGS) to local livestock producers or shipped via truck or rail to distant livestock feed markets. The sale of distillers grains contributes substantially to the economic viability of ethanol manufacturing (up to \$0.10 per liter of ethanol produced, depending on DDGS sales price), and is thus a vital component to each plant's operations. Because of the dynamics of the free-market economy, as this industry continues to grow the quantity of processing residues—and the ability to utilize them—will, in turn, significantly impact the future of the industry.

Historically, the ethanol industry's only outlet for non-fermentable residues has been as livestock-feed ingredients. This approach is well established, but needs to be augmented and optimized if it is to retain its high-value returns, especially as the generated quantities of these residues increase. Increased supply of distillers grains will affect the potential sales price *vis-à-vis* feed demand, which could severely impact the production economics of the industry in the near future. In order to address these challenges, the ethanol industry

needs a diversified utilization strategy, instead of the current unidirectional approach. If estimates of future ethanol production hold true, utilization as livestock feed alone may not prove to be sustainable and thus alternative avenues must be pursued. Potential routes should include value-added animal feeds, human foods, and industrial products. One of the major hurdles that must be addressed (even prior to developing these new uses) is to improve the storage and handling characteristics of these materials.

STORAGE, HANDLING, AND FLOWABILITY CHALLENGES

With the exponential growth of the fuel-ethanol industry in the past several years, substantial quantities of distillers grains are now being produced, and even more are anticipated in the foreseeable future. To utilize these as feeds, however, these materials are increasingly being transported greater distances via truck and rail, and must be stored in various structures, such as bins and silos, until final use. Unfortunately, discharge flow is often problematic, due to caking and bridging between particles, which frequently occurs during storage and transport. In fact, flowability has become a major issue to be addressed for effective sales, marketing, distribution, and utilization of distillers grains (Rosentrater and Giglio, 2005; Schlicher, 2005; Rosentrater 2006b). For example, because these co-products do not easily flow from rail cars, in order to induce flow, workers often hammer the car sides and hopper bottoms. This leads to severe damage to the rail cars themselves, repairs of which have become very expensive to ethanol-manufacturing companies. Large carriers, such as the BNSF and UP railroads have even prohibited DDGS shipments.

Even though anecdotal knowledge regarding flowability is present in the industry, it is often incomplete and proprietary in nature. Furthermore, no formal scientific studies have yet investigated handling or flow properties of distillers grains. From studies of other granular materials, though, it is probable that flowability problems may arise from a number of synergistically interacting factors, including product moisture, fat content, particle size distribution, storage temperature, relative humidity, time, compaction pressure distributions within the product mass, vibrations during transport and/or variations in levels of these factors throughout the storage process (Craik and Miller, 1958; Johanson, 1978; Moreyra and Peleg, 1981; Teunou *et al.* 1999; Fitzpatrick *et al.*, 2004a, 2004b).

Generally speaking, flowability is defined as the ability of granular solids and powders to flow. It is, in fact, not an inherent natural material characteristic, but rather is the consequence of several interacting properties that simultaneously influence material flow, environmental conditions, and the equipment used for handling, storing, and processing (Prescott and Barnum, 2000). Flow behavior is thus multidimensional, depending on many physical and chemical characteristics. Because of this, no single test can quantify a product's flowability; instead a suite of tests is required. In addition to the factors listed above, other properties that affect flowability can include protein, starch, and carbohydrate levels, as well as addition of flow-conditioning agents (Peleg and Hollenbach, 1984).

Knowledge of physical and flow characteristics of bulk solids is essential for the design of reliable storage systems and handling equipment. Toward this end, shear testers are the primary equipment used to measure the strength and flow properties of granular materi-

als. A shear test consists of two stages: measurement of consolidation (*i.e.*, compaction over time) and determination of particle strength. The measured strength depends on the degree of consolidation, and how it was achieved (*i.e.*, stress history). Each of these aspects is highly dependent upon the other (Schwedde, 2002). It has been found that stress history and anisotropic behavior have a strong influence on the particle strength of a bulk solid. It has also been concluded that a reliable prediction of the strength of a bulk solid can be achievable only if the stress history, and the directions of the major principal stresses during consolidation and failure, are known for specific applications.

Jenike (1964) developed the fundamental method for determining these flow characteristics. To analyze flow in bins and hoppers, and to develop a flow/no-flow criterion for various materials, Jenike used the principles of plastic failure with the Mohr-Coulomb failure criteria (Thomson, 1997). From a physical standpoint, the general principle is that granular flow is equivalent to solid failure due to shear. In ideal, free-flowing materials, resistance to flow is only the result of friction; in cohesive materials, however, inter-particle forces are enhanced by compaction, which can, in turn, produce mechanical strength and, thus, flow resistance (Peleg, 1983). Over the years, Jenike's direct shear cell tester and associated methodologies have become benchmarks for determining appropriate industrial design criteria for storage bins and silos. Jenike's shear cell has been used by many researchers for characterizing various granular materials. For example, the shear cell has been used to study the flow properties of various powders (Ashton *et al.*, 1965), cement (Schrämli, 1967), fine lactose powder with and without flow conditioners (York, 1975), wheat flour and sugar (Kamath *et al.*, 1993), wheat flour (Kamath *et al.*, 1994), confectionary sugar and detergent (Duffy and Puri, 1994), grains (Duffy and Puri, 1999) and milk powders (Fitzpatrick *et al.*, 2004b).

Carr (1965a, 1965b) also developed a number of standard procedures that permit the evaluation of flowability of granular materials, involving the determination of four main physical properties: angle of repose, compressibility, angle of spatula, and coefficient of uniformity (*i.e.*, cohesion). It does not, however, account for consolidation or stress history. Even so, the information determined by this methodology is also extremely useful for designing bins and hoppers so that appropriate material handling and particle flow can be achieved. This is especially true when used in conjunction with Jenike shear data.

Even though the Jenike and Carr procedures are commonly used in industry, to date no formal studies have investigated handling or flow properties of distillers grains. Determining the specific physical or chemical factors, or interactions thereof, that cause flowability problems for these materials should be undertaken, because solving this problem will have substantial economic ramifications throughout the fuel-ethanol industry. Storage and handling operations must be improved *vis-à-vis* current technologies and practices, especially as sales and distribution of these materials move beyond regional areas and become more national in scope. Preliminary studies in our laboratory indicate that consolidation may very well be a main contributor to many flowability problems observed in distillers grains; the other synergistically acting factors, however, remain to be analyzed and quantified.

VALUE-ADDED ANIMAL FEEDS

As with many food and organic processing residue streams, feeding distillers grains to livestock is a viable method of utilization because of their high nutrient levels. Over the years, numerous research studies have been conducted in order to assess co-product use as animal feed, including investigations focused on beef rations (Firkins *et al.*, 1985; Ham *et al.*, 1994; Lodge *et al.*, 1997; Peter *et al.*, 2000 Al-Suwaiegh *et al.*, 2002), dairy diets (Nichols *et al.*, 1998; Powers *et al.*, 1995; Schingoethe *et al.*, 1999; Hippen *et al.*, 2004; Kalscheur *et al.*, 2004), swine rations (Wahlstrom *et al.*, 1970; Cromwell *et al.*, 1993; Noblet *et al.*, 1994; Gralapp *et al.*, 2002; Shurson *et al.*, 2004; Whitney and Shurson, 2004), and poultry diets (Waldroup *et al.*, 1981; Parsons *et al.*, 1983; Noll *et al.*, 2002; Ergul *et al.*, 2003; Lumpkins *et al.*, 2003; Roberson, 2003). Aines *et al.* (1986) and UMN (2007) provide comprehensive reviews of this research.

But, much additional research must be done in order to maximize the inclusion of these residues in animal feeds, especially in light of the fact that as the processes employed in the industry evolve, the resulting quality and composition of the co-products thus continue to change. Distillers grains are often used in beef and dairy rations and, to a lesser extent, in swine and poultry diets; aquaculture feeds and pet foods are two market segments that are, as yet, untapped.

Protein-rich DDGS from ethanol plants have been used as livestock feed for many years. Feed conversion efficiency in fish, however, is typically much higher compared to traditional livestock. The cost of processing fish feed is one of the challenges for profitable fish cultivation. Due to the exponential increase in number of ethanol plants in recent years, though, DDGS are becoming readily available as a reasonably priced base material. And because they have a relatively high protein content, they may have potential as a fish-feed substitute for fish meal. Even though much literature is available on incorporation of distillers grains into the diets of various livestock species, very little has been accomplished in the aquaculture arena. Fish require unique physical and functional properties compared to other animal feeds (such as specific nutritional profiles). Additionally, pellet floatability is essential to many fish species; this can generally be achieved via extrusion processing. To date, only a little research has been carried out on utilizing DDGS as a protein source in aquaculture feed; limited work has investigated feeding trout, tilapia, prawns and catfish (James *et al.*, 1993; Webster *et al.*, 1993; Wu *et al.*, 1996, 1997; Cheng and Hardy, 2004a, 2004b; Cheng *et al.*, 2003; Coyle *et al.*, 2003, 2004). These studies have found that DDGS, in combination with other feed ingredients, could partially or even totally replace fish meal as a protein source, and that fish-growth performance could be maintained at acceptable levels.

Much work remains to improve and maximize the utilization of these co-products in animal feeds, both for ruminants as well as for mono-gastric species. Five key priorities must be addressed:

- densification, via pelleting or cubing, of DDGS streams and/or specific fractions in order to improve the bulk density, storability, transportation, and delivery for animal utilization—essential considerations include pellet compressibility, dura-

bility, digestibility, and other physical and nutritional properties of the densified feed products;

- processing of DDGS streams and/or specific fractions into value-added feed products, including aquaculture feeds and pet foods, which are untapped market segments and have much potential for growth;
- processing of DDGS streams and/or specific fractions with other relatively low-value processing/organic waste streams, in order to augment nutritional contents and produce novel feed ingredients;
- quantifying and enhancing storability, shelf life, and preservation of these resulting feed products (especially wet products); and
- feeding, growth performance, and acceptability testing of these novel feed products.

Preliminary trials in our laboratory indicate that extrusion processing is a promising technology for achievement of many of these priorities.

HUMAN FOODS

Historically, the benefits of diets containing high levels of dietary fiber have become well documented, including lowering of serum cholesterol levels, blood pressure, risk of heart disease, chance of various cancers, and improved weight loss/control (Burkitt, 1977; Anderson *et al.*, 1987; Anderson *et al.*, 1994; Mehta, 2005). Recently, diets that also contain low levels of carbohydrates (especially starch), such as the Atkins (Atkins, 1992) and South Beach diets (Agatston, 2003), have also become popular (Angelich and Symanski, 2004; Sloan, 2004; Hursh and Martin, 2005). Not only do diets that contain high fiber and low starch promote weight loss and control, but current research into glycemic response and resulting after-meal satiety indicates that these diets also have substantial health benefits for diabetic patients as well as those suffering from obesity (Li *et al.*, 2003; Brand-Miller, 2004; Gross *et al.*, 2004; Hofman *et al.*, 2004; Layman and Baum, 2004; Rendell *et al.*, 2005), not only for blood-sugar control in diagnosed patients, but also for prevention of diabetes and obesity onset. Because distillers grains are high in fiber and low in starch, they have potential for use in such dietary regimes.

Over the years, several studies have examined distillers grains as functional ingredients for human foods, including Bookwalter *et al.* (1984), Wall *et al.* (1984), Kim *et al.* (1989), Maga and Van Everen (1989), Rasco *et al.* (1990), Abbott *et al.* (1991), Brochetti *et al.* (1991) and Van Everen *et al.* (1992). These, and other prior investigations into use of distillers grains as food ingredients, have been thoroughly compiled and reviewed by Rosentrater and Krishnan (2006). Most prior studies have focused primarily on breads and cookies. To a lesser extent, other food products, including pastas, blended ingredients, extruded products and other miscellaneous food items have also been investigated. As Rosentrater and Krishnan (2006) have discussed, incorporation of distillers grains has generally been shown to impact the resulting organoleptic quality of food products, especially as inclusion/substitution rates increase. Most food products become darker in appearance when distillers residues are included. Most of the products studied indicated

a decreased functionality compared to the original components replaced by distillers grains, including resulting volume and expansion during baking, moisture absorption, texture, and mouth-feel. Moreover, products incorporating distillers byproducts at relatively high inclusion levels have shown a definite impact on flavor and are typically rated as marginally acceptable to not acceptable at all. Poor flavor could be improved, though, by bleaching and deodorizing prior to inclusion in the food matrix, because fatty acids that influence off-flavor development can be neutralized. Because of these challenges, it is not surprising that there is currently no commercial food product that incorporates ethanol-processing co-products.

As a direct result of the energy crises of the 1970s, the US fuel-ethanol industry began a slow but steady growth. Development of food products from distillers grains from this industry is not a new concept. In the 1980s, twenty-three studies were conducted and forty-seven food products were investigated. After the 1980s, the ethanol industry continued to grow, but interest in food products from distillers co-products waned considerably. In the 1990s, only eight studies were conducted and ten products investigated; in the 2000s, however, only one study and five products have been investigated thus far. As a result of this decline in interest, the lack of product-development work in last 15 years has become a hindrance to the utilization of distillers grains in food products, especially in light of the changes that these residues have undergone during this time period.

Numerous manufacturing improvements and process modifications have been realized over these years, particularly with the advent of the corn dry-grind production process. Now many of these “next generation” plants are in operation, and, in fact, comprise almost 80% of the entire industry (RFA, 2007a,b). Moreover, many additional dry-grind facilities are currently under construction. Dry-grind plants produce distillers grains with considerably different nutrient contents and physical properties from those produced by their predecessors—the corn wet mills of the 1980s (Spiehs *et al.*, 2002; Rosentrater *et al.*, 2005). As this industry continues to expand, many ethanol plants are increasingly interested in construction and operation at food-grade status, in order to expand the opportunities for utilization of distillers grains beyond traditional livestock feed. But, they do need market outlets for these new materials in order for this pursuit to succeed. Thus, a dedicated product-development initiative needs to address and optimize the use of these new processing residues, especially DDGS.

In order for viable food products to be successfully manufactured and marketed, considerable research is needed:

- analysis of current commercial DDGS streams and/or specific fractions for food-grade applicability, especially nutritional contents and chemical levels, including vitamins, minerals, nucleic acids, pigments, heavy metals, and toxic and other compounds that may be present;
- methods for processing and upgrading DDGS streams and/or specific fractions into food-grade ingredient streams, including:
 - various pretreatments, such as separation and concentration of proteins, fibers, lipids, or other compounds,

- washing, cleaning, and other quality-upgrading steps,
- bleaching,
- deodorizing,
- drying,
- sterilizing,
- milling into corn flour,
- storage stability and preservation, and
- analysis of any residues that result from these upgrading steps;
- nutritional enhancements that may be necessary to improve functionality, flavor and utilization potential;
- developing specific, marketable food products such as bakery goods, noodles, pastas, or other low-starch/high-protein/high-fiber foods;
- quantifying storability, shelf life and preservation of these resulting food products; and
- sensory analysis and acceptability testing of the resulting food products.

MANUFACTURED PRODUCTS

Beyond the realms of traditional livestock feed and potential human-food ingredients, very little work has been undertaken to develop other value-added applications for ethanol-residue streams. Initial trials have been conducted using these co-products as soil amendments and fertilizers (Erdem and Ok, 2002; Ramana *et al.*, 2002a, 2002b), extracting oil to produce industrial compounds and chemicals (Singh and Cheryan, 1998; Singh *et al.*, 2001; Kwiatkowski and Cheryan, 2002; Singh *et al.*, 2002), and extrusion processing (Rai *et al.*, 2004). Although manufacturing of distillers grains into industrial products is currently an untapped area, it is a potentially high-value avenue that should be pursued.

Modern manufacturing involves complex interactions among many factors, including product design, raw materials, manufacturing processes, as well as product distribution and sales. Thorough overviews of these topics have been provided by Creese (1999), Kalpakjian and Schmid (2001) and Geng (2004). In recent years, interest has grown in incorporating non-traditional, biological materials into traditional manufacturing operations to produce high-quality, cost-competitive, biodegradable finished products.

Progress in industrial biomaterials has accelerated in the last few decades as environmental consciousness has increased and production processes have become more efficient. A wide variety of viable bioproducts are produced industrially (Aberg *et al.*, 2002; Gandini and Belgacem, 2002), ranging from processing biomaterials into completely biobased finished products to utilizing them as additives or reinforcements in composites (Mohanty *et al.*, 2002). Available literature shows diverse applications, including biomedical (*e.g.* degradable protein sutures and implants), food-processing containers, packaging materials and structural members, to name only a few. The three product categories that

currently encompass the greatest number of viable biomaterials, however, are films, foams and composites.

Because of disposal problems with conventional films, many studies have targeted development of biodegradable counterparts (Thring *et al.*, 1997; Godbole *et al.*, 2003; Kayserilioglu *et al.*, 2003; Intabon *et al.*, 2004; Kumar *et al.*, 2004; Wang *et al.*, 2004b; Zhang and Whistler, 2004; Imam *et al.*, 2005), using compounds found in biological materials, such as alginic acid, arabinoxylan, cellulose, chitin, curdlan, lignin, soy protein, starch, xanthan, xylan, whey and zein. Biofilms are currently used in many products, including agricultural applications, such as landscaping and greenhouse construction (Briassoulis, 2004a, 2004b), as well as coating and packaging materials (Li and Chen, 2000). In addition to biodegradability, many of these studies have reported improved toughness and tensile strength by the inclusion of biological materials. Preliminary data indicate that distillers grains are a potential source of concentrated zein, which could be used for film production, although the functional state of these molecules is not yet known.

As most ultimately end their service lives in landfills, foams represent another area where biodegradability would be a tremendous asset. Biological materials have been used in a variety of insulation, packaging, and buoyancy products. Many foaming-development studies have been conducted using a host of biological materials, including wood fibers, starch, corn-stover fibers, and soybean oil (Fang and Hanna, 2000; Guo *et al.*, 2003; Ganjyal *et al.*, 2004; Javni *et al.*, 2004; Lee *et al.*, 2004). Many of these foams, however, although completely biodegradable, do not have sufficient mechanical strength and lack water resistance, both of which are barriers to widespread use. To address this, Fang and Hanna (2001) added degradable co-polyester to improve starch properties; the resulting foams exhibited water resistance and excellent resiliency against deformation while maintaining biodegradability. These foams were comparable to traditional polystyrene, which is not biodegradable and has limited recyclability. Preliminary studies in our laboratory indicate that distillers grains can be utilized to produce biodegradable foams as well; these trials have indicated excellent foaming and final-product properties, and thus warrant further study.

The third main category of use, composite products, encompasses a broad array of materials. Much research has been conducted in recent years (Lammers and Kromer, 2002; Colom *et al.*, 2003; Jayaraman, 2003; Keller, 2003; Lundquist *et al.*, 2003; Pothan *et al.*, 2003; Joshi *et al.*, 2004; Julson *et al.*, 2004; Wang *et al.*, 2004a). In addition to the production of finished biobased products, many biological materials have also been used to improve the physical and mechanical properties of conventional plastics. Examples cited in the literature often involve alternative use of residue materials produced in large quantities (*e.g.*, as a result of agro processing), as well as specific biomass crops grown for dedicated use in biomaterials: bagasse (Chiellini *et al.*, 2004; Rout *et al.*, 2003), flax fibers (Joffe *et al.*, 2003; Baiardo *et al.*, 2004; Wang *et al.*, 2004a), palm fibers (Sreekala and Thomas, 2003; Abu-Skarkh *et al.*, 2004), sisal fibers (Li *et al.*, 2000; Joseph *et al.*, 2003), jute fibers (Ray *et al.*, 2002; Khan *et al.*, 2005), soy products (Ashby *et al.*, 2004; Swain *et al.*, 2004), and corn-processing co-products (Julson *et al.*, 2004; Montgomery, 2004). Many of these studies show that use of biomaterials as fillers can lead to substantially

improved properties in the resulting composite plastics. Preliminary experiments in our laboratory indicate that distillers grains can be utilized to produce durable biodegradable composites when injection molded with thermoplastics or compression molded with phenolic resins.

The goals of utilizing biomaterials often include offering alternatives for bioprocessing residues and byproducts, decreasing manufacturing costs and improving final product biodegradability. But, the applicability of a given biomaterial must first be determined before it can be used in an actual manufacturing environment, and its compatibility with specific polymers and resins must be determined before it can be used effectively and economically. Findings of previous studies discussed here, compounded with those of many other researchers in the literature, suggest that the potential for biobased products is continuing to increase, and that more focus on investigating compatibility and methods of manufacture is needed for these materials.

Many potential avenues for utilization of distillers grains beyond feed and food do exist, and should be investigated in order to increase possible value-added uses. Based on our own preliminary laboratory investigations, it appears that distillers grains do have much potential for manufacturing into various biobased products, including films, foams, and composites.

CONCLUSIONS

The US corn-based fuel-ethanol industry is currently experiencing unprecedented growth. In conjunction with this expansion, the quantity of distillers grains produced has grown. This industry has continually evolved and technological innovations and process changes have been implemented that have improved process efficiencies, but have also affected the resulting co-product streams. As a consequence, new questions, challenges, and opportunities for utilizing these residues have arisen. As the quantity of these materials continues to grow, it is vital that value-added uses for distillers grains continue to be developed and augmented. Many issues currently face the ethanol industry in this regard. This article has discussed one of these: flowability. Addressing this challenge will have a substantial impact on the industry, as new or improved processes that lead to enhanced DDGS storability and flowability behavior are realized. This article has also reviewed three areas where substantial potential lies for value-added processing and utilization, including animal feeds, human foods, and industrial products. Pursuing these can lead to increased utilization of DDGS, thus preventing saturation of the livestock feeds market with ethanol co-products. Ultimately, addressing the topics discussed in this paper could lead to enhanced economic viability for the entire ethanol industry.

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Bioprocess engineer **KURT ROSENTRATER** is a lead scientist with the United States Department of Agriculture, Agriculture Research Service, at the North Central Agricultural Research Laboratory in Brookings, SD, where he spearheads an initiative to develop value-added uses for co-product and residue streams resulting from biofuel-manufacturing operations. His areas of expertise include

value-added product development, alternative recycling and reprocessing strategies for food and organic waste streams, modeling and simulation of food and organic processing systems, economic modeling, and physical and chemical characterization methods.

Dr. Rosentrater has investigated physical, nutritional, and chemical properties of corn masa, processing byproduct streams and swine slaughterhouse blood and blood components, and he has developed value-added livestock-feed applications for these waste streams by utilizing laboratory and pilot-scale extrusion processing techniques. Additionally, he has developed advanced computer models to simulate process and economic factors to aid the food industry in pursuing value-added recycling/reprocessing alternatives.

Formerly an assistant professor at Northern Illinois University, DeKalb, IL, in the Department of Engineering and Industrial Technology, Rosentrater taught research methods, manufacturing systems, engineering mechanics, and design. While in industry, he was responsible for process and equipment design as well as plant and site layout for large-scale agri-industrial facilities, including biodiesel-manufacturing plants.

Energy-Crop Gasification

R. MARK BRICKA

Mississippi State University

Mississippi State, MS

Biomass may be obtained from many sources. Already mentioned at this conference are switchgrass, corn stover, sawdust, willow, biodegradable waste, *etc.* However, its availability in a variety of forms is problematic. Chemical engineers, of which I am one, like homogeneity; heterogeneity means feeding problems and handling problems; as feed source varies, moisture and chemical content vary. Gasification and combustion are the most readily applicable technologies for processing biomass of various kinds for production of biofuels and other chemicals and materials.

Gasification, which has been around for a long time, is a thermochemical process that converts carbohydrates into hydrogen and carbon monoxide under oxygen-starved conditions. Its use was accelerated during WWII when wood was gasified and converted into liquid fuel for internal combustion engines including electrical generators. In post-war years, some farmers had gasification systems attached to tractors and other equipment, which worked fairly well.

THE PROCESS

In a gasifier, the fuel undergoes three main processes:

- Pyrolysis without O₂
 - also known as devolatilization
 - volatile components of the fuel are released
 - some fuel is converted into char,
- Combustion in excess O₂
 - the volatile products and some char react with oxygen and steam to form carbon dioxide and carbon monoxide, which provides heat,
- Gasification in O₂-starved conditions
 - the char then reacts with the carbon dioxide and steam to produce carbon monoxide and hydrogen, commonly known as syngas.

As a separate process, pyrolysis is used to produce bio-oil; the same equipment can be used for gasification by operating it differently.

GASIFIERS

Several types of gasifiers are available; attendant advantages and disadvantages are shown in Table 1. In the updraft gasifier (Fig. 1), air is blown upward and the biomass is fed downward. The down-draft gasifier is similar, but drawing air from the top and producing cleaner products with less tar (creosote); however, there are problems with the way the material is fed and how it can be handled and moisture tolerance is limited. With both methods the products are carbon monoxide (CO) and hydrogen (H₂)—syngas—which can be converted to a number of products.

The fluidized bed gasifier is the most popular type (Fig. 2). It can use a variety of feeds, usually ground to a powder. However, more tar is formed and particulates are produced due to the turbulence in the bed.

With the circulating fluidized bed (Fig. 3), we basically blow the bed out, separate it in a cyclone and recycle it back around. It is similar to the fluidized bed system, but with even more tars and particulates.

In the entrained-flow gasifier (Fig. 4), the material is entrained in a pipe in the reactor, not in a bed. It works differently and causes different problems.

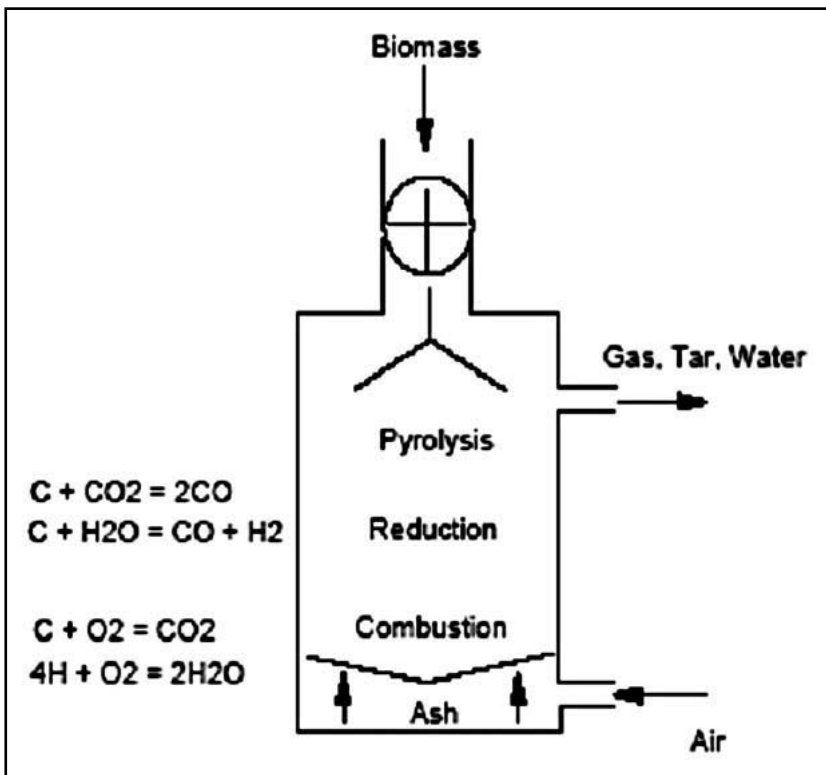


Figure 1. Updraft gasifier.

TABLE 1. GASIFIER TYPES AND THEIR ADVANTAGES AND DISADVANTAGES.

Gasifier type	Advantages	Disadvantages
Updraft	Low carbon in ash Can handle feeds with high moisture content Good for small-scale application	Feed-size limitations High tar yields Scaling limitation
Downdraft	Low particulates in syngas Low-tar content in syngas	Feed-size limitations Sensitive to moisture in feed Scaling limitations
Fluidized bed	Can handle large-scale applications Can handle multiple feed characteristics	Medium tar yield Higher particulate loading
Circ. fluidized bed	Best for large-scale applications Can handle multiple feed characteristics Very versatile	Medium tar yield High particulate loading
Entrained flow	Low tar yield	Particle size limits High particle loading Needs large volumes of carrier gas

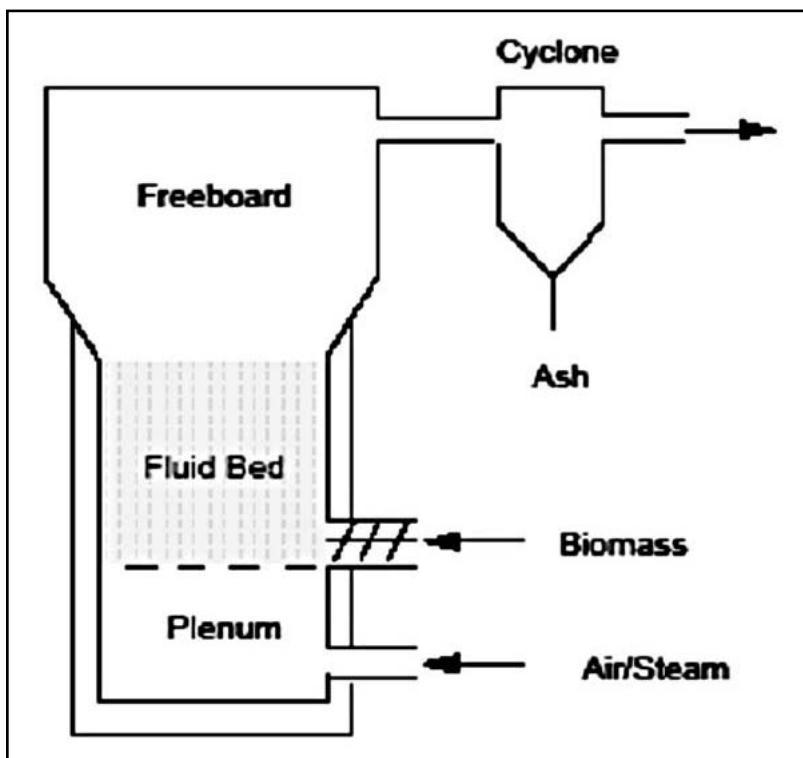


Figure. 2. Fluidized-bed gasifier.

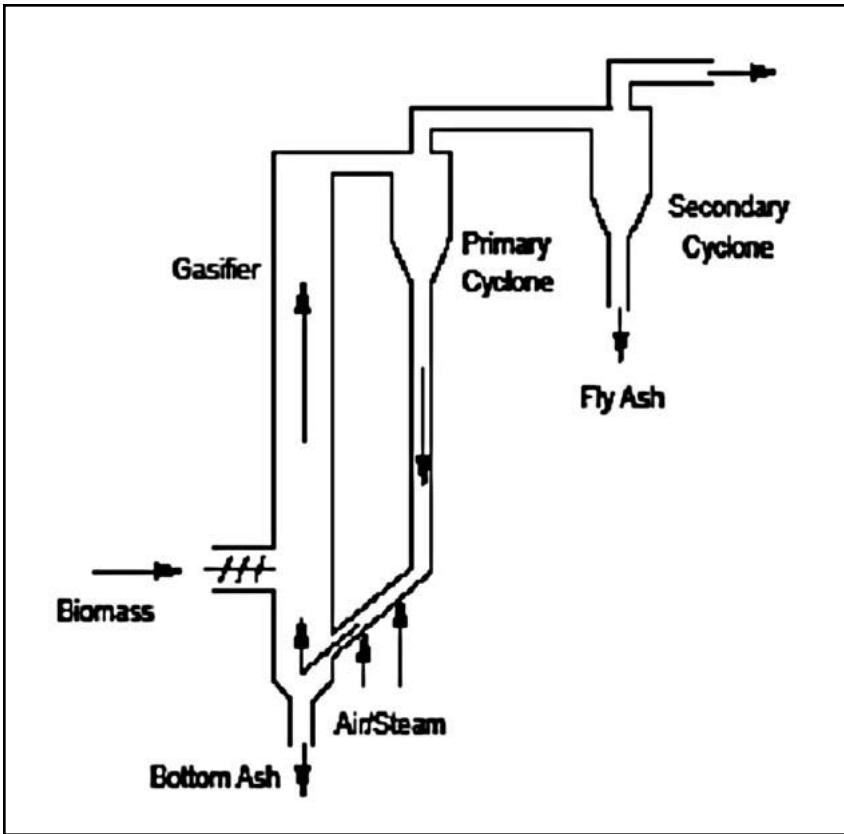


Figure 3. Circulating fluidized-bed gasifier.

SYNGAS

Syngas is used mainly for production of electricity. The heat produced generates steam, which generates electricity. It can also be used to produce chemicals, involving fairly easy catalytic conversions from CO and H₂, *e.g.* via the Fischer-Tropsch reaction. A biofuel product on the horizon is dimethyl ether (DME). Ethanol can also be produced, as can true gasoline and true diesel, from syngas.

RESOLVING PROBLEMS

Figure 5 illustrates one of the processes that we've been working on at Mississippi State University (MSU): biological conversion of syngas to ethanol and refining the ethanol using standard processes. The yield is relatively low and our microbiologists are working on new microorganisms for increased rapidity of production and higher yields.

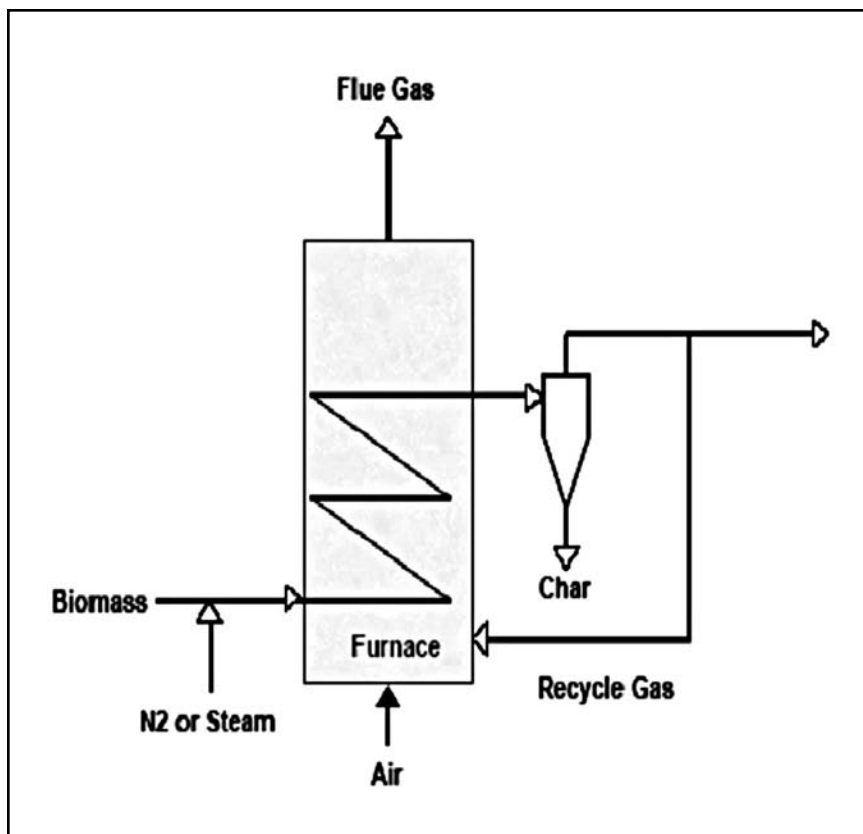


Figure 4. Entrained-flow gasifier.

A major problem is biomass feeding, particularly in terms of low density. Transportation of crop residues, for example, more than about 100 miles would cost more than energy reclaimed from it. Particulate formation is another difficulty, particularly with downstream equipment. Tar is another issue—unwanted hydrocarbons in the gas that decrease its quality. The tars can interfere with downstream biological systems.

Figure 6 shows a power plant at which switchgrass bales are burned to generate electricity. Moisture content is critical, affecting operation of the gas fire and amount of tar produced. A large amount of bulky material is stored outside the facility because covered storage is expensive. In theory it's attractive, but in practice just handling this amount of material is an issue.

On the technical side, there is no standard for particulate level or tar. In other words, we don't know how much tar or how much particulate we can run in certain pieces of

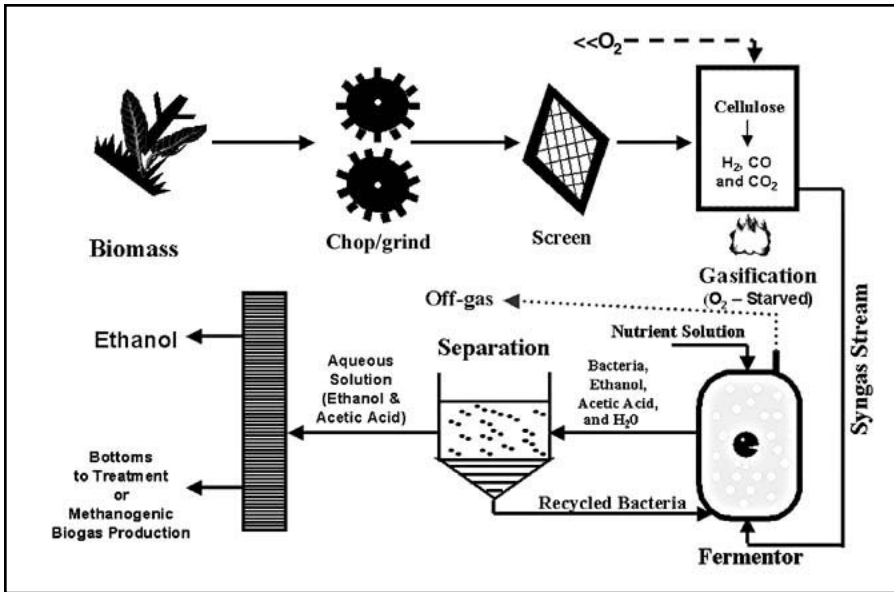


Figure 5. Gasification conversion for ethanol production (biorefinery).

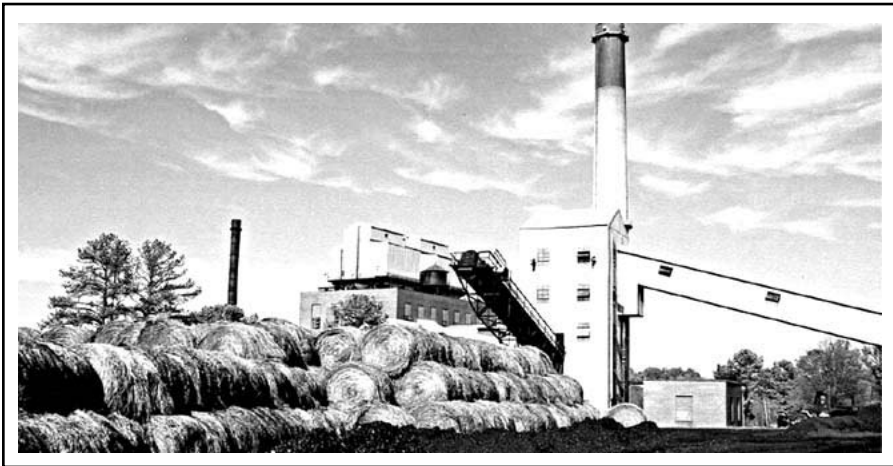


Figure 6. Feedstock storage and handling.

equipment. Furthermore, there's no definition for tar. We know what it is when we see it, but it has not been chemically defined. And there are no standard protocols for sampling. Numerous studies have been done, but, with different protocols used, they cannot be precisely compared. Therefore, when we talk about gasification (and tar, *etc.*) and what we are going to use it for, many issues require resolution.

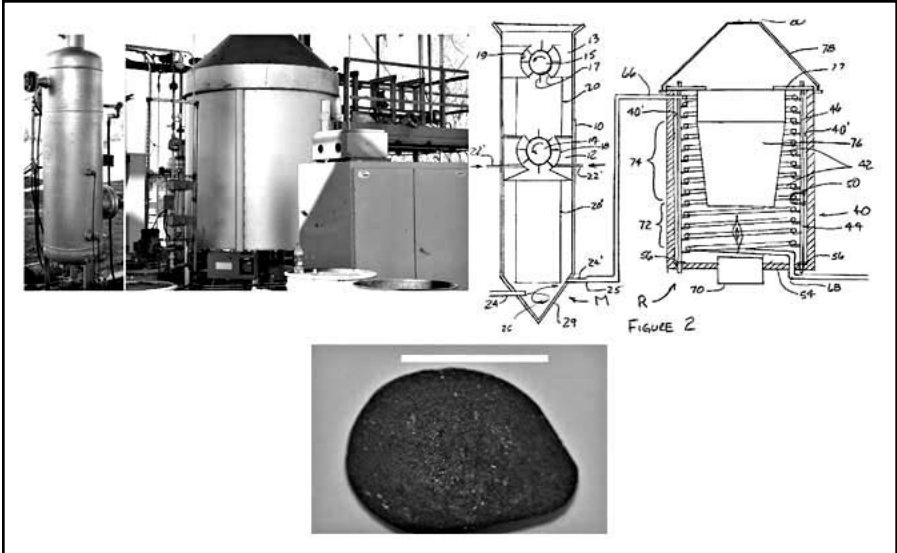


Figure 7. Entrained-flow gasifier with syngas-cleanup module, showing a tar ball (bar=0.5 inch).

As far as end-use is concerned, combustion requires some kind of nozzle for introduction, but if tar is present the injection system will become gummed up as will pistons. Gas turbines are even less tolerant. If the syngas is to be compressed for downstream use, there is even less tolerance. If hydrogen from syngas is eventually used with fuel cells it will have to be extremely clean or the whole process will be contaminated.

Figure 7 shows an entrained-flow gasifier at MSU's Institute for Clean Energy Technology, designed and manufactured by Mississippi Ethanol LLC. A proprietary sprayed-water process is employed in a scrubber with baffles to collect tars and ash that had been gumming up the downstream system, producing tar balls as shown (Fig. 7). Scrubbing cleans up the syngas but produces the environmental problem of disposal of contaminated water and tar balls.

Figure 8 shows a down-draft unit at MSU, manufactured at the Community Power Corporation, in Denver. With input from the National Renewable Energy Laboratory (NREL) we purchased this unit to test. It is intended as a system for purchase by farmers and villages. It was designed originally to accept aspen as the feedstock, and redesigned at MSU to handle pine. The catalytic bed, designed to convert the tar, became plugged when pine was used. Despite this and other operational problems, it now works well enough to produce a number of materials that are under examination in the laboratory.

Figure 9 represents a system that we have designed for on-going study of tars, and effectiveness of various catalysts for their destruction. And Fig. 10 shows a circulating, fluidized bed currently under construction in the laboratory.

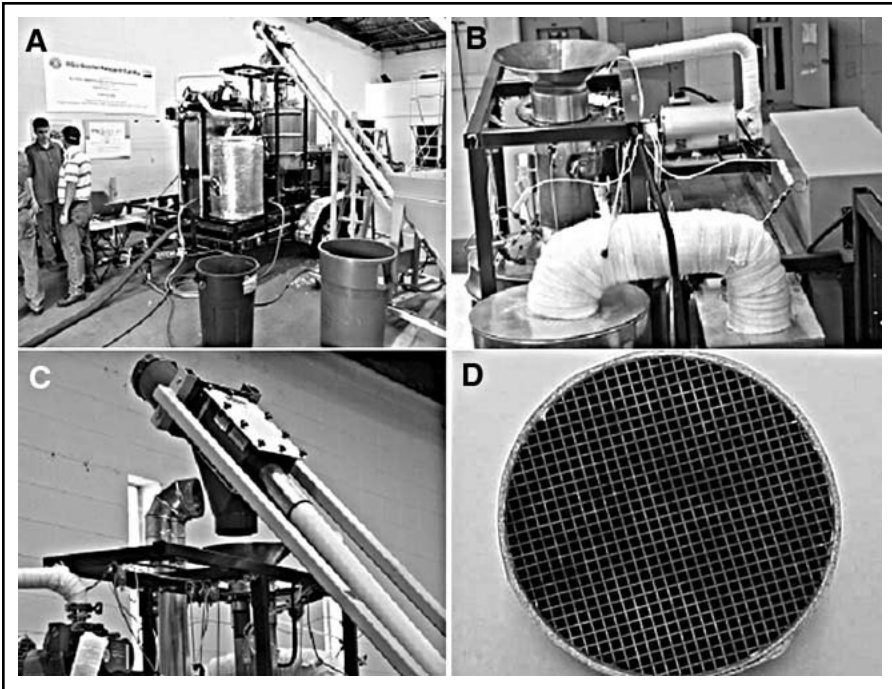


Figure 8. Down-draft gasification unit at MSU; A–overall, B–top, C–feed system, D–Pt/Rh catalyst block.

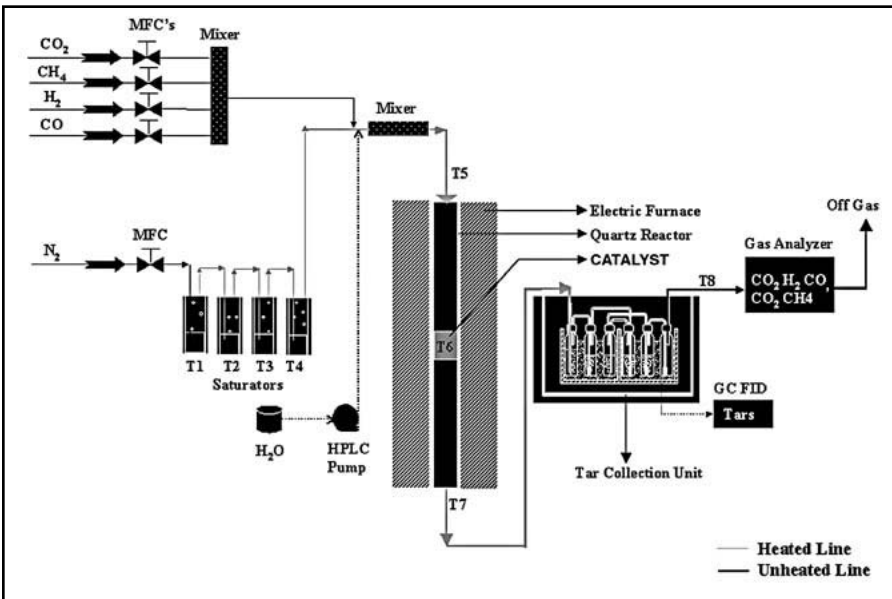


Figure 9. Schematic of a laboratory-scale catalytic reactor tar-treatment study

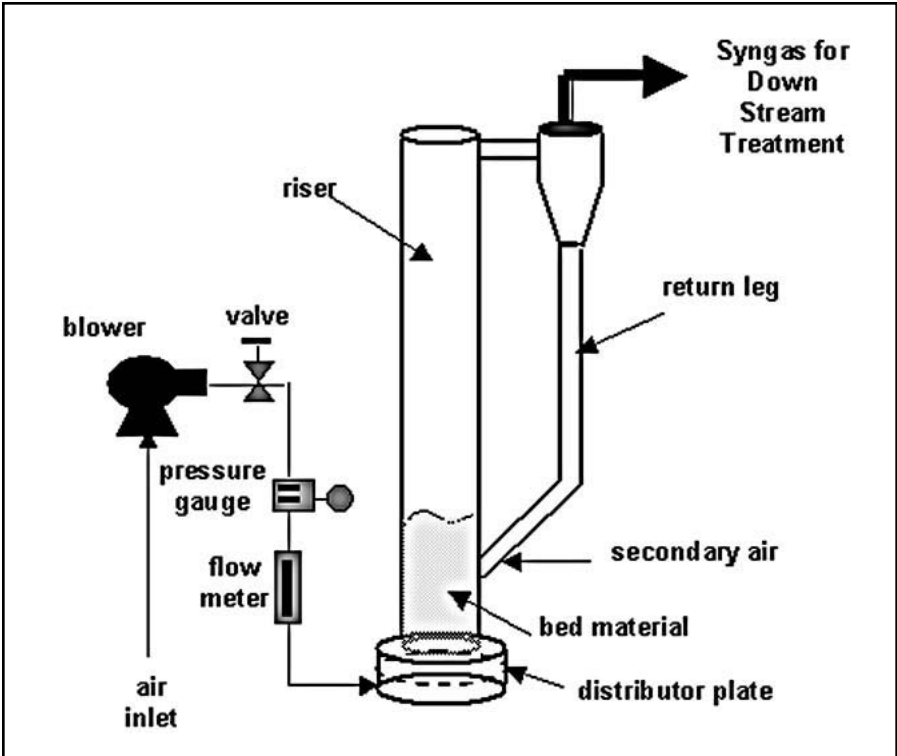


Figure 10. MSU circulating fluid-bed design.

SLEDGEHAMMER ADJUSTMENT

Although gasification is a well developed “sledgehammer” adaptable to many types of feedstock, problems remain to be solved. One of our particular interests is in how best to utilize the product, syngas.



MARK BRICKA is an associate professor in the Dave C. Swalm School of Chemical Engineering at Mississippi State University (MSU) and director of the Environmental Technology Research and Applications Laboratory. Previously he served for 20 years as a research environmental engineer with the US Army Corps of Engineers and was employed as a process engineer at PPG Industries where he applied chemical engineering principals to solve environmental problems. He received his BS in chemical engineering from the University of Alabama in 1982, his MS in chemical engineering from Mississippi State University in 1988 and his PhD in environmental engineering from Purdue University in 1989.

His research interests include alternative energy and environmentally related aspects, including syngas production, cleanup, distributed power generation as well as pyrolysis oil production, stabilization and utilization. He has authored numerous technical papers in the environmental and alternative-energy areas.

Dr. Bricka received numerous army citations for outstanding research and recently was awarded the Sigma Xi Ralph Powel Award for Outstanding Research at MSU. He is director of the Mississippi Chapter of the Air and Waste Management Association and a member of the Mississippi Biomass Council and of the American Institute of Chemical Engineers.

Butanol: The Other Alternative Fuel

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As I motored from Blacklick to Brookings in my 100% butanol-fueled car, several questions occurred to me:

- How much sugar is available from the grasses growing along freeways and in pastures?
- How much energy would it take to process these grasses—with their high content of water and sugar—into butanol?
- Why haven't people recognized the fact that young grasses are low in lignin and cellulose?
- Why haven't people considered that it might be easier to use grass as a readily digestible feedstock for fermentation?
- Why haven't we considered the full potential of pastures, *e.g.* harvesting them four or five times per year as sources of biomass feedstock?

Similar questions led me to butanol 15 years ago.

Butanol is amazing. A gallon in the tank of my '92 Buick improves torque properties and mileage. Even though its BTU content is less than that of gasoline, it gives better mileage. My Buick averages 22 mpg with gasoline, whereas it averaged 25 mpg from Ohio on 100% butanol. Significantly, these results pertained without modification to the engine, whereas modifications are required for automobiles to use E85 (85% ethanol, 15% gasoline).

10,000 MILES ACROSS AMERICA

I uncorked the butanol “genie” 2 years ago when I drove across the United States on 100% butanol in my 1992 Buick without any modification to the engine. That event demonstrated to the public that a power-grade fuel alcohol made from corn is already available—butanol—with the potential to replace gasoline, gallon for gallon.

On May 21, 2007, in Brookings, SD, we finished the first leg of our “2007: 2-K Second Run Across America.” After two demonstration drives using 100% butanol as fuel, I contend that the sooner we start making ButylFuel™, the sooner you will be able to put it into your tank and help stop global warming.

THE NEW BUTANOL PARADIGM AND GLOBAL WARMING

Butanol can be used to power your current car. It is safer than gasoline, will give you better mileage and, above all, it will increase the amount of energy derived from biomass in comparison to ethanol—by 24–42%¹.

The following are questions I’ve asked over the past few years:

- What if we could make a transportation fuel from biomass that requires no engine modification and is safe?
- What if we could make a biomass fuel today that can solve most of the shortfalls of the other alternative fuels?
- Isn’t this what our tax dollars have been searching for?

We could mitigate CO₂ emissions quickly by doing something that is applicable to every gasoline-consuming car already on the road. This is important, particularly in view of the fact that many people are resistant to buying flex-fuel cars that run on E85 or gasoline. People keep their old polluters because they cannot afford these new automobiles. Butanol would enable them to replace gasoline in their existing cars and, thereby, immediately help stop global warming.

Butanol could be introduced into the US fuel grid way beyond the blend of 90% gasoline and 10% ethanol (E10). Higher percentages of ethanol can be burned only in flex-fuel cars. In contrast, we could begin introducing various blends of butanol with gasoline, up to 100% (Bu100). And, as I demonstrated with my 2005 trip across America, and my 2007 drive to South Dakota, we can already run fuel-injected cars with Bu100 in the fuel tank, without engine modification.

SAFETY

In comparison to gasoline and ethanol, butanol is hard to ignite and it burns with a cleaner flame; it is combustible but not dangerously flammable as is gasoline and ethanol. Furthermore, again in contrast to ethanol, butanol can be shipped through existing oil pipelines without causing damage. However, butanol awareness is in its infancy and many unanswered questions remain.

¹Editors’ note: Depending on whether and how hydrogen is captured, see Table 3.

ATTEMPTS TO COMMERCIALIZE

From 1998 to 2003, as I progressed to phase III of a DOE grant, my goal was to commercialize. Two venture capitalists (VCs) decided against investing. One reason was that butanol was not on the National Renewable Energy Laboratory (NREL) or Department of Energy (DOE) databases—no mention of it as an alternative fuel could be found.

The International Clostridia Group had been trying for over 25 years to obtain recognition regarding butanol fermentation; individuals interested only in ethanol had ignored them. Research follows funding, and funding follows extensive lobbying which occurred from groups pushing ethanol research and implementation. At the time, no lobby was pushing for butanol. In fact, we still don't have a butanol lobby, despite a critical need.

Absent the lobby, and out of frustration to try to get the NREL, DOE, and investors to understand the efficacy of butanol, and having used butanol in my John Deere tractor and lawnmower, I finally realized that I had to bite the bullet, and test it in the family car. I put 100% butyl alcohol into the fuel tank of my 1992 Buick and drove across America, coast to coast, during the summer of 2005.

POLLUTION REDUCTION

Before the across-US trip, I drove to the EPA station in Springfield, OH, using butanol I had made in the lab from sugar and corn. They were amazed by the test results: butanol reduced hydrocarbons by 95%, carbon monoxide to 0.01%, and oxides of nitrogen by 37% compared to gasoline. My 13-year-old Buick had never performed so well as during that 120-mile roundtrip.

The EPA staff in Springfield were so impressed by the results that they arranged for free tests at EPA stations in other states. The Springfield results were repeated; my 100%-butanol-fueled car was well below the minimum pollution-emission standards at each testing station.

At that point, I put "Powered by 100% Butanol" signs on the doors and headed to the St. Louis arch, to Albuquerque, the Grand Canyon, Phoenix and on to San Diego. We drove up Mount Palomar, home of the 200-inch Hale telescope, then up and over the Los Angeles Grapevine into Sacramento and San Francisco; then eastward we went, to Washington, DC.

WHY NOT BUTANOL IN THE 1970S?

Butanol amazes others too. People are surprised to learn that it hasn't been firmly on the radar screen as an alternative fuel. On the other hand, butanol *was* on the alternative-fuels map three decades ago. We had a choice to subsidize either ethanol or butanol and we went with ethanol. Produced by the historic "ABE" fermentation process (developed 1919–1920), butanol has been viewed as too expensive to manufacture via fermentation, and too difficult to recover—which it was. On the other hand, bacteria continuously synthesize acetone, butanol and ethanol (ABE) in anaerobic soils and even in manure heaps. So if nature can make butanol and butanol can power my car, "How soon can I make more butanol?" That was my question 15 years ago.

Table 1 provides concentrations, boiling points and yields of ButylFuel™ compared with ethanol and with data for the ABE process. The reasons we did not go with butanol in the 1970s were:

- The ABE fermentation process yields only 1.3 gallons of butanol/bushel of corn, whereas yeast fermentation produces 2.5² gallons of ethanol/bushel of corn.
- Its low final concentration (0.6%) compares poorly with that of ethanol from yeast fermentation (10–15%); the 1–2% alcohol concentration in the ABE-fermentation combination is sufficient to kill the fermenting bacteria.
- Butanol’s boiling point (117°C) is higher even than that of water. At the 1–2% final batch concentration, there is a lot of water to boil off, which is expensive.

TABLE 1. COMPARISON OF YEAST ETHANOL, ABE FERMENTATION AND BUTYL FUEL™.

	Ethanol	ABE			ButylFuel™ butanol only
		Acetone	Butanol	Ethanol	
Final concentration* (%)	10–15	0.3	0.6	0.1	(continuous)
Boiling point (°C)	78.5	56.5	117	78.5	117
Yield (gallons/bushel corn)	2.5 ²	0.70	1.3	0.36	2.5

*Final concentration is the proportion of alcohol to total solution. The ABE process requires a much greater amount of water and thus a much larger facility to produce half the alcohol. This is because anything more than 1–2% concentration kills the bacteria in the ABE process.

SOLVING THREE PROBLEMS WITH ONE PATENT

I asked a simple question: “How could butanol yield be increased and production costs decreased?” I solved the three major problems with the ABE process by:

- increasing the yield of butanol from 1.3 gallons/bushel of corn to 2.5 (thus making it similar to that of ethanol by yeast fermentation);
- overcoming the problem of the low final concentration of 1–2% by developing a recovery process that removes the solvents continuously and precludes accumulation to a level lethal to the microbe; and
- solving the expensive recovery problem associated with the high boiling point by sparging carbon dioxide (produced by the fermentation) through the broth, stripping the butanol and then letting a gravity process increase the concentration before removing the remaining water.

²Editors’ note: A conversion rate of 2.8 gallons of ethanol/bushel of corn is generally used (e.g. <http://www.ethanolmarket.com/corngrains.html>), potentially applicable also in Tables 2 and 3.

Development of the continuous operation eliminated the need for the batch-process clean up every 4–5 days and having to restart the fermentation, as are normal with the ethanol process.

MAKING BUTANOL ONLY

As a physicist, my question was, “Where is all the precious carbon (sugar) in the feedstock going?” The carbon was being used to produce ancillary (undesired) products unnecessary for butanol production. In the ABE process, much of the carbon goes into acetic, lactic, propionic and butyric acids. As the pH drops, the bacteria change morphology and enter a solventogenic phase in which they convert the acids to acetone, ethanol, isopropanol and butanol. The production of butyric acid makes possible the synthesis of butanol. Therefore, I posed another scientific question: “Is it possible to convert carbon (sugar) directly to butyric acid and then to butanol?” In addressing this question, I hypothesized that butyric acid would be converted to butanol; accordingly I added butyric acid at a 3% concentration to an active wort and watched the microbes digest it and make butanol. Eureka! This became my patent. Notwithstanding the origin of the butyric acid, I was able to double the yield to 2.5 gallons of butanol/bushel (calculated) by eliminating the ancillary products (acetic, lactic and propionic acids, and acetone, ethanol and isopropyl alcohol) by a proprietary method. We now produce butyric acid, and continuously convert it to butanol.

MORE ENERGY FROM A BUSHEL OF CORN; THE NEW “BUTANOL ECONOMY” PARADIGM

Examining the various types of processing and focusing on energy content, Table 2 shows that 24% more energy is produced from a bushel of corn by producing butanol (a four-carbon molecule) rather than ethanol (a two-carbon molecule).

TABLE 2. COMPARISONS OF ACCRUALS FROM CORN.

		Gallons/bushel	BTUs/bushel
Ethanol		2.5	210,616
ABE	Acetone	0.59	141,583
	Butanol	1.35	51,845
	Ethanol	0.20	16,712
Total ABE		2.14	210,140
ButylFuel™	Butanol	2.5	262,056
[BTU difference, Butylfuel™–ethanol]			[51,440 (24%)]

Furthermore, hydrogen is generated in the anaerobic fermentation, adding 17–18% of energy captured (Table 3)

TABLE 3. ENERGY COMPARISONS, CORN-PRODUCED ETHANOL VS. THE BUTYLFUEL™ PROCESS.

	Corn	Ethanol	Butanol	Hydrogen	Increase
BTU/pound		12,790	15,511	61,000	
BTU/gallon		84,286	104,854		
Gallons/bushel of corn		2.5	2.5		
Pounds/gallon		6.59	6.76		
Pounds/bushel	56	16.5	16.9	0.62	
BTUs/bushel of corn		210,715	262,136	37,576	
BTU increase, butanol and hydrogen separately and cumulatively over ethanol (%)			24	18	42

The ButylFuel™ process generates hydrogen—which could be captured and used with the ButylFuel™ production facility—a potential capture of 18% more energy, for a total of 42% more energy compared to ethanol (Table 3). This increase is potentially significant in terms of reducing US reliance on foreign oil. Recently Steven Koonin (2006) stated:

Credible studies show that with plausible technology developments, biofuels could supply some 30% of global demand in an environmentally responsible manner without affecting food production.

With the energy captured by the ButylFuel™ process—42% more than from ethanol—we should be able to supply substantially more than 30% of global demand.

Butanol acceptance and development are in their infancy. We still have to go through all levels of tier testing. I see future retrofitting of ethanol fermentation plants. The simple fact is: we capture 42% more energy from the same bushel of corn producing butanol via the ButylFuel™ process, and butanol can go directly into the automobile fuel tank. The sooner we implement this “New Butanol Economy” paradigm, the better it will be for the planet.

SMALL IS GOOD—POWERFUL MICROBES

Figure 1 shows a colony of microbes “huddled” where nutrients pass by and products of fermentation are washed away. This is the ButylFuel™ reactor—axenic and anaerobic.

Ethanol production requires less stringent conditions—pasteurization suffices rather than sterilization. Because of these different requirements, capital equipment investment will be necessary to retrofit ethanol plants for butanol production.

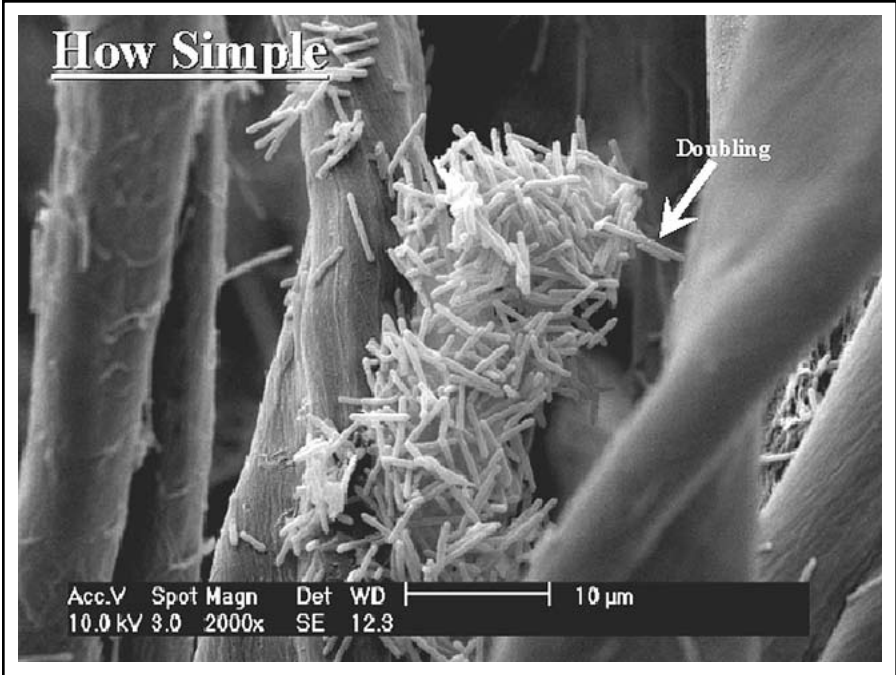


Figure 1. A colony of *Clostridium acetobutylicum* ATCC 824 on an inert cellulosic support, flushed with fresh feedstock and butanol continuously removed.

BIGGER IS BETTER

Butanol is a 4-C molecule whereas ethanol has two C atoms. Table 4 shows that butanol’s larger molecule translates into more energy: 110,000 BTUs/gallon versus 78,000 for ethanol. Table 4 shows also that butanol is safer to use than ethanol and gasoline as a result of its lower vapor pressure (VP)—it is difficult to ignite and it burns slowly. Like diesel, a match has to be held to it for ignition; butanol is combustible but not flammable, whereas methanol, ethanol and gasoline are flammable and potentially explosive.

TABLE 4. PROPERTIES OF FUEL-GRADE ALCOHOLS AND GASOLINE.

	Methanol CH ₃ OH	Ethanol C ₂ H ₅ OH	Butanol C ₄ H ₉ OH	Gasoline
Energy content (BTUs/gallon)	63 k	84 k	110 k	115 k
Motor octane	91	92	94	96
Air:fuel ratio	6.6	9	11–12	12–15
Vapor pressure (psi@100°F)	4.6	2	0.33	4.5

COST PER MILE

An average gasoline consumption of 22 mpg at \$3.00/gallon means a cost of \$0.14 per mile. Table 5 provides cost comparisons for gasoline, E85 and butanol.

The lower cost per mile with butanol (at \$3.00/gallon) is encouraging. On the drive to Brookings, the Buick averaged 25 mpg, extrapolating to \$0.12/mile, less than for E85 (at \$2.80/gallon) or gasoline (at \$3.00/gallon). On our cross-country trip in 2005, we got 27.5 mpg going through the desert, equivalent to \$0.11/mile.

TABLE 5. COSTS PER MILE FOR E85, GASOLINE AND BUTANOL.

			Cost/mile
Cost/gallon	E85	\$2.80	
	Gasoline	\$3.00	
	Butanol	\$3.00	
Average mpg	E85	17.6*	\$0.16
	Gasoline	22	\$0.14
	Butanol	25	\$0.12

*20% less than for gasoline.

HOMELAND SECURITY, ENERGY DECENTRALIZATION AND THE FARMSTEAD

Presently, the United States needs a substitute for foreign oil to generate more energy independence and safely replace gasoline. And we want to revitalize the American farming industry by growing biomass locally and converting it locally to butanol. In doing so, we increase homeland security by decentralizing energy production and distribution. This is exactly what the United States wanted to do back in the 1970s with ethanol after the first OPEC crisis.

For improved security in transportation fuel, ButylFuel LLC proposes building turnkey platforms to enable farmsteads to produce value-added butanol for sale to the energy grid as well as to local communities. A 500-acre farm producing 120 bushels/acre of corn at \$3.00/bushel will gross about \$180,000 a year. In contrast, the same acreage and same yield, used to produce butanol at 2.5 gallons/bushel and sold to neighbors for automobile use at \$3.00/gallon, would gross about \$450,000. Of course, butanol production would entail additional capital.

With butanol, a new positive attitude will emerge from “Not in my backyard” to “Let’s put one on my farm.” An emerging positive and supportive grassroots attitude will make things happen quickly and help spread farmstead biorefineries across America.

BUTYLFUEL™

ButylFuel LLC is gathering energy-balance data to compare the costs for producing butanol using the ButylFuel™ process versus ethanol manufacturing. At the same time, we are establishing the equipment necessary for stable long-term anaerobic, axenic manufacturing practices.

It is expected that initial capital-equipment costs will be more for butanol fermentation parlors because of the different requirements for batch yeast vs. continuous anaerobic butanol production. However, labor and other overheads will be reduced with the continuous process, therefore, encouraging data are expected from our work.

No matter what the biomass stream is, ethanol and butanol entail the same material handling costs up front (*i.e.* for grinding and pulverizing the feedstock). Similar distillation recoveries will be involved in the back-end processing; additionally, there will be similar by-product opportunities (for the unspent corn/distillers grains left over as well as for other solid-waste streams). Only the fermentation parlors will be modified for conversion from ethanol to butanol production.

Pretreatment of biomass produces sugars for digestion. Sugar is sugar. It doesn't matter whether it comes from kudzu or willow, corn kernels or stover, or anything else that grows on planet Earth. Research being done to turn various biomass feedstocks into sugars for ethanol is applicable to butanol production. It takes 14 lbs of sugar to make a gallon of either butanol or ethanol.

MISSIONS

Our primary mission at ButylFuel™ is to stop global warming by impacting the existing automobile fleet. The sooner cars and airplanes begin using butanol, the sooner we will positively affect the planet's health.

We also vigorously promote an agricultural way of life and community throughout the United States by growing feedstock and disseminating ButylFuel™ from the farm. In the 1970s and 1980s, the government encouraged farmstead-ethanol production until several farmers were killed and it was shown that the energy-balance is unfavorable for small farmstead operations (Carley, 1981; Hunt, 1981).

Everyone at this conference wants to get out from underneath the oil thumb, and build US farming communities so that they have a stable and profitable income selling value-added products that will always be in high demand.

STRATEGY

Our strategy is to walk before we run, one step at a time. One step we will take is to scale up from our continuous 50 gallons/week process to a stable 100 gallons/week. Our next step will be to manufacture 1–2 million gallons/year as a pilot plant, using the feedstock slip-stream of an existing ethanol facility. Then we will raise butanol production to 10 million gallons/year.

THE FUTURE

A good farmer is nothing more nor less than a handy man with a sense of humor.

—E. B. White

We in the United States have been like Don Quixote on his noble quest to save Delcinea's honor. He mistook a windmill for another knight and ended up dueling the windmill. On our noble quest to save America's honor by producing energy from biomass, we have

misinterpreted the viability of ethanol and missed the potential of butanol for three decades. Now, we have an opportunity to remedy this.

Not only did we miss butanol's feasibility as a fuel, but we should pay attention to an additional aspect of our "biomass to energy" quest—soil scientists are little involved. Where are they? Many scientists and engineers are focused on solving problems associated with lignin removal and with the use of stover, switchgrass and wood as biomass and their conversion to sugars. But, if we fail to restore the soil's humus and till with aerobic bacteria, 18–24 inches below the surface, we will be in trouble. If we are to leave a "biomass to fuel" legacy to our children, its viability will be determined by how much topsoil we bequeath.

As we compact the soil and deplete its trace minerals, air and nitrogen, its fertility is compromised. Bill Richards³ mentioned that his tractor is equipped with a GPS system that doesn't allow him to take the same path twice through the field. That is great, but we should also make a concerted effort to rebuild the soil. No-till works only at the surface, preventing erosion; it does little to increase the depth of aerobic bacterial activity. A spin-off of good till is a soil that holds moisture more effectively, requires less application of chemical fertilizers and requires less energy to go through the field.

Since I demonstrated the efficacy of this other alternative fuel with my '92 Buick, many would rather build butanol plants than ethanol plants. I encourage them to build ethanol plants and, in due course, retrofit them to produce butanol. We've had 30 years of tax incentives to solve ethanol's problems, whereas butanol is in its early years.

Uncorking the butanol "genie" was a major turning point in the initial acceptance of butanol, stimulating such interest that every person who has ever written a paper about butanol or ABE fermentation has had a job offer.

I guess frustration can help. Certainly it's what compelled me to drive across America. I came back a different person from the lab rat I had been—a proponent of a simple 4-carbon molecule without a voice.

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³Pages 43–46.



Driving 10,000 miles cross-country without using a drop of gasoline, **DAVID RAMEY** arrived back in Ohio on August 17, 2005. Environmental scientist, agriculturalist, physicist, engineer and inventor, Ramey—founder and president of Environmental Energy, Inc. (EEI)—drove his unmodified 1992 Buick, using only butanol.

Ramey's butanol was produced by his own patented process, and for his pioneering efforts to bring this organically derived fuel to market, he was recognized as the "1996 Technologist of the Year" by the Ohio Academy of Science.

Ramey has physics and mathematics degrees from California State University, San Diego. During the past several years he has been a researcher and an inventor in microbiology through a DOE/STTR grant. Also, in collaboration with Dr. S.T. Yang at the Ohio State University's Chemical Engineering Department, he obtained a \$1 million dollar grant through the USDA's SBIR program to research, develop and commercialize butanol fermentation.

Environmental Energy, Inc., is now ButylFuel LLC, which is building a prototype that will produce 50–100 gallons of butanol per week, in order to characterize the process for scale up. The first scale-up will be a pilot plant that will produce 2 million gallons of butanol per year.

Technology: Biomass, Fuels and Co-Products

Q&A

MODERATOR: KEN DASCHIELL

*USDA-ARS North Central Agricultural Research Laboratory
Brookings, SD*

Sonny Ramaswamy (Purdue University): Mark, in your gasifying system, how do you deal with the carbon dioxide that is released as well? It tends to be quite a lot.

Mark Bricka: I'm not real worried because it's not controlled—it's not regulated. If the government comes back in and says you have to control it then you could absorb it. Our students have done some studies on how to absorb and sequester it, but right now it's not an issue.

Wally Tynes (Purdue University): Kurt, you indicated that poultry people aren't interested in the DDG that comes out of the fractionated process and I don't quite understand why. In poultry rations the constraint you hit is fiber and usually the fractionation processes cut both the oil and the fiber. If you need more oil they can get a cheaper oil or you can put the corn oil back in. It's not clear to me why the poultry people or hog people wouldn't be interested in something with lower fiber.

Kurt Rosentrater: I'm not an animal scientist and don't claim knowledge in that arena. I'm reporting what I've heard. I should give you the caveat that they still don't completely understand the DDGS in poultry or swine diets, although there's a lot of work going on right now. An aspect they are really interested in: if we pull out the fiber and if we pull out the oil what can we use to supplement DDGS in these complete rations? Glycerol—a by-product from the biodiesel industry—is a potential source of energy. So, with DDGS from a traditional dry mill plant they've got a product stream that they are still learning about. They haven't completely encapsulated all of the knowledge in terms of feeding. When we start using these modified products, it throws the whole system out of whack and they're going to have to do a lot more research.

Dennis Buffington (Penn State University): I'm interested in water requirements for conventional corn-based ethanol plants and for biomass-ethanol plants.

William Gibbons: For corn-ethanol production plants, they've become extremely good at recycling water and so utilization now is just a matter of 2 to 3 gallons of water per gallon of ethanol. A lot of that is due to recycling and reuse of the thin stillage stream and they do a lot of evaporation which, of course, is energy-intensive. Nobody really has a good feel right now for biomass, cellulosic ethanol, what that's going to entail. The demonstration plants the DOE is helping to fund will hopefully answer a lot of those questions, but, just anecdotally, corn-ethanol plants now typically run in the 15% to 18% ethanol concentration range in their fermentation streams and with biomass—just due to low bulk density—you might be able to reach 7% to 8% ethanol tops, before you start running into problems in terms of flowability issues. So, those numbers show you have significantly more water in the system. Now you are not going to dispose of that water, it's going to cost you in terms of evaporating that water, concentrating the resulting stream so the net use might end up being fairly similar. But there is going to be a lot more water flowing around in the plant during the operations.

Audience Member: Mark, you mentioned that Europe is ahead of us in technology as far as gasification is concerned. Are we in the US trying to advance their technology or create a better mousetrap?

Bricka: A lot of people are working on gasification and are in close communication with colleagues in Europe. We're trying to expand upon what they've done—not necessarily reinventing it, but improving it.

Maria Wellisch (CANMET Energy Technology): Kurt, I understand that antibiotics are used in commercial ethanol fermentation. Are issues or concerns raised regarding antibiotics in DDGS and potential impacts in terms of feed and so forth?

Rosenrater: Prior to this year I hadn't heard much talk of antibiotics in DDG. It was just one of those "don't mention it, don't think about it, don't talk about it" things. Antibiotics are used from time to time. In fact, in several states, the FDA is starting programs to monitor antibiotics and DDG. It's on the radar screen. In fact, the meeting I was at last week, with the Distillers Grains Technology Council, had a presentation on this subject. There's one antibiotic that is not necessarily approved yet, but they haven't said it can't be used. So it's a growing concern and it's on the FDA's radar screen.

Gibbons: A side-note to that—several companies are looking at alternative materials to antibiotics to control contamination in ethanol plants.

John Gross (Farm Service Agency): A two-part question for Kurt: One, has there been any cost study on pelleting distillers grains, because I know there's a problem shipping them

to the west coast and getting them out of railcars. Number 2, many are concerned about what to do with all of the distillers grains and other by-products. I visit dairies and within the past 2 months was told by the management of a very large operation in the upper Midwest that this might be the last year they use products from ethanol plants as feed. The reason is that poor digestibility is causing lower butterfat content. To get high butterfat you feed rough hay and a lot of fiber. When a person milking 3,000 cows makes that kind of comment, it's something for you to think about.

Rosenrater: Regarding pelleting: I've received several calls this past year about pelleting DDG, specifically from West River South Dakota. Several ranchers are interested in feeding the material, but they can't logistically handle it. In my laboratory we're looking at approximately ¼-inch diameter pellets. We can make them for somewhere between \$1 and \$3 a ton and we've had success working with some of the pellet mill manufacturing companies. There's potential, not just for West River but also for west-coast rail shipment. Pelleting DDGS reduces propensity for flowability issues. It increases flowability, it increases bulk density, so you can actually get more of your DDG on your rail cars, up to 20% to 30% more. That has interesting implications for the logistical side of things. Whether between \$1 and \$3 a ton is justifiable economically is for specific plants to look at.

Regarding question #2, every once in a while I come across people who say that they are not going to feed DDG or the wet grains any more, but 99% of the time the people that I interact with say they want more. I've talked to several dairy producers and they can't get enough of it. In fact, last year the price of DDG was relatively high compared to those of other feedstocks. There was a tight supply of DDG, yet people couldn't get enough. That pressure is going to be somewhat alleviated this year as more plants come on line. There's still a lot of opportunity for research on how best to use DDG in animal rations, whether it's dairy-cow or grower/starter diet for pigs.

Tony Shelton (Cornell University): This is a question for Richard Flavell. You work primarily with perennial crops and mentioned that you are using traditional plant-breeding techniques as well as looking at genetic engineering. What traits would you be able to introduce into your plants only through genetic engineering? And do you have any concerns, especially with perennial plants, about obtaining approvals in the United States as well as other countries?

Richard Flavell: There are the sorts of properties that don't exist in those species, *e.g.* some sorts of pest resistance or disease resistance. One might focus on composition; how do you change cell-wall structure in a way that's going to open up the economics of what we've been talking about. Another aspect is that the genetics of these crops is very complicated and, therefore, getting all the right alleles together in the right plant—commercially and agronomically—will be more difficult than with corn, for example. So, it may turn out that if you have a form of drought tolerance that is existent in that species but it's hard to get it into an array of desired cultivars efficiently, then put it in transgenically.

On the second issue—reactions from the general community, the environmentalists, the regulators, are hard to know. I suspect there will be a lot of caution, a lot of concern, and that is clearly going to delay taking up any opportunities that are perceived to be valuable. That's why, on my last timescale slide, we put transgenics much further back. It's not that they couldn't be brought in earlier, but I think the reality is it's going to be a slower process due to acceptability. I would add that there are good reasons why one would want to control pollen flow from and seed viability of transgenics, and that's why companies like ours are making sure that we have the toolbox to stop seed production and pollen flow if and when there are characters that we want to introduce with transgenes, but we don't want to contaminate the rest of the species with those features.

Rick Brenner (Agricultural Research Service): David, you had some difficulty with venture funds. Have you looked at any state-operated funds or even something available through rural development? If you have, what are you seeing as the barriers from these sources?

David Ramey: Basically name recognition. I'm not the greatest grant writer in the world. Dr. Yang wrote our grant for the DOE, but I submitted a couple of proposals after phase 3 came into effect and was rejected. So we tried to find a source in the private sector. I think now that we've got a person who understands that we've just got to make 50 gallons a week. When we achieve that, we'll probably be able to access some state and federal funds to leverage that money. Money definitely helps, but microbes are different critters. They take time to mature and we're after stability. Once you get one of these reactors up it's like a cat or a dog, it's a living entity that can survive for years. So, we're really after stable runs and scaling up bigger and bigger.

Biofuels, Energy-Security and Global-Warming Policy Interactions <i>Wallace E. Tyner</i>	155
Capital and Sustainability <i>Roger Wyse</i>	167
Food vs. Fuel? An Integrated Approach to Producing Both <i>Mark Kraeger</i>	173
Development and Sustainability of the Biofuel Industry in Canada <i>Danny G. Le Roy & K.K. Klein</i>	177
Biofuels and Biorefinery Development in Canada: The Question of Sustainability <i>Maria Wellisch</i>	187
Q&A	195

Biofuels, Energy-Security and Global-Warming Policy Interactions

WALLACE E. TYNER
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Within the past 5 years, there has been a significant movement in political consensus towards an energy future with a substantially larger renewable-energy component. One of the major drivers is the perception that importing over 60% of our oil reduces our national security. A recent estimate of the hidden cost of oil dependence amounts to about \$3 per gallon of liquid fuel excluding multiplier effects (Copulos, 2007). This estimate includes incremental military costs, supply-disruption costs and direct economic costs. Many argue that energy security is a major issue that must be addressed in today's policy environment.

Another issue is global warming. The United States now acknowledges that global warming is real and that it is caused by human interventions. Over two dozen national and international corporations have joined forces with environmental groups to ask Congress to enact cap and trade policies as quickly as possible (US Climate Action Partnership, 2007). The link between biofuels and global warming is that biofuels, especially cellulosic-based biofuels, emit much less carbon dioxide into the atmosphere than conventional petroleum sources. While all biofuels provide net reductions in greenhouse-gas (GHG) emissions, cellulosic ethanol can, under certain production conditions, be carbon negative; that is, it actually sequesters carbon even after including the CO₂ released when the ethanol is used in vehicles. If we are able to enact cap and trade GHG policy in the near future, biofuels would receive a credit through the cap and trade system. In other words, the GHG-emissions reduction achieved by biofuels could be sold to other entities needing to purchase the reductions. However, we will assume here that the United States does not adopt a cap and trade system quickly, so other policy mechanisms will be needed to credit biofuels for their GHG-emission reductions.

So what we have with biofuels are two kinds of market failures, that economists call externalities:

- energy security, and
- GHG emissions linked to global warming.

Economists argue that externalities need to be “corrected” through taxes, subsidies or some form of regulation. While the nation may be paying an energy security cost of up to \$3 per gallon for liquid fuels, consumers do not pay that cost at the pump. In other words, markets have no way of incorporating the energy-security cost into the market transaction. To correct that market failure, we must either put an additional, substantially higher, tax on petroleum fuels, subsidize alternatives to petroleum, or create fuel standards that require liquid fuel vendors to procure a certain percentage of their liquid fuels from domestic alternatives to petroleum. In the US political context, the tax route is very unlikely to happen, so we will focus in this paper on alternative fuel subsidies and fuel standards. Since our energy security is increased in direct proportion to the extent to which a domestic alternative displaces petroleum, we will focus on petroleum import displacement in this analysis.

Similarly, there is currently no market mechanism to “price” GHG-emission reductions achieved by biofuels. Thus, if we want to credit biofuels for that reduction, we will need to incorporate a GHG credit into our subsidy mechanism

In the rest of this paper, we will discuss and evaluate a set of alternative biofuel policies that could be designed to achieve the energy-security objective alone or the energy-security and GHG-reduction objectives together.

ETHANOL ECONOMICS

Ethanol has been produced for fuel in the United States for almost 30 years. The industry launch was initiated by a subsidy of 40 cents per gallon provided in the Energy Policy Act of 1978. Between 1978 and today, the ethanol subsidy has ranged between 40 and 60 cents per gallon. The federal subsidy today is 51 cents per gallon. Throughout, the subsidy has been a fixed amount that is invariant with oil or corn price (Tyner and Quear, 2006).

Ethanol gets its value from the energy it contains and as an additive. It has value as a gasoline additive because it contains more oxygen than does gasoline (and, therefore, causes the blend to burn cleaner) and because it has a much higher octane (112 compared with 87 for regular gasoline). Historically, ethanol prices have been higher than those of gasoline because of the additive value and because of federal and state subsidies. It is interesting to portray these values in terms of the relationship between crude-oil price and the maximum a corn dry mill could afford to pay for corn at each crude price (Tyner and Taheripour, 2007).

Figure 1 displays the relationships between crude-oil price and break-even corn price on the basis of energy equivalence, energy equivalence plus additive value (assumed to be 35 cents per gallon for this illustration), and energy equivalence plus additive value plus the current federal blending subsidy of 51 cents per gallon. The energy equivalence line was done assuming a figure of 70%, slightly more than the direct energy equivalent.

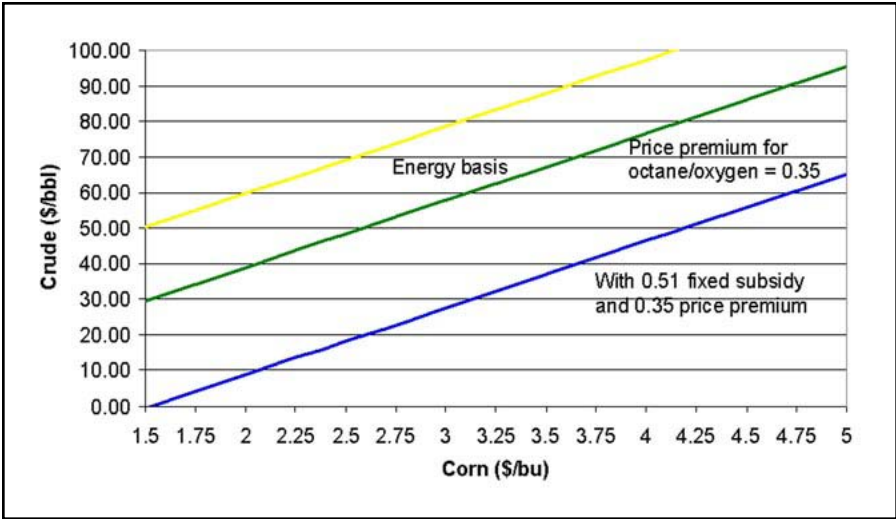


Figure 1. Breakeven corn and crude prices with ethanol priced on energy and premium bases plus a \$0.51 ethanol subsidy.

Using Fig. 1, one can trace out the break-even corn price for any given crude-oil price. For example, 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. This figure is for a new plant and includes 12% return on equity and 8% debt interest. If we consider an existing plant with capital already recovered, we add \$0.78 per bushel to yield a break-even corn price of \$5.50. It is important to note that additive value is currently 20 cents higher than the value assumed here, so ethanol producers can afford to pay another 53 cents per bushel under current market conditions, which are not likely to persist.

During the period 1984–2003, crude-oil prices ranged between \$10 and \$30 per barrel, with only one very short-term peak above \$30. With crude-oil prices in that range, the fixed federal subsidy did not put significant pressure on corn prices. However, with crude oil today around \$60, there is significant pressure on corn prices. During the past 3 years, ethanol investments in the United States have been highly profitable, with very short payback periods. This high profitability has attracted significant new investment in the industry and added substantially to corn demand. In just a few months, corn prices increased from about \$2.25 to around \$3.60 per bushel, an increase of about 60%. This leap is leading to an emerging opposition to ethanol subsidies on the part of animal agriculture, export markets, and other corn users. Some are also concerned about the \$4 billion cost of the subsidy in 2007 that will grow rapidly as ethanol production increases.

FUTURE POLICY ALTERNATIVES

In essence, we are living an unintended consequence of the fixed ethanol subsidy. When it was created, no one could envision \$60 oil; but today \$60 oil is reality, and many believe oil prices are likely to remain high. So given this reality, what future federal policy options

could be considered that would support the ethanol industry but provide less incentive for rapid growth in the industry leading to abnormally high corn prices? Several possible policy alternatives may be considered:

- Make no changes and let the other corn-using sectors (particularly livestock) adjust as needed.
- Keep the subsidy fixed, but reduce it to a level more in line with crude oil prices around \$60.
- Convert from a fixed subsidy to one that varies with the price of crude oil.
- Construct a subsidy policy with two components:
 - a national security component (either fixed or variable) tied to energy content of the fuel, and
 - a component tied to GHG-emissions reductions of the liquid fuel.
- Provide higher subsidies for cellulose-based ethanol in hopes of accelerating development and implementation of that technology.
- Use an alternative fuel standard instead of subsidies to stimulate growth in production and use of alternative fuels.
- Use a combination of an alternative fuel standard and a variable subsidy

No Changes

Certainly, one option is to do nothing—to let the other corn-using sectors adjust to higher corn prices. But as can be seen from the results in the ethanol economics and sensitivity analyses sections above, that option could lead to substantially higher corn prices than we have seen historically. It certainly would lead to higher costs for the livestock industry (happening already) and ultimately for consumers of livestock products. It also would lead to reduced corn exports. The breakeven corn prices provided above are maximums the ethanol industry could pay to retain profitability. Whether these prices would be reached would depend on the rate of growth of the ethanol industry compared with the rate of growth of corn supply. The March planting intentions report revealed an expected 90.5 million acres for corn, an increase of 15% over 2006. With that report, the high corn prices moderated somewhat. However, we can certainly expect to see continued pressure on corn prices if no change is made in federal subsidy policy.

Lower Fixed Subsidy

Since the current pressure on corn prices comes from the combination of \$60 oil and the 51 cent per gallon subsidy, one option would be to maintain a fixed subsidy but lower it to a level more in line with the higher oil price. Figure 2 depicts the corn breakeven prices with a 25 cent per gallon subsidy instead of the current 51 cent per gallon subsidy. The corn breakeven price for \$60 oil becomes \$3.90 instead of \$4.72 under current policy. However, the fixed subsidy still has the disadvantage of not responding to possible future changes in oil prices. If oil fell to \$40, the corn breakeven would be \$2.84, and it would be \$4.43 for \$70 oil.

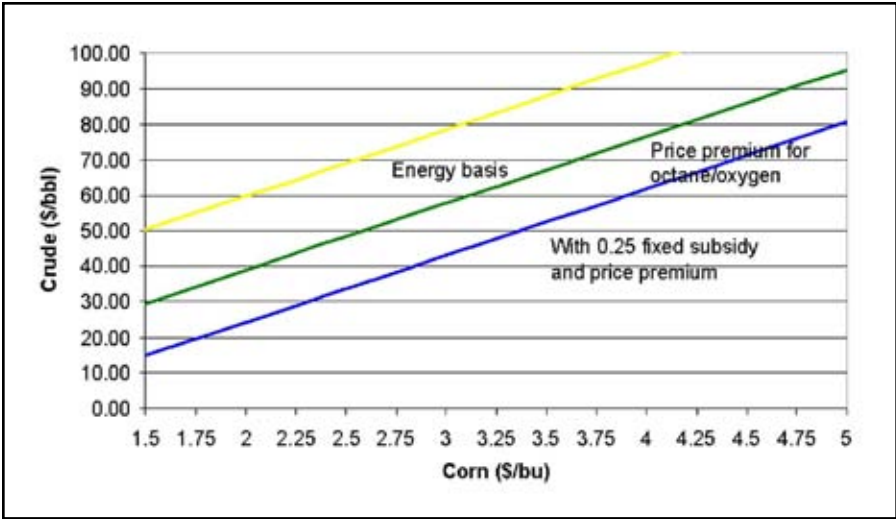


Figure 2. Breakeven corn and crude prices with ethanol priced on energy and premium bases plus a \$0.25 ethanol subsidy.

Variable Subsidy

Both the current fixed subsidy and a variable subsidy are intended to handle the energy-security externality described above. In designing a variable subsidy, there are two key parameters:

- the price of crude oil at which the subsidy begins, and
- the rate of change of the subsidy as crude oil price falls.

We will illustrate the variable subsidy using \$60 crude as the point at which the subsidy begins. That is, when crude is higher than \$60, there is no subsidy, but some level of subsidy exists for any crude oil price lower than \$60. In this illustration, we will use a subsidy change value of 2.5 cents per gallon of ethanol for each dollar crude oil falls below \$60. Thus, if crude oil were \$50, the subsidy per gallon of ethanol would be 25 cents. If crude oil were \$40, the ethanol subsidy would be 50 cents per gallon. Therefore, for any crude-oil price above \$40, the ethanol subsidy would be lower than the current fixed subsidy. For any crude price less than \$40, the subsidy would be greater than the current fixed subsidy of 51 cents per gallon.

Figure 3 illustrates the corn break-even price for different crude oil prices if this variable subsidy were in effect. In this case, the corn break-even price at \$60 oil for a new ethanol plant would be \$3.12 per bushel, compared to \$4.72 with the fixed subsidy shown in Figure 1. With oil at \$50, the corn break-even would be \$2.90 for a new plant with the variable subsidy. \$40 oil would support a corn price of \$2.69 for a new plant and \$3.47 for an existing plant with capital recovered. \$70 oil would yield a breakeven corn price of \$3.65 with no ethanol subsidy. So the variable subsidy provides a safety net for ethanol producers without putting inordinate pressure on corn prices.

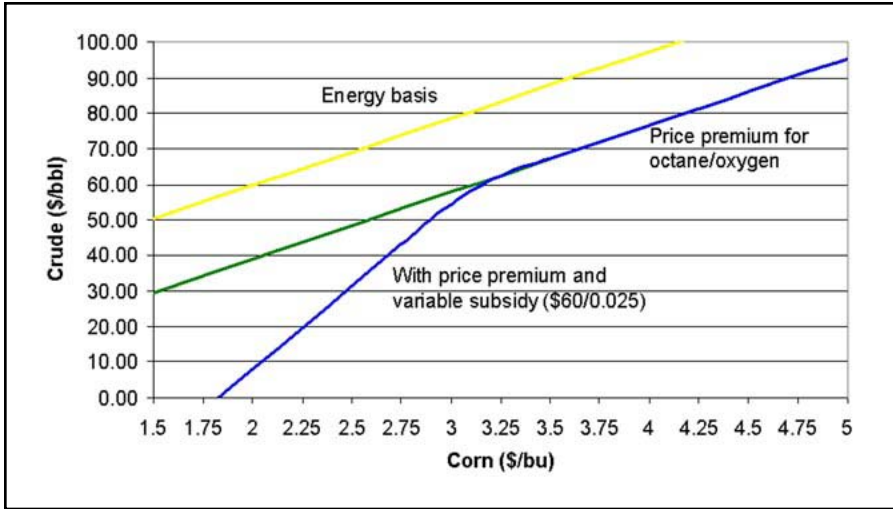


Figure 3. Breakeven corn and crude prices with ethanol priced on energy and premium bases plus a variable ethanol subsidy.

For any crude-oil price above \$60, there is no ethanol subsidy with the variable system, so ethanol-plant-investment decisions are made based on market forces alone instead of being driven by the federal subsidy. For any crude price between \$40 and \$60, the variable subsidy is less than the fixed subsidy, thereby providing less incentive to invest and less pressure on corn prices, but maintaining a safety net. However, with the fixed subsidy, ethanol-plant-investment decisions continue to be heavily influenced by the government subsidy even at crude-oil prices that render ethanol very profitable in the absence of a subsidy.

Two-Part Subsidy

The two-part subsidy derives directly from the externality discussion provided above. For this illustration, we will construct the national security part of the subsidy based on energy content of the renewable fuel. Thus, ethanol from corn or cellulose would have the same energy-security subsidy since the energy content is the same, but biodiesel would have an energy-security subsidy 1.5 times larger since it has 150% of the energy content of ethanol. Similarly, biodiesel would have a larger GHG-reduction component than corn ethanol—but lower than cellulose ethanol—because of the differences in GHG-emission reduction. The GHG component would be invariant with the price of crude oil, but the energy security part could be fixed or variable. In this illustration, we will assume it is fixed.

Hill *et al.* (2006) indicate that corn-based ethanol provides a 12% reduction in GHG (compared to gasoline), and soy biodiesel provides a 41% reduction (compared to diesel).

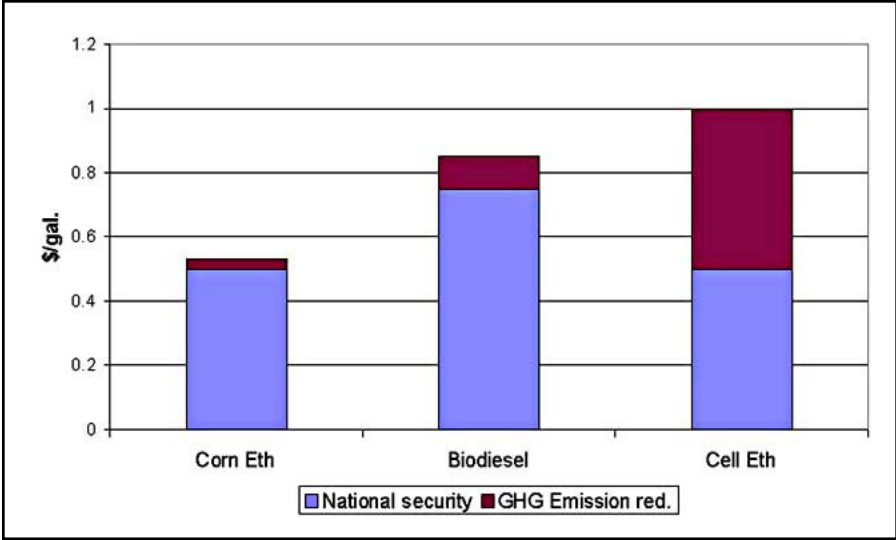


Figure 4. Two-part bioenergy subsidy.

Tilman, Hill, and Lehman (2006) indicate that switchgrass can actually be carbon-negative; that is, more carbon is sequestered than is released in combustion. For cellulose ethanol, they calculate a 275% reduction in CO₂ emissions. Actual carbon balance depends on the production conditions. For purposes of this illustration, we will assume that cellulosic ethanol yields a 200% reduction in GHG. One could envision a GHG component of the subsidy keyed to an index. For simplicity, we will use these three percentage figures for the index values for corn ethanol, soy biodiesel, and cellulose ethanol respectively.

For the energy security component, we will key it to energy value, *i.e.* to the energy content of oil displaced. The two-part subsidy is illustrated in Fig. 4. For this illustration, we keyed the base values for the national security component and GHG component to yield a corn-ethanol subsidy roughly equivalent to the current federal ethanol subsidy of 51 cents. The base assumptions are 75 cents for the national-security component per gallon of gasoline equivalent and 25 cents per gallon for 100% reduction in GHG emissions.¹ The resulting total subsidy values are 53 cents for corn ethanol, 85 cents for soy diesel, and \$1.00 for cellulose ethanol. Clearly, these values are just illustrative to demonstrate that a two-part subsidy encompassing both the national-security and GHG-emissions externalities would be possible to accomplish.

¹For this illustration, a relatively high carbon price of \$27.50 was assumed to calculate the GHG credit. Soy diesel and gasoline were assumed to have the same energy level and ethanol two-thirds of that level.

Incentives for Cellulosic Ethanol

Clearly, incorporation of the GHG credit as in the two-part subsidy described above would help stimulate production of cellulosic ethanol. However, if that is not possible or deemed desirable, other cellulose-targeted incentives may need to be considered. Use of cellulose instead of corn would also reduce the implications of ethanol production for corn exports and animal feed. If the state or federal government wants to provide incentives for the industry to move towards cellulose sources instead of corn, then targeted incentives might be appropriate. One method would be what is called a reverse auction. In that approach, the government requests that firms supply some fixed quantity of cellulosic ethanol for the next 10–15 years. Companies then bid for the contract to supply the ethanol with the lowest bidder winning the contract. Another option would be to provide a tax credit to cellulose processors for each dry ton of cellulose converted into fuels. With either of these alternatives, the government could assist in launching the cellulose-based industry. So long as corn-based ethanol is highly profitable, it will be difficult to stimulate investment in cellulose technology, because it is much more uncertain and at present more costly than corn-based ethanol production. Thus, targeted incentives might be needed.

Alternative Fuel Standard

In his 2007 state-of-the-union message, President Bush proposed a relatively large alternative fuel standard of 35 billion gallons by 2017. That is roughly seven times current ethanol production. A fuel standard works very differently from a subsidy. It says to the industry that you must acquire a certain percentage of your fuel from alternative domestic sources. In the president's proposal, the sources could be renewable fuels, clean coal liquids or other domestic sources. With a fuel standard that is perceived to be ironclad, the industry is required to procure these alternative fuels no matter what their cost in the market. Most of the change in cost of the fuels is passed on to consumers, either through cheaper or more expensive fuel at the pump.² In other words, if crude oil is much cheaper than alternative fuels, consumers would pay more at the pump than they would in the absence of the standard. If it turns out that alternative fuels are eventually less expensive than crude oil, consumers would actually pay less at the pump. So, in a sense, an alternative fuel standard is a different form of variable subsidy—one in which consumers see a price at the pump different from that without the standard. 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.

Figure 5 illustrates the functioning of an alternative fuel standard. The two lines represent \$40 and \$60 crude oil. The horizontal axis is the cost of the alternative fuel (unknown at this point), and the vertical axis is the percentage change in consumer fuel cost compared to the no-standard case. Clearly, in the left side of the graph with low alternative fuel costs, consumers see little or no change in fuel cost. But with high costs

²Recent studies of the demand elasticity for gasoline (Hughes *et al.*, 2006) conclude that it is very low (–0.03 to –0.08) and is lower than in previous time periods. With very low demand elasticity, most of the price change due to supply shifts would be passed on to consumers.

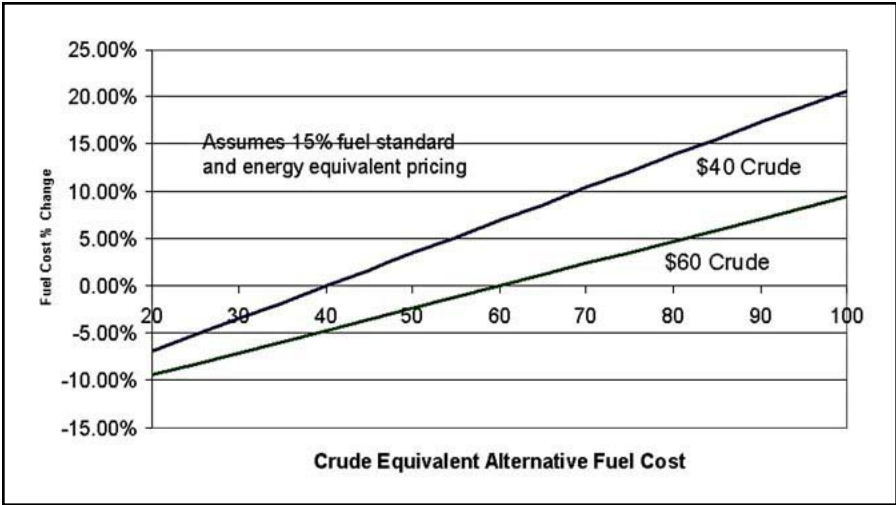


Figure 5. Fuel-cost change from fuel standard.

of alternative fuels (current state of technology), consumers could see significantly higher pump prices. 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.

Alternative Fuel Standard Plus Variable Subsidy

In the event that crude-oil prices turn out to be quite low, consumers could see significantly higher pump prices than without a standard. One option to limit the consumer exposure would be to combine a variable subsidy with a fuel standard. Essentially, there would be no subsidy unless crude-oil prices fell below some predetermined level, say \$45. Then a variable subsidy would kick in, which would limit the price increase consumers would see at the pump. In a sense, it is a form of risk sharing so that in the event of very low oil prices, the government budget would take part of the hit instead of pump prices. This option is illustrated in Figure 6. In this case, the horizontal axis is crude-oil price, and the curve is done for a \$60 alternative fuel cost. The line on the left side that begins at \$45 crude illustrates the impact of the variable subsidy combined with the fuel standard.

CONCLUSIONS

Ethanol has been subsidized in the United States since 1978 from 40 to 60 cents per gallon. Currently the subsidy is 51 cents per gallon, and combined with \$60 oil, ethanol production has become highly profitable. This profitability has stimulated a huge increase in ethanol production capacity with 6 billion gallons of new capacity under construction as of January 2007. This increase in production is increasing corn demand and prices. Under the current policy, ethanol producers could still invest profitably in new produc-

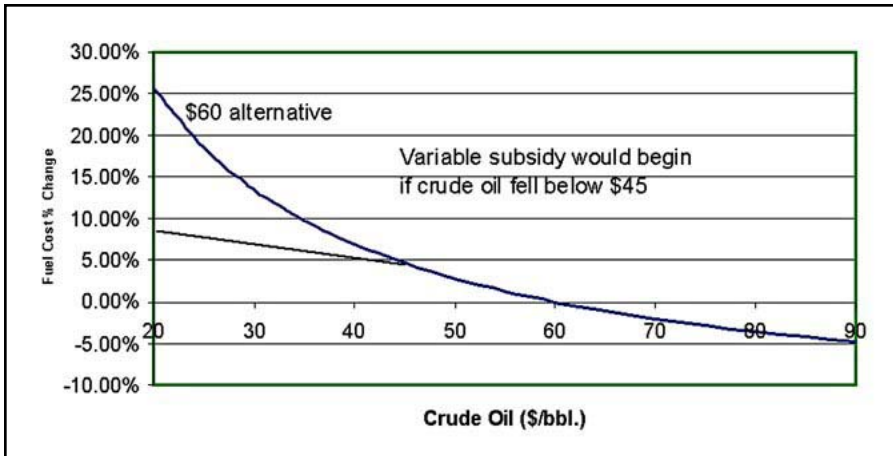


Figure 6. Cost of a fuel standard with a variable subsidy.

tion with a corn price as high as \$4.72/bu. Other assumptions could yield substantially higher corn prices.

One option, clearly, is to make no change in current policy. With this alternative, the other corn-using sectors such as livestock production and corn exports would be forced to make the needed adjustments. Less corn would be used in these sectors, and prices for all livestock products likely would increase.

If government is interested in reducing upward pressure on corn prices, alternatives to the current fixed subsidy of 51 cents per gallon could be considered. One option would be to lower the fixed subsidy. This alternative would reduce the pressure on corn prices but would still provide ethanol subsidies under higher oil prices when they are not needed. It is also invariant to underlying market conditions.

A second option would be a subsidy that varies with the price of crude. The option evaluated in this paper provided no subsidy for crude oil price above \$60, and a subsidy that increased 2.5 cents per gallon for each \$1 that the price of crude is below \$60. This option yields a breakeven corn price for \$60 oil of \$3.12 per bushel compared with \$4.72 under the current policy.

If we want to correct both the energy-security and global-warming market failures, we can adopt a two-part subsidy that combines credits for energy security with credits for reductions in GHG emissions. That option would provide a greater incentive for cellulose-based ethanol. If it is not attractive, other cellulose-targeted incentives could be considered.

Instead of continuing subsidies, another policy path would be to switch entirely to alternative fuel mandates. The mandate approach takes the cost of stimulating production and use of alternative fuels off the government budget and, instead, puts it directly on the pump price of liquid fuels. If we want to consider both the energy-security and global-warming dimensions, then it would be appropriate to partition the standard between corn and cellulose-based ethanol. If the risk of high pump prices in the face of possible

low oil prices is deemed unacceptable, another policy choice would be an alternative fuel mandate combined with a variable subsidy that kicks in at very low oil prices. In that way, higher pump prices could be avoided if oil prices were quite low.

It is clear that much work is needed in delineating the impacts of alternative policy pathways. This paper attempts to illustrate some of the alternatives that will need to be considered.

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Dr. Tyner and his students have received research awards from Purdue and the American Agricultural Economics Association (AAEA); in 2005 he received the AAEA Distinguished Policy Contribution Award. He teaches a graduate course in benefit-cost analysis and an undergraduate course in international economic development.

He has (co)authored three books: *Energy Resources and Economic Development in India*; *Western Coal: Promise or Problem* (with R. J. Kalter); and *A Perspective on U.S. Farm Problems and Agricultural Policy* (with Lance McKinzie and Tim Baker).

Recent publications include "U.S. Ethanol Policy – Possibilities for the Future," Purdue Extension Publication ID-342, 2007; "Comparison of A Fixed and Variable Corn Ethanol Subsidy," *Choices* 21(3) 2006; and "Economics of Ethanol," Purdue Extension Publication ID-339, 2006.

Capital and Sustainability

ROGER WYSE

Burrill & Company

San Francisco, CA

I will provide an investor's perspective on the dramatic changes occurring in agriculture. At Burrill & Company, we invest across the life sciences—in therapeutics and drugs, industrial biotechnology, agriculture, and health and wellness. From my perspective, much of the innovation coming from universities and going into early-stage companies is where the innovation will occur to enable the area of industrial biotechnology as a whole, of which biofuels is one part. At Burrill we have ~\$850 million and we have a banking group that's assisting companies in doing deals across the life sciences—a merchant banking operation. In terms of current funds, we are investing about half of our portfolio, ~\$400 million, which we expect to increase to ~\$1 billion in the near future. It's a significant amount of capital to be investing. I will provide the perspective of our obligations to our investors as we look now at opportunities to invest in the emerging area of industrial biotechnology.

SUSTAINABLE AREA FOR INVESTMENT

The most important question is, "Will this be a sustainable area for investment?" It's gotten frothy very quickly. So, as we go forward, where will the money come from? Where will the certainty needed to make investments come from? What is the regulatory environment going to look like? Investors abhor uncertainty. There is a misperception that venture capitalists invest in high-risk companies. We don't. We try to avoid all the risk possible. 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.

TIPPING POINT

In 2005, industrial biotechnology hit a tipping point and the ride since has been interesting. Obviously it caught attention, all the way up to President Bush, who commented on it in his 2005 state-of-the-union address. In California, Governor Schwarzenegger has taken the lead in making significant investments to reduce emission of greenhouse gases. These developments are all about energy security and politics, in particular rural politics. The price of oil rose dramatically whereas the price of corn stayed the same, ~\$2/bushel, as it has been for many years. That discrepancy provided the incentive for rural politics to engage, to begin looking at options for increasing the value of the commodity crops that we produce. The other factor was global security of the oil supply; many of the countries from which the United States purchases oil are in political turmoil. Then Katrina struck and revealed additional insecurities in US refining capacity. All of this happened at about the same time and then suddenly “green” became politically correct.

I have been concerned for some time that industrial biotechnology is long on technology and short on markets. A good example in the Midwest is the Dow-Cargill joint venture, NatureWorks LLC, with almost a billion dollars spent in developing the technology and the plant in Blair, NE. That plant had economic problems until Wal-Mart said, “We’re going green. We’re going to use your product for disposable packaging for the future.” Suddenly that plant looks like a much more economically viable investment. This example demonstrates that you can have all the technology in the world but market timing is important.

So, around 2005 there was a perfect storm. We had enabling technologies in the United States in various energy bills and the ag bill, and in the European Union, policies were put in place favoring biodiesel, for example. Much technology had been developed and we’d sequenced a lot of organisms. We understood how to convert plant-made feedstocks into valuable commodities and market-pull came in, enabling things to happen fast. Some would argue that things happened almost too fast. There was a rapid increase in the number of ethanol plants, as was expected. A significant fraction of the US corn crop is going into ethanol production, corn prices have risen dramatically and we are now in a debate about feed vs. fuel. Additionally, investors saw this as an opportunity. The “cleantech” guys had been looking at alternative-energy investments for a number of years and suddenly there was a dramatic shift of equity capital into this space.

RURAL REVITALIZATION

Rural America is uniquely energized. I met with a farm-credit group recently, considering putting money into venture capital to invest in rural America—the revitalization occurring in the Midwest is amazing. I gave a talk in Wall Street a while back and made the argument that ethanol was getting too frothy, that they should invest in John Deere, considering what farmers do when they make a lot of money—they buy a new tractor or pick-up truck and they remodel their wife’s kitchen. The implications for us have been dramatic both in rural development as well as in terms of companies developing technologies and bringing new products to market.

An important point is that this is not just about energy. We are looking at dramatic growth in the area of industrial applications of biotechnology. The Mackenzie reports have talked about a \$500 billion increase in the chemical industry, half coming from inputs from biotechnology. So, a lot will happen outside the area of biofuels and we have the technologies in hand to make those changes. There will still be improvements, but we can now move into those areas as well. It's all about the economics.

Another important aspect is that when we invest in a company, we work hard to grow its value. However, until we can exit that company, until we can sell it to some larger company or until we can take it public, it's not a good investment for us. Public markets have gotten very interested in alternative energy and sustainability. Metabolix was a small company that developed a technology for production of plastics in plants and via fermentation; after a deal with ADM, they announced that they had a name for their product and their stock price went up dramatically. The markets are beginning to look at this area as important space and they are looking also at John Deere, Monsanto, *etc.*—the people who are investing in it—and their stock prices are growing nicely as well.

INVESTMENT COOLING OFF

However, the biofuels area got a lot of frothy investment that tapered off dramatically. A lot of the ethanol plays that went into the public marketplace saw much activity, but then cooled off because of uncertainty in policy and in the price of corn. If I look at investing in an ethanol plant and see corn at around \$4, that's not a good investment. Twelve percent on your money is not a venture investment. We are seeing the economic reality of these investments setting in, which will shake out over the next couple of years.

VC INVESTMENT IN INNOVATIVE COMPANIES

Another important aspect is that a large number of small innovative companies have developed. Those that have technology—or are aggregating technologies—will enable this industry into the future. A few of those small companies are listed in Table 1. For example, LS9 is Chris Somerville's in conjunction with Jay Keasling. They are putting genes from plants into microorganisms, enabling new pathways for exploitation in fermentors. Khosla Ventures—in the newspapers almost every day—is one of the funding sources. Another biotech company is Amyris, a spin-out from Berkeley, that has put the isoprenoid pathway into *E. coli*, achieving high levels of production for use as an anti-malaria drug. This is another Khosla investment. Muscoma, a company converting cellulose for ethanol production, recently raised \$30 million.

Today's innovations, which will be tomorrow's enabling technologies, are attracting venture-capital investments to such an extent that we are almost back to the “dot-com” era. Some technologies coming to us are still in the laboratory stage. Recently we saw a conversion technology for glycerol, with proof-of-concept in an Erlenmeyer flask and they were talking about pre-money valuations of somewhere around \$8 million, whereas it's probably a \$500,000 value at that state. So, things are getting frothy again, and people like us are going deep into universities to find technologies that can be put into companies. At Burrill we are very cautious about the kinds of things we are looking for and looking at.

TABLE 1. NEW COMPANIES FORMED AND FUNDED BY VENTURE CAPITAL.

Company	Location	VC source	Funding to date (\$ million)
LS9	San Carlos, CA	Flagship Ventures Khosla Ventures	5
Amyris Biotechnologies	Emeryville, CA	Khosla Ventures KPCB, TPG	20
Mascoma, Inc.	Cambridge, MA	Atlas, Flagship General Catalyst KPCB, Pinnacle VPVP, Khosla	30
Seattle Biodiesel	Seattle, WA	Nth Power Technology Ventures Vault Capital Vulcan Capital	7.5
Aurora Biofuels	Alameda, CA	Noventi Oak Investment	3.2
Greenery	London, UK	Cargill	(25% equity)
E3 Biofuels	Mead, NB	Unknown	
Mission Biofuels	Malaysia	Unknown	
Southern Biofuels	Jackson, MS	N/A	10
Earth Biofuels	Dallas, TX	Apollo, Cornell Downsview, Evolution Heights, Polygon Kamunting, Ramius RG Capital, Sandell	52.5
United Biofuels	York, PA	Agrifuel	

To provide perspective, \$25 billion were invested in 2006 across all ventures, including the life sciences, IT and high tech. About \$5 billion of that went into biotechnology. In Fig. 1 I haven't dissected out of the cleantech sector, what was bio and what was solar, fuel cells, wind, *etc.*, but there has been dramatic growth in cleantech, exceeding \$2.9 billion in 2006. We are on track for around \$4.5 billion in 2007—a tremendous movement of capital into this space. Revenues from the biotech industry approached \$100 billion in mid-2007. The amount coming out of industrial biotech is in the \$20–30 billion range. Clearly, 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.

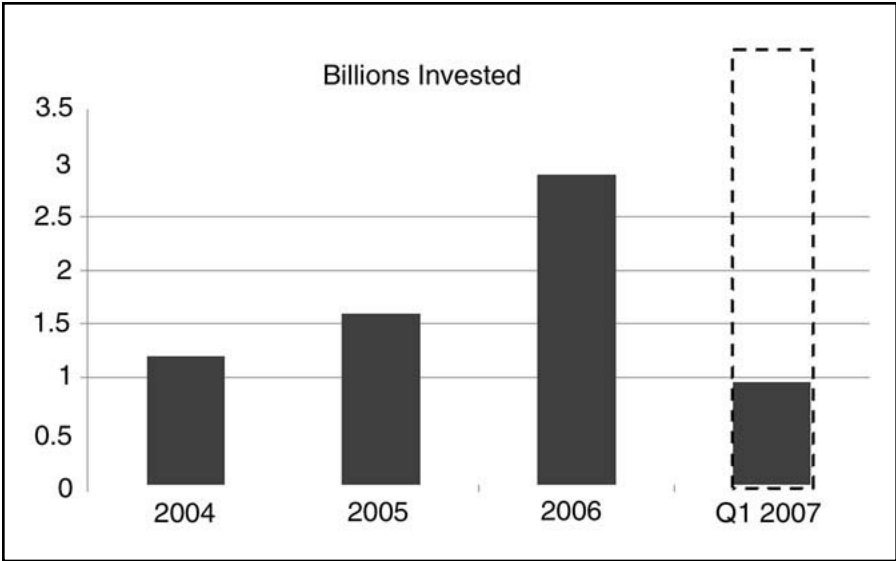


Figure 1. Venture investments in cleantech are growing rapidly; total venture investments in 2006: \$25 billion, biotech VC: \$5 billion.

CHALLENGES

The real question for us on a daily basis as we look at investment opportunities is: is this all sustainable from an investment standpoint? I think that food vs. fuel will continue to be an issue—it's getting prominent play today. Is all this change too disruptive? When I talk to farmers, they say they are making money off the ethanol plant they invested in, but they are losing on the livestock side because of high costs of feed. Don't discount challenges we have had with monoculture of corn in the Midwest. If we grow wall-to-wall corn, also using stover to make cellulosic ethanol, we may be heading for an ecological disaster. I still think corn is the right source of feedstocks for the industrial area but it may not be corn grown in the Midwest.

At a broader conference we'd be talking about wind, solar, fuel cells—even nuclear—as other options for investment. The bio-area has gotten very frothy for obvious reasons, but we have to think about the competition. As prices rise, investment money is going to move elsewhere, where it's already getting attention. However, a lot of people, including myself, think it will be sustainable. I think we've seen a real change in how we are going to approach sustainability. Bill Joy, one of the founders of Sun Microsystems with Vinod Khosla—a very aggressive investor in this space—stated recently at a cleantech forum in Germany: "A global response to climate change will spur a business revolution bigger than the internet." This effect will be particularly dramatic in the chemicals industry and much greater than it has been in the area of healthcare.

IN SUMMARY

Biotechnology—the underlying understanding of life processes that can be applied in the industrial area—has reached the point where we can be efficient and effective in implementing technologies for solutions in the industrial area. The technology is in place and we will continue to improve it, and markets are there now and ready for the products. Things are in alignment and there will be a long-term investment play. We're going through a frothy period, but it will settle out in a few years and stabilize with policies in place. We'll understand the markets and it will be a long-term and exciting place to be.



ROGER WYSE is managing director and general partner of Burrill & Company, a life-sciences merchant bank and leading venture-capital firm located in San Francisco. He joined Burrill in 1998 and has led the development of its agriculture, nutraceuticals, health and wellness, and industrial biotechnology-related activities in venture capital investing, partnering and the spinout of technology from large companies. The firm has over \$850 million under management.

Dr. Wyse chairs or serves on the boards of eleven private companies. He is co-chairman of the newly formed \$150 million Malaysian Life Capital Fund, and is a member of the International Advisory Panel for Biotechnology (BioIAP) for the prime minister of Malaysia. He was founder and chairman of the Alliance for Animal Genome Research.

Immediately prior to joining Burrill, Wyse served for 5 years as dean of the College of Agricultural and Life Sciences at the University of Wisconsin-Madison, and from 1986 to 1992 he served as dean of research at Rutgers University.

His basic studies in plant biochemistry produced more than 150 scientific papers. He received the Arthur Flemming Award in 1982 as the Outstanding Young Scientist in the US Federal Service, and was elected a fellow of both the Crop Science Society of America and the American Society of Agronomy.

Food vs. Fuel? An Integrated Approach to Producing Both

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The current focus on biofuels is obviously relative to energy. Webster’s definition of “energy” is:

The capacity to do work; the property of a system that diminishes when the system does work on any other system, by an amount equal to the work so done...

“Fuel” has other definitions:

Combustible matter used to maintain fire, as coal, wood, oil, or gas, in order to create heat or power

Something that gives nourishment; food

An energy source for engines, power plants or reactors

The “coal, wood, oil, or gas” reference is interesting. In his book *The End of Oil* (Boston: Houghton Mifflin, 2004), Paul Roberts spelled things out well: an energy crisis struck Great Britain in the eighteenth century—shortage of wood for heating and cooking—led people to figure out they could dig a hole in the ground, bring up coal and heat with that. Some see another energy crisis looming. A *BusinessWeek online* article on February 5, 2007, led with:

Food vs. Fuel As energy demands devour crops once meant for sustenance...

And an April 7, 2007, article in the *Kansas City Star* led with

It’s food vs. fuel in the battle for corn As more of the grain goes toward ethanol, less of it may make its way to the hungry.

That's an interesting concept considering current concerns over obesity. It's amazing how public perception changes. In February, Tyson's CEO voiced concern that biofuels will lead to higher food prices domestically and across the globe. I didn't realize that Tyson cares what the price of food is, and that's another interesting concept. A recent paper from the Center for Agriculture and Rural Development at Iowa State University stated: "In response to higher feed costs, livestock farm-gate prices will increase enough to cover the feed cost increase." Was anyone here feeding cattle in 1996? As corn prices went up, cattle feeders had no opportunity to raise livestock prices.

PATENTED PROCESS

At PRIME Biosolutions we use a patented method that ties cattle feeding with anaerobic digestion and ethanol production. It's the process used by E³ BioFuels; our companies share ownership of the patent. The ethanol plant is unusual in that we've removed the dryers, thermal oxidizer and evaporator. It takes in grain (corn, sorghum, barley) and produces ethanol, wet distillers grains that are directed to the feedlot, thin stillage that can be used as feedstock for the anaerobic digester and carbon dioxide that is used in nutrient removal. The anaerobic digestion unit is fed with manure from the feedlot as well as with thin stillage from the ethanol plant. Heated by waste heat from the ethanol plant, the digester serves as a cooling tower. The digester produces all of the gas needs of the facility, which, otherwise, would be natural gas in the ethanol plant. The digester facilitates economic removal of nitrogen, phosphorus and potassium; we are able to "harvest," those nutrients from the back-side of the system, for recycling. The feedlot consumes all of the distillers grains. There's no drying or hauling—saving freight is a significant advantage. Because the manure goes to the digester, odor is controlled and there is no concern with run-off. Although it's a concentrated animal feeding operation, we have no permitting problems related to run off, *etc.* The cattle are under a roof, standing on concrete slats. The feed lot at Mead, NE, was built in 1969 and is well proven.

KICKS AT THE CAT

It's a simple concept: energy from the sun is converted by photosynthesis into starch, oil, and fiber and stored in the corn kernel. Our process takes the kernels to the ethanol plant and produces ethanol and distillers grains. In turn, the distillers grain are fed to the cattle. Manure from the cattle goes to the digester along with thin stillage from the ethanol plant. Biogas from the digester is burned in the boilers to create the heat to cook the corn entering the ethanol plant.

Solids from the digester are collected in a pile and we think we know how to take that through a cellulose conversion to generate more ethanol. That completes the loop. Instead of, "Is it food or fuel?" we believe that it's both, although it's all harvested solar energy. We're taking several kicks at the cat. As the corn goes through the ethanol plant we get the first, the biggest and broadest stroke of energy out of what was stored in the corn. What's left then goes to the cattle. The cattle get their opportunity to harvest some energy from those distillers grains. When the manure goes to the digester, that's the third kick—the

digester pulls the energy out of the manure that passed through the animal that passed through the ethanol plant that came from the corn that started with the sun.

The fourth kick is when we process the cellulose in the fiber from the digester and produce more ethanol. So, those are the four components in the harvest of solar energy. There are lots of ways to do it: corn-starch to ethanol, switchgrass to ethanol, yard waste to ethanol or biogas, soybeans to biodiesel, sunflowers to biodiesel, mustard to biodiesel. Soybean growers via the soybean board have done a great job of promoting biodiesel. Soybeans have been grown mainly to produce protein to balance livestock diets. However, we won't need that protein to balance livestock diets anymore if we are going to produce ethanol from corn and have distillers grains left. So, the whole protein market is shifting. Rather than viewing oil as a by-product of soy protein extraction, we've reversed emphasis. Whether geneticists change what we extract from soybean or whether we grow other crops like brown mustard as a source of oil, it's going to be interesting as reasons for growing specific crops change.

HOW MUCH CORN?

Can agriculture produce enough corn? We started setting land aside in the 1950s and 1960s with the federal land bank. We set aside idle acres in the 1970s and there was the pit program in the 1980s with freedom to farm with LDPs and CRP acres. And now in 2007 we can't grow enough corn. American farmers have not been allowed to grow corn for almost two generations, begging the question, "How much can we grow?" We don't know. We can predict and we can guess and we can do calculations and that's all fine, but let's see what we can do. In recent decades seed companies have been focussed on reducing costs via herbicide tolerance, insect resistance, drought resistance, and fewer days to maturity. We haven't emphasized productivity for many years, so it will be interesting to see how much corn can we produce on an acre. Where can we plant those acres? Pioneer is measuring productivity not just in bushels per acre but as gallons of ethanol per acre, *e.g.* as highly fermentable corn or increased starch percentage. At a recent conference I attended, a farmer asked, "What if we overproduce corn again?" We've gone from "we've got too much" to "now we don't have enough," and these guys are concerned about what happens if we produce too much. But, that's where E85 will come in. We're not going to change the whole country to E85, but there's a wide range in terms of what we can do and the possibility of overproducing ethanol is small.

EMPHASIS ON METHODOLOGY

From my standpoint, the emphasis should be on the method of producing biofuels, not just how much. Our approach is one, obviously there are others.



MARK “BUMP” Kraeger has a BS degree with a major in animal science and several years management experience in feedyards in the Nebraska/Kansas area including Mead Cattle Co. near Mead, NE. Currently he is chief operating officer of PRIME BioSolutions, Omaha.

PRIME BioSolutions’ patented integrated biorefinery (IBR) system involves a number of factors that are intended to reduce the cost of ethanol production from corn, including placing the ethanol production facility adjacent to a cattle-feeding operation, using biogas from cattle manure to provide a significant portion of the energy needed to operate the ethanol facility, and subsequently feeding cattle with wet distiller’s grain, a by-product of ethanol production from corn, without incurring significant drying or transportation costs.

PRIME’s business plan includes construction of ten IBR complexes within the next seven years.

Development and Sustainability of the Biofuel Industry in Canada

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The production and use of first-generation biofuels (ethanol from cereal grains, biodiesel and biogas) has been increasing rapidly throughout the world. In 2000, total world production of ethanol for fuel was less than 20 billion liters and by 2005, production had more than doubled to over 45 billion liters (IEA 2004; RFA 2007). This provided about 3% of the motor gasoline use in the world, with a slightly smaller percentage in North America (IEA, 2004). In a review of recent policy initiatives, the International Energy Agency projected that total ethanol production in the world will rise to 65 billion liters by 2010 (and account for about 4% of motor gasoline use) and to 120 billion liters by 2020 (and account for about 6% of motor gasoline use) (IEA, 2004). However, rapid increases in several countries, especially in the United States may result in even greater increases in ethanol production in the next several years.

The rapid expansion of production of ethanol in the United States and of biodiesel (and to a lesser extent, biogas) in Germany, and other countries in Western Europe, has created a boom with far-reaching effects on the global demand for grains and oilseeds. World consumption of cereals grains has exceeded production for 6 of the last 7 years (Brown 2006) with the result that world-grain carryover stocks have shrunk to the equivalent of only 57 days of consumption, the lowest level since 1974.

The effects of the boom have extended into Canada, not only as a consequence of rapidly changing global supply-demand balances for grains and oilseeds, but as a result of domestic policies to assist the rapid expansion of biofuel production. As in other countries, governments in Canada have implemented measures to stimulate production and consumption of biofuels, including, among others, preferential taxation, subsidies, import tariffs and consumption mandates. The purpose of this paper is to describe the main policies guiding the development of the Canadian industry and to discuss economic and environmental implications.

POLICIES GUIDING INDUSTRY DEVELOPMENT

Ethanol, the predominant biofuel in Canada, has been used for some time as a gasoline oxygenate. Ethanol has been produced commercially in small quantities in Ontario and Québec since the mid 1970s and in the prairie provinces more recently. Among first-generation biofuels, ethanol can most easily (*i.e.*, physically and economically) be substituted or combined with traditional fossil fuels and used to power internal combustion engines. Widespread use of biodiesel in Canada, in comparison, faces additional challenges due to an absence of pre-existing commercial capacity and because of a warm cloud point, which can create significant cold-flow problems. At present, electricity generated from biogas in Canada is not competitive with traditional alternatives. To displace even a small proportion of domestic consumption, electricity generated using biogas will require relatively more government intervention than currently necessary for ethanol or biodiesel. The upshot is that ethanol is the major opportunity for mass-market biofuel in Canada.

Energy security is not propelling the political demand for ethanol in Canada, as it is in the United States. Figure 1 illustrates that Canada is a net exporter of all kinds of energy: oil, coal, natural gas, uranium, hydro-electricity and others. Instead, the 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.

Ethanol development in Canada has been much slower than in the United States for reasons of grain supply and government policy. However, the federal and provincial governments are adopting some of the same means of promoting ethanol as in the United States. For example, there is an exemption of excise tax for ethanol. In Canada, the exemption is C\$0.10 per liter.

Domestic ethanol suppliers have received and continue to receive production incentives in the form of subsidies. For example, in August 2003, the Ethanol Expansion Program provided C\$250 million in grants toward capital costs of new or expanded ethanol plants. A Biomass Ethanol Program, also dating from the same time, provides C\$140 million in lines of credit to ethanol plants if the excise tax is ever re-imposed.

On December 20, 2006, the federal government announced C\$345 million in taxpayer transfers for two agriculture programs to subsidize the development of a biofuel industry. To encourage more farmer participation, C\$200 million is to be made available through the Capital Formation Assistance Program (now called the EcoAgriculture Biofuels Capital Initiative). The remaining C\$145 million is to be directed through the Agricultural Bioproducts Innovation Program to promote R&D.

The 2007 federal budget (presented in the House of Commons on March 19, 2007) offers C\$1.5 billion in subsidies over 7 years for producers of ethanol and biodiesel. Government assistance will be up to C\$0.10 per liter for renewable alternatives to gasoline

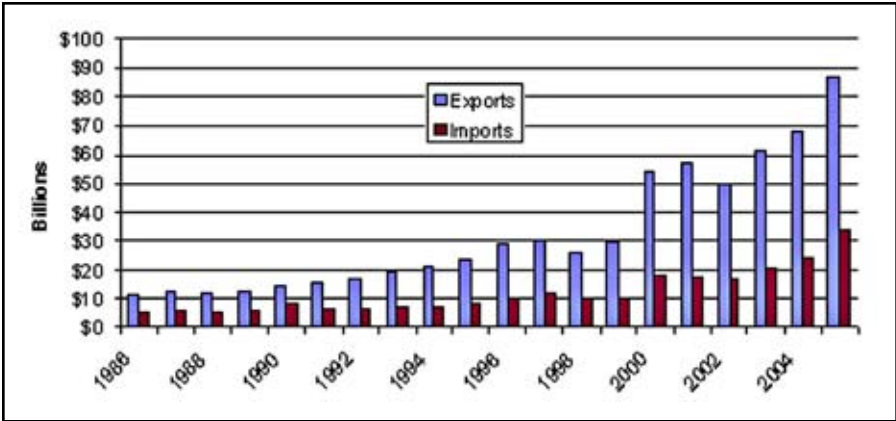


Figure 1. Canada's energy trade balance, 1986–2005 (Statistics Canada, 2007).

and up to C\$0.20 per liter for renewable alternatives to diesel for the first 3 years, after which point the subsidies are then to decline. In addition, transfers totalling C\$500 million over 7 years will be made to producers of next-generation renewable fuels, such as ethanol from agricultural and wood waste products (wheat straw, corn stover, wood residue, switchgrass, *etc.*).

Several provinces announced major biofuel incentive programs in 2006. The Ontario Ethanol Growth Fund makes up to \$520 million available over the next 12 years to ethanol producers. The Alberta government announced a 4-year, \$209-million Renewable Energy Producer Credit program that will offer tax credits to ethanol and biodiesel producers and distributors. The rate of subsidy will be reviewed annually to ensure it is competitive with other jurisdictions. The Québec government announced a twenty-four-point action plan to help realize some objectives of the Kyoto Protocol. Part of the plan involves a tax on producers of hydrocarbon energy during each of the next 6 years. The government expects to collect \$200 million per year from the carbon tax, which will be transferred to a Green Fund.

On top of the taxes, tax credits and subsidies, most provincial governments have implemented mandates of renewable fuel consumption. The Ontario government has a policy that requires all the gasoline sold in the province contain 5% ethanol as of 2007. The governments of Manitoba and Saskatchewan will require a proportion of ethanol in all the gasoline sold to be a minimum of 5% to 10% starting when local production is sufficient. The plan of the Québec government is that before the end of 2012, all of the gasoline sold in the province will contain a minimum of 5% ethanol.

The federal government also has mandated an annual average renewable content of 5% in gasoline by 2010. In addition, there is a 2% renewable content requirement for diesel fuel and heating oil by 2012. The idea is similar to the renewable fuel mandates implemented by some state governments (*e.g.*, Minnesota, Montana and Hawaii).

Canadian Ethanol Production

Corn and wheat are used to meet the demand for ethanol in Canada. Eastern Canada is a net importer of increasingly expensive corn from the United States. In western Canada, the only viable feedstock for cereal-based ethanol is feed wheat, the supply of which is variable and usually unpredictable. The ethanol yields per tonne of corn and wheat are similar, but corn historically has been less expensive.

Currently, there are eleven ethanol plants operating across Canada, most of which are located in the central provinces of Ontario and Québec. These plants, excluding Iogen Corporation's cellulosic ethanol demonstration plant in Ottawa, have an annual production capacity of 764 million liters. In addition, eight plants are under construction or expansion. When completed, these plants will add more than 1.2 billion liters of production capacity annually, an increase over current capacity of 161%.

Based on total use projections in Canada, however, the renewable fuel mandate will create a minimum demand for 3.1 billion liters of ethanol by 2010 (Canada Gazette, 2006). To meet the renewable fuel standard without imported ethanol, an additional capacity of 1.11 billion liters needs to be built in the next 3 years. This would require an increase over existing capacity and that under construction of almost 56%.

Only four ethanol plants in Canada produce more than 100 million liters of ethanol annually. Despite the recognized cost advantages from larger-scale production of ethanol (Government of Manitoba, 2002; Whims, 2002; Tiffany and Eidman, 2003; Shapouri and Gallagher, 2005; Gallagher *et al.*, 2007), smaller plants are being promoted in some parts of Canada. There may be some opportunities for these small enterprises if they were integrated with a feedlot or food manufacturer that can profitably use the distillers' dry grains (DDGs), carbon dioxide (CO₂) and other co-products from ethanol production. If small plants require government incentives to be built or operated, the significant advantages of large-scale low-cost plants may render the small plants uneconomic.

The heterogeneity of the provincial tax exemptions (amounts, eligibility and duration) is creating an unusual pattern of trade within Canada. Until recently, almost all of the ethanol produced in Alberta was exported to the United States because Saskatchewan's tax exemption applies only to provincially produced ethanol. Meanwhile some ethanol produced in Saskatchewan was sold to buyers in Alberta where the provincial tax exemption does not place restrictions on the source of the ethanol. The impact of these interprovincial trade barriers is not well understood and more study is required.

IMPLICATIONS FOR FARM INCOMES

One of the driving forces behind attempts to establish a successful biofuels industry in Canada is to improve farmer incomes. Certainly, grain and oilseed producers struggle financially in Canada and much of the rural infrastructure is running down as a result. Net farm incomes across Canada have stagnated (AAFC, 2005). An increase in the number of ethanol and biodiesel plants across the country that use cereal grains and oilseeds (and eventually plant residues) will increase demands for these feedstocks providing opportunities for growers to get higher prices for their products.

Table 1 shows that within the past year, the prices of all major feed-grain prices have risen in Canada: corn by 54%, soybeans 24%, oats 35%, barley 51%, and feed wheat 36%, much of it due to the extra demand for producing biofuels.

TABLE 1. PRICES OF CEREAL GRAINS AND OILSEEDS, IN CANADA, 2006–07 (AGRIWEEK, 2007).

Commodity	May 2006	May 2007
Corn, CBOT future, next-nearest month, C\$/bu	C\$2.63	C\$4.05 (↑54%)
Soybean, CBOT future, next-nearest month, C\$/bu	C\$6.66	C\$8.27 (↑24%)
Oats, CBOT future, next-nearest month, C\$/bu	C\$2.08	C\$2.82 (↑35%)
Feed barley, WCE future, next-nearest month, C\$/tonne	C\$120.00	C\$181.00 (↑51%)
Feed wheat, WCE future, next-nearest month, C\$/tonne	C\$116.00	C\$158.00 (↑36%)

*Spot exchange rate C\$/US\$: 2007 (0.9044); 2006 (0.9095).

Although prices of grain and oilseed have increased (and, indeed, show signs of increasing further due to the strong expansion of the biofuel industry across North America), this does not necessarily imply that net farm incomes will increase. Net income is the critical factor, *i.e.*, gross income minus total cost of production. In anticipation of higher returns from corn, land prices and rents have risen rapidly in the United States and are rising in Canada as well. However, because of increased demand for inputs to produce the higher priced grains and oilseeds, prices also are rising for all necessary inputs to produce these crops, such as fertilizer, equipment and storage. So as grain prices are increasing, market processes are rationing the demand for inputs by way of higher prices. As individuals adjust to new price information, the transition will be profitable for some but costly to others.

Sustained higher prices for grains and oilseeds encourage farmers to bid up land prices. The capitalization of higher farm revenues into land prices also extends to other farm assets such as equipment and buildings. Under these circumstances, higher revenues do not yield higher net farm incomes. On the contrary, they boost the demand for farm assets and increase the cost structure of the entire industry. While increased asset values improve the equity position of property owners, tenants and farm workers are likely to receive little benefit and aspiring farmers will face higher entry costs.

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. Feed represents more than 80% of the costs of production in a western Canadian beef feedlot. Feed can represent as much as 65% to 75% of the costs of hog and poultry production. Many livestock farms in Canada are small-margin, large-scale enterprises. The ethanol frenzy is placing them under a tremendous cost-price squeeze. Higher feed prices are providing an incentive for some producers to substitute towards alternative feeds, to move their operations closer to sources of lower-priced inputs, and for others to exit the industry.

Higher feeding costs for livestock will have three major effects (though the extent of these effects has not been studied thoroughly). First, some part of the increased feed costs inevitably will be borne by producers of calves and weanling pigs. To offset higher feed costs, feedlot enterprises will bid lower for feeder animals, which not only reduces the quantity of feeders offered for sale, but also the weight at which fed animals are sold. Second, in response to the potential decrease in supply of meat due to higher production costs, consumers will face higher prices for meat products. This will reduce consumption of meats both domestically and abroad. Third, higher costs will be faced by canola crushers, flour millers, and other users of grains and oilseeds.

To counteract the rise in feed prices, farmers may be able to substitute DDGs as part of their livestock rations. While DDGs contain a high percentage of protein and may be used successfully in some rations, especially for beef cattle, they also present several challenges.

First, DDGs create flow problems for handlers, particularly if the moisture content is 12% or more. DDGs tend to bind to the interior walls of hopper cars, which makes them difficult to unload.

Second, pork producers may be able to feed low levels of DDGs in grower-finisher diets, but higher levels of DDGs can cause significant problems. Feeding high levels in the diets (*e.g.*, at 20% and 30%) may result in lower average daily gains and dressing percentages (Lawrence, 2006).

Third, depending on the feedstock used to make ethanol, the resulting co-products are nutritionally different and have different economic values in various types of animal feeds. The nutrient content of DDGs can vary across plant species and has been shown to vary over time even within species (Spiehs *et al.*, 2002). In addition to consistency issues, there also are concerns about deficiencies in lysine digestibility in rations with a high proportion to DDGs and the amount of by-pass protein in ruminants. As nutrients in the DDGs become concentrated through the process of fermentation, the same is true for substances that are harmful to livestock, such as mycotoxin, which also appear in increased concentration.

IMPLICATIONS FOR NATURAL CAPITAL

The fundamental justification for expanding biofuels in Canada is the reduction in CO₂ emissions that results from the displacement of petroleum-based energy. Though a lot of fossil fuels are used in the production of first-generation biofuels, life-cycle analysis generally reveals a reduction in greenhouse gases, carbon monoxide and other undesirable compounds. According to the government of Canada (2006), consumption mandates are anticipated to lead to reductions in greenhouse-gas emissions of 2.7 million tonnes per year on a life-cycle basis. There is a greater reduction in greenhouse-gas emissions from production and use of ethanol produced from cellulosic feedstocks than from cereal-based ethanol.

The desired environmental benefits do not come without environmental costs. Expanding ethanol production in the United States has worried some that cropland will be shifted from the Conservation Reserve Program to provide more land on which to plant corn (Shapouri, 2007). This could happen in Canada as well. Following the end in 1995

of the Western Grain Transportation Act (which subsidized the freight rates to transport grains from the prairies provinces to export terminals and, therefore, artificially increased feed-grain prices on the prairies), some land around the fringes of the main crop-growing areas were taken out of crop production and planted to grasses and other perennials. This was a more sustainable use of fragile soil resources in these regions. However, the rapid rise in grain prices (and the subsequent economic stress this places on the livestock industry) threatens to reverse this activity. It seems likely that marginal quality land (*i.e.*, land that is easily erodable, has higher salt content, or other characteristics that make it environmentally sensitive) will again be converted to crop production to take advantage of the higher prices for grains and oilseeds.

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. This could lead to additional leaching of nutrients into ground water and run-off into drainage systems. Increased intensity of crop production could lead to more monoculture and increased soil erosion, not to mention the greater need for fossil fuels to power the more intense farming practices.

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. More than 85% of the global supply of palm oil comes from two countries: Malaysia and Indonesia (Blumenthal, 2007). Existing biodiesel plants and those under construction have greatly increased demand for palm oil. Logging and burning of some of the most biologically diverse forests is well under way to plant more palm trees. Reductions in their habitats could endanger orangutans, Sumatran tigers, elephants, rhinoceroses, and the world's largest butterflies (Blumenthal, 2007).

There also is the issue of water use to produce biofuels. Production of one liter of ethanol requires between four and eight liters of water, depending on the process. The 130 million-liter ethanol plant recently opened in Lloydminster, Saskatchewan, will likely require more than 500 million liters of water per year for its production process (or about 1.5 million liters per day). Most of the water must come from underground sources, which could reduce water tables in the aquifer. Increased demands for water resources by industry, agriculture, municipalities and for recreation, combined with melt of existing glaciers, are threatening this already scarce resource. Widespread use of water to produce transportation biofuels could further threaten its sustainability.

CONCLUDING REMARKS

The markets for commodities like corn, wheat, gasoline and ethanol are global. The exportable supply of grains in the United States has a strong influence on world prices. Canada is much less important in world markets for grains and oilseeds, though still a large exporter. Renewable energy policies in the United States will likely have greater economic impacts on Canadian agriculture than will domestic biofuel policies. The policy effects in both countries have benefited landowners by way of sharp gains in land prices. Following a short period of adjustment, however, there will be little gain in net farm incomes. The long-term impact on natural capital is mixed with perhaps as many (or more) negative environmental consequences as there are positive results.

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The foci of Dr. Le Roy's research are livestock production, marketing and trade, emerging markets for irrigation water in Southern Alberta, and the impact of renewable energy policies on Canadian agriculture. He has been involved in numerous studies involving systems modeling of farms in Canada and assessments of agricultural policy and trade alternatives.

Le Roy has served as an executive member of the Alberta Agricultural Economics Association and the Tiffin Conference Organizing Committee. He has published in and reviewed papers for the *Canadian Journal of Economics*, *Current Agriculture, Food and Research Issues*, *Canadian Public Policy* and the *Western Economic Forum*. He has been nominated twice for the Distinguished Teaching Award at the University of Lethbridge, and in 2004, he received the Agricultural Students Association Distinguished Teaching Award.

Biofuels and Biorefinery Development in Canada: The Question of Sustainability

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Ottawa, ON*

*Biotechnology Research Institute
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I will provide an overview of what's going on in Canada with respect to biofuels and then focus on the question of sustainability, drawing on my work in the strategic planning area of the biobased economy and on presentations and data from colleagues in Natural Resources Canada, Agriculture and Agrifood Canada, Environment Canada and Industry Canada. We are approaching this issue through an interdepartmental committee.

My key messages are:

- The sustainable development (SD) challenge—especially on the environmental side—is large. If biofuels are developed carefully and deliberately, they can be the foundation for a more sustainable future.
- The Canadian context is different from that of the United States. Danny Le Roy covered this and I will elaborate on it. How biomass will be utilized in Canada represents a major shift requiring many adaptations.
- There are economic, environmental and social aspect to SD. Although we consider these aspects when we support projects and make investments, we are missing an opportunity to really design bio to provide solutions for a more sustainable future. We need to start by assessing the impacts of our first-generation investments, and then design accordingly.

From the environmental perspective, the global human population is not living sustainably. Our ecological “overshoot” occurred in the 1980s and the human ecological footprint is now 25% beyond that threshold, and rising. Meeting the challenge will require dramatic changes—substantially beyond incremental improvements—in design and efficiency. We must re-examine not only how we produce but how we consume and dispose of goods. If properly designed and carefully integrated with the petroleum-based economy, the use of biomass and biotechnologies can contribute to a more sustainable future.

However, not all products from biomass are sustainable. Different bioproducts have different benefits, and the entire life cycle—including mode of usage and end-of-life—should be examined.

Agricultural biotechnology holds the promise of providing new feedstocks for energy production and other industrial products. Industrial biotechnology can be applied to both biobased and non-bio feedstocks, supplying processes that are less energy or chemically intensive.

A European review of life-cycle assessments of nine categories of bioproducts showed a range of benefits in terms of CO₂ reduction *vis-à-vis* their petroleum-based counterparts. There were differences between products, and wide variations within some product categories. Some products, such as biopolymers, even showed a negative CO₂ benefit, depending on how they are disposed of (Fig. 1).

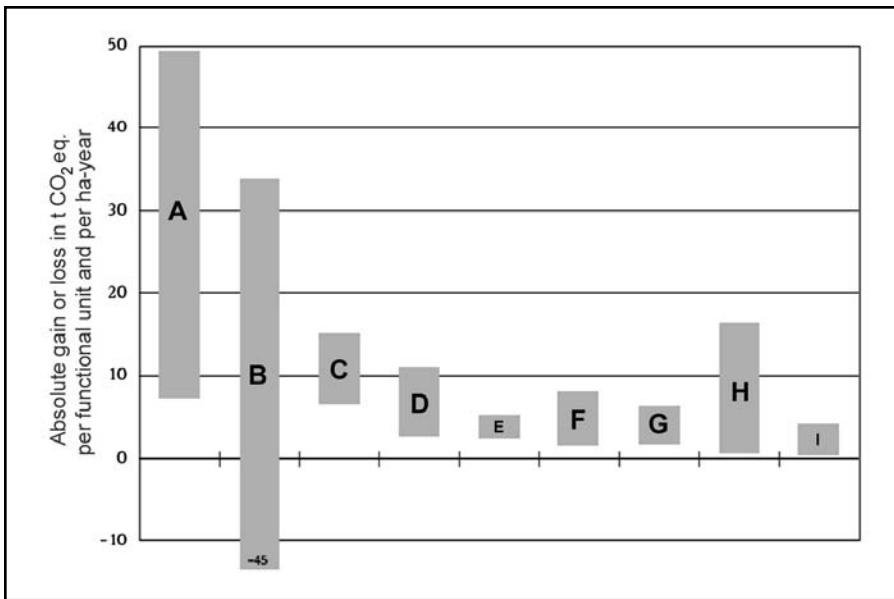


Figure 1. Impact of bioproducts on CO₂ emissions versus petroleum-derived equivalent (ADEME, 2004). A=agrimaterials; B=biopolymers; C=agricultural biomass (bio-energy); D=forest biomass (bio-energy); E=ether alcohols (biofuels); F=ester oils (biofuels); G=hydraulic oils and lubricants; H=surfactants; I=solvents.

Canada has a long history of natural-resource-based industry, with established infrastructure and much know-how. However, new business models are required, and the need for these industries to reinvent themselves is a significant driver for the development of Canada's biobased economy. Unlike the United States, energy security is not a driver. Canada is a net energy exporter. In general, there are long distances between feedstock sources and manufacturing facilities, and Canada's industry structure is mainly comprised of small-to-medium-sized enterprises.

A significant change is underway in terms of biomass utilization. Traditionally, it has been used to produce food, feed and wood fiber. Unutilized residues from forestry and agriculture operations and urban communities, along with some crop production are now being converted into bioenergy and biofuels. This is occurring at a relatively rapid pace, albeit on a smaller scale than in the United States. We are seeing new interest in small-scale bio-energy- and biofuel-production plants. We are exporting biomass feedstocks—in particular wood pellets and canola seed and oil for biofuels and bio-energy production in other countries—and are developing new bioproducts, including diverse co-products, and biorefineries.

Canada must work out how best to use biomass feedstocks and various biotechnologies and how to integrate them with existing resources and industry.

SUSTAINABLE DEVELOPMENT

Sustainable development was defined in the 1987 Bruntland Report as development that *meets present needs without compromising the ability of future generations to meet their own needs*. We consider environmental, economic and social dimensions in our decisions and we track these indicators. Canada lacks a national SD plan, in contrast with countries in the European Union, for example. And, with the development of our oil sands, we are even shying away from the concept of sustainability. Therefore, although we are making progress towards SD, we have yet to adopt a concerted top-down approach. A bottom-up approach to SD is taking shape and we see some good things happening with respect to forest and agricultural production. Sustainable forest management became a critical issue in the 1990s as a result of a boycott of Canadian pulp and paper products, and sustainable agriculture is developing albeit at different paces within different provinces. At the municipal and regional levels, we see growing interest in sustainability planning; more and more communities are looking at development through a sustainability lens, which is encouraging. Large corporations and utilities have been triple-bottom-line reporting as in the United States and two provinces have adopted SD legislation.

Also, there's been significant advancement in the world of SD research. Many new tools are available and we have criteria for sustainable biomass production. Many have referred to the "perfect storm." Certainly many factors appear to be coming into alignment. The time is good for biobased industries to be developing as part of the movement to a more sustainable future.

PATH TO SUSTAINABILITY

Canada's official reasons for supporting biofuel development are to lower air emissions, to reduce greenhouse gasses and to provide economic opportunities for farmers. Like other countries, the challenge of decreasing transportation emissions is significant compared with those from industrial plants; biofuels promise to be part of the solution. Unofficial reasons include the fact that we are in pre-election mode and the current government has had strong rural support.

Nevertheless, we believe we are on the right path—finding new uses for our renewable resources, including residues. Residue use is an important driver for both forestry

and livestock production, providing significant environmental and economic benefits. In summary, we have large volumes of biomass and great opportunities for new biobased industries that contribute to clean new economic development.

Federally funded projects are judged in terms of economic, environmental and social criteria. The Canadian Environmental Act mandates public consultation, but this is directed towards meeting current standards versus making the stretch to targets necessary for sustainability.

We have some large questions still to answer relating to the collective impacts of our biodevelopment, the impacts on other sectors, and whether to produce ethanol or other products from our land base. Other questions include:

- Which feedstocks should be chosen to go beyond the proposed 5% renewable content?
- What will be the impacts on land use, nitrogen applied, biodiversity and soil quality?
- Which conversion technology should be chosen—thermochemical or biochemical?
- Which high-value co-products should be focused on—which chemicals?
- Which fuels should be produced—butanol, Fischer-Tropsch, H_2 , *etc.*?
- Given US investment in lignocellulosic ethanol, should Canada adapt this technology or focus on others and other products?

The most frequently raised questions with regard to the sustainability of first-generation biofuels are:

- Economic
 - Future prices: ethanol, oil
 - Feedstock supply and cost? (Ontario is importing corn.)
 - Energy costs?
 - High-value co-products needed to break even?
 - Increased farmer income?
 - How many jobs?
 - Impacts on livestock sector?
- Environmental (re: production, manufacturing, infrastructure development, use)
 - Energy balance (net energy)?
 - Competition for water? Land?
 - Impacts on water? And soil?
 - Biodiversity impacts?
 - GHG impact? (N balance as important as C balance?)
- Social (including human health)
 - Developing and retaining expertise?

- Noise, odor, truck traffic associated with industrial development?
- Residual antibiotics in meat (*i.e.* animals fed DDGS)?
- Health impacts of combustion of biofuels?

ECONOMICS OF BIOFUELS

We are assessing the impacts of our first-generation investment, with several departments examining various angles. Scientists at Agriculture Canada are doing economic modeling work using the CRAM model—the regional, economic and agricultural production model. They are looking at effects of biofuel production on agricultural sub-sectors in terms of farm income and regional distribution. The international perspective is being appraised using the AGLINK model. At the projected feedstock price, the model indicated that the minimum oil prices for profitability were US\$55 for ethanol and US\$65 for biodiesel, and below these government incentives would be needed. Also, it was found that to a large extent policies outside of the country have a much bigger impact than what occurs internally.

GREENHOUSE-GAS EMISSIONS

The GHG impacts (reductions) attributed to biofuels are significant but not large. Although we've been selling this as a way of mitigating climate change, the impact is small. Environment Canada has reviewed biofuel-lifecycle data from around the world and available environmental information. Energy consumption and CO₂ emissions are best understood, but there are many gaps with respect to other environmental parameters. As more plants are built and more data become available, a comprehensive picture will emerge of all of the benefits and impacts.

Natural Resources Canada has used the GHGenius model to examine the lifecycle of GHG emissions, showing that E10 from various feedstocks results in reductions in CO₂ emissions of 4.1% to 6.3%—small but significant.

SHARED VISION OF SUSTAINABILITY

Sustainable development has to be planned and designed. Biofuels production represents a route for developing infrastructure and demand, although it is not the ultimate goal for Canada. It is important to communicate that completing a checklist of “environmental, economic and social” parameters does not mean a project is sustainable. We have to educate the public that there's a difference between this checklist and taking action for sustainability. We need to do much better than baseline, much better than the gasoline-equivalent or business-as-usual comparison if we are to achieve SD. In our work, we recommend that developers of new bioprojects create a shared vision of sustainability and describe specifically how the use of biomass and/or biotechnology will contribute to this vision.

The design for SD must be flexible to avoid becoming locked into a given technology. In terms of targets, it will likely take time for groups to agree on what numbers to aim for. The following principles [referred to as the *The Natural Step* system conditions

(<http://www.naturalstep.ca/system-conditions.html>)] can be used to define a proposed project's contributions to the development of a sustainable future by helping to reduce or eliminate:

- ongoing build-up of substances taken from the earth's crust,
- ongoing build-up of substances produced by society,
- ongoing degradation of natural systems by physical means, and
- undermining the ability of people to meet their needs.

I am involved in several SD-related activities including an initiative in Alberta starting in June 2007, in which stakeholders will be invited to develop a shared vision for a large triticale biorefinery initiative, which hopefully will lead to a superior design. Also planned is an international forum on applied sustainable development hosted by the Université de Sherbrooke in Sherbrooke, Québec. And we will release the third edition of the *Sustainability Assessment Framework and Tool* (SAFT) guide (Five Winds International, 2006), a qualitative assessment framework for biobased systems.

Dramatic changes in how we do things will be needed. Renewable biomass and new technologies are part of the solution. We need to figure out how to develop this biobased economy where it makes sense and where it makes sense for Canada, which may differ from rationales for other countries. The real economic, environmental and social impacts of first-generation biofuel investments should be evaluated before moving ahead "too fast in the fog." We need to elucidate the attributes of a sustainable bio-economy for Canada, and build with that end in mind.

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MARIA WELLISCH graduated from McGill University in chemical engineering (1984) with a minor in environmental studies. She has spent over 20 years in environmental planning and lifecycle-management work for natural resource-based companies in Canada, originally for the forest-products industry and more recently in the development of new bioproducts and bioprocesses.

Ms. Wellisch joined Canada's public service in 2002, and is currently on secondment with the National Research Council as advisor for Bioresources Conversion and Sustainable Development. Her current work centers on strategic sustainable development of the new biobased economy, exploring the use of various sustainability planning and assessment tools in the evaluation and design of various bio-pathways.

Economics and Sustainability

Q&A

MODERATOR: VAN KELLEY
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Brookings, SD*

William Gibbons (South Dakota State University): The Farm Bill is coming up. What is the status of the policy proposals?

Wally Tyner: The policy proposals are all over different pieces of legislation. Senator Lugar has introduced the variable subsidy in a bill by itself. The Senate bills that were referred to yesterday contain the biofuel standard. No one yet is doing the two-part subsidy. We just finished the initial work on that last week, but the paper that I did today is on Senator Lugar's website on the two-part subsidy, and, if they decide they are interested in that, it will go in another piece of legislation. Most of these things will probably end up more in energy legislation than in ag legislation, but, at the end of the day, who knows? Right now, everybody is trying to get their names on some bill. Everybody wants to be "green." Everybody wants to be "bio-energy." All kinds of bills are floating around to do all kinds of things. Most of them will die, but I'm optimistic that we will get some kind of significant policy change, but we will need to adjust it as we go.

Audience Member: I have a question about current US farm policy. You said we don't like to tax, but consumers pay military expenses from their income tax and also the subsidy for ethanol. Do you think it might be better for consumers to decrease fuel consumption and pay a little more at the pump than finance these two policies?

Tyner: You're right. These costs are paid by consumers through the government budget. Some of them are paid by consumers through the level of activity in the economy, so it depends on which one of the costs we are talking about. But consumers pay one way or the other, either through the government budget or through economic activity. I didn't mean to imply that I would be opposed to taxes. I'm a realist and what I see are possibilities. People that I work with on the Hill indicate that they are interested in supply-side alternatives, such as subsidies, or demand-side alternatives such as standards or regulations, or combinations of those. So that's what we have focused on so far. But if the door is open to other alternatives we'd be happy to look at them. Right now we've been told, send a clear message, that these are the ones we want to look at.

Audience Member: This is a question for our Canadian colleagues. Is there a significant amount of importation of biofuels into Canada, or is it like the United States where farm lobbies are opposed to such importation?

Danny Le Roy: In terms of HS codes, ethanol could possibly come in in two separate codes and given the way the statistics are recorded it's not evident to a user such as myself or perhaps even to Wally, to decipher the amount of alcohol coming in and what proportion is vehicle fuel. Having said that, the amount imported is relatively small. Given the mandate in Canada, it's clear that we're not going to realize targets without some increase in imports. And the question is: where is it going to come from? We have a counterproductive policy in Canada, *e.g.* an import tax on ethanol from Brazil. There's some work to do.

Maria Wellisch: I understand that Ontario is importing. It's one of the provinces that has its own mandate and I think it's importing from Brazil. The amounts are small but will have to grow because production won't be sufficient to meet that renewable-content regulation.

Audience Member: Professor Tyner, you are quoted in this morning's *Argus Leader* regarding the biofuels bill introduced by Senator Thune from South Dakota and Senator Nelson from Nebraska. One quick question and then probably a follow-up. Have you read the specific legislation yet?

Tyner: No, they got me on the phone and summarized what the bill said. I had read a draft of it. My comments were based on my recollection of what was in the draft plus what is in the press release.

Audience Member: The *Argus Leader* may not have given you a good description of the bill, but you're quoted as saying that a "build it and they will come" notion on either side doesn't work, that you have to have firm signed contracts before you plant. You are also quoted as saying that you don't see any reason why we need to have this switchgrass sitting around waiting on somebody to think about someday, maybe, possibly deciding to build a plant. I don't know if that's a correct quote, but it's probably at least fairly close. The legislation itself—since I don't know if you've seen the final version actually—requires that it be within a 70-mile radius of an existing or proposed facility. It also has to have a letter of intent from the facility to use that biomass. As you are well aware, the technology isn't quite there yet—hopefully within 5 to 10 years we'll have it. Producers right now aren't growing switchgrass. There's no commercial use for it. If we start growing it now, then by the time it becomes economically viable we'll have a crop to use in place. I'd say it's wrong that they have to have a facility. It's not a "build it and they will come" thing for them to actually be a part of this project. There has to be a facility or a proposed facility there. And I don't know if you had seen that in the legislation yet.

Tyner: If that is true, then you don't need it either, because if it's true that there is a proposed facility the first thing a facility is going to do is get a contract signed. They can't afford to break ground until they have feedstock. If Roger Wyse were still here, he would tell you that's absolutely the case. So, the first step is to guarantee a feedstock. They have to have it under long-term contract. These plants are really expensive and there are many sources of risk. It's technology, it's oil price, it's raw material, and one of the risks that you can reduce is the raw material risk and you do that by getting signed contracts and you do that *before* you build the plant. Nobody can put the hundreds of millions of dollars into these plants and hope that maybe there would be feedstock there. They have to have that ahead of time.

Audience Member: Very fair point. There's actually the industry that signed off on this aspect of it because they're not going to get folks to turn around and build something which they can't collect anything on for 5 to 10 years. I understand your concern with corn to cellulosic ethanol, that transition, but with corn at current prices, why would a farmer or producer give up that cash cow to put in switchgrass, when they aren't going to receive any money for 5 to 10 years. Processors are not going to be able to lock up contracts; producers are going to rather just do corn. Switchgrass is 5 to 10 years down the road, but, to make it economically viable, producers must be involved and the purpose of the legislation includes mediating some of the risk you are talking about. The producers are going to have a risk and that's the purpose of the legislation. The main thing I wanted to know is if you had actually seen the final product of the legislation.

Tyner: Many alternatives will be put on the table, and we have to try to find those that are least costly. My assessment is that that particular approach is a pretty costly approach, but we have to keep them all on the table. We have to look at them all, do the analyses and see what shakes out.

Audience Member: For our Canadian colleagues: Canola was not on your list, although it's a pretty big Canadian crop. I know that folks in the southeastern United States are thinking about using canola as a biodiesel feedstock. Can you address why you didn't include it and if the cost of canola oil is too high for biodiesel?

Le Roy: That's the story. Given the current price of diesel in Canada, making biodiesel from canola is very expensive. It was recently announced that Dominion Energy Services is building a 100-million US-gallon biodiesel plant in Alberta, for which a major feedstock will be rendered animal fats from the packing plants in that part of the province. In terms of the inputs to make biodiesel, the price of canola is high. Several other inputs could be used at much lower cost. It wasn't mentioned in my presentation because at this point it's not economic, and probably will not be economic in the foreseeable future.

Wellisch: We are exporting canola to Europe for biodiesel production. Same comment on high-input cost. There's a little bit in terms of the regulation—the 2% replacement

of diesel with renewable—and there's a little caveat there that it needs to be shown to be effective, *etc.*, so they have a question mark on the biodiesel target and perhaps are leaving a little bit of room to wiggle out of it. We were initially told that we were going to be using all this waste grease to produce all this biodiesel—and that's happening to a certain extent—but also we hear of some operational difficulties. Canola is easier to work with, but more expensive, so we need to work that out.

Audience Member: Dr. Tyner, does the increase in markets for co-products and/or concurrent development of biomaterials significantly impact the economic development and/or policy positions?

Tyner: Certainly—I assume you are talking about DDGS and other similar co-products—absolutely critical. DDGS went up from \$80 to \$130 as corn went up. It's back down to \$105 now. It's not a throw-away product. It's critical to the economics of ethanol production and all the numbers that I showed—we have a quantitative relationship between corn prices and DDGS prices built in to all those breakeven numbers. All of the co-products are important.

Audience Member: What about biopolymers and other materials?

Tyner: They could be very important down the road. We don't have them in any of our models. We develop process models for each one of the technologies and then we overlay the policy alternatives on those, and we haven't yet developed process models for the biopolymers/biomaterials. It's a much more complicated process. If somebody has funding we'd be happy to do it, but we haven't done that yet.

Ralph Hardy (NABC): As you are planning long term and you look at agricultural starches to ethanol, you look at perennial grasses, you look at woody crops like willows and you look at forestry—a huge resource in Canada compared to the United States—as we look 10 years down the road, assuming we have technology to economically convert biomass to ethanol by that time, which of those is going to be the prime source for a bioliquid fuel in Canada?

Le Roy: I guess the flippant answer is that my crystal ball is as cloudy as yours. But, I think that you are right when it comes to the forestry resources and wood chips. There might be some potential with switchgrass and at this point it might be technologically feasible. Iogen has been in the news an awful lot in Canada; it was even mentioned in the federal government's budget in March. But, it's a long way off yet and I'm reluctant to make a forecast 10 years out.

Wellisch: We'll see a mixture of solutions. Across the country we have different opportunities in terms of feedstock and different capacity and capital capacity; it's going to depend on where you are. On the lignocellulosic side, we have a huge forest resource.

But the industry is in very poor shape and they are working on some forest biorefineries, *etc.* Right now we see more support federally for agriculture, helping farmers to increase income. I think we are going to see the lignocellulose side move ahead using agricultural feedstocks, drawing on the US DOE developments. But we are also going to see biogas projects, gasification and pyrolysis of a mixture of feedstocks, municipal solid waste for example. So I think the thermochemical conversion and then transformation into fuels may be closer in the near term. Sustainable Development Technology Canada (SDTC) has a biofuels roadmap and they list the near-term technologies and where they see things fit on a time line. That's a good resource for a better picture.

Allan Eaglesham (NABC): Mark, what do you do currently with the solid material that's produced at the back end of your process? You mentioned possibly using it for cellulosic ethanol in the future. What critical aspects will influence your decision as to whether you develop this cellulosic ethanol potential?

Mark Kraeger: Right now, it's simply composted and goes to the land—it's a fertilizer product. Wal-Mart is buying it. I have a love-hate relationship with Wal-Mart. As far as what stands in the way of going on with cellulosic ethanol, it's really just proving the process. We've identified a company that, interestingly enough, is struggling. They've had some venture capital put into them and they can't seem to make their system work economically. They can make it work, but they can't make it work economically. With our system, because of all the other components that already exist, we don't have to have a distillation column. We don't think that we need another fermentor. Certainly no freight is involved in getting the feedstock. It will work within our system if, in fact, they can crack those molecules like they think they can. Testing is hopefully going to start here in the next 60 days and we'll start learning some things.

Tony Shelton (Cornell University): Dr. Tyner, I wonder if you could explain to me—a non-economist—the current subsidy for ethanol of \$0.51/gallon. What are the components that go into that \$0.51 and who gets it?

Tyner: The \$0.51 is the federal subsidy that's known as a blender's credit and it's paid directly to the entity that blends the ethanol—domestically produced or foreign produced—with gasoline, either in E10 or E85. The *initial* payment is to the blender. VeraSun might sell ethanol to Shell Oil, and Shell will blend it with their gasoline. So Shell gets the subsidy. Shell is able to pay Verisun more for the ethanol because they are getting that subsidy so a good part of it—most of it—is passed back to VeraSun, passed back to corn and as someone said today, that ultimately a lot of it gets passed back to the landowner in today's world. During the last 25 years most of it has stayed in the system, off the land, but now that the demand has pulled the corn price up as we've heard several times, a lot of the subsidy is heading straight back to the land like most income strings from agricultural commodities. So the initial payment is to the blender, then to the producer of the ethanol, then to the corn grower, then to the landowner. That's the economic trace of that subsidy.

Larry Smart (College of Environmental Science and Forestry): Mark, how reliably is your anaerobic digester working? What is your down-time? Is it a batch or is it a continuous process? How much power are you generating? Are you generating heat only or are you also generating electricity?

Kraeger: The process is continuous. No electricity is made because the efficiency of BTU conversion to electricity is something like 30% whereas to thermal heat is 80%, and so we rely on the high-efficiency BTU conversion. Reliability—it's been operating every day since August so the process is still in start-up. The technology we are using was designed at RCM in Berkeley, California—Mark Mosher put the engineering together. He has facilities that have been operating continuously for 20 years with zero down-time. The down-time he experiences is with the electricity generators because they have to stop and change the oil, whereas we're burning it all on boilers and there's no down time there.

PART IV—BREAKOUT SESSIONS

Workshops Summary	203
<i>Kenton E. Daschiell & Van C. Kelley</i>	

Workshops Summary

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Three breakout workshops were held during NABC 19, with the following topics:

- *Sustainability: Impacts and Issues*
- *Technology: Biomass, Fuels, and Co-Products*
- *Economics and Sustainability.*

Eight groups, each with a facilitator and recorder¹, met for 1-hour sessions to discuss predetermined questions. This report provides key points that emerged from the discussions².

Workshop I – *Sustainability: Impacts and Issues*

Question 1: What are the chief food/feed/fuel competition concerns? What actions are recommended to minimize these concerns?

- This is an emotional issue and initial negative perceptions may become reality for some people; price increases for food crops are expected, possibly affecting people's diets; the pulp and paper industry is concerned that wood prices will increase due to competition for feedstock; in the near future, livestock prices may increase more than for other foods; there could be a negative impact on roads, especially rural roads near ethanol plants; the need to produce feedstock for the biofuels industry will add to the competition for land from urbanization, conservation programs, food production, *etc.*, and we are unsure of international implications.

¹These duties were shared as follows: Facilitators—Tom Cheesbrough, Jeremy Freking, Wade French, Darrell Grandbois, Doug Raynie, Craig Russow, Evert VanderSluis and C.Y. Wang; Recorders—Theron Cooper, Basil Dalaly, José Gonzalez, Jim Julson, Joan Kreitlow, Tyler Remund, Lisette Tenlep and Tom West.

²Views expressed are not necessarily those of the authors, the Agricultural Research Service or South Dakota State University.

- The economics of growing crops in developing countries may improve, creating export opportunities.
- Factors that may minimize concerns include that food- and fuel-crop market shares will be rectified by the market; the cost of raw agricultural products such as corn and wheat are a small part of the total cost of processed foods; subsidies may be needed by the livestock industry to reduce the effect of rising feed costs; a labeling system for biofuels would reduce public confusion; good information needs to be in the hands of the general public to influence decision makers; there is a need for a massive education campaign for the general public; there is a significant need for more research; technology transfer and research on food production will be important for self-sufficiency of developing countries; the feed/fuel competition could be made into an opportunity to develop food/fuel systems in developing countries; research is needed on developing foods utilizing DDGS; and there is a need to consider some non-traditional approaches to solving this problem—for example, developing a technology for algae to harvest CO₂ from coal and convert it into a usable oil.
- A major action item is to reduce demands for conventional and biofuels through public education programs.

Question 2: What incentives and technologies are needed to induce farmers to grow cellulosic crops?

- Guaranteed stable markets will encourage farmers to invest in equipment and make changes in their farming systems; estimates of required farm-gate price for biomass varied from as low as \$40 to as high as \$100/ton; strong markets need to be developed for energy crops, because government subsidies should not be needed in the long term.
- Infrastructural issues related to transportation of ethanol/butanol need to be resolved; convert textile, paper and similar processing plants for energy-crop refining; research is needed on processing options such as distillation, direct combustion and pyrolysis; research is needed also to develop co-products such as fibers for clothing and oils for plastics; demonstration plants will stimulate producer interest; there is need to solve densification, transportation, and equipment issues.
- Changes in cropping systems will be more probable if technologies are developed to open up pivot corners and other unproductive lands to grow energy crops; availability of drought-tolerant energy crops for planting in marginal soils; appropriate modification in Conservation Reserve Program (CRP) rules; producers need to participate in a carbon tax credit trading system with incentives for soil and other conservation practices.

Question 3: What measures and policies should be adopted to address environmental concerns over cellulosic biofuel crops?

- As more land is planted to these crops, policies should be instituted to preserve biodiversity.
- Standards for sustainable removal rates will need to be developed to protect soils (including carbon sequestration), water quality and wildlife habitat; for example, the harvesting of switchgrass on CRP land may impact water and wildlife; policies will be needed to preclude over-stripping biomass from land to avoid negative impacts on soil, wildlife, and water quality.
- Perennial crops have more environmental benefits than negatives.
- Water-quality and environmental policies must complement the incentives given to promote cellulosic biofuel crops.
- Water-resource issues must be addressed in both crop production and processing, and national policies also need to work at the local level.
- Broader use of switchgrass as a coal-fuel blend would help address environmental concerns; lignin from switchgrass can be burned with coal; coal-firing is the most feasible method for powering these plants.
- Fly ash must be carefully used as its metal content can be detrimental to soil quality.
- The environmental impact of removing forest biomass needs to be better understood.
- Is perennial grass biomass sustainable over a long period of time?
- Education and research programs are needed to understand environmental advantages and disadvantages.
- The general public and industries need to more efficiently use energy—we should not be growing cellulosic crops to keep wasting energy from other sources.

Question 4: What is the likelihood—and potential impact—of deploying genetically modified (GM) perennial energy crops?

- It will occur and the impact will be positive as with row crops.
- Recombinant DNA technology will be necessary for rapid genetic improvement of perennial energy crops.
- It will be important to prove that GM crops will have no negative environmental effects; societal acceptance will be more likely if the GM crops are not for food use; there is a possibility of a GM crop becoming a super weed, therefore, it may be appropriate to try native plant species before turning to genetic engineering.
- The main reasons for using GM crops will be for greater yields and increased resistance to insects and diseases.
- Perennial crop traits that need genetic improvement will need to be precisely identified.

Workshop II – *Technology: Biomass, Fuels, and Co-Products*

Question 1: What technologies and agronomic practices need to be applied or developed to improve the quality and quantity of biomass crops?

- Equipment for efficiently harvesting biomass needs to be developed, *e.g.* for high-speed collection of corn and stover in a single pass.
- Logistics of transportation and storage of low-density biomass is a significant issue. In-field or localized processing may offer a solution if the economics of scale can be overcome.
- A huge ramp up will be needed to bring 50 million acres of biomass into production; seed availability will be an issue; region-specific cultivars with appropriate drought tolerance, wet tolerance and disease/insect resistance are in short supply.
- Crop-breeding programs including the use of GMOs need to be started at universities even though private companies will also have breeding programs; one important focus of a breeding program would be to increase cellulose while decreasing lignin.
- Tillage, fertilizer, and other agronomic practices for production (quantity) need to be developed to maintain/improve soil quality; mono-cultures vs. diverse stands should be evaluated for competition effects, weed control, and disease control; soil-fertility research for biomass production and the development of nitrogen-fixing energy crops is critical.

Question 2: What are the priorities for processing technology improvements and how can we encourage development of these technologies? (Or, are market forces sufficient drivers?)

- More research is needed on on-site processes such as densification and pelletization, pre-processing and distributed gasification. Processing facilities need to be developed that can be scaled down for local use without losing efficiency.
- Simple pre-treatment processes need to be developed, allowing good quality control, including use in developing countries.
- Processes also need to be robust enough to accommodate heterogeneous feedstocks.
- Metrics for indexing feedstock quality would allow more standardization of protocols and procedures.
- Developing new high-value co-products with unique uses, will help develop new markets and increase profitability.
- Consolidating processes into one enzymatic breakdown and developing enzymes for fixation in a column or bed for prolongation of activity could lower processing costs.
- Reducing water use during processing as well as in crop production will always be important.

- Venture capitalists and entrepreneurs will be major sources of funds for innovation; market forces are not always sufficient drivers to get new technology adopted—subsidies, price supports and tax credits will be needed to minimize risk until the technology is established.
- More effort is needed on the translation of technologies from the lab to the marketplace; intellectual property issues are important in the marketing of technology; the difficult task of translating new technologies from the laboratory to the market place would be facilitated if land-grant universities were more effective in public relations.

Question 3: How do we evaluate the overall sustainability of various renewable energy systems—biofuels, biopower, or hybrids of the two?

- A process that is carbon neutral and allows recycling carbon instead of releasing trapped carbon is beneficial. A process that captures CO₂ has even greater benefit.
- Sustainability will require maximizing energy output subject to constraints in terms of CO₂ balance, nutrient balance, water quantity and quality and soil quality.
- Rural community development is closely tied to the possibility of new income sources that are sustainable.
- Renewable energy may not be sustainable without government subsidies.
- The values of biofuels and biopower are linked to the demand of petroleum; sustainability is important to avoid conflict over a conceivably limited energy supply; encouraging efficient use of energy to reduce consumption will be key to achieving system sustainability.

Question 4: 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.

- The phosphorus (P) content of DDGS is important; when manure is used for crop fertilization, a large area of land is needed to achieve a balance with crop uptake of P.
- The generation, handling and quality control of co-products is important to the success of the biofuels industry; variability of DDGS affects market value; DDGS quality will be affected by oil extraction or by the amount of cellulose converted to ethanol; research is needed to develop high-value uses for co-products such as building materials, antibiotics and high-value chemicals.
- Biodiesel producers in the south are having difficulty disposing of glycerol even though it can be used in cattle feed and as an energy source for algae; it can be used on gravel roads to reduce dust.
- Research is needed to make new products from the co-product CO₂.
- The amount and type of antibiotics in DDGS affect its use in organic markets.

Workshop III – *Economics and Sustainability*

Question 1: What policies will maximize investment in processing plants, distribution infrastructure and consumer adoption of biofuels?

- Consumer adoption will occur when there is economic incentive, *e.g.* lower prices for biofuels or blends at the pump.
- Consumer demand can be created by instituting blending standards; the timing of when fuel standards are phased in should be carefully coordinated with available technology—abrupt introduction of a fuel standard may get ahead of the vehicle technology or refining technology; blending standards will help corporations to stand on their own without subsidies.
- Improved communication with consumers will help to eliminate misinformation on biofuels. Issues such as fuel quality and vehicle compatibility with biofuels are concerns that impede adoption.
- Funding for biofuel-distribution infrastructure will broaden availability.
- Domestic and international policy predictability with long-term consistent goals will promote investment in biofuels infrastructure because investors will feel that they can avoid risk; policies should also reduce environmental and national security risk.
- Perfecting the carbon-credit trading system could offer economic incentives to farmers as well as biofuel consumers.
- Development of a public mentality or sense of mission similar to that of the space program in the 1960s or the Manhattan project could increase public support for biofuels—long-term off-shoots from the biofuels program may be created.
- US policies need to look beyond corn ethanol to ease the transition from corn to cellulose ethanol; minimizing “road block” policy and supporting “fast track” technology and providing incentives for co-location of plants near other industries that utilize co-products could increase biofuels production.

Question 2: What policies to stimulate renewable fuels production seem reasonable?

- Government procurement policies, government mandates such as requiring biofuels to be used by public transportation, requiring auto manufacturers to produce flex-fuel vehicles and favorable prices for electricity production.
- Policies requiring fuel blends that are most efficient and requiring blender pumps will make renewable fuels more available.
- Development of new biofuel ideas need to be completely tax free or even subsidized during startup and beyond, in particular for biofuels from feedstocks that have never been used before.
- Bioenergetic analyses of cellulosic feedstock production and long-term policy in developing cellulosic ethanol production would help to guide the industry.

- The EPA should consider relaxing standards for clean operation of older biofuel plants to help keep them economically viable.
- Government promotion of conservation policies and education programs of non-rural consumers and youth could be effective.
- Forgivable loans for farmers to plant renewable fuel feedstock such as switchgrass would help to provide stable sources for fuel processors.

Question 3: What is the role of the public sector (USDA and universities) in assisting agriculture in its response to the energy situation?

- Key research, extension and teaching areas include: plant breeding of new crops, soil science, plant diseases and insects, agronomic management of crop systems with reduced energy input, processing of co-products, economic analysis/economic policy, water problems raised in Q 4, and support for the transition from starch- to cellulose-based ethanol.
- Universities can play a key role in teaching industry employees and in workforce development; cooperative education programs that allow students to alternate semesters between industry and school can provide a well-trained source of new talent.
- Universities can make a contribution to development of rational public policy by serving as a forum to discuss controversial ideas and serving as a voice for farmers and other sectors of society.
- Research parks located in close proximity to public research centers and universities provide good places to increase industry-public sector interactions; the USDA can play an important regulatory role in the future of the biofuels industry.
- Universities can provide libraries that are useful for industries and help forge public/private partnerships by facilitating networking with commodity producers and end-users.

Question 4: 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?

- The issues of usage of energy and water in processing facilities are critical for the sustainability of the industry.
- Green alternative energy must be economical for processing plants because economics will win over philosophy; there may not be a “one size fits all” solution; there must be long-term benefits for the entire system that allows industry to afford to use renewable power sources.
- Closed-loop systems with an integrated approach such as locating plants near feedlots may reduce petroleum use.
- Interdisciplinary sharing may help develop a more rational understanding of the environmental impacts of the renewable fuels industry.

- Water conservation is already a large focus in the processing industry and technology allowing economical recycling of water back into the plants could help mitigate regional water-usage issues; returning process water to groundwater creates several environmental concerns.
- Water use in the production of energy crops is a bigger issue than the water use in processing the energy crop; water use in cellulosic ethanol production may cause additional pollution concerns.

PART V—THE STUDENT VOICE

Student Voice at NABC: The Concept	213
Student Voice at NABC 19 <i>Clairmont Clementson, Sarah Collier, Haluk Gedikoglu, Chinnadurai Karunanithy, Alissa Meyer, Arijit Mukherjee, Thomas Niehaus, Kari Perez & Buck Wilson</i>	215

Student Voice at NABC: The Concept

To help increase graduate-student participation at NABC conferences, the *Student Voice at NABC* initiative was launched ahead of NABC 19. Grants of \$500¹ were offered to graduate students at NABC-member institutions (one student per institution) to assist with travel and lodging expenses. Registration fees were waived for the grant winners.

Student Voice delegates are expected to attend all of the annual-meeting plenary sessions as well as the breakout workshops then to meet as a group to identify current and emerging issues relevant to the conference subject matter. For the inaugural *Student Voice*, the students' discussions were focused on agricultural biofuels and agricultural biotechnology in general. Their report to NABC 19 is provided on pages 215–216.

¹The *Student Voice* grants for NABC 20—*Reshaping American Agriculture to Meet its Biofuel and Biopolymer Roles*, hosted by the Ohio State University at the Hyatt Regency Hotel, Columbus, OH, June 3–5, 2008—will be up to a maximum of \$750. Information: <http://oarc.osu.edu/nabc20>.

*Student Voice*¹ at NABC 19

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KEY ISSUES FOR AGRICULTURAL BIOFUELS

- Public awareness/education is needed on biofuels, emphasizing potential environmental benefits, effects on greenhouse gas emissions and global warming, and possible effects with regard to crude oil import bill/Kyoto Protocol.
- A comprehensive approach is needed, involving plant breeders, agronomists, bioprocess engineers, biotechnologists and microbiologists.
- 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.
- Pre-treatment and enzymes are the most costly components of ethanol production. Many groups are working on these aspects, but effort should be intensified to reduce ethanol cost so that it can compete with fossil fuels.

¹The *Student Voice* concept is described on page 213.

²Ms. Perez and Mr. Karunanithy reported briefly on the *Student Voice* discussions at the conclusion of NABC 19.

- Develop of microorganisms for simultaneous fermentation of pentoses and hexoses in biomass.
- Introduce flexible-fuel vehicles with higher mileage.
- In order to meet the US government goal by 2025, at least 2 billion gallons of biodiesel should be produced. The transesterification process produces biodiesel and glycerol; disposability of the latter must be addressed.
- Butanol is a viable alternative to ethanol/gasoline owing to its higher energy content as well as direct use in existing cars.
- Economic and social implications: Once competitive cellulosic ethanol technology is available, there will be competition between food and fuel. Farmers will decide on crops/land-use patterns based on income. This will lead to land scarcity, therefore, there is need to develop marginal lands for energy crops.
- If all agricultural residues are harvested as biomass, the issue of soil-fertility maintenance must be addressed.
- Like starch ethanol, there should be long-term incentives/tax benefits for cellulosic ethanol.
- *Student Voice* grants should be continued.

KEY ISSUES FOR AGRICULTURAL BIOTECHNOLOGY

- Education and outreach—K–12 outreach; identify what is biotechnology and what are the risks and non-risks.
- Intellectual property
 - Address patenting issues (public sector vs. private ownership)
 - Address issues of biopiracy.
- Develop GMO regulations and policy that are uniform and reconcile public and scientific concerns and promote application
 - Stress importance of separate policies for edible food crops vs. non-edible GMO applications
 - Emphasize research for the genetic control of transgenes.

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Index

- 20 in 10 35, 79, 162
25×'25 23, 35, 44–45, 51, 70, 72
30 by 30 35
2001 28
- Abrahamson, Lawrence 85–92
ADM 169
Advanced Energy Initiative 34
Agricultural Biofuels: Technology, Sustainability
and Profitability 3–11
agriculture, see also Farm Bill, soil, water
43–46
bills 168
biofuel effects 31, 32, 57
biotechnology 36, 82, 188, 213, 215, 216
cover crop 53
complex systems 69
conservation reserve program (CRP) 46, 52,
175, 182, 204
disaster 171
dramatic changes 167
enhancement 43
farm income 43, 51, 51, 55, 178, 180–182,
183, 189, 204, 207
fertilizer 31, 56, 80, 87, 89, 115, 146, 181,
183, 199, 206, 215
history 27, 36
intensification 183
land use 45, 50, 55, 56, 70, 86, 295
no-till 43–44, 45, 53, 54, 206
opportunities 31, 32
state departments of 53
sustainable 43–44
underused land 46
user and producer 36
yield improvement 27, 43, 51, 73, 80, 81, 82,
87, 88, 89, 90
- air quality 43, 46, 67, 189
Alaska 16
Alberta 60
algae 204
alternative fuel, see fuel, alternative
- American Chemical Society vii
Amyris 169
animal feed, see livestock feed
antibiotics 150, 207
Appendices 227–248
Appendix I vii n, 229–236
Appendix II vii n, 237–248
aquaculture feed, see livestock production
Aquafinca St. Peter Fish 58
Argus Leader 196
artichoke, Jerusalem 100
Aspen Institute 66
Atkins diet 113
- Banquet and Luncheon Presentations 13–40
Bantz, Steven 59–67, 70, 72, 73, 74, 75
Bartosh, Abby vi
billion ton report 32, 33, 51
biobased chemicals 31, 36, 37, 115, 127, 130,
171, 207
biobased economy, see bioeconomy
biobased products, see bioproducts
bio-belt 50–51
biodiesel, see also alternative fuel, bioenergy, bio-
fuel, feedstock 23, 31, 51, 57–58, 75, 149,
160–161, 168, 177, 183, 197, 207, 216
canola 51, 182, 189, 197, 198
castor bean 57
fat/grease 58, 62, 197, 198
glycerol, see co-products
jatropha 57–58
mustard 175
oilseeds 31, 57–58, 177, 180, 181, 182, 183
palm oil 183
poverty alleviation tool 57
production 31, 62
rapeseed 56
soybean 51, 160, 161, 175
species endangerment 183
sunflower 175
vegetable oils 56
biodiversity 53, 86

- bioeconomy, see also economic issues 27, 187, 188, 192
 creation of 36–39, 49–54
- bioenergy, see energy
- biofuel, see also alternative fuel, biodiesel, energy, ethanol, feedstock, process 17, 18, 21–25, 31, 35, 36, 38, 50, 60, 62, 169, 173, 175
 adverse issues 50–51
 blends 21, 22, 56, 57, 73, 137, 138, 175, 199
 certification 57
 consumption 62
 first-generation 177, 178, 182, 187, 190, 191, 192
 key issues 215
 lifecycle analysis 55–56, 60–62, 64, 86, 191
 data uncertainty 64, 70, 191
 GHGenius model 191
 market failures 156
 next-generation 17, 114, 179
 non-food 62
 sustainability 55–56, 57, 177–184, 187–192, 207, 209
 threats 72
- Biofuels and Biorefinery Development in Canada: The Question of Sustainability 187–192
- Biofuels: An Important Part of a Low-Carb Diet 59–67
- Biofuels, Energy-Security and Global-Warming Policy Interactions 155–165
- Biofuels for Transportation Sustainability 55–58
- Biofuels Initiative 35
- biogas 3, 175, 177, 178, 199, 200
- biomass, see feedstock
- Biomass Program 35
- Biomass Working Group 50
- biomaterials, see bioproducts
- bio oil 52
- biopolymer 188, 198
- bioproducts/biomaterials, see also biobased chemicals 35, 36, 37, 115–117, 198
 differential benefits 188–189
 feedstocks 116–117
 films 116
 foams 116
 composites 116–117
- biorefinery, see also ethanol plant 22, 80, 81, 96, 132, 192, 199
 power sources for 209
- biotechnology 100, 170, 171, 172, 187, 189, 191, 216
 agricultural 36, 82, 188, 213, 215, 216
 industrial 167, 168, 169, 170, 188
- Biotechnology Industry Organization vii
- Bono 73
- Boxer bill 65
- BP 74
- Brazil 56, 57, 196
- Breaking America's Addiction to Oil through Agriculture 15–18
- breakout sessions 10–11
 Workshops Summary 203–216
- Breeding, Selection and Testing of Shrub Willow as a Dedicated Energy Crop 85–92
- Brenner, Richard 152
- Bricka, Mark 127–136, 149, 150
- Bruntland Report 189
- Bu100 138
- Buffington, Dennis 150
- Buick 4n, 137, 138, 139, 144, 146
- Building a Prosperous Future in which Agriculture Uses and Produces Energy Efficiently and Effectively 27–40
- buildings, energy efficient 30, 38
- Burrill & Co. 167, 169
- Bush, George 18, 35, 51, 60, 162, 168
- Business Week 173
- butanol 4, 137–146, 190, 216
 blends 138
 ButylFuel 140, 141, 142, 144–145
 CO₂ mitigation 138
 economics 142–145
 energy accrual 141–142
 engine compatibility 137, 138, 216
 lobby 139
 pollution reduction 139
 process 139–143
 properties, physical 143
 safety 138
 solvent removal 140–141
 transportation of 138, 204
 yield 140, 141,
- Butanol: The Other Alternative Fuel 137–146
- ButylFuel, see butanol
- by-products, see also co-products
 inhibitory 97
- CAFE standard 63, 75
- California 29, 63, 65, 74, 168
 Board of Agriculture 45

- carbon-fuel standard 57, 65
- carbon intensity standard 63
- incentives 63
- Cameron, Kimberly 85–92
- Canada 3, 16, 57, 86, 177–184, 187–192
 - Agricultural Bioproducts Innovation Program 178
 - Agriculture and Agrifood Canada 187
 - Agriculture Canada 191
 - Alberta 179, 180, 192, 197
 - biodiesel 178
 - bioeconomy 187, 188, 192
 - biofuel 177, 178, 179, 180, 181, 182, 183, 187, 188, 189, 190, 191, 192, 196
 - importation 196
 - sustainability 177–184, 187–192
 - biogas 178, 199
 - biomass 188–189
 - utilization 187, 189
 - bioproducts 188–190
 - Canadian Environmental Act 190
 - co-products 180, 190
 - CO₂ 180
 - distillers dry grains 180, 182
 - development-related issues 190–191
 - Dominion Energy Services 197
 - eastern 180
 - EcoAgricultural Biofuels Capital Initiative 178
 - economic issues 190, 191
 - energy exporter 178, 179, 188
 - environment 190, 192
 - Environment Canada 191
 - Ethanol Expansion Program 178
 - ethanol production 178, 180, 199
 - farm income 178, 180–182, 183, 189
 - feedstock of choice 198
 - gasification 199
 - grains 177, 188
 - Green Fund 179
 - greenhouse gas 178, 182, 188, 189, 191
 - GHGenius model 191
 - Industry Canada 187
 - Iogen Corp. 180, 198
 - key points 10
 - land price 181
 - livestock issues 181, 190
 - Natural Resources Canada 187, 191
 - oil 25
 - oilseed 177, 181
 - Ontario 178, 180, 196
 - Ontario Ethanol Growth Fund 179
 - policy 178–179, 183
 - incentives/disincentives 177, 178–179, 180, 191, 196, 199
 - mandates 179, 180, 182, 196
 - objectives 178
 - Québec 178, 179, 180
 - Renewable Energy Producer Credit 179
 - rural revitalization 178
 - Saskatchewan 180, 183
 - Sustainable Development Technology Canada 199
 - The Natural Step 191–192
 - trade barriers, interprovincial 180
 - TransCanada 25
 - western 180
 - wood, 198–199
 - Western Grain Transportation Act 183
 - canola 51, 182, 189, 197, 198
 - Capital and Sustainability 167–172
 - carbon
 - credit 72
 - sequestration 43, 50, 53, 54, 60, 72, 86, 149, 155, 161, 205, 207
 - carbon dioxide, see greenhouse gas
 - carbon monoxide 127, 128, 139, 182
 - Carsrud, Jena vi
 - Carver, George Washington 46
 - Case 44
 - castor bean 57
 - Caugherty, Janean vi
 - CDS, see co-products
 - cellulose, see feedstock
 - cellulosic ethanol, see ethanol
 - cell wall 37, 80, 81, 82, 151
 - Center for Agricultural and Rural Development 72–73, 174
 - Center for Bioprocessing Research and Development 97
 - Central Minnesota Ethanol Cooperative 52
 - Ceres, Inc. 79, 82
 - Challenges on the Road to Biofuels 93–103
 - Chandrea, Smita vi
 - Cheesbrough, Tom vi, 203
 - chemicals, see biobased chemicals
 - Cheriton Valley powerplant 52
 - Chesapeake Bay 56
 - Chicago Climate Exchange 72
 - China 28, 29
 - Chippewa Valley Ethanol Co. 52
 - Christianson, Liz vi

- Chu, Steven 45
 cleantech 168, 170, 171, 209
 Clementson, Clairmont 215–216
 climate change 15–16, 17, 22, 27, 28–29, 49, 55,
 56, 63, 69, 74, 85, 156, 164, 191, 215
 business revolution spurred 171
 cap and trade policies 155
 discourse on 74
 closed-loop system 173–176, 209
 Clostridium acetobutylicum 142–143
 CO₂, see greenhouse gas
 coal, see energy
 Coal Gasification Work Group 50
 Collier, Sarah 215–216
 combustion, see gasification
 commercialization 21, 24, 27, 32, 37, 52, 53,
 82, 87, 90–91, 100, 104, 114, 139, 147,
 178, 179, 196
 communication improvement 54
 Community Power Corporation 133
 Conference Overview 1–11
 Congress 22, 24, 29, 44, 45, 60, 63, 65, 70–71,
 155
 conservation, see energy
 conservation tillage, see agriculture/no-till
 consumer awareness, see societal acceptance
 Convention on Biological Diversity 81
 conversion, feedstock, see process
 Cooper, Theron vi, 203
 co-products, see also human food, livestock
 feed 32, 105–125, 115–117, 198, 204,
 206, 207
 CO₂ 108, 174, 190, 207
 distillers grains 105, 106, 109, 150–151,
 174
 CDS 108, 109
 DDG 105–106, 108–109, 149, 151, 180,
 182
 DDGS 106, 108–109, 149, 150, 198, 204,
 207
 digestibility 151
 DWG 108, 174
 food source 113–115, 117
 flowability 106, 110–111, 151, 182
 phosphorus content 207
 price 198
 quality 106, 112, 113, 207
 research priorities 106, 112–113, 114–
 115
 storability 106, 110–111, 113
 diversification needed 110
 glycerol 149, 169, 207, 216
 key issues 7
 integrated use for ethanol production 173–
 175, 209
 thin stillage 150, 174
 zein 116
 corn/starch, see also feedstock 17, 21, 22, 23, 31,
 32, 43, 45, 51, 52, 53, 56, 61, 62, 64, 65,
 69, 79, 93, 106, 110, 113, 115, 116, 158,
 174, 175, 180, 198, 206, 209, 216
 area planted 17, 45, 158, 175
 demand 32, 163, 175
 exports 158, 162
 price 31, 70, 72, 73, 106, 158, 163–164, 168,
 169, 174, 199
 vs. oil price 156–160
 productivity 175
 use for ethanol 17, 21, 22, 23, 31, 32, 51, 52,
 56, 61, 62, 64, 65, 79, 93, 175, 198, 209,
 216
 yield 51, 86
 corncob, see feedstock
 corn stover, see feedstock
 corporate average fuel economy standard 63
 credit 75
 cotton 72
 Craddock, Wendy vi
 CRP, see agriculture
 CTL, see energy/coal
 Dalaly, Basil vi, 203
 Daschiell, Kenton vi, 149, 203–210
 Daschle gasoline 18
 Daschle, Thomas 15–19
 DDG, see co-products
 DDGS, see co-products
 dedicated energy crop, see feedstock/energy
 crop
 Deere, John 44, 45, 168
 Department of Energy, see DOE
 Detroit 75
 developing countries 29, 57, 204, 206
 Development and Sustainability of the Biofuel
 Industry in Canada 177–184
 diabetes 113
 digester, see biogas
 dimethyl ether 130
 direct seeding, see agriculture/no-till
 disease resistance 22, 81, 151, 205, 206, 209
 distillers grains, see co-products
 Distillers Grains Technology Council 150

- DOE 22, 35, 38, 38, 45, 53, 70
 - funding 63, 80, 139, 152
- Doolittle, James vi
- Double A Willow 90, 91
- Dow Cargill 168
- Doyle, Jim 50
- drought tolerance 22, 26, 81, 151, 175, 204, 206
- DuPont 37
- DWG, see co-products

- E³ Biofuels 174
- E10 73, 138, 191, 199
- E85 21, 22, 137, 175, 199
- Eaglesham, Allan iii, vi, vii–viii, 3–11, 199
- ecological issues, see environment
- economic issues, see also policy 9–10, 23–24, 29, 37, 44, 49, 50, 51, 59, 72, 156–157, 162, 187, 190, 191, 208–210, 216
 - AGLINK model 191
 - butanol 142–145
 - CRAM model 191
 - externalities 156
 - lifecycle analysis, see biofuel
 - partnerships 22, 36, 38, 39, 52–53, 57, 82, 209
 - rural development/revitalization 25, 51, 55, 69, 72–73, 85, 144, 168–169, 178, 207
- Economics and Sustainability 153–200, 203, 208–210
 - Q&A 195–200
- education 27, 36, 38–39, 70, 73–74, 191, 204, 209, 215, 216
- Egypt 3
- electric vehicle 74
- Empacador Toledo 58
- End of Oil 173
- energy/renewable energy, see also biodiesel, ethanol, feedstock, alternative fuel, oil 24, 85
 - Advanced Energy Initiative 34
 - Apollo Project needed 45
 - bioenergy 27–40, 51, 55, 161, 189, 195
 - traits 85, 87–91, 105
 - wiki 71
 - biomass, see feedstock
 - butanol 141–142
 - challenges, strategic, economic and environmental 59
 - coal 25, 30, 50–51, 52, 173, 205
 - CO₂ harvesting 204
 - gasification 60
 - liquefaction (CTL) 60, 61, 63, 162
 - Congressional bills 168
 - conservation 33, 67, 195, 203, 204, 205, 207, 216
 - conversion 30, 200
 - crop, see feedstock/energy crop
 - digester 3, 175, 177, 178, 199, 200
 - economic development, and 29
 - efficiency of use, see also energy/conservation 23, 24, 27, 29–30, 31, 36, 38, 49, 79, 205, 207, 208
 - electricity 24, 31, 50–51, 60, 208
 - fuel cell 30, 35, 38, 50, 60, 133, 170, 171
 - gasoline 21, 22, 31, 32, 35, 51, 60, 61, 62, 64, 73, 74
 - geothermal 30
 - heat and power, combined (CHP) 85–86
 - hydroelectricity 30, 44, 49
 - hydrogen 30, 35, 50, 60, 127, 128, 133, 190
 - butanol process 138n, 142
 - integration 24–25
 - interdisciplinary approach needed 37, 39, 209, 215
 - legislation, see also policy 33–34
 - Manhattan Project needed 45
 - market interest 169
 - natural gas 25, 30, 50–51, 52, 173
 - nuclear power 35, 44, 171
 - overview 27–40
 - security 28, 49, 55, 59, 69, 106, 144, 155, 156, 159, 164, 168, 178, 188
 - cost 156
 - solar 23, 25, 30, 44, 170, 171
 - war 44
 - wind 30, 34, 44, 49, 170, 171
 - Energy-Crop Gasification 127–135
 - Energy Futures Coalition 44
 - Energy Policy Act 63, 156
 - energy star 39
 - Ensyn 52
 - environment, see also global issues 24, 27, 39, 44, 57, 59, 67, 69–70, 85, 139, 151–152, 171, 183, 187, 190, 204–205, 209, 210
 - dead zone 56
 - enhancement 43, 46, 70
 - key issues 6–7
 - legislation 33–34, 151–152
 - risk 56, 63
 - sustainability 43–46
 - Environmental Protection Agency, see EPA

EPA 39, 70, 139, 209
 biofuel impact 70
 states vs. EPA 29
 lifecycle analysis 64
 Escherichia coli 169
 ethanol, see also alternative fuel, biofuel, energy,
 process 18, 22–23, 31, 51, 174
 additive see blends below
 blender's credit 199
 blends, see also E10 and E85 21, 22, 56, 57,
 73, 137, 138, 175, 199
 subsidy 156, 199–200
 cellulosic 17, 32, 34–35, 37, 45, 50, 51, 52,
 61, 62, 95–101, 150, 155, 158, 162, 171,
 182, 204–205
 development 63, 79, 190, 199, 216
 transition to 197, 209
 closed-loop system 173–176, 209
 CO₂, see co-products
 co-products, see co-products
 cost, see also life-cycle analysis 34, 37, 51, 52,
 53, 64, 81, 93, 100, 106, 140, 144, 145,
 150, 162, 163, 178, 180, 190, 206, 215
 distillers grains, see co-products
 economic issues, see economic issues
 gasification 132
 industry status 106–110
 lignocellulosic, see cellulose above
 plant, production, see also biorefinery 17, 22,
 50, 64–65, 93–96, 105, 106–107, 168,
 189
 profitability 171
 process see process
 production, see also process 31–32, 93–95,
 144, 175, 177
 limits 62, 65, 73, 95
 promotion of 17
 solution to problems 16–17
 starch-based 22, 31, 32, 56, 61, 62, 64, 65,
 79, 93, 175, 198, 209, 216
 subsidy 139, 156–161, 162, 163, 164,
 199–200
 transportation of 138, 204
 Ethanol Processing Co-Products: Economics,
 Impacts, Sustainability 105–125
 ethylene 36
 European Union 56, 57, 150, 177, 189, 197
 Exxon 74

 Farm Bill
 1985 43
 1990 43
 2002 24, 33
 2007 24, 33, 70, 71, 195, 196–197, 198
 energy title 24
 programs 24
 FDA 150
 feed, see co-products, livestock
 feed vs. fuel, see food vs. fuel
 feedstock, see also energy, process 37, 52, 127,
 196, 209
 agricultural resources 33
 aspen 133
 barley 174
 big bluestem 17, 53
 billion ton report 32, 33, 51
 biomass, see also energy crop 23, 30, 31,
 49, 52, 70, 79–82, 106, 116, 127, 128,
 131, 137, 138, 144, 145, 146, 150, 187,
 188–189, 190, 191, 192, 196, 198, 204,
 205, 216, 206
 breeding 51, 54, 80–82, 85, 152, 206,
 215
 improvement 206
 stock planting 81, 82, 90, 206
 Biomass Program 35
 biomass R&D Initiative 35
 bulk/energy density 37, 90, 99, 112, 131, 150,
 151, 204, 206, 215
 canola 51, 182, 189, 197, 198
 castor bean 57
 cellulose, see ethanol/cellulosic
 choice 55–56, 190
 old vs. new 51
 sustainability 44
 coal, see coal
 conversion, see process
 corn, see corn
 corn cob 23
 demand 180
 densification 204, 206
 energy crop, see also biomass 36, 38, 43, 44,
 45, 46, 51, 53, 70, 79–82, 85–92
 breeding 51, 54, 80–82, 85, 205
 gasification 127–135
 genetically engineered 81–82, 151–152,
 205, 216
 desirable traits 81
 molecular markers 81–82
 pollen flow 152, 216
 research needed 46, 51, 53, 80
 seed viability 152

- stock, planting 81, 82, 90, 206
- traits, 81, 215
- fat/grease 58, 62, 197, 198
- forestry resources, see also wood 33
- germplasm availability 82, 90
- grains/oilseeds 31, 56, 177, 180, 181, 182, 183
- grasses 46, 50, 52, 53, 72, 106
 - C4 80
- guarantee 197
- hemicellulose 79, 81, 97
- jatropha 57–58
- key issues 7–8
- legumes 106
- lignin 81, 97, 99, 116, 137, 146, 205, 206, 209, 215
- lignocellulose, see also ethanol/cellulosic 95–101
- limitation 63
- miscanthus 52, 80, 81, 90
- mustard 175
- natural gas, see energy
- new 36
- non-renewable 30
- oil, see oil
- oilseeds/grains 31, 56, 177, 180, 181, 182, 183
- perennials, see also biomass and energy crop 46, 50, 52, 54, 63, 72, 80–82, 85–92, 106, 151, 205
 - costs 72, 204
- pine 133
- poplar 56, 86
- product markets 31
- quality indexing 206
- rapeseed 56
- residues, see waste
- sorghum 52, 100, 174
- soybean 51, 160, 161 175
- starch, see corn
- stover 23, 45, 52, 53, 106, 171, 179, 206
- straw 23, 52, 106, 179
- sugar beet/cane 56, 80, 81
- sunflower 175
- switchgrass 17, 23, 46, 51, 52, 56, 80, 81, 127, 131, 175, 179, 196, 197, 209
 - co-firing 52, 131, 205
 - profitability 70
 - targets 71–72
 - types 80
- transportation and storage 26, 52, 53, 72, 79, 80, 93, 131–132, 204, 206
- triticale 192
- waste 30, 32, 56, 85–86, 127, 175, 179, 216
- wheat, see wheat
- willow 85–92
- wood, see also cellulose, hemicellulose, lignin 23, 30, 31, 33, 45, 52, 53, 54, 56, 85–92, 127, 133, 173, 189
 - undervalued 46, 86
 - Canada, in 198–199
 - yield improvement 36, 37, 51, 53, 71, 79, 183, 205
- feed system, see gasification
- fermentation, see processing
- fertilizer 31, 56, 80, 87, 89, 115, 146, 181, 183, 199, 206, 215
- Fischer, James 27–40
- Fischer-Tropsch 130, 190
- fish feed, see livestock/aquaculture
- Flavell, Richard 70, 71, 79–83, 151–152
- flex-fuel vehicle 21–22, 39, 75, 138, 208, 216
- fly ash 205
- Food and Drug Administration 150
- Food, Feed, Fiber and Fuel: A New World for American Agriculture and Environmental Sustainability 43–46
- food, human 16, 23, 25, 27, 36, 46, 73, 105, 112, 142, 180, 189, 203, 205
 - co-products with ethanol 113–115, 117, 204
 - fiber, dietary 113, 115
 - food system 30
 - price 71, 72, 174
- food vs. fuel 50, 57, 69, 73, 79, 142, 168, 171, 173–176, 203, 204, 216
 - key issues 7, 203–204
- Food vs. Fuel? An Integrated Approach to Producing Both 173–175
- Ford, Henry 75
- forestry, see also feedstock/wood 23, 30
 - management 53
- fossil fuel, see natural gas, oil
- Freking, Jeremy vi, 203
- French, Wade vi, 203
- fuel, alternative/renewable/transportation, see also biodiesel, biofuel, ethanol, 52, 85, 189
 - carbon intensity 59–67
 - cultural shift needed 73
 - benefits from 24
 - dimethyl ether 130

- efficiency of use 35, 62, 63, 67, 73, 74, 75
- engine compatibility 137, 138, 216
- goal 70
- infrastructure 24, 138, 204
- key points 5–6
- mandates 164–165
- market size 63
- policy roadmap 24
- production 31–32
- properties 143
- silver bullet, not 62
- solution to problems 16
- South Dakota's leadership 21–25
- standard 156, 158, 162–163, 164
- targets 23, 32, 35, 36, 44–45, 70, 72, 79, 162
- fuel cell 30, 35, 50, 60, 170, 171
- furfural 95
- Future Farmers of America 38

- Ganesan, Vyku vi
- gasification 46, 52, 54, 97, 127–135, 150, 199, 206
 - coal, of 60
 - combustion 127, 204
 - ethanol production 132
 - gasifiers
 - circulating fluidized bed 128, 129, 130, 135
 - down-draft 128, 129, 133, 134
 - entrained flow 128, 129, 131, 133
 - fluidized bed 128, 129
 - updraft 128, 129
 - pyrolysis 127, 204
 - slag formation 53
 - syngas 127, 128, 129, 130, 133, 135
 - tar 128, 129, 131–132, 133, 134
- gasoline 21, 22, 31, 32, 35, 51, 60, 61, 62, 64, 73, 74
- Gedikoglu, Haluk 74, 215–216
- genetically engineered energy crop 81–82, 151–152, 205, 216
- genetically modified organism 36, 216
- genomics 31
- geothermal energy 30
- Germany 57, 177
- Gibbons, William vi, 74, 93–104, 150, 195
- global issues 37
 - ecological footprint 187
 - ethanol production 177
 - geopolitics 28
 - grain demand 177
 - key points 4–5
 - oilseed demand 177
 - population 29, 57
 - warming, see climate change
- glucose 36, 99
- glycerol, see co-products
- GMO, see also genetically engineered energy crop 36, 216
- Gonzalez, José vi, 203
- Gore, Al 74
- grains/oilseeds 31, 56, 177, 180, 181, 182, 183
- Grandbois, Darrell vi, 203
- Gray, Boyden 44
- Great Britain, see United Kingdom
- Great Plains Institute 49, 54
- greenhouse gas, see also climate change 27, 29, 39, 50–51, 55, 56, 63, 64, 75, 79, 85, 155, 168, 178, 182, 188, 189, 191, 215
 - biodiesel impact 160–161
 - ethanol impact 160–161
 - China 29, 59
 - credit 156, 164
 - data uncertainty 64, 70
 - developing countries 29
 - ethanol method impact 65
 - feedstock impact 56, 60–61
 - GHGenius model 191
 - India 29
 - Kyoto Protocol 29, 179, 215
 - quantification 70
 - states vs. EPA 29
 - subsidy linked 158
 - transportation, from 59, 138
 - US reduction 63, 65–66
- Gross, John 150
- Guatemala 55, 58, 67
- Gulf of Mexico 56

- 4-H 38
- Hanley, Carol 73
- Hardy, Ralph iii, vi, vii–viii, 3–11, 71, 72, 198
- Hartinger, Barb vi
- Hawaii 179
- hemicellulose 79, 81, 97
- herbicide 53, 86, 89, 175
- Hereen, Derek vi
- Hofer, Brett vi
- Hoiuum, Mike vi
- Honduras 55, 58
- human food, see food, human

- Hunt, Suzanne 55–58, 69, 70, 71, 73, 74, 75
 hybrid vehicle 30, 65–66, 85
 hydrocarbon 131, 139, 179
 hydrogen, *see* energy
- ICM vi
 incentives, *see* policy
 India 29, 67
 Indonesia 183
 industrial biotechnology 167, 168, 169, 170, 188
 insect resistance 175, 205, 206, 209
 intellectual property 207, 216
 International Clostridia Group 139
 International Energy Agency 177
 international issues, *see* global issues
 investment 17, 18, 23, 69, 74, 85, 91, 142, 157, 160, 162, 168, 169, 170
 challenges 171, 172
 new companies 169–170
 sustainability 167–168, 171
 cooling off 169
 Iogen Corp. 180, 198
 Iowa State University 38, 72–73, 174
 Iran 16
 Iraq 28, 44
 isoprenoid pathway 169
- jatropha* 57–58
 John Deere 139
 Jordan, Brendan 49–54, 70, 71, 72, 74
 Joy, Bill 171
 Julson, James vi, 203
- Kansas City Star 173
 Karunanithy, Chinnadurai 215–216
 Katrina, hurricane 168
 Keasling, Jay 169
 Kelley, Van vi, 195, 203–210
 Kephart, Kevin vi, 3
 Khosla Ventures 169
 Kirby, John vi, 69
 Klein, K.K. 177–185
 Kluyveromyces marxianus 100
 Knorr, Amanda vi
 Kraeger, Mark 173–176, 200
 Kreitlow, Joan vi, 203
 Krishnan, Padu vi
 Kruger, Kraig vi
 Kyoto Protocol, *see also* greenhouse gas 29, 179, 215
- Lafayette Road Experiment Station 87–88
 Lakota people 69
 land-grant institutions 38, 50, 53, 207
 land price 181
 land use 45, 50, 55, 56, 70, 86, 181, 190, 204, 216
 Lantmännen Agroenergi 87
 LDP 175
 Lee, William vi
 Lemme, Gary vi, 3
 Le Roy, Danny 177–185, 196, 197
 lifecycle analysis, *see* biofuel
 lignin 81, 97, 99, 116, 137, 146, 205, 206, 209, 215
 lignocellulosic ethanol, *see* ethanol/cellulosic
 livestock production, *see also* co-products, food
 vs. fuel 32, 72, 113, 151, 158, 174
 aquaculture 112
 feed 23, 32, 46, 79, 105, 106, 109, 110, 112, 113, 114, 115, 117, 149, 150, 151, 162, 168, 175, 180, 181, 182, 207
 cost 32, 72, 171, 174, 181, 182, 183, 204, 171, 181–182, 204
 densification 112–113
 digestibility/quality 151, 182
 fiber 149, 151
 oil source 175
 protein market 175
 value added 112–113
- Lipari, Susanne vi
 liquid smoke 52
 loan deficiency payment (LDP) 175
 Lockrem, Mike vi
 Loutsch, Jeff vi
 Low Carbon Fuel Standard 17
 LS9 169
 Lugar, Richard 16
 Luncheon Presentations, *see* Banquet
- Machado, Tanner vi
 Mackenzie reports 169
 Malaysia 183
 Marella, Chenchiah vi
 McCarthick, Josh vi
 McMillan, Ryan vi
 medicinal plants 69
 Melampsora spp. 87
 Metabolix 169
 Meyer, Alissa 215–216

- Meyers, Jay vi
 Michael, Nick vi
 Middle East 16, 17, 24, 25, 28
 Midwest 17, 50–51, 56, 168, 171
 universities 93
 upper 64, 70, 151
 Midwest Assoc. of State Depts. of Ag. 50
 Midwest Governors Association 23, 50
 Midwest Renewable Energy Tracking System 50
 Milbank biodigester viii, 3
 Minnesota 179
 miscanthus, see feedstock
 Mississippi Ethanol LLC 133
 Mississippi State University 130, 133
 Institute for Clean Energy Technology 133
 Mobley, Paul vi
 Mohr-Coulomb criteria 111
 Molengraaf, Terry vi
 Monsanto 169
 Montana 179
 Moseley, Jim 43
 Mosher, Mark 200
 Muench, Louis vi
 Mukherjee, Arijit 215–216
 Muscoma 169
 Muthukumarappan, Kasiviswamanathan vi

 NABC v, vii, 23
 NABC 12 vii
 NABC 19 vii–viii, 18, 39
 modules viii, ix–x
 Conference Overview 1–11
 Breakout Sessions 201–210
 NABC 20 viii
 NABC News viii
 reports available v
 Road Forward document vii, vii n, 36, 237–248
 Student Voice viii, 36
 concept 213
 NABC 19, at 215–216
 targets 36
 Vision Statement vii, vii n, 229–236
 NASULGC 38
 National Agricultural Biotechnology Council, see NABC
 National Biomass Action Plan 35
 National Renewable Energy Lab 50, 96, 97, 133, 139
 natural gas 25, 30, 50–51, 52, 173

 NatureWorks 168
 Nebraska 196
 Nelson, Ben 196
 Nelson, Willie 57
 Netherlands 57
 New York State Energy R&D Authority 91
 Nichols, Sharon vi
 Nielson, Chad vi
 Niehaus, Thomas 215–216
 Niger 3
 nitrogen fixation 31, 206
 North Central Bio-Economy Consortium 50, 54
 North Central Sun Grant vi
 North Dakota and Minnesota Farmers' Union 72
 no till 43–44, 45, 53, 54, 206
 nuclear power 35, 44, 171

 Oakridge National Lab 50
 Obama, Barack 17
 Obama-Harkin bill 65
 obesity 113, 174
 Ohio State University viii
 oil/petroleum, see also energy 44, 50–51
 addiction/dependence 16, 17, 18, 27, 28
 Canada 25
 China 28
 companies 16, 29, 74
 costs, hidden 155
 importation/consumption 16, 24, 28, 60, 61, 155–165
 peak 28
 price 17, 163, 164–165, 168
 vs. corn price 156–160
 replacements 60
 reserves 16
 security 28, 49, 55, 59, 69, 168
 shale 44
 tar sand 25, 59, 61, 189
 tax 156
 oilseeds/grains 31, 56, 177, 180, 181, 182, 183
 Olson, Andrea vi
 OPEC 17, 144

 palm oil 183
 paper/pulp 30
 participants 217–226
 partnerships 22, 36, 38, 39, 52–53, 57, 82, 209
 Pasikanti, Sri vi

- Patterson, Deb vi
- perennials, see feedstock
- Perez, Kari 215–216
- petroleum, see oil
- Pickard, Jennifer vi
- Pickens, T. Boone 28
- Pikul, Joe vi
- Podesta, John 44
- POET vi, 22
- policy/regulatory issues 9–10, 15, 17, 24, 29, 33–34, 63–65, 66, 69, 72, 149, 152, 155–165, 167, 168, 178–179, 183, 205, 209, 216
- cap and trade 155
- conservation 203, 209
- edible vs. non-edible crops 216
- energy legislation 33–34
- GMO-related 216
- incentives/disincentives 17, 21–22, 23–24, 33–34, 37, 50, 53, 57, 63, 74, 146, 156, 162, 177, 178–179, 180, 191, 195, 204, 204–205, 207, 208, 209, 216
- subsidy 139, 156–161, 162, 163, 164, 199–200, 204, 207, 208
- key issues 9–10
- mandates 164–165, 179, 180, 182, 191
- options supporting ethanol industry 156–161
- procurement 208
- South Dakota 21–22, 23
- political issues 49, 50
- poplar 56, 86
- potato leaf hopper 87
- Powering the Plains 49
- prairie ecosystem 69–70
- Pravecsek, Max vi
- PRIME BioSolutions 174
- process 22, 34, 36, 37–38, 51, 133, 205, 206
- antibiotics 150, 207
- bioreactor 100–101, 142–143
- butanol 139–143
- clean fractionation 97–98
- closed-loop system 173–176, 209
- conversion, see also cell wall, enzymes, microorganisms and pretreatment below 37, 38, 45, 51, 79, 80, 82, 93, 97, 99–100, 174, 190, 206
- platforms 95–96
- dry-grind 93, 95, 107
- enzymes, see also cell wall, pretreatment below 37, 79, 100, 206, 215
- extrusion 97–99, 113, 115
- fermentation, see also microorganisms below 79, 81, 97, 99, 100, 105, 107, 108, 109, 137, 139, 140–141, 142, 145, 146, 150, 169, 182, 216
- butanol 139–140, 142–143, 146
- diauxic 97
- key issues 8–9
- solid state 100
- thermotolerant yeast 100
- gasification, see gasification
- hydrolysis 97
- improvement priorities 206–207
- key points 8–9
- liquification, see gasification
- microorganisms 37, 100, 130, 169, 216
- options 97, 204
- pretreatment, see also conversion and gasification 36, 37, 52, 79, 81, 97–99, 114, 145, 206, 215
- reactor design 100–101
- technology transfer 36, 39, 204, 207
- thermochemical, see gasification
- wet-milling 93, 107
- product commercialization 21, 24, 27, 32, 37, 52, 53, 82, 87, 90–91, 100, 104, 114, 139, 147, 178, 179, 196
- propanediol 37
- public awareness/opinion 44, 49, 56, 73–74, 75, 151–152, 187, 216
- pulp/paper 30
- pyrolysis, see gasification
- Ramaswamy, Sonny 149
- Ramey, David 137–147, 152
- Rand Corporation 45
- rapeseed 56
- Raynie, Doug vi, 203
- RCM 200
- Redepinning, Annette vi
- regulatory issues, see policy
- Remund, Tyler vi, 203
- renewable energy, see energy
- renewable fuel, see alternative fuel
- renewable fuel standard 16–17, 60, 63, 65, 66, 195
- Research Foundation of the State Univ. of New York 90
- research, research needs 18, 22–23, 24, 27, 36, 37, 39, 46, 50, 52, 53, 64, 80, 86, 106, 111, 112, 113, 114, 116, 117, 139, 145, 149,

- 151, 189, 204, 205, 206, 207, 209, 216,
Reshaping American Agriculture, see NABC/
NABC 20
RFS 16–17, 60, 63, 65, 66, 195
Richards, William 43–47, 70, 71, 72, 73, 74–75,
146
Riedel, Walter vi
Roberts, Paul 173
Rohweder, Angela vi
Rosentrater, Kurt vi, 95, 105–126, 149, 150,
151
Rounds, Mike 21–26
Roundtable on Sustainable Biofuels 57
rural development/revitalization 25, 51, 55, 69,
72–73, 85, 144, 168–169, 178, 207
Russia 59
Russow, Craig vi, 203
Rusten, Sandy vi
- Saccharomyces cerevisiae 100
Salix, see also willow
 dasyclados 88, 90
 eriocephala 87, 90
 miyabeana 88, 90
 sachalinensis 90
Saudi Arabia 16
Schwarzenegger, Arnold 17, 168
Shae, Ernie 44
Shaw, George Bernard 18
Shell Oil 29, 74
Shelton, Anthony vi, 3, 151
Smart, Lawrence 85–92, 200
Smith, Read 44
societal acceptance 44, 49, 56, 73–74, 75,
151–152, 187, 216
soil
 erosion 43, 46, 56
 fertility/quality 43, 46, 50, 51, 53, 70, 205,
206, 207, 216
 marginal soils, use of 57, 86, 183, 204
Soil Conservation Service 44
Solar Decathlon 38
solar energy 23, 25, 30, 44, 170, 171
Somerville, Chris 169
sorghum 52, 100, 174
Sorona 37
South Dakota 17, 18, 57, 67, 196
 Agricultural Heritage Museum 3
 biofuel leader 18, 21–25
 centers of excellence 22
 ethanol 22–23
 fuel sufficiency 22–23
 investment in 17
 key points 10
 2010 research centers 22
 South Dakota Certified Beef vi
 South Dakota Corn Council vi
 South Dakota Pork Producers Council vi
 South Dakota State University (SDSU) vi, vii,
3, 15, 17, 53, 93
 Sun Grant Center 22
 tax incentives 21–22, 23
 South Dakota's Leadership in Production and
 Adoption of Agricultural Biofuels 21–25
soybean 43, 51, 62, 72, 86, 116, 160, 161,
175, 181
South Beach diet 113
Soviet Union 18
species endangerment 183
Sputnik 18
stakeholder consensus 49–50
starch, see corn, wheat
State Univ. of New York College of Env. Sci. &
Forestry 87
stover, see feedstock
straw, see feedstock
Student Voice at NABC, see NABC
Sun Grant Initiative 22–23
Sun Microsystems 171
Supreme Court 29
Sustainable Biodiesel Alliance 57
sustainability 85
 agricultural 43–44
 biofuel 55–56, 57, 177–184, 187–192, 205,
207, 209
 investment 167–168, 171
 market interest 169
Sustainability Assessment Framework and Tool
192
Sustainability: Impacts and Issues 41–75,
203–205
 Q&A 69–75
Sustainable Biodiesel Alliance 57
Swanson, Seth vi
Sweden 86
switchgrass, see feedstock
syngas 127, 128, 129, 130, 133, 135
Taiwan 3
tar 128, 129, 131–132, 133, 134

- targets 23, 32, 35, 36, 44–45, 70, 72, 79, 162
- tax (dis)incentives, see policy/incentives
- Technology: Biomass, Fuels and Co-Products
 - 77–152, 203, 206–207
 - Q&A 149–152
- technology transfer 36, 39, 204, 207
- Telkamp, Rylene vi
- Tenlep, Lisa vi, 203
- The End of Oil 173
- thermochemical process, see gasification
- Thompson, Meredith vi
- Thune, John 196
- Thurlow, Jenny vi
- tilapia 58
- transportation sector 22, 24, 26, 31, 35, 36,
 - 50–51, 56, 62, 63, 85, 93, 95, 138, 144, 183, 189, 208
 - pollution from 59–60
 - sustainability 55–58
- Tschetter, Emery vi, xii, 12, 263
- Tulley Genetics Field Station 88
- Turning Biomass Crops for Biofuels into Commercial Reality 79–82
- Tuskegee University 46
- Tyner, Wallace 149, 155–166, 195, 196, 197
- Tyson 174
- Union of Concerned Scientists 59
- United Kingdom 57, 86, 173
- United States
 - Department of Agriculture, see USDA
 - Department of Energy, see DOE
 - Department of Labor 38
 - Department of Transportation 22
 - energy goals 24–25
 - key points 4–5
 - federal legislation, see also policy 33–34
 - greenhouse-gas reduction 63
 - national issues, key points 4–5
 - national security 16, 24, 27, 28, 155
 - oil importation/consumption 16, 24, 28, 60, 61, 155–165
 - policy/regulatory issues, see policy
 - priorities 24
 - Supreme Court 29
 - transportation pollution 59–60
- Université de Sherbrooke 192
- universities' role 209
- University of Florida vii
- University of Minnesota 53
- University of North Dakota
 - Environmental Research Center 53
 - University of Tennessee 45
 - University of Toronto 87
 - Upper Midwest Hydrogen Initiative 50
 - USDA 22, 27, 35, 38, 70, 209
 - ARS vi
 - education and extension 36, 209
 - goals 36
 - North Central Ag. Research Lab. viii, 3
 - research programs 36, 80, 209
 - science and education 27, 39
 - technology transfer 36
 - Ushering in a New Bio-Economy 49–54
- VanderSluis, Evert vi, 203
- vegetable oils 56
- Venezuela 16, 25
- Venn diagram 49
- venture capital 139, 152, 167, 168, 169, 170, 171, 199, 207
- VeraSun vi, viii, 3, 22
- Volk, Timothy 85–92
- Wal-Mart 168, 199
- Wang, C.Y. vi, 203
- water 56, 97, 99, 100, 106, 133, 137, 140, 183, 190, 206, 209
 - consumption/conservation 56, 80, 100, 150, 183, 205, 206, 207, 210, 215
 - quality 43, 50, 51, 53, 205, 207, 210
- Webster's 173
- weed control 86, 205, 206
- Wellisch, Maria 150, 187–193, 196, 197–198
- West, Tom vi, 203
- Western Governors Association 23
- wet tolerance 206
- wheat 16, 23, 52, 72, 111, 179, 180, 181, 183, 204
- wildlife habitat 46, 50, 51, 53, 55, 86, 205
- willow 56, 85–92
 - energy ratio 86
 - improvement, genetic 87–91
 - logistics as an energy crop 86–87, 90–91
 - pollination 87
- Wilson, Buck 215–216
- wind 30, 34, 44, 49, 170, 171
- wood, see feedstock
- Woolsey, James 44
- workforce availability/development 93, 209
- Workshops Summary 203–216

World Congress on Industrial Biotech vii

Summary Proceedings vii n

Worldwatch Institute 55

Wyse, Roger 167–172, 197

Yang, S.T. 152

Yeutter, Clayton 43

zero tillage (no till) 43–44, 45, 53, 54, 206

Zimiga, Art 69

Zsuffa, Louis 87





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