New Directions for Research in Bioenergy and Biobased Products

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In my 40 plus years as an agricultural scientist and administrator, I’ve never experienced such exciting times. As a student and young professor, I came along during the heyday of agricultural chemicals in the 1950s and 1960s, and then the era of biotechnology in the 1980s and 1990s. But the era of bioenergy and bioproducts is clearly the biggest challenge in agriculture in 200 years. It is also a time of tremendous opportunity for scientists, industry, and agriculture to make a real difference for our future. Agriculture offers untapped resources that could help create a more secure economic future, not only for rural America but also for industry—while improving the environment.

Bioenergy and biobased products are hot topics today and for good reason. Our Nation’s dependency on foreign sources for many materials vital to both industry and defense is a major concern. Some of these materials are in limited supply; in some cases, as with petroleum, much of the known reserves are located primarily in unstable regions of the world. There is a danger that a country that does not agree with US policies could take retaliatory action and refuse to export certain items that are needed for industrial production or for defense purposes. Besides petroleum, these essential products include minerals and products derived from plants such as fats and oils (coconut, palm, castor), waxes, resins, gums, tannins, rubber, specialty and industrial chemicals, and pharmaceuticals. Research, development, and technological innovation, especially related to new or improved materials and processing technologies, are important factors that could affect our long-term economic competitiveness. Having a reliable domestic supply for these vital materials is also necessary for our economic and national defense systems to be able to react and adjust to potential shortages of critical minerals and materials. Because of the need to address these issues, the Administration and Congress have developed policies and implemented legislation to decrease our Nation’s vulnerability. The Federal government is taking positive action that will promote our national security, help ensure a healthy and vigorous economy, create American jobs, and protect America’s natural resources and environment.

While industry and defense are compelling national interests for promoting bioenergy and biobased products, there are other important interests at stake, such as better environmental stewardship and support for the rural economy. Today, American agriculture faces increasing intense competition in the global marketplace. Agricultural production has increased faster than demand in many areas, resulting in commodity surpluses, low prices, and unreliable profitability. Biobased products and bioenergy can help increase demand for many agricultural commodities that can serve as feedstocks for production of bioenergy and biobased products. By substituting domestically produced biobased products for those made from oil-based products we can decrease the US reliance on foreign oil and natural gas.

Additionally, sustainable environmental stewardship is promoted because biobased products are produced by less polluting processes than in the petrochemicals industry. As a renewable energy source, biomass does not contribute to carbon dioxide in the atmosphere in contrast to fossil fuels. Biobased products and bioenergy also add to economic development in rural America by creating new markets for agricultural products. Biobased products also often cost less than their petroleum-based counterparts especially when you consider the life cycle costs associated with using toxic chemicals or petroleum-based fuels.

In view of their importance, the Department of Agriculture (USDA) has established two Departmental-level groups to provide coordination and guidance for bioenergy and biobased programs. Last December, Secretary of Agriculture Mike Johanns established the USDA Energy Council, chaired by Under Secretary for Rural Development, Thomas Dorr. The Energy Council coordinates implementation of USDA’s energy strategy. The Council works with the Department of Energy, Environmental Protection Agency, and others in an effort to achieve the Renewable Fuels Standard set by the Energy Policy Act of 2005. The standard requires an annual usage rate of 7.5 billion gallons of renewable fuel by 2012. The Biobased Products and Bioenergy Coordination Council (BBCC), for which I have responsibility, provides a forum through which USDA agencies coordinate...
research, development, commercialization, and marketing of biobased products and bioenergy. This includes promoting information sharing and strategic planning, and providing policy advice to the Secretary. USDA has a long history in developing biobased materials, including bioenergy from agricultural products. Since research is an important aspect of USDA's overall bioenergy and biobased strategy, there are numerous research projects underway to find new uses for agricultural products, including new ways to produce bioenergy. USDA also funds food and agricultural research, including bioenergy research, primarily through the State Land Grant system at many colleges and universities. USDA scientists often work with university researchers giving us a tremendous capacity and knowledge base.

My area of responsibility, the Research, Education, and Economics (REE) mission area, is one of seven USDA mission areas. REE includes the Agricultural Research Service; the Cooperative State Research, Education, and Extension Service; the Economic Research Service; and the National Agricultural Statistics Service. Within REE, we have 2,500 scientists located at about 100 laboratories throughout the United States, and that's just our in-house capability.

**RESEARCH PROGRAMS**

Various research agencies in my Mission Area are involved in biobased and bioenergy research.

**Agricultural Research Service (ARS)**

ARS is USDA's chief scientific research agency, responsible for solving agricultural problems of national importance. ARS has over 100 research laboratories across the United States and in four foreign countries.

ARS has a broad bioenergy program geared toward producing sustainable, efficient, and economic energy from agricultural products. Program components include developing new plants, or “energy crops” for biofuel production. Programs to develop new ethanol processing technologies include developing new microbes and enzymes for converting biomass, and developing valuable co-products from ethanol production.

ARS also has a biodiesel program which is working on enzymatic processes to convert animal fats, vegetable oils, and restaurant greases into biodiesel. This research program is also helping to improve the quality and performance, including storage stability, cold flow, and emissions reductions of biodiesel.

Other aspects of ARS bioenergy research program are aimed at meeting on-farm and rural community energy needs for fuel, electricity, and heat. ARS research is developing wind and wind-diesel hybrid systems to provide electricity to pump water and other needs at remote locations, as well as developing systems to produce methane from agricultural and animal wastes. With a view toward a future hydrogen economy, ARS scientists are working on ways to convert biomass into hydrogen through thermochemical and biological processes. Allocated are $20.1 million in 29 research projects utilizing the equivalent of 51 full-time research scientists in bioenergy/biofuels research.

The bulk of ARS research on biobased products is administered under the Quality and Utilization of Agricultural Products national program. This program is aimed at identifying sources of natural products for biobased lubricants, hydraulic fluids, metal-working fluids, composites, biodegradable plastics; and developing technologies and processes to convert agricultural products into important value-added products. Research also includes identifying alternate sources and creating technologies that lead to an expanded, diverse range of value-added food and nonfood products from commodities and undervalued byproducts of agriculture.

In fiscal year 2006, ARS invested $49.9 million in 60 research projects utilizing the equivalent of 125 full-time research scientists in bioenergy/biofuels research.

ARS research on bioenergy and biobased products is conducted primarily at the four ARS Regional Research Centers in Albany, California; New Orleans, Louisiana; Peoria, Illinois; and Wyndmoor, Pennsylvania. About 15 other ARS labs around the country also do some biobased and bioenergy research.

ARS’ thrust is to develop, modify, and utilize new and advanced technologies to convert animal and plant components—protein, oil/fat, starch, fiber—and processing by-products into new products and to develop new crops to meet niche market opportunities. These efforts are geared toward the development of industrial products that expand market opportunities for US agriculture, replace petroleum-based products and other imported strategic materials, and meet environmental needs.
An important location for biobased and bioenergy research is the Eastern Regional Research Center at Wyndmoor, Pennsylvania. ARS scientists at Wyndmoor have made substantial progress in improving the efficiency and lowering the cost of ethanol production. For example, ARS scientists have developed two valuable co-products from corn fiber, a low-valued byproduct of ethanol. Both products are found in the fibrous hull that forms the kernel’s outermost layer, and both are now being commercialized. The sale of valuable new co-products, such as these, from fuel ethanol production lowers the overall cost for ethanol.

In partnership with the University of Illinois, ARS has also developed a new enzymatic wet milling process for ethanol production. This new “green” process uses new enzymes to replace sulfite, a toxic chemical, in the commercial process used to turn corn into corn oil, high-protein feeds, and starch, which is used to make fuel ethanol. The new enzymatic process not only avoids the use of toxic sulfites, but produces higher yields of starch, lowering the overall production costs for making fuel ethanol. One of the world’s largest enzyme companies is currently licensing this patented technology. Recently, one of our scientists, David Johnston, who played a key role in this discovery, received the Presidential Early Career Award for Scientists and Engineers for his research. This award represents the highest honor that a young scientist or engineer can receive in the United States, so we are all extremely proud.

The National Center for Agricultural Utilization Research, in Peoria, Illinois is the largest of ARS’ four regional research centers. There, ARS scientists are creating metabolic engineering technologies to convert agricultural commodities such as corn and crop residues into biofuels and chemicals, enzymes, and polymers. They are also developing new microorganisms and biocatalysts and improving existing ones for use in converting renewable agricultural materials into high-value bioproducts.

An outstanding example of some of the work being done at ARS’ Peoria Center is the development of a new metalworking fluid made from soy oil. In tests by Alcoa, at its aluminum-casting plant in Reno, Nevada, the biobased lubricant outperformed equivalent mineral oil lubes, while also being cost-effective. Alcoa plans to conduct more trials next year in other large plants in the United States and elsewhere. The company is hoping to replace petroleum-based products with biobased ones to reduce the amount of volatile organic compounds (VOCs) its plants produce and decrease worker exposure to potentially harmful substances.

The Southern Regional Research Center (SRRC) conducts biobased products and bioenergy research geared towards meeting the needs of Southern agriculture. One current program is developing cotton based medical textiles that accelerate healing in chronic wounds. ARS scientists are also conducting research and development on a variety of products including cotton fabrics that accelerate blood clotting, integrated bedding sheet systems that prevent bed sores, and antimicrobial barriers.

Other SRRC scientists have successfully produced activated carbon and ion exchange resins, used as adsorbents to remove metals from wastewater, from such diverse sources as poultry and pig manure, tree nutshells, soybean hulls, and corn stover. These biobased adsorbents are as effective as commercial products made from coal and oil and cost significantly less. For example, carbon adsorbents created from nutshells adsorbed two to three times more metals from wastewater than commercial carbons evaluated under identical experimental conditions.

Scientists from SRRC are also exploring high-cellulose sugarcane and grasses for their potential as bioenergy feedstocks. They are making crosses between sugarcane and its near relatives Miscanthus and Erianthus. If successful, these novel new plants will be able to be grown in areas of the South much farther north than where sugarcane is currently grown in Louisiana, Florida, and Texas.

ARS scientists at the Western Regional Research Center in Albany, California are working to develop both improved industrial use plants as well as in developing new processing techniques.

They are genetically engineering wheat, rice, guayule, sunflower, castor, and grasses for use as feedstocks for fuels and bioproducts. Converting crops (wheat, rice, guayule), processing co-products, residues, and by-products into value-added biobased industrial products; and creating new enzymes through the use of directed molecular evolution for production of ethanol, biopolymers, and industrial chemicals.

In addition, SRRC is also working on methods of processing starch composites into molded articles and methods of processing agricultural fibers into biodegradable packaging, building materials and moldable products. SRRC’s bioenergy projects include enzymes and processes to convert starch to glucose at lower tempera-
ture, enzymatic conversion of cellulose to sugars, ethanol based biorefining for food and non-food applications, and membrane-based separation for recovery of ethanol and other chemicals.

Having access to genetic diversity is essential in developing new bioproducts as well as developing better feedstocks for bioenergy. ARS administers the National Plant Germplasm System, one of the largest national genebank systems, which conserves more than 470,000 samples of more than 11,700 species. The collection includes 13,154 accessions of industrial use plant species. The system includes more than 20 different genebanks located throughout the United States.

Cooperative State Research Education, and Extension Service (CREES)

While ARS represents USDA’s in-house research capability, CSREES is USDA’s primary external research, education, and extension funding agency. CSREES provides Federal extramural research and extension funding primarily to the land-grant institutions in each state and also provides national program leadership for extension, which includes such programs as 4-H. CSREES provides funds for research and extension in 11 emphasis areas, including biobased and bioenergy research.

CSREES supports research and development in biobased products primarily through the National Research Initiative (NRI), Small Business Innovation Research (SBIR) and the Agricultural Materials Program.

The NRI is a competitive grant program utilizing a peer review process. The topic area Biobased Products Bioenergy Production Research focuses on technology development for biomass conversion, development of biocatalysts, and co-product development. Other topic areas, though not focused on biobased products or bioenergy, are related, such as agricultural plant biochemistry and rural development. Alternative/renewable energy production and conservation is an overarching theme for the entire SBIR program for 2007. Development of new crops is included in the solicitation for the Industrial Applications topic area.

Some of the projects CSREES is funding include research at Rice University to develop a new fermentation process for the anaerobic conversion of glycerol and CO₂ using *E. coli*. This process will turn these two byproducts of biofuels production into succinic acid, an industrially important chemical having a domestic market of more than $1.3 billion per year. Through the Small Business Innovation Research Program (SBIR), CSREES is sponsoring a project in Montana to grow *Camelina sativa* and to develop ways to efficiently produce omega-3 products for human and animal consumption, as well as producing industrial biofuels and biolubricants.

CSREES also provides funding for about 45 energy projects or projects that include an energy-related objective. Some key examples of these projects include Purdue University’s Genetic Engineering of Yeast for Co-Fermenting all Five Cellulosic Sugars to Ethanol, which will improve the conversion of biomass to ethanol; Genetic Engineering of Cellulose Biosynthesis in Trees at North Carolina State University; and Biomass-Based Energy at an Oklahoma/Mississippi Consortium which combines gasification and fermentation technologies to produce ethanol and chemicals, using grasses and crop residues for gasification. The synthesis gas (syngas) produced is then also used to drive the fermentation process.

CSREES is funding the Iowa Biotechnology Consortium which brings together faculty, scientific staff, and industry research and development specialists to develop technologies to recover and recycle energy, chemicals, and materials from agriculture- and biotechnology-related wastes. Additionally, the National Alternative Fuels Laboratory at the University of North Dakota is developing an aviation-grade ethanol that has been certified by the Federal Aviation Administration.

CSREES also funds the Biodiesel Fuel Education Program at the University of Idaho, which provides education and outreach to the public about the benefits of using biodiesel. The agency leverages a $400,000 investment to the total Working Group investment of $6 million to support metabolic engineering for bioproducts and biofuel production.

CSREES interacts on a regular basis with the Department of Energy’s (DOE) Office of Biomass to collaborate on evaluation of progress in key topic areas and provide input to the Biomass Technical Advisory Committee, which was established by the Biomass Research and Development Act of 2000.

CSREES and DOE also cooperate and coordinate on plant and microbe sequencing. CSREES is also funding a project in Louisiana directed at finding a way to extract rare or novel polyphenol compounds with potent antioxidant properties from common and renewable agricultural waste products such as tree bark and nut shells.
Economic Research Service (ERS)

Another very important part of our research mission is carried out by the ERS, the primary source of economic information, research, and analysis at the Department of Agriculture. ERS develops and distributes economic and social science information and analyses including more than 400 briefings for policymakers, 90 market analysis updates, and 50 major reports annually.

ERS conducts a research program to inform public and private decision-making on economic and policy issues involving food, farming, natural resources, and rural development. Much of the information I quoted on agricultural energy use and efficiency was the result of ERS research and analysis. A recent example of ERS’ work applicable to bioenergy includes a recent study on how expanding ethanol use may affect corn markets and how rising energy costs may affect agriculture and rural communities. Information on ERS can be obtained from visiting their website to read their award-winning magazine, Amber Waves.

National Agricultural Statistics Service (NASS)

In order to analyze data, you first have to collect it. NASS is the agency that collects and provides production data on more than 120 crops and 40 livestock commodities. This data includes price, sale, and expense data for $200 billion in agricultural products; environmental data related to 938 million acres; and demographics on 3 million farm operators and 6.6 million household members.

NASS conducts the Census of Agriculture every 5 years. For the upcoming 2007 Census producers will be asked if their operation generated energy or electricity on the farm including such sources as wind, solar, or methane digester to show the number of farms currently directly involved in the generation of energy.

SUMMARY

Our agricultural and forest lands have enormous potential to provide a significant amount of feedstocks to develop a biobased economy. A recent collaborative report with DOE estimates that we have the capacity to provide over 1.3 billion dry tons of biomass annually in a sustainable manner to replace 30 percent of current petroleum consumption by the year 2030. Additionally, American agriculture can help the Nation to become more self-reliant for many materials and chemicals currently imported.

We can produce biodiesel, ethanol, and many chemicals from a variety of plants. We can potentially produce large quantities of ethanol from all types of cellulosic material; crops such as switchgrass and hybrid poplars; wastes such as wheat stover, corn stover, and forest residues.

Agriculture and rural America also have a new opportunity to use agricultural lands as alternative energy sites. Here is the opportunity to develop more sites for solar panels and wind mills on farms and ranches. In the future, we may have opportunity to provide much of our power needs or even provide power back into the grid.

We have the capacity, capability, and most importantly the ingenuity to achieve a more self-reliant, biobased economy. We now have the momentum to push forward and make a real contribution toward a better future.