NP 307 Bioenergy Action Plan (1999 – 2007)

Introduction

The last decade has been characterized by huge U.S. trade deficits. In fact, petroleum imports for transportation purposes alone were $50 billion in 1996. America's dependency on foreign oil (now at 60 percent and rising) is not only an economic issue, but is one of national security, particularly in times of global unrest. These factors, coupled with environmental concerns regarding the use of fossil fuels and production of CO_2, fostered the expansion of the fuel ethanol industry. The industry has become an important partner with American agriculture and the USDA estimates that 17,000 jobs are created for every billion gallons of ethanol produced. Similarly, a nascent biodiesel industry has been developing in recent years. The capacity of the U.S. industry now exceeds 2.1 billion gallons per year. More than 1.8 billion gallons of ethanol were produced last year in the United States, utilizing 750 million bushels of corn and supporting an estimated 30,000 jobs. As attractive as ethanol is as an environmentally desirable alternative to imported petroleum, the relatively high cost of ethanol production remains an important constraint on its use as a fuel additive.

It is of particular importance to note that if the fuel ethanol industry is to expand significantly, as is predicted to result from the recent California legislative rulings regarding the use of ethanol as a gasoline oxygenate in lieu of MTBE, new markets must be found for the resultant major increase in the amount of coproducts from ethanol production. The development of new value-added coproducts will strengthen the economic stability of the fuel ethanol industry, making it less dependent on corn prices and tax policies. The developed value-added bioproducts will help American agribusiness keep its competitive edge in the global economy, and exert a positive influence on the balance of trade.

Current use of ethanol and biodiesel as fuel additives or alternative fuels (e.g., E-85 and neat biodiesel) depends on many factors, including political actions, tax policies, agricultural practices, regulatory issues, and international economic trends. The relatively high cost of ethanol production and the very high cost of biodiesel production, however, remain as important constraints on their use.

Removing technical constraints to lowering production costs is the key to a viable biofuel industry of the future.

A likely market for alternative energies is within agriculture itself. Low-cost alternative fuels can be used to power farm tractors and small agricultural production and processing facilities within rural communities. Wind and solar energy, as well as biofuels, may also be used to supply or supplement electrical energy for water pumping, small-scale irrigation systems, and other farmstead needs.

While the Department of Energy has traditionally concerned itself with processing lignocellulosic materials to make ethanol, there is obvious complementarity with the ARS programs. The use of marginal farmland to produce biomass involves soil and water conservation research, and crop breeding questions. Similarly, a likely early user of the lignocellulosic technology is the existing starch to ethanol industry, and the integration of new technologies into a stable, successful operation involves ARS consideration of process technologies and organisms.

National Program 307 is comprised of four research components: (1) Ethanol, (2) Biodiesel, (3) Energy Alternatives for Rural Practices, and (4) Energy Crops. These components address research issues related to Bioenergy and Energy Alternatives. Many ARS projects are associated with more than one National Program because their objectives are broad enough to encompass more than one area, and because National Programs overlap in order to address problems of U.S. agriculture. Bioenergy is very closely linked to the biobased product research management under the Quality and Utilization of Agricultural Products National Program and programs in the Natural Resources and Sustainable Agricultural Systems Area. Individual research projects associated with this National Program are listed at the end of this action plan. As this action plan is implemented specific research areas will be identified, locations and projects involved will be determined, and timelines and milestones for measuring progress toward achieving the goals will be developed. This approach will result in coordinated, multi-location research, conducted by ARS scientists and their cooperators, to address high priority regional and national research needs. All projects associated with the Bioenergy and Energy Alternatives National Program were evaluated for scientific quality by an external peer panel in May 2004.

Vision Statement:
America's energy needs met using renewable sources

Mission Statement:

To create jobs and economic activity in America, reduce the Nation's dependence on foreign oil, and improve the environment by developing alternate energy sources and increasing the use of agricultural crops as feedstocks for biofuels.

Program Objectives:

- Reduce our Nation's dependency on foreign oil
- Decrease environmental pollution
- Enhance farm income
- Create jobs in the rural sector and elsewhere
- Sustainably use renewable agricultural resources
- Alleviate America's trade imbalance

National Program Workshop - April 15, 1999, Beltsville, MD

This workshop was a critical component of the development of this Action Plan. In general, the stakeholders supported the ongoing research in ethanol and biodiesel. One outcome of the workshop was the decision to add Energy Crops research as a component of the Bioenergy and Energy Alternatives National Program.

Component I: Ethanol

Advances in enzymology, microbiology, chemical, biochemical and process engineering are required to underpin development of ethanol production technology. Technologies are needed to reduce the cost of producing ethanol from cornstarch (95 percent of production). In addition, the conversion of biomass, a vastly more abundant feedstock, is an economic necessity. The program's first biomass target is corn fiber, due to its ready availability at ethanol plants and extremely low value. Immediate integration of corn fiber to ethanol at the plant is feasible and would result in at least a 10 percent production increase. These research findings will be applicable to other forms of biomass as well, ranging from agricultural and forestry wastes to fast-growing crops that could be grown solely for energy production. Research will focus on, but not be limited to, developing new enzymatic processes for saccharification and improved microorganisms to ferment the multiple sugars found in biomass. Development of biocatalysts for the biomass-to-ethanol industry remains a significant technical challenge. These biocatalysts must be both capable of fermenting lignocellulose to ethanol and suitable for use in an industrial process. At the April 1999, Bioenergy and Energy

Alternatives National Program Workshop, stakeholders identified value-added coproducts as the number one research priority for the existing fuel ethanol industry. Conventional (existing) coproducts already play an extremely important role in the economics of fuel ethanol production. The term 'net corn' is used to describe the cost of corn as partially defrayed by the value of the coproducts. Coproducts are obvious targets for economic and process improvement since they are primarily sold as low-value animal feeds or feed additives. Corn gluten feed and its components, corn fiber and stillage residues, as well as corn gluten meal, are of particular interest as high-volume, relatively low-value materials.

Problem to be Addressed

Ethanol cannot be produced from any agricultural feedstock today at a selling cost competitive with petroleum sources.

Approaches

Process Efficiencies

Goal: To alter traditional unit operations, develop new ones, develop new organisms, and increase process conversions. To create enzymes with the capacity to convert starch to glucose without the need for cooking or for a multi-step conversion as is common in 'wet' grain process technologies.

Coproduct Development

Goal: To develop higher-valued new coproducts or improve the existing ones from the non-starch portion of the grain, resulting in a reduced net cost of the starch used for producing ethanol.

Intermediate Outcome

Process Efficiencies

Ethanol yield will be improved by partial saccharification of corn fiber, by the use of new organisms which ferment pentoses, or do not produce succinate, or which ferment xylose without glucose repression. The cost to produce ethanol will be reduced by new unit operations which require less energy to separate the ethanol, or which facilitate greater conversion of the starch to ethanol.

Coproduct Development

The development of aquaculture feeds will provide outlets for excess, low valued corn gluten feed, distiller's dried grains and corn gluten meal. The development of a process for a low cost zein product will provide an outlet as biodegradable and edible films. The development

of new fermentation products from fuel ethanol residues will reduce the net cost of the ethanol.

Long-Term Outcome

Process Efficiencies

Technologies will be completed to eliminate competing fermentation products from the first generation of new ethanol producing organisms. Membrane pervaporation will significantly improve the productivity of biomass hydrolysate fermentations. New technologies that integrate feedstock pretreatment, biological conversion and product recovery processes, as well as fundamental knowledge regarding fermentation, milling and membrane separations, will result in a reduction in capital and processing costs associated with biofuel production.

Coproduct Development

Higher value coproducts generated from current low-value production byproducts. Envisioned coproducts include specialty oils, novel polysaccharides that will compete with imported gums, sugar alcohol food additives which are currently imported, enzymes, and inexpensive aquaculture feeds.

Impact

Starch-derived ethanol which is a more competitive and profitable fuel

Linkages

Other ARS Biofuels programs
Other ARS grain and oilseed utilization programs
ARS Soils and Crops programs
USDA programs: CSREES, Forest Service/Forest Products & Harvesting Research
OCE/Office of Energy Policy & New Uses
U.S. Dept of Energy/National Renewable Energy Laboratory and Oak Ridge National
Laboratory

ARS Locations for This Work

Albany, California; Peoria, Illinois; and Wyndmoor, Pennsylvania

Component II: Biodiesel

Vegetable oils and animal fats and their derivatives (biodiesel) are attractive as alternative fuels, extenders and additives for compression

ignition (diesel) engines. Opportunities for biodiesel include off-road markets such as underground mines, marine applications, mass transit (subways, trains) and stationary power generation. However, research is needed to improve cold start-up and operability, to identify and reduce harmful exhaust emissions (e.g., nitrogen oxides), to develop a rapid and low-cost fuel quality test, and to reduce feedstock and formulation costs. Development of these technologies will increase market penetration and widespread use of biodiesel.

Problem to be Addressed

The adoption of biodiesel fuel in the United States is hindered by high cost, and the lack of adequate standards and tests. Before widespread commercialization of triglyceride-based biodiesel fuels and fuel additives are realized, several hurdles must be overcome. Problems that are addressed by ARS research programs include: exhaust emissions, fuel quality standards and on-line testing, feedstock costs, cold flow properties, and storage stability.

Approaches

Combustion and Exhaust Emissions

As with all fuels, biodiesel must meet increasingly stringent exhaust emissions regulations. Especially problematic for biodiesel are nitrogen oxides (NOx) emissions. Additives, known as cetane improvers, reduce NOx emissions for petroleum diesel fuel. A similar approach is feasible for biodiesel. Cetane (ignition quality) testing of biodiesel components and of potential cetane improvers as well as engine testing with the identification of exhaust emission levels will provide the necessary technical insights and results to overcome this problem.

Fuel Quality Testing and On-line Process Control

A non-technical impediment to the widespread use of biodiesel is its higher production cost compared to petroleum diesel fuel. Checking biodiesel fuel quality against current ASTM protocols is time-consuming and labor-intensive. Rapid, easy-to-use process control and fuel quality analysis can significantly reduce these costs. Analytical methods tailored to biodiesel fuel and its production will be developed.

Reduce Cost of Feedstocks

Another means to improve the economics of biodiesel is to develop low-cost agriculturally derived lipid materials such as tallow, greases, and soapstocks as feedstocks for biodiesel production. New conversion technology will be required for producing biodiesel from non-conventional feedstocks.

Cold Flow Properties
Biodiesel from nearly all feedstocks has inferior cold flow properties. This means that engines powered by biodiesel and blends will have operability problems during cooler months in moderate temperature climates. Fundamental knowledge on phenomena influencing cold flow properties will be acquired and applied. Cold-solvent extraction, solubilization with surfactants, newly synthesized additives and other approaches will be investigated for its potential to mitigate cold flow limitations.

Storage Stability
The relatively poor oxidative and hydrolytic stabilities of biodiesel are a serious concern with respect to fuel quality during storage. Factors reducing stability of biodiesel during short and long-term storage need to be identified. Rapid, sophisticated methods for testing fuel quality under accelerated conditions will ensure fuel quality. Approaches for improving oxidative stability during storage are needed.

Intermediate Outcomes

Combustion and Exhaust Emissions
Engine tests will be developed to evaluate cetane improvers, for performance, exhaust emissions, and formulations. Biodiesel fuel components and cetane improvers will be tested for ignition quality.

Fuel Quality Testing and On-line Process Control
New rapid analytical methods will be developed to monitor biodiesel production, and quality.

Reduce Cost of Feedstocks
New processes will be developed for lower-cost production of biodiesel from vegetable oils and other non-conventional feedstocks.

Cold Flow Properties
Strategies are developed for synthesizing, testing, and field-testing novel compounds as cold flow improvers.

Storage stability
A more accurate lipid quality index will be developed as an alternative to existing indices for predicting oxidative stability of biodiesel fuels. This will allow phenolic and other antioxidants to be evaluated for their compatibility when mixed with biodiesel/petroleum-diesel blends and for their potential to improve resistance to oxidation.

Long-Term Outcomes

Combustion and Exhaust Emissions
A biodiesel fuel with reduced exhaust emissions, especially NOx, that will be in compliance with current and future environmental regulations.

Fuel Quality Testing and On-line Process Control
More rapid, cost-efficient, easy-to-conduct analytical methods for assessing biodiesel fuel quality and for the on-line monitoring of biodiesel production.

Reduce Cost of Feedstocks
Feedstocks and new processes that allow production of cost-competitive biodiesel.

Cold Flow Properties
The cold flow operability limiting temperature for biodiesel is reduced by at least 10-degrees Celsius (18-degrees Fahrenheit). The cold flow operability of 20-percent biodiesel/petro-diesel blends (B-20) improved to a level equivalent to that of petro-diesel. Cold flow improvers that inhibit crystal nucleation in biodiesel fuels are identified.

Storage Stability
Reasonable conditions are established for handling and storage of biodiesel and blends to safeguard compliance with industrial fuel specifications. Methods and instrumentation for evaluating oxidative stability of biodiesel under accelerated conditions are developed. Analytical methods are developed to track fuel quality of biodiesel during short- and long-term storage.

Impact

Biodiesel fuels from agricultural lipid sources which are more uniform, environmentally beneficial, and cost-competitive

Linkages

Other ARS Biofuels programs
Other ARS grain and oilseed utilization programs
ARS Soils and Crops programs
USDA programs: CSREES, OCE/Office of Energy Policy & New Uses
U.S. Dept of Energy/National Renewable Energy Laboratory

ARS Locations for This Work

Peoria, Illinois and Wyndmoor, Pennsylvania

Component III: Energy Alternatives for Rural Practices

Autonomous water pumping systems are needed to supply livestock water in semiarid areas where precipitation is sufficient for forage production, but is not adequate for watering livestock. Renewable energy systems are well-suited for this application because they are independent of environmentally hazardous, expensive distribution systems. Remote renewable energy systems are needed to supply additional electric power to rural areas that are under-supplied by overloaded rural electric distribution systems. On-farm electric generating systems powered by a combination of wind, solar, and biofuels will be developed.

Problem to be Addressed

Providing a reliable, safe drinking water supply is essential for agricultural livestock and humans. For many rural areas, some form of pumping is required to lift the water from a well or stream. Renewable energy technologies of wind and solar power offer excellent possibilities to provide the energy required to pump this water. Another need is to provide basic electricity to rural areas where electric utility lines are not available or are too expensive. Under the proposed electric deregulation legislation, utilities will no longer be required to provide electric service to all that request service. One fear of deregulation is that agricultural customers will be charged so much for electrical service that it will be the same as denying them service.

Approaches

Develop and evaluate autonomous wind- and solar-powered water pumping systems for irrigation, livestock, and farmstead water and to develop hybrid wind/diesel (biofuel) electric generation systems for rural and remote areas.

Intermediate Outcome

The efficiency and reliability of solar and wind water pumping systems is demonstrated to be satisfactory to meet the needs of livestock when a five day storage tank is included.

Long-term Outcomes

Improved long-term (5-, 10-, 15-yr., etc.) performance, maintenance, and serviceability of wind and solar pumping systems.

Impact
Independent, reliable electrical power and water available at remote farms

Linkages
U. S. Department of Energy/Sandia National Laboratories, United States National Renewable Energy Laboratory, and National Energy Technology Laboratory

ARS Location for This Work
Bushland, Texas

Component IV: Energy Crops

In the Northern Plains and Midwest Regions of the United States, over 19 million acres of highly erodible and marginal cropland needs to be converted back to grassland to meet national soil and water conservation goals. In addition, over 69 million acres of rangeland in the Northern Plains are in need of renovation to reduce and reverse natural resource deterioration (National Resource Inventory, USDA-NRCS, 1994). This research program will: a) Develop technology to convert erodible and marginal cropland to grasslands, b) Develop technology to restore or reclaim productivity of degraded grasslands, c) Develop improved perennial grasses for use in grassland establishment and utilization, d) Develop improved germplasm and management practices to make switchgrass a viable biomass fuel crop for these regions.

Research under this program is ongoing at many different locations to account for climatic, regional and geographical variations, as well as many different combinations of pests, diseases and agricultural products, each with unique problems calling for unique research approaches and solutions.

Problem to be Addressed

The United States has agricultural lands in excess of that needed to meet the food and fiber needs of the nation. Currently about 40 million acres of land are in the Conservation Reserve Program to remove the land from production and to stabilize sites prone to erosion. Perennial, herbaceous plants such as switchgrass can produce high yields of biomass on marginal lands while reducing soil erosion to negligible

levels. In the Midwest, initial research indicates that over 500 gallons of fuel ethanol could be produced per acre from switchgrass if adequate cropping systems and conversion technology can be developed. Research to develop a biofuels industry based on biomass crops such as switchgrass could convert subsidized idle land into an energy factory leading to reduced dependence on imported fossil fuels while maintaining or improving soil and water quality.

ARS's research effort on bioenergy has been focused on conversion of commodity crops to liquid fuels. Research of cellulosic feedstocks or biomass fuel crops and their conversion has been limited to harvesting and processing legume hay for value added by-products at Madison, Wisconsin, and a cooperative ARS and Department of Energy (DOE) project at Lincoln, Nebraska, to develop switchgrass into a biomass fuel crop for the Midwest. DOE has funded research on evaluating both woody and herbaceous plants for their potential as biomass crops, research on developing improved plants and basic production practices, and conversion research. DOE research has clearly demonstrated the feasibility of using biomass crops to produce a significant portion of the nation's energy. Research has not been conducted by either ARS or DOE on the development of integrated field-to-factory biomass crop production systems including producing, harvesting, handling, storing, and transporting the biomass crop to conversion plants. Although biomass conversion technology has been significantly improved due to research conducted by DOE, USDA, and others, conversion methods need to be further improved to reduce the cost of deriving liquid fuels from biomass. Crop residues such as corn stalks and wheat straw also could be used for biomass fuel production but the amount of residue that can be removed without deleterious effects needs to be determined.

Approach

Coordinated research teams will be established at locations that represent the principal biogeographic regions of the United States where precipitation and suitable soils make the production of biomass crops feasible. These locations will develop biomass plants and associated production systems and will document the environmental benefits associated with biomass crop production systems. At specific locations or laboratories, research will be conducted on development of handling, storage, and transportation systems, and improved conversion technology. All aspects of the program will be interfaced with existing or planned DOE research to eliminate duplication and to maximize synergistic efforts. ARS will

lead research efforts in developing biomass production systems and assessing environmental benefits of these systems.

Intermediate Outcomes

Switchgrass germplasm with improved yields and biomass fuel characteristics.

Management strategies developed to expedite the establishment of fully productive switchgrass stands and to optimize productivity of established switchgrass stands for production of biomass fuels.

Long-Term Outcome

Oil imports for motor vehicles will be significantly reduced. The rate of increase of atmospheric carbon will be significantly reduced or stabilized by reduced use of imported fossil fuels and by carbon sequestration in soils by biomass plants. Soil and water quality on millions of acres of land will be improved. Land payments for set-aside programs will be significantly reduced. Rural economies will be enhanced due to the development of a new crop and because conversion plants will need to be located in rural areas.

Impact

Plant materials, production systems, handling, storage, and transportation systems, and improved conversion technology will be developed by 2015 that will enable the United States to provide liquid fuel for 40 million vehicles from biomass produced in systems that improve soil and water quality and reduce the carbon load in the atmosphere. Biomass crops will be grown on land unsuitable or not needed for food or fiber production resulting in a significant reduction in land set-aside payments.

Linkages

Other ARS Biofuels programs
ARS Soils and Crops programs
USDA programs: CSREES, OCE/Office of Energy Policy & New Uses
United States Department of Energy/National Renewable Energy Laboratory and Oak
Ridge National Laboratory.

ARS Locations for This Work

Lincoln, Nebraska and Madison, Wisconsin