



Overview: Developing New Energy Sources from Agriculture

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In the early 1900s, energy sources around the world were mostly agriculturally derived and industrial products were primarily made from plant matter. Early motor fuels also came from agriculture — Henry Ford used ethanol in his original engine and Rudolf Diesel's engine could run on peanut oil. By 1920, petroleum emerged as the dominant energy source for transportation fuels and industrial products. For over 80 years, the United States and other industrialized countries have relied on petroleum as an economical and dependable source of energy. However, this reliance on petroleum is becoming a major issue as our domestic oil supplies shrink and our dependence on oil imports grow.

Since the energy crisis in the 1970s, policymakers have been looking to agriculture as a source of energy supply and legislation has been passed to encourage renewable energy production and fund research on developing ethanol, biodiesel, solar and wind power, and bioproducts. More recently, the security risks of imported oil and environmental concerns have intensified the interest in developing renewable energy sources and replacing petroleum products with more environmentally friendly bioproducts. The U.S. Congress responded to the recent energy situation by passing two major bills providing incentives for renewable energy production; the 2002 farm bill contained the first energy title in farm bill history and the Energy Policy Act of 2005 was the first Federal energy law passed since 1992.

Projections indicate that worldwide energy use could grow by more than half in the next two decades, and U.S. energy use is expected to increase by one-third during this time. Heavy reliance on fossil fuels could continue, with related concerns about air pollution, greenhouse gases, and increasing dependence on oil from unstable countries. In his State of the Union Address, President Bush outlined

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The Advanced Energy Initiative that promises to break America's dependence on foreign energy by replacing more than 75 percent of our oil imports from the Middle East by 2025. In 2005, about 25 percent of our crude oil came from the Middle East, mostly from Saudi Arabia. Canada and Mexico are currently the leading oil importing countries, followed by Saudi Arabia.

The President's goal is ambitious, but realistically achievable through the development of biofuels, biopower, bioproducts, and other alternative energy sources. Renewable energy is abundant, diverse, and widely distributed throughout the United States. Commercial technologies are currently available that are harnessing energy from agricultural crops, animal fats, and waste materials. Moreover, research may currently be on the verge of providing a number of technological breakthroughs leading to a significant expansion in our renewable energy resource base.

The majority of U.S. oil imports are used for transportation, so achieving energy independence will require domestic energy resources to produce biofuels for motor vehicles. The most common biofuel used today is ethanol, which is made mostly from corn. Although ethanol is a gasoline substitute, it has been primarily used in the United States as a gasoline additive to reduce harmful air emissions or to boost octane. Although ethanol growth has

been impressive in recent years, it still is less than 3 percent of total annual gasoline consumption. About 14 percent of the U.S. corn crop was utilized for ethanol in 2005 and USDA predicts the annual corn production used for ethanol will rise to 23 percent by 2016. Clearly, the supply of corn is relatively small compared to gasoline demand, so other domestic sources of transportation fuel are needed to achieve our energy goals.

Biodiesel, which is just beginning to establish a market in the United States, is a biofuel substitute for petroleum diesel. Similarly to ethanol, it is rarely used in neat form and is most commonly blended with diesel fuel at levels of 20 percent or lower. The majority of the 91 million gallons of biodiesel produced in 2005 came from soybean oil, but, it can also be made from other oilseed crops, animal fats, and grease. Biodiesel can extend diesel fuel supply, but it too is limited compared to total petroleum diesel demand. A much larger quantity of energy feedstocks is needed to allow biofuels production to reach a larger scale.

The desire to replace a significant amount of imported oil beyond our current capabilities has created much interest in producing biofuels from feedstocks other than row crops. These feedstocks, called biomass, include agricultural forestry and crop residues, wood waste, municipal solid waste, trees, and grasses. There are basically two technologies for converting biomass into a biofuel. The first is a process developed in the 1940s that uses a gasification method. With the gasification process, biomass is gasified at high temperatures to produce synthetic gas called syngas. The syngas then goes through a process that synthesizes the gas into a transportation fuel (e.g., diesel fuel). The second process con-

verts biomass into ethanol, often referred to in the literature as cellulosic ethanol. This process uses genetically engineered bacteria to break down the more complex sugars found in the woody material of biomass. The sugar extracted from the biomass can then be used to produce chemicals, ethanol, and other biofuels. However, the technology for producing cellulosic ethanol is not fully developed.

Developing domestic renewable sources of energy for generating power and producing heat is another important component of the President's plan to increase domestic energy supplies. As recently as 1999, North American natural gas reserves were considered plentiful and growth of the U.S. utility industry was dependent on natural gas. However, recent supply disruptions and major price shocks have transformed natural gas from a fuel of choice to a fuel of risk. Estimates of natural gas reserves in North America were adjusted downward during the first half of 2004 and industry analysts doubled their price projections for the next several years.

Currently, both large- and small-scale technologies are being developed to generate solar and wind power. Some small-scale solar applications are already commercially available that provide electricity for lighting, battery charging, small motors, water pumping, and electric fences. There is also an emergence of solar technology that is being used in homes and in the industrial sector to provide hot water and space heating.

Wind is another abundant renewable energy source, and windmills do not produce harmful environmental emissions. Wind power is already making a small contribution to the U.S. electricity system. Utility-scale turbines have been increasing in

number, due to government support and advances in technology that have substantially reduced production costs, especially in areas with consistently high wind speeds. Small wind systems are also being developed that in the future may allow farmers to economically generate electricity in remote areas to avoid paying for expensive transmission wires.

Biomass can also be used to generate electric power by direct burning, using gasification systems, or mixing biomass with coal in coal-fired electrical generation facilities. Currently, biomass supplies over three percent of U.S. energy consumption. The primary feedstocks include wood waste used by the pulp and paper industry for industrial heat and steam production. In addition, forest residues and municipal solid waste are used to generate electricity.

Another potentially large source of renewable energy is animal waste that can be turned into methane gas through anaerobic digestion. Anaerobic digestion has been used for years by municipal wastewater treatment plants in the United States to convert waste solids to methane gas, which can be converted into heat or electricity. More recently, research and demonstration projects have focused on producing methane gas from confined livestock operations. Currently there are only about 40 anaerobic digesters located throughout the United States on swine, dairy, and poultry operations. However, anaerobic digesters are growing in popularity to help dairy farmers and other livestock producers meet new state and Federal regulations for controlling animal waste. Anaerobic digesters can help control water pollution and odor from animal waste, as well as provide electrical and thermal energy. In addition, methane, a potent greenhouse gas, is not emitted

into the atmosphere when animal wastes are converted into energy.

Obviously, it is going to take a variety of alternative energy sources to solve our energy supply problems. Biofuels can replace a significant amount of oil imports; however, increases in energy efficiency and other technological advancements will also have to play an important role in gaining our energy independence.

There is much uncertainty over the future potential of renewable energy. However, there is no doubt that the world demand for oil is increasing rapidly and competition over the world's remaining oil reserves will intensify. Thus, it seems reasonable to suggest that future generations will eventually replace petroleum with alternative sources of energy. One long-run vision is the emergence of a biorefinery industry, designed after oil refineries, with the capability of converting large quantities of biomass into a number of energy and biobased products. Biorefineries have the potential to replace nearly all petroleum-based products, including transportation fuels, elec-

tricity, natural gas, and petrochemicals.

In the shorter term, we should be able to produce enough biofuel to replace a significant portion of our oil imports. Just reducing our dependence on our most unstable trading partners could prevent future energy supply disruptions and severe price shocks. Adding biofuels and other diverse sources of energy to our Nation's energy portfolio will significantly reduce economic and national security risks.

The selection of papers for this theme will look at agriculture's current role as an energy producer and explore opportunities to enlarge its contribution to domestic energy supply. The first article, by Duffield and Collins, reviews U.S. renewable energy policy, which has been critical in advancing the development of renewable fuels.

The article by Eidman examines the economic and environmental aspects of ethanol and biodiesel. It also discusses the drivers behind the recent rapid growth of these two biofuels, evaluates current feedstock supply, and looks at the prospects for continued growth in the future.

The third article, by Gallagher, goes beyond traditional feedstocks and examines the existing supply of biomass in the United States and estimates the amount that can be economically harvested from U.S. farmland. It also provides a review of current and potential processing technologies for converting biomass to biofuels.

The fourth article, by Fischer, Finnell, and Lavoie, focuses on current and future technologies for generating renewable energy from solar, wind, and geothermal power.

In the final article, Conway and Duncan discuss the development of bioproducts made from agricultural materials, such as hydraulic fluids, lubricants, and biopharmaceuticals. They outline the necessary steps to bring these products to the marketplace through public policy, research, and market development.

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Evolution of Renewable Energy Policy

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Historically, renewable energy policies were first adopted to establish domestic fuel reserves during emergencies, such as wartime, when imported and regional fuel supplies could be interrupted (Yergin, 1991). As U.S. dependence on foreign oil increased, energy policies began to focus on encouraging new domestic energy production, including renewable energy. For example, in response to the energy crisis of the 1970s the U.S. Congress funded the Alaskan pipeline and created the strategic petroleum reserve. Policymakers began to look to agriculture as a source of energy supply, and Federal and State legislation was passed to encourage renewable fuel production and fund research on developing ethanol, biodiesel, solar, and wind power. More recently, President George W. Bush's National Energy Policy Group advocated the use of Federal programs to promote alternative fuels, including ethanol and biodiesel, to help reduce U.S. reliance on petroleum-based fuels.

The energy crisis also motivated the Government and private sectors to adopt a number of policies aimed at conserving energy. American households became more conservation-minded and industries increased their energy efficiency. U.S. farmers also decreased their energy use significantly. Between 1978 and 1993, energy (excluding electricity) used by agriculture declined 25% (USDA, 1997; USDA, 1980-94). The U.S. Congress set fuel efficiency standards for the automobile industry. The U.S. government adopted building energy-efficiency standards and required government motor fleets to purchase alternative fueled vehicles. Supply and demand adjustments helped reverse the trend of rising oil prices of the 1970s and 1980s.

However, by the end of the 1990s, increasing world energy demand began to exert upward pressure on oil prices and supply disruptions in the natural gas industry caused major price shocks in the U.S. energy sector. Uncertain energy supplies and homeland security concerns

triggered by the terrorist attacks on September 11, 2001 have caused policymakers to intensify their efforts to secure our long-term energy sources. The purpose of this paper is to review U.S. renewable energy policy and describe its effectiveness in advancing the use of renewable fuels.

The Role of Energy Policy

There have been several approaches used to adopt renewable energy policies, including Federal energy legislation adopted to increase the use of renewable energy through mandates and tax incentives. Federal environmental policies, which indirectly affect renewable energy use, have been passed by Congress in recent years with a major effect on renewable energy development. In addition, State legislation has been used as an effective tool to stimulate renewable energy demand. Finally, agricultural legislation has recently been used to create renewable energy policies and programs.

Federal Energy Legislation

One of the earliest energy policies aimed at increasing the domestic energy supply and addressing energy security concerns was the National Energy Act of 1978 (NEA). The NEA established the Public Utility Regulatory Policies Act of 1978 (PURPA), a regulatory mandate that encouraged facilities to generate electricity from renewable energy sources (Gielecki, Mayes, & Prete, 2001). A major goal of PURPA was to foster the development of biopower by requiring utilities to buy electricity generated from small power plants using renewable energy sources (Energy Information Administration, 1996).

Much of the success of corn ethanol can be attributed to government incentive programs starting in the 1970s. The motor fuel excise tax exemption was originally passed by the Energy Tax Act of 1978, giving ethanol blends of at least 10% by volume a \$0.40/gallon exemption on the

Federal motor fuels tax. Enacted in 1980, the Energy Security Act offered insured loans to small ethanol plants, producing less than one million gallons per year. Also in 1980, the Crude Oil Windfall Tax Act extended the ethanol motor fuel excise tax exemption and provided blenders the option of receiving the same tax benefit by using an income tax credit instead of the fuel tax exemption. Since 1980, various tax laws have been adopted changing the level of the tax credit that currently stands at \$0.51/gallon through 2010.

The Energy Policy Act of 1992 (EPACT) extended the fuel tax exemption and the blender's income tax credit to two additional blend rates containing less than 10% ethanol. The two additional blend rates were for gasoline with at least 7.7% ethanol and for gasoline with 5.7% ethanol. The EPACT also established a number of alternative-fueled vehicle (AFV) requirements for government and state motor fleets that have encouraged biofuel use. The Energy Conservation Reauthorization Act of 1998 amended EPACT to include biodiesel fuel use credits. Under this law, fleet operators are allowed one alternative-fueled vehicle credit for using 450 gallons of biodiesel.

The use of AFVs is also increasing in the private sector, primarily due to the Alternative Motor Fuels Act that was passed in 1988 to encourage auto manufacturers to produce cars that are fueled by alternative fuels, including an ethanol/gasoline blend containing 85% ethanol called E85. The law provides credits to automakers towards meeting their corporate average fuel efficiency (CAFE) standards. Automakers can lower their average fuel economy requirements by receiving credits for producing alternative-fueled vehicles that meet government

requirements. Several auto manufacturers offer various models that run on both E85 and gasoline. About 3.5 million of these vehicles, called flexible fuel vehicles (FFVs), were on the road in 2004 (National Ethanol Vehicle Coalition, 2004). This program, however, has been criticized because most FFV owners usually use gasoline instead of ethanol, because E85 fueling stations are few in number.

Biodiesel received a fuel tax credit, similar to that of ethanol, with the American Jobs Creation Act of 2004, called the Jobs Bill. Starting in 2005, biodiesel blenders can receive a credit of \$1.00 per gallon of biodiesel made from oil crops and animal fats and a \$0.50 per gallon credit for biodiesel made from recycled fats and oils. The tax credit was initially set to expire on December 31, 2006; however, it was extended through 2008 by the Energy Policy Act of 2005. In addition, the jobs act extended the ethanol tax credit to 2010.

The the biodiesel tax credit has already had a major impact on the emerging biodiesel industry. Largely due to this tax credit, biodiesel production increased from about 25 million gallons in 2004 to over 90 million gallons in 2005. According to the National Biodiesel Board, there are currently 53 plants producing biodiesel in the United States, with another 40 plants expected to come online soon.

Production tax credits have also been used to encourage electricity generated by qualified energy resources, including biomass, and some animal wastes (Gielecki, Mayes, & Prete, 2001). The EPACT established a 10-year \$0.018 per kilowatt-hour (kWh) production tax credit for biomass plants, wind energy, and other renewable energy production. This program has been especially

important to growth in the wind industry that depends on the tax credit to encourage investment. When the tax credit expired in 2003, financing of new wind power installations came to a halt. Fortunately for wind-energy advocates, the production tax credit was extended to the end of 2005 by the Jobs Bill, and the Energy Policy Act of 2005 extended it through 2007.

Environmental Policies Stimulate Renewable Energy Demand

Policy makers have recognized that there is a significant opportunity to reduce pollutants and greenhouse gas (GHG) emissions by replacing fossil energy with renewable energy and bioproducts derived from agriculture. Ethanol and biodiesel are prime examples. Ethanol, which is 35% oxygen, improves combustion, and reduces carbon monoxide emissions, particulate matter, and other harmful air pollutants (Environmental Protection Agency, 2002). Likewise, biodiesel has many desirable environmental properties. It is nontoxic, biodegradable, and biodiesel exhaust emits less toxic air emissions, carbon monoxide, and particulate matter than petroleum diesel (Graboski & McCormick, 1998). Biodiesel also contains no sulfur.

GHG emissions can be reduced using ethanol and biodiesel compared with gasoline and diesel. Biofuels have the advantage that the plants grown each year to produce the fuel sequester carbon, which offsets the carbon released during fuel combustion (National Renewable Energy Laboratory, 1998; Wang, Saricks, & Santini, 1999; Levelton Engineering Ltd., (S&T)² Consulting Inc., & J.E. & Associates, 1999). Another potentially large source of renewable energy is livestock waste that can be turned into electricity through anaer-

obic digestion, which also reduces methane emissions from manure.

The first environmental policy to have a major effect on renewable energy was the Clean Air Act Amendments of 1990 (CAA). Provisions of the CAA established the Oxygenated Fuels Program and the Reformulated Gasoline (RFG) Program to control carbon monoxide and ozone problems. Both program fuels required 2% oxygen, and blending ethanol became a popular method for gasoline producers to meet the new oxygen requirements mandated by the CAA. The CAA also has provisions for controlling stationary sources of air pollution, such as the Acid Rain Program, that set tighter restrictions on sulfur dioxide and nitrogen oxides. Under this program, utilities may apply for bonus emission allowances as a reward for undertaking energy efficiency or renewable energy measures. Qualified renewable energy sources include wind, solar, geothermal, and biomass energy (U.S. Environmental Protection Agency, 2004); however, these energy sources are not widely used in the program.

Recent EPA diesel fuel regulations could have a major effect on the demand for biodiesel as a lubricity additive. EPA's low sulfur highway diesel fuel regulations begin July 2006 and the nonroad diesel fuel regulations begin June 2010. Lowering the sulfur in diesel fuel also lowers the fuel's lubricity. As a result, the demand for diesel fuel lubricity additives is expected to increase significantly. Research suggests that biodiesel is an excellent fuel lubricity agent (Schumacher, 2004). Only a small amount of biodiesel (1% to 2%) is needed to restore the lubricity level of ultra-low-sulfur diesel fuel. The lubricity additive market could provide a much larger market than the

niche markets that currently exist for biodiesel.

State Renewable Energy Programs

There are also many U.S. state programs designed to encourage the growth in renewable energy use. States encourage renewable energy use through tax credits, production incentives, and renewable energy mandates. For example, over 20 states have "Renewable Energy Portfolio Standards" that require utilities to generate a certain percentage of their power from renewable energy sources (North Carolina Solar Center, 2005). The most aggressive state in promoting renewable fuels is Minnesota, which has consumption mandates for ethanol and biodiesel.

Farm Policy Directed at Energy

Farm policies have only recently been directed at energy, becoming an explicit policy goal in farm programs in the late 1990s, with a provision in the USDA's FY 2000 Appropriations Act. This provision authorized the establishment of pilot projects for harvesting biomass on lands set aside from crop production under the Conservation Reserve Program (CRP).

In 2000, USDA initiated the Commodity Credit Corporation (CCC) Bioenergy Program to stimulate demand and alleviate crop surpluses, which were contributing to low crop prices and farm income, and to encourage new production of biofuels. Since ethanol dominates the renewable fuels market in the United States, most of the funds went to ethanol plants. However, the few biodiesel plants that were in operation in 2000 took advantage of the CCC payments and the Program spurred new investment in biodiesel facilities.

Major agricultural disaster and crop insurance legislation, the Agri-

cultural Risk Protection Act of 2000 (ARPA), was signed into law in June 2000. Title III of ARPA, the Biomass Research and Development Act of 2000, directed the agriculture and energy secretaries to cooperate and coordinate policies to promote research and development leading to the production of bioproducts. In particular, Title III established a biomass research and development initiative that authorized financial assistance for public and private sector entities to carry out research on bioproducts. The objectives of the initiative include enhancing the productivity and sustainability of biomass production and decreasing its cost. While the Department of Energy (DOE) initially undertook research activities under the statute, USDA did not receive funding for the initiative until enactment of the Farm Security and Rural Investment Act of 2002 (2002 Farm Bill).

The 2002 Farm Bill contained the first energy title in Farm Bill history. The energy title, Title IX, created a range of programs through 2007 to promote bioenergy and bioproduct production and consumption. Key provisions include Section 9002, which mandates the Federal Biobased Product Procurement Preference Program (FB4P). Modeled on the existing program for purchase of recycled materials, the FB4P requires all Federal agencies to prefer bioproducts in their procurements.

Another program, the Biodiesel Fuel Education Program created by Section 9004, awards competitive grants to educate governmental and private entities with vehicle fleets and the public about the benefits of biodiesel fuel use. Section 9006 created the Renewable Energy Systems and Energy Efficiency Improvements Program, a loan, loan guarantee, and grant program to assist eligi-

ble farmers, ranchers, and rural small businesses in purchasing renewable energy systems and making energy efficiency improvements. Another program aimed at encouraging renewable energy investment in rural areas is the Value Added Grant Program (VAGP). The VAGP makes funds available to farm families and rural businesses to help them develop new value-added products, such as ethanol and biodiesel. The VAGP was created by the Agricultural Risk Protection Act of 2000 and amended by Section 6401 of the 2002 Farm Bill.

The energy title of the 2002 Farm Bill also amended the Biomass Research and Development Act of 2000 by extending its termination date to September 30, 2006, and by providing funding to USDA for the research initiative. A wide range of projects have been funded, from addressing biomass production issues to improvements in biorefinery production processes.

Section 9010 of the bill codified the CCC Bioenergy Program and broadened it to allow biodiesel made from animal byproducts and fat, oils, and greases (including recycled fats, oils, and greases). Initially, only biodiesel made from oil crops received payments. This program expires in 2006.

The 2002 Farm Bill was also notable for greatly expanding natural resource conservation and environmental programs, such as the Environmental Quality Incentives Program (EQIP), which was created by the Federal Agriculture Improvement and Reform Act of 1996 (1996 Farm Bill), and reauthorized in the 2002 Farm Bill. EQIP offers incentive and cost-share payments to implement conservation practices, including the use of electric generators that run off of methane gas produced from ani-

mal waste. The CRP was continued and a new program, the Conservation Security Program (CSP) was authorized. The CSP was conceived as a way to reward producers who have been good stewards in the past and those who can improve their conservation performance in the future. The program provides financial and technical assistance to producers for conservation and improvement of soil, water, air, energy, plant, and animal life on cropland, grassland, prairie land, improved pasture, and range land, as well as forested land that is an incidental part of an agriculture operation.

Energy Policy Act of 2005 – H.R. 6

With recent record oil and natural gas prices and increasing energy supply uncertainty, there has been much interest in passing new energy legislation. In early 2001, President Bush's National Energy Policy Development Group laid out a proposal for a long-term, comprehensive strategy to lessen the impact of energy price volatility and supply uncertainty (NEPDG, 2001). The U.S. Congress responded to the energy situation and President Bush's energy strategy by enacting the Energy Policy Act of 2005. The 2005 Act reflects President Bush's general approach by creating programs and policy aimed at increasing and diversifying domestic energy production. It includes key provisions to help diversify domestic energy production through the development of renewable fuels. The 2005 Act mandates a renewable fuel phase-in called the renewable fuels standard (RFS), requiring U.S. fuel production to include a minimum amount of renewable fuel each year, starting at 4 billion gallons in 2006 and reaching 7.5 billion gallons in 2012. After 2012, renewable fuel produc-

tion must grow at least the same rate as gasoline production. The RFS provision also eliminates the requirement for reformulated gasoline to contain 2% oxygen and establishes a credit trading system. This gives gasoline suppliers the flexibility to use less renewable fuel than required by the RFS and still meet the standard by purchasing credits from suppliers who choose to use more renewable fuel than required. The RFS is expected to be satisfied by ethanol and biodiesel, but ethanol will likely provide the bulk of the mandated fuel.

The 2005 Act creates a Cellulosic Biomass Program to encourage the production of cellulosic ethanol. Under this provision, every one gallon of ethanol made from biomass, such as switchgrass, crop residues, and tree crops, counts as 2.5 gallons towards satisfying the RFS. Beginning in 2013, the applicable volume of renewable fuel required by the RFS must include a minimum of 250 million gallons of fuel derived from cellulosic biomass. However, the technology for converting biomass into "cellulosic" ethanol has not been fully developed, so a number of other provisions were adopted to stimulate research and development on biomass conversion technologies that could take advantage of less expensive energy crops and significantly expand the resource base for ethanol production. The Cellulosic Biomass Program also has the authority to provide loan guarantees for up to \$250 million per production facility. A \$650 million grant program was authorized to fund research on cellulosic ethanol production, and \$550 million is authorized for the DOE to create an Advanced Biofuels Technologies Program.

The biodiesel fuel excise tax credit was extended to 2008. In addi-

tion, a small biodiesel producer credit was created that grants biodiesel producers a \$0.10 per gallon income tax credit. Only biodiesel plants that have an annual capacity of 60 million gallons or less are eligible for the producer tax credit. This provision also modified the small producer tax credit received by ethanol producers. Under previous legislation, small ethanol producers were already eligible for a \$0.10 per gallon production income tax credit if their capacity was 30 million gallons or less. The 2005 Energy Bill increased the small producer capacity limit for ethanol plants to 60 million gallons per year or less. The tax credit can only be taken on the first 15 million gallons of production for both ethanol and biodiesel producers and it is capped at \$1.5 million gallons per year. The bill also provides a 30% tax credit for the cost of installing fueling facilities for alternative-fueled vehicles that run on 85% ethanol, natural gas, liquid natural gas, propane, hydrogen, and any blend of diesel fuel and biodiesel containing at least 20% biodiesel.

The 2005 Energy Act updates the Biomass Research and Development Act of 2000 (as modified under section 9008 of the 2002 Farm Bill). Originally a competitive grant program aimed at achieving scientific break-through leading to the development of biofuels, biopower, and bioproducts, the 2005 Act refines the program's objectives and redirects research emphasis.

The Sugarcane Ethanol Program was established to create a program to study the conversion of sugarcane, bagasse, and other sugarcane byproducts to ethanol in Hawaii, Florida, Louisiana, and Texas. The Sugar Ethanol Loan Guarantee Program was authorized to help finance commercial demonstration projects for etha-

nol derived from sugarcane, bagasse, or other sugarcane byproducts.

A USDA grants program was established by the 2005 Act to assist small biobased businesses, encourage bio-economy development in rural areas, and support energy feedstock production demonstration projects by farmer-owned enterprises. In addition, USDA was authorized to establish an education and outreach program to provide training and technical assistance to feedstock producers and encourage investment in processing facilities. Funds were also authorized for public education and outreach to familiarize consumers with biofuels and bioproducts.

For More Information

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Renewable Liquid Fuels: Current Situation and Prospects

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Ethanol produced from grain and biodiesel produced from vegetable oils and animal fats are the major renewable liquid fuels being produced in the United States. Cellulosic ethanol and Fischer-Tropsch diesel are also renewable liquid fuels of considerable interest, but additional development is needed before they become significant parts of the renewable liquid fuels market. Thus, the discussion in this article will focus on ethanol from grain and biodiesel.

The production and use of both fuels has been favored by state and federal government programs. The rationale for this encouragement is not only to improve the air and water quality and reduce dependence on foreign oil, but also to shore up farm prices, save on farm program expenditures, and promote economic growth in rural areas. Both fuels have increased in consumer acceptance as the quantities consumed have increased in recent years, and the recent increases in petroleum prices have stimulated interest in the possibility of producing both fuels as extenders of the gasoline and diesel fuel supplies. This paper discusses the drivers behind the rapid growth in ethanol and biodiesel production and use, and the prospects for continued growth in the future. It briefly notes the economics of production under current price conditions and U.S. capacity to produce larger amounts of these fuels from agricultural products.

Ethanol

Ethanol is typically sold in the United States in various ethanol-gasoline blends. Blends of 10 percent or less ethanol are consumed with almost no reported incompatibility with vehicles and equipment. Nearly all recent-model conventional gasoline vehicles produced for international sale are fully operable with such blends.

Ethanol is also sold as E85, a blend of 85 percent ethanol and 15 percent gasoline. High ethanol fuels are more corrosive and have a lower vapor pressure than gasoline. The flexible fuel vehicles (FFVs) sold in the U.S. to consume E85 include compatible components for rubber fuel lines and o-rings, and stainless steel for parts subject to corrosion. The FFVs typically have an engine control and sensor system that recognizes the combination of fuel being used. The engine can run on gasoline, E85, or any mixture of the two. A computer calibrates the fuel flow and injection system to provide smooth performance.

Industry Structure

The ethanol industry experienced a rapid rate of growth over the past 15 years, with production increasing to 4 billion gallons in 2005. The industry is composed of a combination of wet mills (producing ethanol, corn gluten meal, corn gluten feed, corn oil, and CO₂) and dry mills (producing ethanol, dried distillers grains and solubles, and CO₂). Approximately 25 percent of the production during 2005 was from wet mills and the remainder from dry mills. Most of the new plants built during the past decade are dry mill plants because they have lower investment costs. The industry continues to add new capacity at a rapid rate. Production is expected to reach 5.0 billion gallons in 2006.

Growth during the past decade was composed primarily of the entry of a number of new companies building medium-sized dry mill facilities. Many of the companies that initially built plants of 15 to 25 million gallons annual capacity (mmgpy) expanded them to 40 to 50 mmgpy within the past five years. With the addition of more small to medium plants, ownership of the industry capacity became more fragmented over time. In 1990, 13

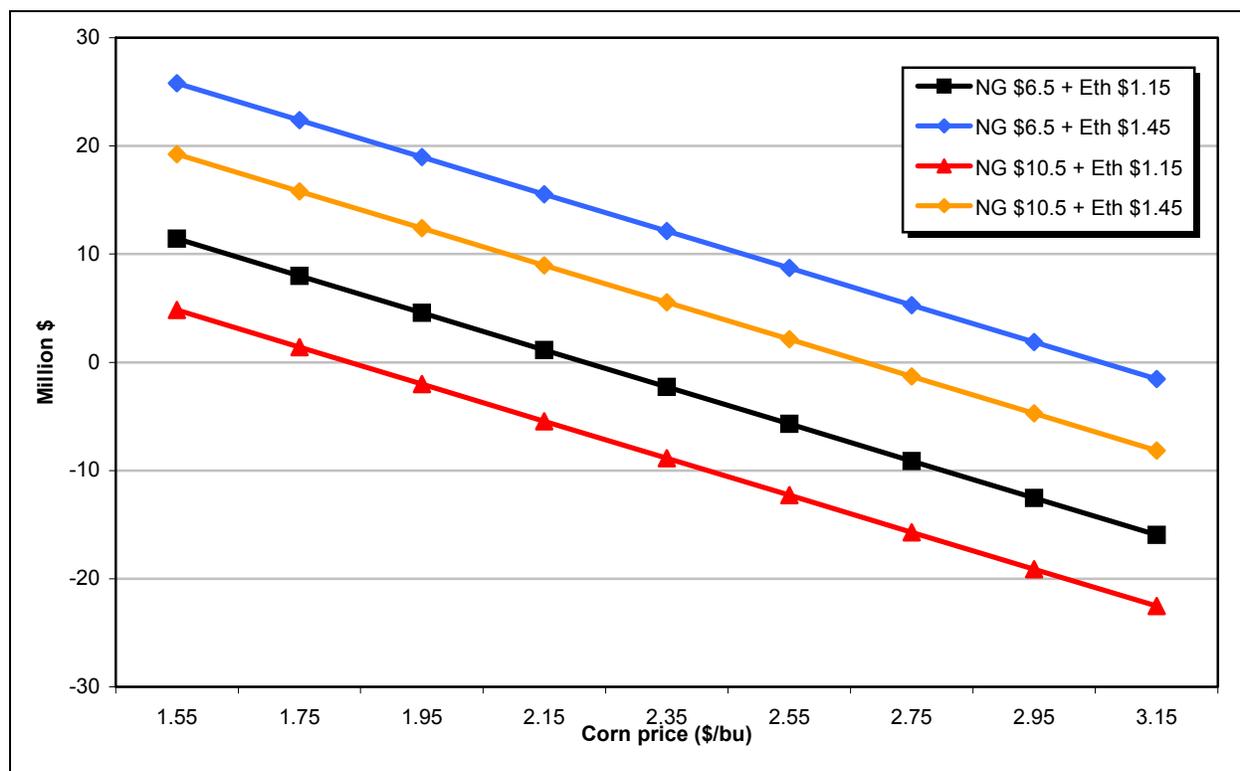


Figure 1. Net margin for 48 MMGPY dry mill plant for selected corn, ethanol, and natural gas price combinations.

companies operated 17 facilities with 1.11 billion gallons of annual capacity. One firm owned 55 percent of the capacity. In mid 2005, 71 organizations operated 84 facilities with 3.7 billion gallons of annual capacity. The largest firm owned 29 percent of the capacity.

Much of the procurement of corn and natural gas, and marketing of the ethanol and byproducts, as well as risk management, is being handled by a few firms that specialize in this area. Thus, the industry structure that has evolved is ownership of the production facilities by a large number of relatively small firms, with the marketing concentrated in the hands of a much smaller number of firms.

Economics of Ethanol Plants

Producing ethanol is a commodity business with wide swings in profitability, dependent largely on the price of the feedstock (primarily corn, with some grain sorghum), the price of

ethanol, and the price of natural gas. The sensitivity of the plant's net margin to these factors is illustrated in Figure 1. Given the price of ethanol and natural gas, all four lines in Figure 1 indicate that raising the price of corn reduces profitability of the plant. The figure also illustrates that for any price of corn and natural gas, increasing the price of ethanol greatly increases the net margin. Finally, the figure shows that raising the price of natural gas for given corn and ethanol prices reduces the net margin. The figure illustrates that an increase in the price of natural gas from \$6.50 per million British Thermal Units (Btu) to \$10.50 reduces the annual net margin of a 48 mmgpy plant by approximately \$6.6 million.

The net margins presented here do not include any subsidies paid to the plant by the state and federal governments. Receipt of subsidies would obviously increase the profitability of a plant, other things being equal.

Two types of production subsidies have been available in recent years from the federal government. Both apply to small plants. New plants and those expanding production have been eligible for the Commodity Credit Corporation Bioenergy Program. This program, scheduled to end in 2006, provides incentive cash payments to U.S. ethanol and biodiesel producers that increase their purchases of agricultural commodities and convert that commodity into increased bioenergy production. A second program provides a 10-cent per gallon production income tax credit on up to 15 million gallons of production annually. Originally, the size of the plant eligible for the income tax credit was limited to 30 million gallons per year. Under the Energy Policy Act of 2005, the size limitation on the production capacity for small ethanol plants increased from 30 million to 60 million gallons. The credit can be taken on the

first 15 million gallons of production. In addition to the federal programs, many states offer incentives for ethanol plants built in their state.

Ethanol Demand

The domestic demand for fuel ethanol has developed over time largely as a result of various federal and state policies. The recent boost in ethanol demand is largely the result of several states banning the use of a gasoline additive called MTBE because of its propensity to contaminate drinking water. Ethanol is the only economic substitute for MTBE. Ethanol is expected to receive another major boost due to the renewable fuels standard (RFS), a provision of the Energy Policy Act of 2005. The RFS requires the U.S. fuel industry to produce a minimum of 7.5 billion gallons of renewable fuel by 2012. (See Collins and Duffield in this set of papers for a complete discussion of federal policies).

Many in the U.S. ethanol industry feel the outlook is bright for an expanding market, particularly because they feel the oil industry will replace more MTBE with ethanol and use more ethanol as a fuel extender. Some argue that the RFS could expand demand more rapidly than the domestic industry can supply, significantly boosting opportunities for the countries in the region that have preferential access to U.S. markets, such as through the Caribbean Basin Initiative, and those with low production costs that can pay the \$0.54 per gallon import tax duty.

The recent increase in petroleum and gasoline prices seems to have opened a new market for ethanol as a fuel extender. This is potentially a very large market, and one that should absorb any amount of ethanol the industry could produce in the foreseeable future. The U.S. con-

sumed 136 billion gallons of gasoline during 2004. Compared to the 2005 ethanol production level of 4.0 billion gallons, ethanol was only 2.9 percent of U.S. gasoline consumption. If the oil industry uses ethanol as a fuel extender, the price of gasoline will effectively place a floor on the price of ethanol (net of the tax credit and blending costs).

Production Potential

What are the implications of the expanding ethanol industry for the way we use the U.S. corn and sorghum supplies? Approximately 11.7 percent of the corn supply and 11.3 percent of the sorghum supply were used to produce ethanol in 2004. Assuming that the proportion of ethanol made from each crop remains about the same as ethanol production increases to 5.0 billion gallons in 2006, more than 17 percent of both crops will be required. That is, the 5.0 billion gallons will require 1,845 million bushels of corn, more than 17 percent of what is currently considered to be a normal corn crop of 10.8 billion bushels. Although large carryover stocks are expected to provide part of the increased corn needed in 2006, when the stocks are reduced to more normal levels, continuing to produce ethanol at this and higher levels will require some adjustment in the way the U.S. corn supply is used. Additional corn needed for ethanol production could be diverted from the export market or from feed usage. Increases in ethanol demand could also lead to planting more acres of corn.

Biodiesel

Biodiesel can be used as an alternative to petroleum diesel in its pure form (B100) or as a blend with petroleum diesel at various ratios,

such as B20 (20 percent biodiesel and 80 percent petroleum diesel). Engine performance with biodiesel is generally comparable to that of petroleum diesel, with some advantages and disadvantages concerning engine emissions.

Industry Structure

The biodiesel industry in the United States began to organize much later than ethanol, and is in an earlier stage of industry development. Production of biodiesel increased from 0.5 million gallons in 1999 to 91 million gallons in 2005. Production capacity, however, is much larger and growing rapidly. The National Biodiesel Board reports 53 commercial biodiesel plants in early 2006 with listed production capacity of 354 million gallons. The average size is about 6.7 million gallons, with some larger plants in the 30 million gallon range. The National Biodiesel Board reports an additional 40 plants and 4 plant expansions under construction that will add 329 million gallons of annual capacity. Thus the industry has the processing capacity to increase production rapidly as demand increases.

Economics of Biodiesel Plants

Haas et al. (2005) estimate the capital and operating costs of a 10 million gallon annual capacity industrial biodiesel production facility. They assume current production practices, equipment and supply costs, and model a continuous-process vegetable oil transesterification plant with ester and glycerol recovery. The analysis is based on purchasing degummed soybean oil as the feedstock.

With the plant operating at capacity, the estimated cost per gallon ranges from \$1.48 with degummed soybean oil costing \$.15

per pound to \$2.96 with degummed soybean oil costing \$0.35 per pound. The analysis assumes 7.4 pounds of virgin degummed soybean oil are required per gallon.

The feedstock cost is the largest single component of the biodiesel production costs. Recycled fats and oils are less expensive than virgin oils and can also be used to produce biodiesel. Yellow grease and trap grease are the most common types. Yellow grease is produced from used cooking oil collected from large-scale food service operations. Renders collect used cooking oil and trap grease and remove the solids and water to meet industry standards. These products are limited in supply, and they have other uses. For example, yellow grease is used in animal feed and also to produce soaps and detergents. Assuming a yellow grease price of 49 percent of soybean oil prices (the historic relationship) and that the amount required to produce a gallon of biodiesel is somewhat greater, 7.65 pounds, the cost per gallon ranges from \$0.94 to \$1.68 per gallon. The lower cost of biodiesel from yellow grease suggests that the market for biodiesel will bid up the price of yellow grease relative to soybean oil.

Biodiesel Demand

The amount of biodiesel demanded has remained relatively low because until recently, the cost of biodiesel has been well above the wholesale price of petroleum diesel. However, as was the case for ethanol, several pieces of federal legislation, including a new tax credit and the Renewable Fuels Standard (RFS), are expected to enhance the demand for biodiesel. In addition, new diesel fuel standards that require refiners to produce ultra-low-sulfur diesel fuel beginning in July 2006 could create a new market for biodiesel as a lubricity additive

(again these are discussed in Collins and Duffield in this issue).

At the state level, many states passed legislation favorable to biodiesel in recent years ranging from tax exemptions to infrastructure incentives. Minnesota enacted a statewide law requiring the state's diesel fuel to be comprised of 2 percent biodiesel. The law became effective in September 2005 when the state's biodiesel production capacity moved above 8 million gallons per year.

An important source of current biodiesel demand is for specialized uses where the air emission characteristics of biodiesel are a major advantage. These uses include marine craft and diesel engines operating in enclosed areas, such as mines. In addition, the National Biodiesel Board reports that in May 2004, more than 400 fleets associated with school districts, city governments, state governments, and federal agencies were using biodiesel. Much of this growth can be attributed to the Energy Policy Act of 1992 (EPACT) that requires government entities to purchase alternative-fueled vehicles. These uses are expected to grow as government policies continue to contribute to this demand in the future. The Energy Information Agency estimates the EPACT use will increase to 6.5 million gallons of biodiesel per year by 2010. The 2 percent Minnesota mandate will add about 17 million gallons of demand per year. The ultra-low-sulfur diesel rule could expand the biodiesel market significantly. EIA notes that if refiners use 1 percent biodiesel to improve the lubricity of diesel fuel, this will add 470 million gallons to demand by 2010.

The current use of 91 million gallons per year, plus the potential markets, total more than 500 million gallons per year. With the excise tax

credit in place, biodiesel would also be competitive as a fuel extender, but how much can the United States produce from the available feedstocks?

Production Potential

The feedstock used for biodiesel production depends largely on the available supply and its price. Potential feedstocks for biodiesel are the vegetable oils, yellow grease and other grease, lard, and edible and inedible tallow. Over the 2000-2004 period, soybean oil made up 57 percent of the total U.S. annual feedstock supply, while yellow grease and other grease made up 8 percent. Other vegetable oils made up smaller percentages of the total supply and had higher prices during the past five years than soybean oil and yellow grease. Among animal sources, inedible and edible tallow made up 11 and 6 percent, respectively. Large proportions of the inedible tallow are exported, suggesting these oils may be candidates for biodiesel production. However, the animal fats are less uniform than the processed vegetable oils and require more processing to produce a uniform biodiesel product. Considering price, uniformity of product, and supply, yellow grease and soybean oil are considered to be the preferred feedstocks for biodiesel production.

Yellow grease and other grease have alternative uses in livestock feed and the production of soaps. There is also the difficulty of collecting and transporting the yellow grease to a biodiesel plant that is processing this material. Considering the alternative uses and the logistical problems, perhaps one-half to two-thirds of the total yellow grease and other grease could be processed into biodiesel. This total would provide 172 to 228 million gallons per year.

A recent U.S. Department of Agriculture (2002) study estimated the effect of increasing the amount of biodiesel produced from current levels to 124 million gallons in 2012. This study, conducted to analyze the effect of a RFS for motor vehicle fuel, assumed all of the biodiesel was produced from soybean oil. The projected increase in the demand for soybean oil required to produce the biodiesel leads to an increase in the domestic price of soybean oil. The domestic price of soybean oil is projected to increase 17 percent over the baseline as a result of a RFS. Higher prices reduce other domestic uses of soybean oil and exports. Processing additional soybeans puts downward pressure on soybean meal prices and leaves the price of soybeans about 1 percent above the baseline. The change in protein prices results in minor changes in livestock production and profitability over the decade.

These data suggest the U.S. could produce 300 to 350 million gallons of biodiesel from yellow grease and soybean oil without major disruption of soybean oil markets. It appears the United States would need to utilize other feedstocks or import other oils to expand biodiesel production much beyond this level.

Concluding Comments

Ethanol and biodiesel appear to be moving into a new market environment brought on by a combination of the increase in petroleum prices and some new legislation and regula-

tions. The increase in petroleum prices moved the wholesale price of regular gasoline and diesel fuel up rapidly during 2005, while the cost of producing ethanol and biodiesel has not increased appreciably, except for the cost of natural gas used in the processing plants.

For ethanol, the new energy bill replaces the mandated markets with a Renewable Fuels Standard (RFS). While the industry's production capacity will exceed the RFS, the petroleum industry is expected to purchase the additional ethanol to produce reformulated gasoline and for use as a fuel extender. This additional demand is expected to keep the ethanol markets reasonably strong as long as petroleum prices remain high, encouraging further growth of the industry. As the industry expands beyond this level in future years, the ethanol industry is expected to place some pressure on the market for corn and sorghum, reducing exports and/or increasing the acreage planted to these two crops.

With the new excise tax credit and current prices, biodiesel has an opportunity to compete in the diesel fuel market as a fuel extender and a lubricity additive. However, the country's supply of feedstock fats and oils will limit biodiesel to a small part of this potential market.

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Energy Production with Biomass: What Are the Prospects?

Paul W. Gallagher

JEL Classification: Q3

The advantages and limitations of the U.S. ethanol industry have both become apparent during the current period of high petroleum prices. One advantage is that ethanol is cost-reducing as a gasoline additive and as a gasoline replacement using E85 (motor fuel blends of 85 percent ethanol and just 15 percent gasoline). However, corn supply limits ethanol's role in energy markets; ethanol-based corn demand will surpass exports when the 7.5 billion gallon Renewable Fuel Standard is fully implemented; and even if the Midwest were to secede from The Union, the entire Midwestern corn crop could only supply two-thirds of regional gasoline demand with ethanol. Clearly, a broader resource base and other processing technologies are needed if bioenergy is going to expand its role in the national energy scene.

There are wide ranging assessments of biomass-energy's potential role in expanding our national energy supplies. Those accustomed to pumping liquid petroleum scoff at the idea that an energy industry could be based on bulky crops or residues from farm land or forest. Or biotechnologists sometimes multiply laboratory processing yields times the physical intensity of biomass on land times land area, resulting in an enormous estimate for biomass energy potential. Somewhere in between zero and the enormous estimates we should find reality.

This paper examines the primary factors that limit the potential size of a biomass-energy industry in the United States. First, the fraction of the existing biomass that can be economically harvested from farmland is reviewed. Second, the current and potential processing technologies and practices are discussed. And finally, the unknowns and uncertainties of bioenergy supply that could be shaped by public policy are also reviewed.

Recent Studies of Biomass Supply

Current thinking with regard to energy crops is that switch grass, willow, and poplar hold the most potential. Switch grass yields are highest in the southeastern United States, where sunshine and rainfall are ample. Poplar may be the energy crop choice in the north-central states with extensive sunlight in summer. Willow yields appear highest in the middle/east section of the U.S. where there is extensive rainfall. Most research evaluating the extent of economically accessible biomass supply has looked at adding these new crops on the boundary of existing commercial agriculture.

Crop residues from existing crops, mainly corn and wheat, could also provide significant amounts of biomass because residue mass roughly equals the volume of the crop. Crop residues intrigue industry because costs are lowest for this unused resource. Also, residue and food crop production are complementary, whereas growing crops for energy use instead of food production can reduce food supply. Finally, our research suggests that harvesting residue from crop production can be consistent with soil quality maintenance, when reduced tillage and other appropriate conservation measures are taken (Gallagher et al., 2003b).

Energy crops on commercial cropland are a marginal enterprise, owing to values and yields that are moderate in comparison to food crops. Fortunately, the farmland that can contribute to bioenergy production extends beyond commercial cropland. Many biomass crops are sustainable on land that is not suitable for annual crops; switch grass is established once and harvested for several years, and agroforestry crops are planted and harvested on a 10-year rotation. Furthermore, willow is water-tolerant and even thrives with wet feet. Hence, the land base for biomass

Table 1. Biomass from agriculture: Potential supply and cost.

Source:	Volume (mil. ton)	Typical Farm Entry Price (\$/ton)
Crop residues	142	15-25
Crops	188	35-45
Subtotal	330	
Midwest/East pasture	261	30-40
Forested farmland	155	30-40
Total	746	

crops extends to farmland with steep slopes and to some wet lowland areas that are generally not used for annual crops. Caution should be used when considering pastureland from the Great Plains states because inadequate rainfall could severely limit biomass yield. Commercial forestland should also be excluded because the infrastructure for harvest does not exist and other industries already compete for the land.

Bringing together several recent studies, my estimate of economically accessible biomass supply is given in Table 1 at 330 to almost 750 million tons. Initial supply prices range from a low of around \$15/ton for corn residues to \$35/ton for commercial cropland. Conversion of the first 330 million tons from current land use to biomass production might occur within five years, by harvesting residues, switching crops, and returning some CRP land to production. The conversion of pasture and forested farmland may be a longer-run proposition; dominated by agro-forestry crops, conversion could easily take 15 or 20 years. Conversion of this land would likely occur after a prolonged period of high energy and biomass prices. Complete use of marginal lands for energy would also intensify land competition with pasture for livestock, increase land use values,

and significantly increase biomass costs from marginal lands, according to my preliminary estimates. Otherwise, one-half to two-thirds of the marginal lands could be used for biomass production without significant increases in land values. More biomass supply from commercial cropland could also be obtained at moderate price increases and without extensive increases in land values, but it would likely get more expensive to maintain the status of the CRP program.

Processing Technology Situation

There are five major crop-based processes for producing bioenergy products. The characteristics of these processes are summarized in Table 2. Characteristics include pretreatment and secondary processing, technical status, product yield, and cost when available. The processes are ordered according to market readiness. Processes (1) and (2) are operating today. Process (3a) has operated in a commercial setting with coal in South Africa, but not with biomass. The integrated pretreatment and secondary processes of (3b) and (4) are apparently technically feasible. But only a few batches have been made successfully with process (4) in a non-laboratory setting. Process (5) has potential for the future.

In general terms, the present technical challenge for biomass processing is to break down long and complex cellulose and hemi-cellulose molecules into smaller components that are more useful chemicals and energy products. A complicated pretreatment process is not required for agricultural crops because the wood-like component is not present. Otherwise, cellulose can be burned without pretreatment. But, conversion to liquid chemicals and fuels requires an extensive pretreatment process, which is difficult and expensive. This

fact helps explain the pattern of market readiness and costs found in Table 2.

Ethanol production from corn, process (1), is now widely adopted, but the development of this industry took about 30 years. A subsidy was initiated in the mid 1970s to encourage plant construction. This resulted in moderate improvements in fiber conversion yield, reductions in operating costs due to lower energy use, and reduced enzyme cost. In addition, the industry reached economies of scale that lowered capital costs. Then the stage was set for the recent wave of adoption, which occurred very quickly in response to profits, high energy prices, and the increased demand provided by the renewable fuel standard.

The production of electricity and byproduct heat from burning biomass, process (2), is another process that operates commercially today. In California, rice straw is the biomass input and Denmark uses wheat straw. The biomass industries in both California and Denmark depend on government subsidies to continue operating. The reported electricity production costs from California compare favorably to recent consumer prices of electricity.

Gasification with catalytic conversion to a set of chemicals that includes ethanol, process (3), was developed in Germany during WWII. Gasification with a coal input was also used in South Africa while it faced an oil embargo. Optimizing yields with biomass input continues to be an active area of engineering research.

Processes (4) and (5) are both based on the fermentation of sugars, including the 5-carbon and 6-carbon sugars that occur when the wood-like material in biomass crops is broken down. The development of geneti-

Table 2. Actual and anticipated bioenergy crop-based processes.

Raw Material	Pretreatment		Secondary Treatment		Technical Status	Yield ^c		Production Cost ^d	Capital Cost
	Process	Products	Process	Products		Current	Potential		
(1)Commercial crops ^a	Mechanical	Glucose	Fermentation	Ethanol	Operating	106	106	\$1.12/gal	\$1.10/gal
(2)Biomass ^b		None	Combustion	Steam/ Electricity	Operating			\$0.07/kw-hr	
(3a)Biomass ^b	Gasification	Syngas: H ₂ CO	Catalysis: Fischer- Tropsch, Pearson	Ethanol Methanol Proponal	Commercially Feasible	63	137	expensive	
(3b)Biomass ^b	Gasification	Syngas:	Fermentation	Ethanol Electricity	Technically Feasible			Unknown	\$2.40/gal
(4) Biomass ^b	Hydrolysis with acid	Glucose Xylose	Fermentation	Ethanol	Technically Feasible	52		\$1.80/gal	\$4.70/gal
(5) Biomass ^b	Hydrolysis with base		Fermentation	Ethanol	May be available in future	----	120	\$0.75/gal	\$2.40/gal

^aCorn, wheat, or sugar; ^bCrop residues, switchgrass, poplar, willow, or MSW (municipal solid waste); ^cIn gallons fuel per ton of biomass input; ^dIncludes annual allowance for capital repayment.

Table 3. Biomass-fuel processing plants: Commercial and quasi-commercial facilities in North America.

Location	Process	Fuel Capacity (mil. gal.)	Primary Input	Yield (gal/ton)	Status
Ottawa, Canada	Process (4): acid hydrolysis & fermentation	1	wheat straw	72	occasional short operation periods
Lacassine, LA	Process (4): acid hydrolysis & fermentation		woodchips bagasse		under construction
Pollock, LA	Process (3a): Gasification & catalysis	110	woodchips	58	planning
Knoxville, Tennessee	Process (3b): gasification & fermentation	13 (& 14 Mega-Watts of electricity)	Municipal solid waste	59	planning

cally engineered bacteria that can ferment all of these sugars with high yields is one of the most promising technological developments in biomass processing. One view of the problem in process (4) is that the pretreatment process used to break woody materials into sugars uses acid. The genetically engineered bacteria or yeast do not tolerate residual acid left from the pretreatment process, inhibiting ethanol yields. Process (5) represents a potential solution to this problem, using pretreatments with non-acidic solutions. Ideally, this pretreatment will allow actual sugar yields to reach potential. If the experimental pretreatment in process (5) were to become technically feasible,

very high ethanol yields and low production costs could be obtained.

Technology Adoption: Barriers and Prospects

Referring to table 3, there are no full-scale biomass/biofuel plants operating in North America, but there are plans to construct one facility in Louisiana. There are two demonstration scale plants, a wheat straw fermentation plant operating in Canada, and a municipal solid waste gasification/fermentation plant planned for Tennessee (Table 3). Looking at the cost estimates in Table 2, one can conclude that producing ethanol from processes other than crop fermentation have not

been adopted because the profit picture has not been favorable.

Biomass processing could become profitable in the future with improvements in technology. The U.S. Department of Energy (DOE) has emphasized research on fermentation ethanol for some time. In addition, DOE has recently developed several projects that are aimed at reducing the high cost of pretreatment enzymes and fermentation bacteria, an important barrier to adoption. One project aims at reducing enzyme costs from \$.50/gallon to about \$.10/gallon. Some of the major energy and chemical processing companies involved in this project anticipate that a few commercial processing plants based on

improved hydrolysis pretreatment will be built by 2010 and technology development will be complete by 2015. However, some critics in the corn processing industry challenge this conclusion, observing that biomass ethanol has been 5 years away for about 20 years now. Further, it is important to realize that licenses for enzymes and genetically engineered bacteria are the scarce fixed factor where rents to new technologies reside. Based on experience in the corn-ethanol industry, it could take 20 years to get enzyme costs down.

Hence, it is going to take a number of technical advances before biomass-fermentation adoption becomes economical. First, if we could get a yield improvement comparable to the one that occurred in the corn-ethanol industry over the past 30 years, biomass yield would approach 90 gal/ton. Second, enzyme costs for biomass-ethanol must fall to the low levels of the corn-ethanol industry. With these advances, biomass ethanol might approach the breakeven point with the corn-ethanol process. But biomass-ethanol's high capital costs relative to corn processing would still remain. It could take very cheap biomass, like corn residues, or high corn prices to offset the capital costs.

The biomass-energy processing sector could evolve in several directions as the technological possibilities become known. Eventually, biomass fermentation (processes 4 and 5) will either become commercially successful or be judged as an unsolvable puzzle. A similar evaluation will occur for producing transportation fuel using the gasification process with biomass feedstocks (process 3). If neither fermentation nor gasification lead to low cost production of transportation fuels, attention could shift back to the existing biomass-electricity industry (process 2) and the bio-

mass energy industry would serve local electricity needs for rural communities and rural processing plants.

Shaping the Role of Biomass-Based Fuel in the National Energy Picture

The eventual role of biomass-ethanol in national energy supply depends upon the success of fuel processing technologies and the extent of prolonged energy price increases. Three scenarios indicate the qualitative range of outcomes. First, if there are no further improvements in fuel technology, biomass ethanol could supply about 10% of national gasoline consumption using crop residues and available cropland. Assuming sustained high energy prices under this scenario, 20% of gasoline consumption could be replaced with large-scale conversion of suitable pasture and forested farmland. But, biomass-ethanol would still be on the margin even at currently high fuel prices. Second, if costs could be reduced about \$0.25 per gallon with moderate improvements in fuel technology, then gasoline replacement could be up to 15%, assuming no major land conversion and 30% with major land use conversion. Third, if someone really solves the biomass pretreatment problem and further cost reductions of \$1.05 per gallon were achieved, then biomass fuel could replace 20% of gasoline without major land conversion and about 45% with land conversion. In short, biomass fuel by itself won't solve America's energy problems, but it could be a significant part of the solution.

In turn, the biomass-fuel industry that we get in 30 years depends on our public investment today. With increased public research support, we increase the odds of a moderate

improvement or a quantum leap in processing technology. Further, improving current processes deserves increased emphasis; biomass power could replace some natural gas used for electricity consumption and corn-ethanol production; and gasification/catalysis may be a very practical fuel technology for biomass. If someone solves the fermentation pretreatment problem, so much the better! Finally, the emerging demonstration plants deserve support because average production costs are inversely related to an industry's cumulative output; learning-by-doing has been important for other processing industries; it will be important for biomass energy, too.

This time, America's energy problem may be a prolonged state of higher petroleum prices instead of a market disruption; oil price outlook reports do remain high beyond the intermediate term. Oil processors are investing in Canadian oil sands, a process with costs similar to E85. But, the private sector interest in biomass energy is still limited in comparison. Perhaps biomass energy is too distant for serious consideration by the commercial energy sector. Or perhaps the profit vision of a multinational corporation with its resource base and human capital grounded in the petroleum industry does not see the critical role of biomass in America's energy future. Therein a justification for an oil profits tax may lie, especially if revenues are spent on biomass energy for America's future.

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Renewable Energy in Agriculture: Back to the Future?

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JEL Classification: Q3

There is significant potential for agricultural involvement in the production and consumption of solar, wind, geothermal, and biomass energy. Renewable resources are abundant and widely distributed throughout the United States. A number of commercial technologies are available to harness these resources, and with appropriate support, additional technologies – some potentially paradigm-shifting – could be brought to market.

In many ways, this is a “back-to-the-future” scenario, including a movement toward more self-sufficient farms and a central role for agriculture in the U.S. energy supply. Increased renewable energy in and from agriculture calls to mind Henry Ford envisioning automobiles fueled by alcohol, and windmills powering water pumps. Renewable technologies are now supplying or supplementing many on-farm energy requirements, from water pumping to space heating. Increasingly, farmers and ranchers are selling energy (e.g., electricity generated from wind turbines, biofuels, and products from biomass). This is contributing to greater energy security in agriculture through increased diversity of energy sources, more self-supply of energy, and reduced environmental impact.

The United States faces a choice of energy futures. Continuing the present course is one alternative. Fossil energy for mechanized agriculture has been an important driver of the “Green Revolution” of increasing farm productivity. Today, three energy inputs (diesel fuel, fertilizer, and electricity) account for more than three-quarters of farm energy use. (Miranowski, 2004). At predicted levels of oil production and consumption, America will be increasingly dependent on foreign oil imports in the years ahead, making the Nation even more vulnerable to oil disruptions and price spikes (Figure 1). In agriculture, an energy supply disruption of even a short duration could mean a substantial reduction or the complete loss of an

entire growing season. As price-takers for their commodities, farmers are generally unable to pass price increases for energy or fertilizer on to the consumer, and therefore receive a lower return for their products when prices rise (Costantini & Bracceva, 2004).

Renewable energy can address many concerns related to fossil energy use. It produces little or no environmental emissions and does not rely on imported fuels. Renewable resources are not finite (as fossil fuels are) and many are available throughout the country. Price competitiveness has been a concern, but costs have decreased significantly since the initial wave of interest in renewable energy in the 1970s. These technologies now provide 6.1 quadrillion British Thermal Units (Btu) for domestic energy consumption (Figure 2).

Different renewable technologies are at different points in their development. Some are commercially available or nearly so, and others have potential for the longer term. Unfortunately, many benefits that renewable energy can provide are not monetized — they cannot be perceived through price signals. Policies are needed to push or pull these new technologies to full commercial development. This article examines the domestic status and opportunities for a number of renewable energy technologies — solar, wind, geothermal, and biomass.

Solar

Solar technologies produce electrical or thermal energy. Photovoltaic (PV) cells (or “solar cells”) that convert sunlight directly into electricity are made of semiconductors such as crystalline silicon or various thin-film materials. Solar thermal technologies collect heat from the sun and then use it directly for space and water heating or convert it to electricity through conventional steam cycles, heat engines, or other generating technologies (concentrating

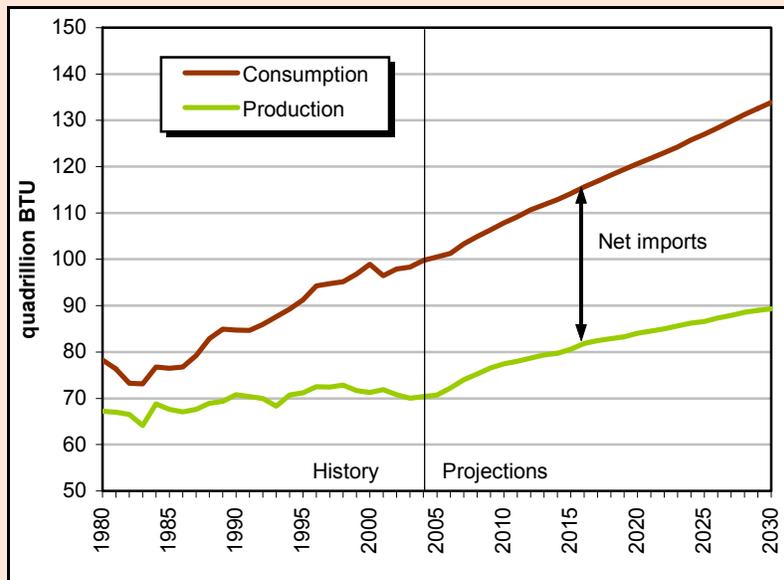


Figure 1. Total energy production and consumption: 1980-2030.

Source: Energy Information Administration, Annual Energy Outlook 2005, <http://www.eai.doe.gov/oiaf/aeo/overview.html>.

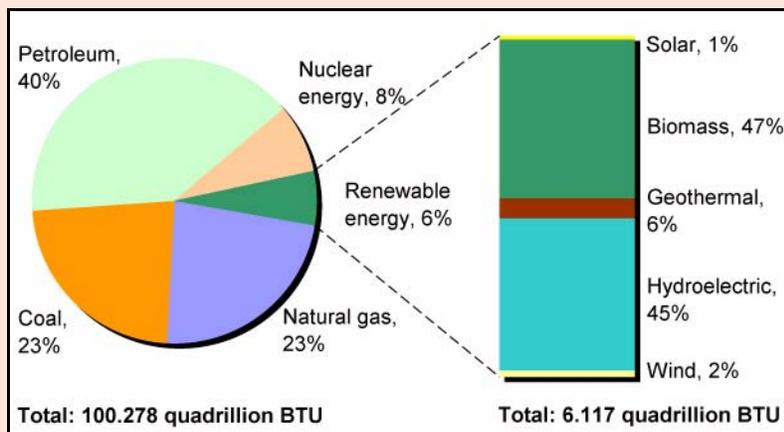


Figure 2. The role of renewable energy consumption in the Nation's energy supply, 2004.

Source: Energy Information Administration, Renewable Energy Trends, 2004 edition, <http://www.eai.doe.gov/cneaf/solar.renewables/page/trends/rentrends04.html>.

solar systems). In the future, solar energy could produce hydrogen to provide transportation fuels, chemicals, and electricity, and to serve as energy storage at times when the sun is not shining.

As a result of technological advances, the costs of these technologies have been steadily decreasing, and high electricity costs can bridge the gap further. Although solar resources are greatest in the South-

west (about 25 percent higher than the national average), solar electricity may be more cost effective in states with high electricity costs. For example, New York electricity prices can be 50 percent higher than in Arizona (U.S. Department of Energy, Solar Energy Technologies Program, 2003). In agriculture, PV can economically provide electricity where the distance is too great to justify new power lines. Solar electric sys-

tems are used to provide electricity for lighting, battery charging, small motors, water pumping, and electric fences.

Livestock and dairy operations often have substantial air and water heating requirements. For example, commercial dairy farms use large amounts of energy to heat water for cleaning equipment. Heating water and cooling milk can account for up to 40 percent of the energy used on a dairy farm. Solar water heating systems may be used to supply all or part of these hot water requirements. Other solar applications include greenhouse heating and solar crop drying (National Renewable Energy Laboratory, n.d.).

The number of solar energy applications is expected to grow as new technologies increase solar cell efficiency and reduce costs. New "quantum dot" materials could theoretically more than double efficiency, converting 65 percent of the sun's energy into electricity, as compared to the best commercially available solar cells today, which have conversion efficiencies of up to 30 percent. Research is also being conducted to reduce the cost of solar water heating systems through the use of materials like plastics instead of metals and glass.

Wind Energy

Wind technologies provide mechanical and electrical energy. Wind turbines operate on a simple principle: Wind turns rotor blades, which drive an electric generator, turning the kinetic energy of the wind into electrical energy. The wind is a renewable energy source, and windmills do not produce harmful environmental emissions. Utility-scale turbines range in size from 750 kilowatts (kW) to 5 megawatts (MW), with

most turbines exceeding 1 MW. Turbines are often grouped into wind farms, which provide bulk power to the electrical grid. Small wind turbines range in size from 0.4 to 1.5 kW generators for small loads, such as battery charging for sailboats and small cabins, to 3 to 15 kW systems for a home, to those that generate up to 100 kW of electricity for larger loads, such as small commercial operations.

Wind power technology is already in widespread use due to substantial progress in reducing costs for areas with consistently high wind speeds. At the end of 2005, wind was responsible for 9,149 MW of electrical generating capacity in the United States. At an average capacity factor of 31 percent, this is equivalent to producing the annual amount of electricity that is used by over 2 million average American households. There are commercial wind energy installations in 30 states (American Wind Energy Association, 2006). Today's state-of-the-art wind turbines, operating in high-wind areas, can produce electricity for a few cents per kilowatt-hour (kWh), which is competitive with the cost of fossil fuel-fired plants.

Small wind systems can serve agriculture in traditional ways, such as using mechanical energy to pump water or grind grain. As costs decrease, small systems used to generate electricity may also become economically efficient by avoiding the expense of installing transmission wires, especially in more remote applications. Where connected to the electricity distribution grid, small windmills can generate revenue through electricity sales when generation exceeds internal requirements. Decentralized wind systems can be combined with other energy sources to create a hybrid energy system,

where the low cost and intermittent wind resource is supplemented by more expensive small generators such as diesel generators or batteries, to provide power that is both relatively inexpensive and reliable (Bergey, 2000). The small wind turbine industry estimates that 60 percent of the United States has enough wind resources for small turbine use, and 24 percent of the population lives in rural areas where zoning and construction codes permit installation (National Renewable Energy Technology, 2004). As technological improvements continue to increase the economic efficiency of wind energy, agricultural producers are likely to increase their use of wind power to lower energy costs and become more energy self-sufficient.

Geothermal

Geothermal technologies produce electrical or thermal energy. Three types of geothermal power plants are operating today: dry steam plants, flash steam plants, and binary-cycle plants. High-temperature geothermal resources (greater than 300°F) are used for power generation.

Individual power plants can be as small as 100 kW or as large as 100 MW. The technology is suitable for rural electric mini-grids, as well as national grid applications.

The heat from geothermal energy can also be utilized directly. Geothermal fluids can be used for such purposes as heating buildings, growing plants in greenhouses, dehydrating onions and garlic, heating water for fish farming, and pasteurizing milk. Generally, low-to-medium temperature resources (between 70°F and 300°F) are used. Another technology, geothermal heat pumps, can provide space heating and cooling. This technology does not require a hydrother-

mal (hot water) resource, but instead uses the near-surface ground as a heat source during the heating season and as a heat sink during the cooling season.

While the costs of geothermal electric plants are dependent on the character of the resource and project size, the average cost of geothermal-generated power has been decreasing. In 1980, geothermal electricity costs ranged from 10–14 cents per kWh. Due to improved technologies that have reduced exploration, production field, and power plant costs, it now ranges from 4–7 cents per kWh.

Installed geothermal electricity capacity provides over 2,500 MWe in the United States at capacity factors often exceeding 90%. This is equivalent to providing the power needs for almost 2 million households.

Direct or non-electric generation provides over 10,000 thermal megawatts (MW_t), including geothermal heat pumps. The power from direct use systems is measured in megawatts of heat as opposed to power plants that measure power in megawatts of electricity (Lund, 2005). Some geothermal projects “cascade” geothermal energy by using the same resource for different purposes simultaneously, such as heating and power. Cascading uses the resource more efficiently and improves economics.

The geothermal resource base for low-to-medium temperatures is much more plentiful and widespread than the high-temperature resource base. Low- and medium-temperature geothermal resources exist throughout the western United States. The Geo-Heat Center in Oregon has identified more than 9,000 thermal wells and springs, more than 900 low-to-moderate temperature geothermal resource areas, and hundreds of sites using this energy for direct use applications in 16 western

states. There are 404 resource sites in these states that are within five miles of communities, with the potential to serve 9.2 million people (Geo-Heat Center, n.d.).

Geothermal energy has many agricultural applications. Vegetables, flowers, ornamentals, and tree seedlings are raised in 43 greenhouse operations heated by geothermal energy. Forty-nine geothermal aquaculture operations raise catfish, tilapia, shrimp, alligators, tropical fish, and other aquatic species. Agri-industrial applications include food dehydration, grain drying, and mushroom culture. The drying of onions and garlic is the largest industrial use of geothermal energy (Lund, 2005).

Ground source heat pumps can be applied in most rural areas. It is estimated that 600,000 – 800,000 ground source heat pumps are now in use in the United States. The majority of the geothermal heat pump installations in the United States are in the mid-west, mid-Atlantic, and southern states (from North Dakota to Florida) (Lund, 2005).

In the future, new technologies such as enhanced geothermal systems (EGS) promise to reduce the cost of geothermal power. These can be developed by fracturing rock to increase underground fluid flow and permit heat extraction. Projects underway in Europe and Australia are advancing knowledge on how to use EGS for power production

Biorefineries

Discussion of renewable energy from biomass centers on the concept of the “biorefinery,” where new technologies are being used to extract energy and other valuable products from biomass resources. Like oil refineries, biorefineries are envisioned as indus-

trial facilities that convert a stream of raw material into a varied slate of products, maximizing value by shifting the mix of output to match dynamic market conditions. Potential biorefinery products include liquid fuels, such as ethanol and biodiesel, electricity, steam, and high-value chemicals and materials. Many of these products have the potential to replace petroleum, either as a vehicle fuel or as a chemical feedstock, resulting in increased energy security and reduced environmental emissions.

In a sense, biorefineries already exist. They process corn into ethanol, corn syrup, animal feed, and other products, or transform trees into a variety of wood products, electricity, and heat, to name two examples. For the next generation of biorefineries, researchers are developing processes for exploiting the large amount of energy contained in plant cellulose — a difficult but potentially rewarding goal. In one biochemical process (referred to as the sugar platform), enzymes are used to break apart cellulose molecules, creating sugars that can be fermented into ethanol or processed further to create industrial and consumer products. A thermochemical process (the syngas platform) involves heating biomass to turn it into a gas composed of a few basic molecules, then processing this raw material into fuels and products through chemical or biological techniques. Researchers are also pursuing ways of turning biomass resources into useful products by using advances in plant genetics and biochemistry to develop crops designed for specific biorefinery endproducts.

Bioproducts may be the key to biorefinery development. They could provide higher economic value than bulk energy production, and increased diversification in the prod-

uct slate for these industrial facilities would provide flexibility in responding to dynamic markets. An example of a product made with biorefinery technology is Toyota Motor Corporation’s bioplastics, used to make automobile components. Already used in the Toyota Raum (sold in Japan), this plastic is made from sweet potatoes and other plants. Another example is DuPont’s Sorona, a family of polymers made from 1,3-propanediol (PDO) that can be used in fabrics, plastics, and in other applications. PDO can be made from sugars derived from corn.

The United States has significant biomass resources. It has been estimated that the cellulose available from just forestland and agricultural land, the two largest potential biomass sources, could amount to 1.3 billion dry tons per year. While this quantity is six times greater than current production, researchers believe that it could be achieved with relatively modest changes in land use and agricultural and forestry practices (Perlack et al., 2005). Another biomass resource with significant potential is municipal solid waste, a byproduct of modern life.

Expanding the Potential of Renewable Energy

Renewable energy technologies are being used in a variety of applications on farms and ranches and there are many opportunities to expand their use in the future. For example, renewable, farm-based biomass and other renewable energy sources may be able to fuel hydrogen production; agricultural vehicles running on hydrogen could have the same efficiency and environmental benefits planned for light-duty cars and trucks; and hydrogen fuel cell tech-

nology could provide power for remote locations and communities.

Where do we go from here to encourage renewable sources of energy that are important to agriculture, such as solar, wind, geothermal, and biomass? The development of a new energy future will require research, development, demonstration, deployment, and commercialization of new technologies. Each of these activities must function as part of a continuum flowing from the research bench to commercial application, with feedback loops among the various steps. Collaboration, education, and policy will all be important.

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Bioproducts: Developing a Federal Strategy for Success

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JEL Classification: Q3

Bioproducts are nonfeed or food industrial goods composed to a significant degree from biological products, renewable domestic agricultural materials, or forestry materials. Hydraulic fluids, lubricants, biopharmaceuticals, chemicals, and building materials all fall within the product range of bioproducts. There are a wide variety of feedstocks that can be used to make bioproducts, including grains, wood and plant oils, agricultural and forestry residues, switchgrass, and hybrid poplar.

Agricultural and forestry groups have long been intrigued by the potential of such a nonfood market for their feedstocks. In 1987, a report from the New Farm and Forest Products Task Force to the Secretary of Agriculture recommended diversification of agriculture as a way to improve the economy through the production of biobased products (New Farm and Forest Products Task Force, 1987). The Task Force cited the development of a bioproducts market as a way to address excess capacity, a loss of competitiveness in the international trade arena, and shrinking export markets. In addition, international trade in high value products was seen as increasing (New Farm and Forest Products Task Force, 1987).

More recently, the cost and security risks of imported oil, environmental concerns, as well as advances in biological sciences have renewed policy interest in biobased products. Biobased products often require less energy to produce than the fossil and inorganic products they replace (Committee on Biobased Industrial Products, 2000). Biobased products can improve air and water quality, as well as reduce waste compared to their competitors. Also, biobased products can sequester large amounts of carbon while adding little if any net carbon emissions to the atmosphere.

A Systems Approach

The efforts of agricultural producers and processors to develop and produce new biobased energy and coproducts have matched growing consumer interest in environmentally friendly products. Bioenergy and bioproducts were largely driven first by government policy research initiatives. Yet, despite substantial investment in research to improve bioproduct production technology, widespread market penetration for bioproducts has not been realized. This does not mean that money for research has been mispent, rather, it is likely that there has been underinvestment in other steps required to bring new biobased energy and coproducts to market.

In the past, the development of bioproducts was focused on basic research. There was a need to determine the efficiency and economics of production from non-petroleum feedstocks to assess their viability and supply. While basic research provided the information to narrow the focus on feedstock choice and the types of products to produce, it has done little to apply the research to real-world conditions that would allow for investment from the business community.

A more "systematic" approach could result in greater penetration of commercial markets by bioproducts. The process of bringing new products to market may be viewed as consisting of links in a casual chain extending from the research bench and its product prototypes to market acceptance and penetration. Those links include research, testing, regulatory initiatives, product development and commercialization, public sector incentives, and financing, as well as education and outreach programs. We discuss below the links in that casual chain and suggest ways to be more successful in creating a demand pull for bioproducts.

Research

Basic Research

Basic scientific research applied to biological systems seeks to understand fundamental questions about plant and animal genetics, physiology, structure, chemical composition and function of living plants animals, bacteria, and viruses. Basic research, an essential ingredient at the beginning of the causal chain, seeks to discover and understand facts, develop theories about the fundamental workings of biological systems, and to revise those theories as new facts are discovered and understood. The focus of this research is on how cells, organisms, and entities work the way they do, rather than on what products are useful to mankind that can be made from them.

Applied Research

Applied biological research can be thought of as the second link in the causal chain, and builds on the discoveries and understanding of basic research/science. It takes those findings, understanding of systems, and theories about biological systems and asks how these can be used to create effects that improve the lives of living creatures, enhance their performance, and better the circumstances in which humankind finds itself. Here the focus is creating product prototypes that have potential to fill market needs.

The Biorefinery Concept

The results from effective basic and applied research can provide bio-based feedstocks that are of increased productivity, more uniform in the characteristics being sought, and can be processed into a wider range of end products at lower cost and greater efficiency. A biorefinery is capable of producing feedstocks into

primary components and reassembling those into a range of end-use products that includes products spanning the value spectrum from lower valued products in greater quantity to more specialized and higher value products, albeit in limited quantity. In many respects, a biorefinery mirrors the refining of petroleum and creation of a wide range of products from that process. A number of biorefinery concepts have been developed, including paper mills, wet corn milling to produce ethanol or high fructose corn syrup, and production of bio-plastics from corn.

Testing

Testing of new bioproducts and product prototypes seems to be a critically important step in bringing them to market. An important component of the attributes embedded in these products (such as biodegradability) relates to their affect on the environment; it is important to know whether these products have lower life-cycle costs and environmental footprints than the fossil energy-based products they will replace. Many products currently in use have industry-or user-determined performance standards that represent the threshold performance levels these products must meet.

Regulation

Regulatory initiatives can play an important role in encouraging firms to try new technologies and new products. One example is the renewable fuels standard from the Energy Policy Act of 2005 that creates a market for transporting biofuels. Regulatory flexibility can encourage the use of best practices for environmental management, which often will incorporate bioproducts. Regulatory initi-

atives also may include tax credits or incentives. Life cycle analysis of bio-based fuels from “cradle to grave” could ultimately provide carbon credits for industry trading, thus lowering the net cost of biobased fuel production.

Product Development and Commercialization

Product development involves refinement and fine-tuning of product prototypes to address specific market demands as well as demonstration projects that test the product in use to determine how effectively it fills a market need. Demonstration projects are a critical step and will likely be an interactive process with research and product testing steps, as the developer seeks to create a product that cost-effectively fills a market need. Product demonstration can also play an educational role as potential customers evaluate the usefulness of a product and learn how it might be used in their applications.

Another important step in commercialization of bioproducts involves procurement preferences for federal, state, and other public sector purchasing. These preferences fill at least three important functions in commercialization: First, they provide a broader based and more diverse opportunity to demonstrate the product in use to potential customers: second, they provide a critically important demand base large enough for suppliers to scale up production, thereby achieving economics of scale and decreasing product cost, and finally: public procurement preferences can stimulate sufficient market demand to bring new suppliers and their competitive efficiencies into the market.

Public sector incentives to support new industries often extend

beyond procurement preferences. Tax credits, such as investment and research tax credits, can be used to decrease both risk and cost to private firms that develop, manufacture, and commercialize a new product, use a new and untried production process, or enter new markets. Insurance coverage can be created to support risk management associated with the use of new and untried technology that might be used in producing a new production process, such as cellulosic conversion of plant lignin for use in a new biorefinery, or a new bioproduct.

A Policy Foundation

Major new industries in the United States typically have been supported by a set of public policies. These policies have signaled the support of public policy makers for the new industry and the willingness of the public sector to reduce, or at least make more quantifiable, the risks associated with the new industry. This has been true for the automobile, radio and television, aircraft, computer, and oil industries. Public policy makers have understood this imperative for the bioeconomy and have developed a support base of public funding for basic and applied research and for stimulating product development through grants, loans, and loan guarantees to start up firms. Other policy initiatives such as renewable fuels targets and excise tax exemptions also have under-girded the growth in demand for these new products - as in the case of ethanol and biodiesel.

The policy role is particularly important in the development of the bioeconomy because the benefits of using the products are widely shared in society - the environmental sustainability, carbon cycle manage-

ment benefits, and public health benefits of biobased products are captured widely by society, not just by those who buy and use the products.

Financing

Financing is a large concern for firms entering into new business ventures or offering new products to the marketplace. The public sector can provide important early stimulus to developing new products and creation of new firms to advance the bioeconomy development. This support typically has been in the form of grants and loans/loan guarantees. Grants are often made available to new business ventures, or to ventures engaging in new product development and marketing. Acquiring equity capital has proven to be an even larger challenge for rural based start-up firms. Equity capital is difficult to acquire, and the tendency, especially with cooperatively organized business firms, is to go forward with the minimal amount of equity capital necessary to support the debt capital used in the start-up. That action can add unnecessary risk to the new business equity because it means there is little built-in financial resiliency to sustain business setbacks.

An array of private sector and public/private sector partnerships can facilitate financing. It is almost always preferable to own part of a successful venture than to own all of a venture with a high risk of failure. Creating competitive access to venture capital and "angel" capital (individual investors) for new business start up and expansion is a problem in rural America, and thus, creating investment networks that focus on rural and biobased businesses may be part of the solution.

Overcoming rate of return barriers on new investments in plants and equipment to support bioproduct production is a particularly difficult issue for private sector firms entering a new and inherently higher-risk market—one that usually has high entrance requirements in terms of capital and technology. Public sector investment partnerships, tax credit plans, and grants can be particularly helpful in enabling the first generation of new production and marketing to gain a competitive foothold.

Access to specialized insurance or other risk-bearing strategies to protect cash flow during periods of business interruptions could prove helpful. Contracts that fix feedstock costs and facilitate market demand also are important for lowering financial risk to levels that business firms are willing to bear.

Education and Outreach

Finally, educational and outreach programs that provide science-based information on biofuels and bioproducts to policymakers, manufacturers, and consumers can be important in obtaining successful market penetration. Understanding product environmental and performance characteristics is key to a product launch. Bioenergy products have to be more than "green"; they also have to be priced competitively and add more value than the competition.

A First Step

USDA is committed to developing a more holistic approach with its programs. On December 7, 2005 Secretary Johanns created an Energy Council under the leadership of Under Secretary for Rural Development, Tom Dorr. The newly formed Council was instructed by the Secretary to review USDA's existing energy

and bioproduct related activities, authorities and resources, and recommend how, with other government and private sector entities, to maximize the effectiveness of USDA's current programs and resources "...so that we have a comprehensive, integrated and intensified effort" (Johanns, 2005).

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