# *Impacts of Cellulosic Ethanol on the Farm Economy*

By Bruce E. Dale*

## Size of the agricultural resource base for cellulosic ethanol

**Background—**Very different claims have been made regarding the potential size of the lignocellulose ethanol industry in the United States. The more pessimistic estimates tend to assume that agriculture and forestry will not change much in response to a large demand for biomass for ethanol production and also that yields of cellulosic biomass will also not change much. Neither assumption seems valid. Agriculture has changed greatly in the past in response to technology and societal demands. For example, prior to World War II less than a million acres of soybeans were harvested in the U.S. Wartime demand for protein and improved agricultural practices, combined with processing technology for producing soybean oil and protein meal, catalyzed the very rapid growth of soybean acreage to approximately 75 million acres today–about one sixth of our total cropland. The total amount of biomass available for cellulosic ethanol will depend on the yield and acreage devoted to such crops. We briefly examine both variables in turn.

**Yield of Cellulosic Crops—**Our existing major crops (corn, soybeans and wheat) have primarily been bred for high production of grain or oilseed. These breeding programs have been very successful. Corn yields have increased by over five fold (from about 30

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bushels per acre to about 150 bushels per acre) in the past 50 years. These yield increases are due partly to increased inputs (agrochemicals, agricultural mechanization, etc.) and also to better plant genetics. We have never bred or developed cellulosic biomass species for high yields-there has been no demand for such cellulosic crops. For example, two promising perennial grass species for ethanol production are switchgrass and *Miscanthus*. The current highest reported yields for these species are between about 10 and 20 tons per acre per year. With the necessary agronomic research effort, it is entirely reasonable to believe that within a decade or two, the high yields can become average yields.

**Land Devoted to Cellulosic Crops—**We have about 450 million acres of cropland in the United States with approximately another 580 million acres of grassland pasture and range. Forest use land totals about 640 million acres, for a total of nearly 1700 million acres of land potentially available to produce feedstocks for ethanol production. Approximately 40 million of these acres are in the Conservation Reserve Program, a government program designed to take more fragile lands out of conventional grain or oilseed production. If we devote only 100 million acres to energy crop production and obtain an average of 15 tons of biomass per acre per year on that acreage and then convert that biomass to ethanol at 100 gallons per ton (approximately 85 percent of the theoretical maximum yield), we will produce 150 billion gallons of ethanol per year. This is equivalent to about 75 percent of the gasoline we currently use, taking into account ethanol's lower energy content per gallon.

**Transition Issues—**How can we start on the road to this promising future? Is there enough biomass to get this industry going in the absence of high yield biomass crops and large acreages devoted to cellulosic ethanol? Yes, there is. A recent comprehensive study by the Department of Energy and the Department of Agriculture identifies a sustainable supply of about 1.3 billion tons per year of biomass available in the near to mid term with proper management practices. The energy value of this much biomass is very nearly equal to 3.5 billion barrels of oil, which happens to be the energy content of the most oil the United States has ever produced in one year.

**Food versus Fuel Concerns—**Some are worried that large scale production of ethanol from cellulose will reduce food supplies in a hungry world. However, the actual world situation seems quite different than this picture. Recent analysis suggests that population growth rates are declining and that world population will stabilize by mid-century. China and India, once large food importers, are now much more nearly food self sufficient. Per capita production of wheat more than tripled in China from 1960 to 2000 while rice production per capita nearly doubled. India achieved less, but still very significant, growth in per capita food production. Also, most agricultural production capacity in the developed world does not feed humans directly, but rather feeds our livestock and humans then consume the meat, milk, eggs, cheese, etc. that the animals produce. Finally, large cellulosic ethanol productions facilities (called "biorefineries") will almost certainly coproduce animal feed just as biorefineries based on corn grain do now. Thus acreage devoted to cellulosic ethanol crops will probably produce both food and fuel.

## Farm Subsidy Issues

**Background—**Direct government payments for agricultural price supports between 1995 and 2004 averaged $14 billion annually, providing six percent of gross and almost one quarter of net farm income. Payments in 2005 were about $24 billion. Loss of these subsidies would be a serious blow to farmers. Recently the World Trade Organization (WTO) ruled that U. S. cotton subsidies provide an unfair trade advantage to U. S. farmers and are illegal. Similar WTO challenges are expected to other U. S. price support programs for grains, oilseeds, rice, sugar and dairy products. Thus traditional government support programs for agriculture are seriously threatened.

**Energy Payments Instead of Commodity Subsidies?—**Energy payments would probably pass WTO muster, or at least not be challenged in the WTO. Currently, farmland conservation subsidies are considered by WTO as "green box" programs, meaning they are not subject to international trade sanction. Payments that provide and leverage the greatest environmental benefits are most likely to sustain challenges to their green box status. Moreover, bringing suit in the WTO is very expensive. Thus there would seem to be little incentive for most countries with a significant cellulose (or sugar or starch) to ethanol program to bring suit, since their own programs would likely be subsidized at least in their early years. Brazil in particular has subsidized its sugar to ethanol program to the tune of about $10 billion over the past 25 years (and thereby has avoided importing about $50 billion worth of petroleum). Far more countries will probably wish to produce ethanol for domestic consumption rather than export it, further minimizing the danger of WTO challenges.

**Potential for Innovative Policy Measures—**Innovative, system wide policy measures can accelerate the growth of cellulosic ethanol while protecting farm incomes and ensuring market discipline. For example, incentives to build the first generation of cellulose ethanol biorefineries should largely rely on the private sector's due diligence process to decide which proposed projects are built. The first generation of these biorefineries will be under extreme financial pressure. Farmer subsidies of $10 or $20 per ton of biomass supplied to the biorefinery could make the difference between profitable operation or failure.

Even more creative policy approaches suggest themselves in this time of transition. For example, farmers might wish to participate financially in the biorefinery to capture some of the value added to their raw materials, in much the same way that farmer coops are participating heavily in the rapidly growing corn dry mill industry. Farmers might choose to provide raw materials to the biorefinery at reduced cost, in exchange for some sort of equity in the plant. Or the government might "buy" partial farmer ownership in the plant in exchange for permanent elimination of subsidies on that farmer's production.

## Impact on Corn Ethanol from Transition to Cellulosic Ethanol

**Background—**Currently about 4 billion gallons of ethanol are derived from corn grain in the U.S. The corn ethanol industry is slated to grow rapidly under the renewable energy standard included in the 2005 energy legislation, nearly doubling from the current 4.0 billion gallons per year to approximately 7.5 billion gallons per year. Corn farmers and ethanol producers are naturally concerned about the effect of a transition to cellulosic ethanol on the profitability of their farms and ethanol plants. These worries may be ill-founded. It seems far more likely that corn farmers and corn ethanol producers will benefit much more from, rather than be harmed by, a transition to cellulosic ethanol.

**Some Relevant Factors—**First, most farmers who produce corn for ethanol production can certainly grow biomass for cellulosic ethanol. High yielding, low input grass crops sold to the biorefinery at $50 per ton might well increase net farmer profit per acre compared with corn. Thus farmers need have no worry that they will not be able to participate in the supply side. Second, on the processing side, the existing capital investment in corn ethanol plants can probably be almost entirely recovered by converting such plants into cellulosic ethanol plants instead. Given their strategic location on rail lines, water transportation routes, etc., it is very easy to see corn ethanol plants becoming the nucleus of much larger cellulose ethanol biorefineries. One possibility is that corn ethanol plants would become the preferred location for converting solid cellulosic biomass to a liquid stream of concentrated sugars. This liquid stream would then be more easily shipped to much larger ethanol biorefineries.

**Transition to Cellulosic Ethanol—**Another important consideration is that corn ethanol producers are likely to be among the "first adopters" of cellulosic ethanol technology. Corn wet and dry mills produce significant amounts of cellulose-rich residues. As cellulose conversion technology develops, it is probable that these residues will be converted to ethanol in existing corn ethanol plants, which already have the infrastructure, supply system and much of the technology required. Given this head start in cellulosic ethanol, as expertise accumulates and production costs decrease, there will be a strong incentive to expand cellulosic ethanol production at these corn ethanol facilities. Expansion will probably occur by bringing in corn stover and/or dedicated biomass energy crops to what were formerly corn ethanol plants, making these facilities the cellulose ethanol biorefineries of the future. Alternatively, corn ethanol producers may eventually decide to use their facilities to produce more valuable biobased chemicals such as succinic acid, propanediol, lactic acid, etc. from corn rather than making ethanol.

**Expanding the Benefits to More Farmers—**Overall, many more farmers in many more states can expect to profitably produce cellulosic biomass than can competitively grow corn for ethanol. The "grass belt" is much broader geographically than the Corn Belt. Modeling done by the University of Tennessee predicts that farmers paid $40 per ton for switchgrass would plant 28 million acres of the crop and would produce 200 million dry tons. Obviously, they would produce even more at higher biomass prices.

If farmers were to receive between $40 and $50 per ton for cellulosic biomass yielding around 8 to 10 tons per acre, their gross receipts per acre would be comparable to those for corn. These biomass yields and prices are aggressive but not unrealistic. Each $10 per ton paid for biomass translates to approximately $0.10 per gallon for the resulting ethanol so that $50 per ton for the raw material translates into $0.50 per gallon of ethanol produced. As cellulose ethanol processing technology matures and processing costs decline, a reasonable goal is that processing will cost about half as much as raw material, so the ethanol will cost about $0.75 per gallon to produce, or about $1.10 per gallon on an equivalent energy basis with gasoline.

As farmers supply biomass for cellulosic ethanol the value of the remaining traditional crops would increase because reduced supply would generate better prices for these crop commodities. Total farmer net income would increase by well over $12 billion and these benefits would be distributed across the country with the largest increases occurring in the Plains states and the Corn Belt. Greater wealth and employment opportunities in rural America arising from cellulosic ethanol, both in crop production and the ethanol biorefineries, would benefit all farming communities, and the farmers who live there. Potential economic impacts of cellulosic ethanol on rural American communities are described more fully below. The cost of food should not be impacted much. Food prices are only affected slightly by crop prices received by farmers. But decreased or stabilized transportation fuel costs and enhanced energy security will benefit all Americans.

## Energy Balance Issues

**"Net Energy": A Brief History of the Controversy—**For about the last 25 years a small but vocal group of ethanol critics has argued that corn ethanol, and more recently, cellulosic ethanol, has a negative "net energy". Simply stated, their argument is that more fossil energy is used in the production of ethanol, for example in fuel for producing, transporting, and processing the corn, than is delivered in ethanol's usable energy. Their viewpoint has been widely disseminated in the country and is a major perceived drawback to ethanol fuel. However, both the basic premise of the net energy argument and their analysis are wrong. Here is why.

**Problems with the Net Energy Analysis—**The critics' most recent such paper[1] concludes that corn ethanol has a -29 percent net energy and also that cellulosic ethanol from switchgrass has about -50 percent. Ethanol's net energy is defined as ethanol's heating value minus the fossil energy inputs required to produce the ethanol divided by ethanol's heating value. Ethanol's heating value is a scientifically fixed, known quantity and is about 68 percent that of gasoline. Thus the only potential point of controversy resides in the fossil energy inputs required to produce ethanol. Here these ethanol critics make three fundamental errors, one of premise and two of methodology. These errors are treated in turn.

**All Btu are Not Created Equal—**Energy markets clearly show us that all Btu are not created equal. Otherwise, we would not pay 12 times as much for a Btu of electricity (at $0.08 per kWhr) as we do for a Btu of coal (at $40 per ton). For accounting convenience, the proponents of net energy analysis assume that one Btu of energy available from any energy carrier is equal to a Btu from any other energy carrier. But is this assumption valid? A little reflection and analysis shows that it is not. We do not value energy *per se* but rather the services or "qualities" that the energy provides. For example, the energy in coal cannot directly light our homes. Coal must be converted to electricity in a power plant to provide many desired energy services. We always lose some energy in such conversion systems, including the conversion of crude oil to gasoline.

**Data and Methods, and Lack of Comparisons—**Recent independent high profile metastudies in the leading journals *Science*[2] and *Environmental Science and Technology*[3] have showed that the ethanol critics used some obsolete data and inadequate methods in their analyses. Further, the ethanol critics were wrong about how energy will be provided in a cellulosic ethanol plant. The metastudies also highlighted a very important fact from all studies of ethanol's energy balance, both pro and con. That fact is that corn and cellulosic ethanol both greatly extend existing petroleum supplies. If we "invest" a barrel of petroleum to produce ethanol we will get much more liquid transportation fuel (on an energy basis) than we will if we invest that same barrel to make gasoline. Thus using ethanol greatly extends the life of our existing petroleum reserves.

A final flaw in the arguments against ethanol's net energy is that they provide no comparisons with alternative energy sources. Comparisons of alternatives are central to science and sound policy decisions, and it is not difficult to do so in this case. Using precisely the same net energy methodology and assumptions of ethanol's critics, one quickly finds that gasoline has a net energy that is no better than -37 percent while electricity's net energy is about -235 percent, compared with corn ethanol's supposed -29 percent net energy. Thus ethanol is actually superior to other fuels in its "net energy".

**What is an Appropriate Energy Efficiency Standard for Ethanol?—**If "net energy" is a poor measuring stick for ethanol's energy efficiency, is there a better one? There is room for discussion on this issue, but two complementary standards suggest themselves. First, ethanol could be rated on its ability to displace petroleum, our most pressing *energy security* issue. One barrel of oil yields about 0.9 barrels of liquid fuels (gasoline, diesel, etc) when refined. It also requires about 0.1 additional "barrels of oil equivalent" in the form of both coal and natural gas to discover, produce, refine and distribute gasoline and diesel, etc. In contrast, one barrel of domestic petroleum "invested" to produce ethanol will give us about 20 barrels of oil on an equivalent energy basis. Thus investing a barrel of oil to make ethanol from corn gives us 22 times (20/0.9) more usable liquid fuel than making gasoline and diesel from the same barrel. The numbers for cellulosic ethanol are similar and can be expected to improve as biomass yields increase. Second, ethanol could be rated on the total displacement of fossil fuels (petroleum, coal and natural gas) required to drive a mile, our most pressing *climate security* issue. Cellulosic ethanol will reduce the life cycle greenhouse gas emissions required to drive a mile by over eight times compared to gasoline.

## Rural Economic Impacts

**Background—**Of all the issues surrounding cellulosic ethanol, the economic impacts (and perhaps detailed assessments of the environmental impacts) are least studied. Thus only general statements providing some ranges of potential economic impacts can be provided at this time, mostly based on similar studies done for corn ethanol. These impacts can be divided roughly into: a) one time benefits from building the biorefineries, b) spending for continuing plant operations, and c) overall U.S. economic impacts.

**One-Time Benefits—**For sake of discussion, we will assume that 100 billion gallons of cellulosic ethanol capacity will be built over two decades. This is enough to displace about 70 billion gallons of gasoline per year, or roughly 50 percent of today's U.S. gasoline consumption. We further assume that these biorefineries will consume 1 billion tons of cellulosic biomass annually at a delivered price of $50 per ton, each biorefinery consuming 10,000 tons per day of biomass. Approximately three hundred such biorefineries will be needed to produce this much ethanol. Assuming they can be built for $1.50 per annual gallon of capacity, then $150 billion will be invested over 20 years to build the plants, or $7.5 billion per year. Using the data for corn dry mills, each dollar in plant construction would generate about $2.40 in a one time boost to the local economies as spending circulates, or about $18 billion per year in one time economic impact, much of it in rural America.

How realistic are these assumptions? A recent USDA/DOE study estimates that 1.3 billion tons of mostly cellulosic biomass can be sustainably produced on our lands, hence the 1 billion ton per year assumption above. A biomass price of $50 per ton is a reasonable target to allow attractive farmer returns and 10,000 tons per day is the approximate biorefinery size at which economies of scale are no longer very significant. Finally, a plant investment of $1.50 per gallon of annual capacity is comparable to that of recent corn dry milling plants for ethanol and seems a reasonable target for very large scale cellulosic ethanol plants, which are more complex than dry mills.

**Benefits from Continuing Biorefinery Operations—**Assuming that each plant spends about $165 million annually for biomass feedstock and that this raw material total represents 70 percent of total plant spending for all supplies and labor, then each plant will spend roughly $240 million per year for operations, or about $70 billion annually among all three hundred plants at the end of the twenty year transition period. Once again using data for corn dry mills, the local economic base surrounding these biorefineries would expand by about $140 billion per year and household income would expand by $25 billion annually, mostly in rural areas. The projected impact is very large, and would probably result in over 50 percent increase in total economic activity in affected areas. Assuming that each $200,000 in plant sales would support one new direct job in the agricultural and biorefining sectors, and an ethanol selling price of $1.00 per gallon, then a *half million new direct jobs* would be created, with a significant multiplier for indirect service and supporting jobs.

These numbers, although imprecise, are not at all unreasonable. Currently the U. S. fuels and chemicals industry employs about 900,000 people, many of them in commodity organic chemicals and fuels with total sales on the order of $1 trillion annually. As domestic oil and natural gas supplies have become more costly and scarcer, the fuels and chemicals industry is increasingly attracted to overseas locations where oil and natural gas are cheaper and supplies assured. As a result both domestic employment and economic activity suffer.

## Overall Impacts on the U.S. Economy

As a full scale U. S. cellulosic ethanol industry takes hold and grows, it will transform our economy in at least two ways. First, the domestic fuels and chemicals industry will be revitalized, with many new jobs being created and new wealth generated. Given the wide distribution and bulky nature of biomass resources these new jobs and new wealth will largely be produced in rural America, rather than near oil production/importing sites on the coast. Second, the entire U. S. economy will benefit by a strengthened fuels and chemicals sector. We will be able to retain more of our fuel dollars at home and our economy will be much better insulated from shocks due to high petroleum prices and uncertain availability.

## Footnotes

1. David Pimentel and Tad W. Patzek, "Ethanol Production Using Corn, Switchgrass, and Wood; Biodiesel Production Using Soybean and Sunflower," *Natural Resources Research,* Vol. 14, No. 1 (2005), pgs. 65-76.

2. Alexander E. Farrell, et al. "Ethanol Can Contribute to Energy and Environmental Goals," *Science*, Vol. 311, 27 January 2006, pgs. 506-508.

3. Roel Hammerschlag, "Ethanol's Energy Return on Investment: A Survey of the Literature 1990-Present," *Environmental Science and Technology*, February 2006.