

## A Research Report on Cellulosic Ethanol Investment

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### Preface:

This research report will look at a newly popular idea in alternative energy, cellulosic ethanol, and give investors useful information and data to use in analyzing the cellulosic ethanol industry. We will begin with an introduction containing a brief historical background of the situation regarding cellulosic ethanol. Then we will answer a few key questions: what is cellulosic ethanol? Is it better than corn-based ethanol? Can it replace gasoline? What will be the demand for it, and when will the supply be ready? We will conclude the report with a section containing profiles of the most interesting companies currently working on cellulosic ethanol.

### Introduction:

In recent years, alternative energy has become increasingly popular among Americans, going from a fringe idea of environmentalists into something embraced by mainstream Americans, and by corporate America. No longer reliant on oil, coal and nuclear, Americans now want more solar power, wind power, geothermal, hydroelectric, and other renewable energy. The purpose of this renewable energy is twofold. First, it will replace old, high-pollution energy sources with new less-polluting sources, reducing greenhouse gas emissions. This will curb global warming, increase air quality and improve the health of the American people. Second, it will improve American energy independence, reducing oil imports that entangle America with dangerous political instabilities in the Middle East and increasing domestic energy supplies that add dollars to GDP and create local jobs. This need has brought together a coalition of supporters, including scientists, industrialists, environmentalists, politicians from both the Left and the Right, and many segments of the American public.

Many solutions have been looked at in answering one of the main questions in renewable energy: how do we replace transportation fuels, which are dominated by petroleum-based gasoline, with a renewable alternative? At various times people have considered hydrogen fuel cells, biodiesel, and plug-in hybrids as viable alternatives to gasoline. But the choice that seemed to have the most promise was ethanol. Ethanol is a gasoline substitute that can be made from corn or sugarcane. Advocates promised that it would pollute less than gasoline, that it would end oil imports, and that it would create jobs. Focusing on American ethanol, which is made mainly from corn, ethanol advocates promised that ethanol would create a renaissance for the Midwestern corn farmers.

Ethanol use in the USA was mandated by Federal law, used to replace an additive blended into all gasoline. This blend, E10 (10% ethanol, 90% gasoline) could be used in any car, and was widely sold. Some gas stations started selling E85 (which is 85% ethanol, 15% gasoline), which is used by “flex-fuel” cars with special engines capable of running on E85. It seemed to some people that there was endless room for growth in ethanol demand.

Based on hype and optimism, these ideas led to a boom in ethanol companies, leading to the building of excessive ethanol capacity and a bubble in ethanol stocks. Unfortunately, as [Altenews.com](http://Altenews.com) predicted over a year before the events unfolded, the

ethanol companies built too much capacity, creating more supply than the demand could handle. This problem arose at the same time as some other disturbing facts appeared. First, a competition between corn for food and corn for fuel began, causing corn prices to go up. This hurt consumers, who bought corn and animals fed on corn, and it also hurt ethanol makers whose raw material was now more expensive. It became obvious that not enough corn could be grown to satisfy both corn for food and an unlimited demand for corn for fuel.

Meanwhile, critics pointed out that the environmental benefits of ethanol had been overstated and over-hyped. Ethanol did not displace enough oil, ethanol plants sometimes burned coal and produced extensive pollution, ethanol plants used too much water, and the use of ethanol as fuel produced some pollution, although how much was still debated. More recently an article in the journal "Science" claimed that when carbon released from changes in land uses are taken into account, the environmental benefit of ethanol is nonexistent.

When all of these problems with corn-based American ethanol emerged, the ethanol stocks collapsed. Now, the situation for corn-based ethanol is seen as dire. Advocates still paint a rosy picture of ethanol, and some people still believe in the promise of ethanol, but the public has become skeptical, and ethanol companies have lost their promising glow.

But a solution appears to be on the horizon, off in the distance but ready to come closer. Something that will solve all of the problems raised by corn ethanol, something capable of doing things corn ethanol just couldn't do. That solution is cellulosic ethanol.

Cellulosic ethanol is ethanol made from the sugar in cellulose. Cellulose is a substance found in all plant matter that forms the basic structure of the cells in plants. Previously it could not be used to make ethanol, but recent technological breakthroughs seem to make it possible that we can take the cellulose in plant matter, extract it, process it and turn it into ethanol. The new feedstock is not the starch in corn, it is "biomass," a term for plant matter used as energy.

There are three competing technologies for the production of cellulosic ethanol. The first, acid hydrolysis, uses acid to break down the cellulose. The second, enzymes, using biologically created, genetically engineered enzymes to break down the cellulose.

The third, thermo-chemical, uses heat and chemicals to turn the cellulose into gas, called “syn-gas,” and then uses a biological or chemical catalyst to turn the syn-gas into ethanol.

If cellulosic ethanol can be commercially viable, if it can be cheaply mass-produced, then it may solve all of the problems of corn ethanol. First, cellulose is found in the inedible parts of the plant, so there will be no competition between biomass for food and biomass for fuel. Cellulose can be found in agricultural wastes, such as corn stover, sugarcane bagasse, rice straw and wheat straw, all of which are naturally occurring byproducts of farming those crops. It can be made from wood chips, which can easily be found as waste products in logging and on construction sites. It can be made from energy crops such as switchgrass and fast-growing trees. It can also be found in garbage and landfills. All of this provides an abundance of feedstock that will not compete with the food supply.

Second, the environmental benefits of cellulosic ethanol, according to the science, will far surpass that of corn-based ethanol. Whereas corn-based ethanol reduced pollution by approximately up to 30% (according to some estimates), cellulosic ethanol may reduce pollution by as much as 80%. It takes less oil to produce it, and it takes less water to produce it. The crops used to produce biomass soak up carbon as they grow, reducing pollution. And also significant is that a byproduct of creating cellulosic ethanol is the extraction of lignin, a substance in plant matter that hold cell walls together. The lignin can be burned to produce power, so that cellulosic ethanol plants can use biomass instead of coal for power and further reduce pollution.

There is also a third way in which ethanol from cellulose is better than ethanol from corn. Because of the limits to corn production and competition from corn for food, corn-based ethanol can only ever replace a small percentage of petroleum-based gasoline, perhaps 10%. But because there is so much available biomass, because cellulose is one of the most abundant biological substances on the planet, it may be possible to make enough cellulosic ethanol to make a serious bid at replacing gasoline as the nation’s favored automotive fuel. By some estimates (which we shall look at later) there may be enough biomass to replace 20% or 30% of gasoline by 2030, and Altenews will conjecture that perhaps, in 2050, with the right technology we might be able to replace gasoline completely.

In the next section we will look at the facts and data and try to discover the truth about cellulosic ethanol, and to distinguish the genuine promise from the hype.

## Section One: Cellulosic Ethanol's Potential for Growth

In this section we will look at the data and facts relating to cellulosic ethanol. The central question guiding this investigation will be a simple one: what is cellulosic ethanol's potential for growth? This leads to other questions: What is the demand for ethanol, both now and in the future? Can corn-based ethanol fill this demand, or is cellulosic ethanol necessary? Is there a "ceiling" to how high corn-based ethanol supply can go? What supply of cellulosic ethanol can be created to satisfy demand? Is there enough biomass to provide raw material for the supply? When will cellulosic ethanol be commercially viable? How much cellulosic ethanol can be made, how much gasoline will it replace, and what will the environmental benefit be? Will cellulosic ethanol create the political, economic and environmental benefits that its advocates promise?

We begin by looking at the demand for ethanol, which is related to the demand for gasoline. 142.569 billion gallons of gasoline was used in 2007, according to DOE EIA data. DOE EIA also provides estimates for gasoline usage in 2030. In 2030, biofuel use is estimated at 29.7 billion gallons, 11.3% of total vehicle fuel (which means approximately 263.7 billion gallons of transportation fuel in use). Ethanol use in 2030 is estimated at 24.3 billion gallons used, 13.3 billion gallons of which will be blended into E10, and 11 billion gallons of which will be sold to flex-fuel drivers as E85. Corn ethanol will provide 15 billion gallons of the 24.3, and ethanol imports will increase after the protective tariff expires in 2009, contributing some sugarcane-based ethanol to that number. But based on this it is still reasonable to assume demand for 9 billion gallons of cellulosic ethanol in 2030. We feel that this estimate is lower than it realistically should be. America will have both the supply and demand for more ethanol usage, as will be shown below. Based on the USA federal mandate, discussed below, the actual demand will be much higher.

The data suggests that demand for ethanol in 2008 is high right now. If gasoline is blended with ethanol at 7.76%, then 10.86 billion gallons of ethanol will be blended into

gasoline. 50% of all gasoline contains ethanol, as E10. The demand for E85 is also high. 1400 gas stations offer E85 right now, and there are 6 million flex-fuel vehicles on the road. GM, Chrysler, Ford have pledged to make half their new vehicles flex-fuel by 2012. DOE projects 11 billion gallons of E85 sold in 2030, but if the number of flex-fuel cars increase, and the gas stations offering E85 increase, then this demand could rise sharply. This may also happen because E85 stations are concentrated in the Midwest (the corn farming region), but cellulosic ethanol will be made all over America, spreading interest in E85.

Some demand for ethanol will be satisfied by imported ethanol (mainly from Brazil), but there should still be a healthy demand for domestic ethanol. In 2007 the U.S. imported 426 million gallons ethanol, 188 million of which was from Brazil. Imported ethanol faces a steep protective tariff in the U.S. This tariff ends in January 2009. However, there is likely to be an intense political battle over whether to extend the tariff or not, and so American ethanol may continue to see some form of protection. To judge the future demand for ethanol, it is necessary to look at the Renewable Fuels Standard, the legal federal mandate for ethanol usage created by the Energy Independence and Security Act of 2007 (HR 6). This law mandates consumption of ethanol, and specifies the mandate for cellulosic ethanol. The mandate from 2009 to 2012 is that in 2009 600 million gallons are mandated, in 2010: 950 million gallons, in 2011: 1.35 billion gallons, and in 2012: 2 billion gallons.

In 2015, 15 billion gallons of ethanol from corn is mandated, and 3 billion from cellulosic ethanol is mandated. The mandate for corn-based ethanol holds at 15 billion gallons a year, but the mandate for cellulosic ethanol grows to 5.5 billion in 2017, and peaks at 16 billion gallons per year in 2022.

These levels are mandated. This will increase the demand for ethanol and make a stable, steady demand. But while corn-based ethanol will reach a “ceiling” at 15 billion gallons/year, cellulosic ethanol might grow much faster and reach a higher level. Even though the mandated levels create a minimum demand, there may be a much bigger maximum demand if flex-fuel vehicles and E85 become popular. It must also be noted that some states have passed their own ethanol mandates, creating more local demand.

To know how much gasoline will be displaced by ethanol, we must know how many gallons of ethanol is equivalent to 1 gallon gasoline? Some estimates hold that ethanol contained only 75% of the power of gasoline. But advocates claim that E10 has little noticeable difference in energy, and E85 flex-fuel engines can supposedly be modified to get only a small difference. Because of this, one may estimate replacement at a gallon for gallon level, or at 80% to 90%.

We have seen that there is a growing demand for ethanol, created by consumers and also mandated by the government. Cellulosic ethanol can count on a minimum demand of 16 billion gallons per year in 2022, and so capacity will have to expand from the absence that exists now to a full 16 billion gallons per year. This, however, is only a minimum, and if E85 becomes popular with drivers the demand could go much higher. More interestingly, if the political realm ever feels that it would be useful to go for the distant but possible goal of replacing gasoline with a domestic, more environmentally friendly alternative, then a mandate could be passed creating demand of as much as 260 billion gallons per year. (Later we will look at whether that capacity is possible.) When the benefits of cellulosic ethanol become popular knowledge, and if environmentalists see this as a cause or “Big Business” see this as an opportunity, that could become a very real possibility.

Demand for automotive fuels is going to remain steady, and may grow considerably. In order for the United States to curb its politically dangerous addiction to oil, and to help prevent global warming from destroying the planet, for political, economic, and environmental reasons, a great portion of gasoline must be replaced with domestically produced ethanol. The supply is supported by government mandates for ethanol usage. But can ethanol supply meet the demand? First let’s look at whether corn-based ethanol can do this, and then consider whether cellulosic ethanol is necessary.

Corn-based ethanol’s demand in the Renewable Fuels Standard is capped at 15 billion gallons per year. But could corn-based ethanol contribute more than that? Can corn-based ethanol satisfy all of the demand for ethanol, or is there a natural limit, a “ceiling,” that limits corn-based ethanol production? The data may provide an answer.

What is the current corn-based ethanol capacity, and what is its expected growth? The corn-based ethanol capacity in 2007 was 7.88 billion gallons. There were 139 bio-

refineries in 21 states. 6.49 billion gallons of corn-based ethanol was actually produced. In 2008 there is expected to be 11.8 billion gallons capacity, with 68 bio-refineries under construction or expanding. There will be 13.42 billion capacity when all current construction on ethanol plants is complete. It would seem that corn-based capacity is poised to reach 15 billion gallons annually, but may not go beyond that.

Now let's look at the raw material, corn. In 2007 approximately 14 billion bushels of corn were collected. Ethanol consumed 2.3 billion bushels, or 18%. In 2007 93.6 million acres of corn were planted. The yield was 153 bushels per acre, for a total of 14.32 billion bushels. In 2007 there was a 1.9 billion bushel surplus. The USDA expects 90 million acres of corn to be planted in 2008. This number may fluctuate, but it could go up to 100 million acres. It is estimated that if wheat and soybeans were replaced with corn (which is not a real possibility) then a full 225 million acres of corn could be planted. It is also expected that yield may go up to 170 bushels per acre in 2017.

Now let us look at what this means for ethanol production. The percentage of the USA corn crop used for ethanol is expected to rise to 30%. It is estimated that 1 bushel of corn yields 2.8 gallons of ethanol, and that 1 acre of corn yields 400 gallons of ethanol. Assuming 100 million acres of corn planted, a yield of 170 bushels per acre, and 30% of the American corn supply used for ethanol, that would allow somewhere between 12 billion gallons and 14.28 billion gallons of ethanol to be produced. Going beyond 15 billion gallons per year would strain the American corn supply to its breaking point. What impact would that have on corn prices, and on the price of raw material for corn-based ethanol plants?

USDA expects corn prices to rise to \$4.60/bushel in 2008, and the price could rise to \$5/bushel in the future. That totals to an input price of \$1.78/gallon just from corn alone at 5\$/bushel and 2.8 gallons/bushel. That is only from the corn, without the costs of operating the ethanol plant and transporting the ethanol taken into account. The cost of making 1 gallon of corn-based ethanol could rise to \$2/gallon. At that price, ethanol is not competitive and ethanol makers will lose their profit margin. Cellulosic ethanol, it is believed, could be made for \$1/gallon or less. If ethanol's need for corn grows, competition between corn for food and corn for fuel could push the price of corn even higher, making both consumers and ethanol makers suffer.

The environmental benefit of corn-based ethanol has also been hyped. It is claimed that corn-based ethanol reduces greenhouse gas emissions by around 30% (more precisely by up to 28% or 29%), and that the use of ethanol in 2007 eliminated 10.1 million tons of pollution. But many ethanol plants operate using coal or oil, and it has been estimated that it takes 1 unit of oil to make 1.3 units of ethanol. This does not displace much oil. Critics claim that 3 gallons of water produce 1 gallon of corn-based ethanol, while 2.5 gallons of water produce 1 gallon of gasoline. Because of this ethanol plants are notorious for using excessive water. Cellulosic ethanol, in contrast, may only take 1 gallon water to make 1 gallon ethanol, and may use 1 unit oil to make 6 units ethanol. Critics have also claimed that corn-based ethanol is not energy efficient, that it takes more energy to make than it gives out, and that it gets much worse mileage-per-gallon than gasoline. All of this is open to debate, and science suggests that the critics' claims are exaggerated, but it is clear that corn-based ethanol is not the solution for a greener future.

The demand for ethanol is there, and is ready to grow due both to consumer choices (flex-fuel cars using E85) and, even more, because of Federal and State mandates for ethanol consumption, with the goal of helping the environment and creating American energy independence. But because of logistics in supply, such as the competition between corn for fuel and corn for food, it is not realistic for corn-based ethanol to go beyond 15 billion gallons/year and meet the goal of replacing 20% or 30% of gasoline with ethanol. There is an inherent "ceiling" that keeps corn-based ethanol production at or below 15 billion gallons annually. Beyond that level of corn being used for ethanol, the competition for corn will drive up food prices and ethanol input prices to a point where everyone, both consumers and ethanol makers, will suffer.

It seems that this has already been accepted, since the Federal corn-based ethanol mandate stops at 15 billion gallons per year. There is no demand with which to extend corn-based ethanol capacity beyond 15 billion gallons per year, nor would the logistics allow for this to happen. Thus it is impossible for corn-based ethanol to replace gasoline as America's car fuel of choice. Also, corn-based ethanol's environmental benefits have been overstated, critics have made the case that corn-based ethanol does not help the environment very much, and something else is needed to curb global warming.

The solution to this problem is cellulosic ethanol. Cellulosic ethanol is energy efficient (it contains 6 times the energy used to make it), pollutes less (as much as 80% less than gasoline), and does not compete with the food supply (it can be made from agricultural waste, forest products waste, and inedible energy crops). Cellulosic ethanol, unlike corn ethanol, according to our predictions, does not have an inherent supply “ceiling” that will limit supply and prevent it from making a bid to seriously replace gasoline as America’s fuel of choice.

What kind of growth in cellulosic ethanol can we expect to see? We can pose this in terms of a minimum expectation and a maximum expectation. The minimum, to meet the Renewable Fuels Standard mandate, is 2 billion gallons annual capacity in 2012, 5.5 billion in 2017, and 16 billion gallons in 2022. This by itself should spark a boom in cellulosic ethanol in the decade from 2012 to 2022. But this is only the minimum, which assumes some ethanol blended into gasoline and some sold as E85 to flex-fuel drivers. There is also a different set of assumptions used to calculate a maximum: some advocates want ethanol to replace 20% of gasoline usage by 2030. We at Altenews think that it would be reasonable to set a goal of replacing 30% of gasoline in 2030, and it may be possible to think about using ethanol to completely replace gasoline at or around 2050. One might optimistically expect as much as 53 or 80 million gallons per year of cellulosic ethanol usage in 2030, which would replace 20% or 30% of gasoline. And if America makes a bid to seriously replace gasoline with ethanol, cellulosic ethanol capacity could go up to 260 million gallons per year, or higher, by 2050. The era from 2012 to 2022 should see a huge increase in cellulosic ethanol capacity, sparking an ethanol boom. The era from 2022 to 2050 might see a massive shift in the structure of the American economy from an oil-based economy to a biomass-based economy. The actual demand for ethanol could be the minimum, the maximum, or anywhere in between.

The question is: does America have the biomass, and the productive technologies, to meet those goals, and to make that capacity commercially viable? And how soon will cellulosic ethanol be ready to be commercially mass-produced? When will it go from the research and development stage to the commercial stage? And which companies will be the ones to take advantage of the opportunities? To look at this we must examine the data regarding cellulosic ethanol.

Cellulosic ethanol can be made with three different technologies, acid hydrolysis, enzyme, or thermo-chemical gasification. Each has advantages and disadvantages, and the many different cellulosic ethanol companies use many different versions of these technologies. Acid hydrolysis is an established method. However, it may not be the cheapest method, and there is some debate about whether it produces more energy than it consumes or not. Enzyme-using methods are becoming more popular. However, these depend upon finding the right fungi and bacteria and genetically engineering them to produce the right enzymes. This technology is being improved in the lab, but there is still more improvement that needs to be done. Thermo-chemical gasification promises to be cheap, and to use as feedstock a wider array of substances than the other two. But it is also in the development stage and needs to be improved.

In spite of the need for the technologies to be improved, it is estimated that cellulosic ethanol technology will be commercially viable and will go from the research and development stage to the industrial stage of commercial production in 4 to 5 years. That will put it on schedule to meet the goals set for 2012. Many companies are currently in the stage of setting up pilot and demonstration plants to develop their technology for use in commercial-sized plants.

Two things should be pointed out about commercial cellulose-based ethanol plants. The first is the idea of the “bio-refinery.” The bio-refinery is postulated to be like a refinery, except that it will use biomass instead of petroleum as feedstock. It will produce fuel and other chemicals typically made from petroleum. It will be large enough to take advantage of economies of scale, so that the products will be cheaper to make. It is believed that the bio-refinery will one day replace the refinery. The companies that are the first to make a real working bio-refinery will be able to take command of large segments of the biofuels market.

Second, cellulosic ethanol can be made from all different types of biomass. It can be made from agricultural wastes such as corn stover, sugarcane bagasse, rice straw, and wheat straw. It can be made from forest wastes such as wood chips and paper pulp. It can be made from energy crops such as switchgrass and fast-growing trees. And it can be made from the vegetable matter in garbage, found in landfills or waste disposal systems. Because of this, the plan of most companies is to locate their bio-refinery very close to

the source of the biomass. This will reduce transportation costs, increasing profit margins. But this means that cellulosic ethanol production will be very regional, so that there will be room all across the country for many different cellulosic ethanol producers to flourish in different regions.

How much will it cost to make cellulosic ethanol? Analysts claim that cellulosic ethanol will have to cost \$1/gallon or less to be competitive. Once the technology is perfected and commercially viable, and large bio-refineries have been built, it is expected that the producers will succeed in producing cellulose-based ethanol for \$1/gallon. Some analysts are even predicting that cellulosic ethanol could be made as cheaply as \$0.50/gallon. The situations of the various companies will dictate the cost of the ethanol. Factors such as the cost of biomass feedstock, the size of the bio-refinery, and the proximity of the location of the bio-refinery to the feedstock source will determine cost. Agricultural and forest residue, energy crops, and the plant matter in garbage or landfills may all have different costs. These various factors will impact the price of the raw material. Bio-refineries located close to the source of the feedstock, and to consumer markets, will pay less for transportation. And larger bio-refineries may find economies of scale. To some degree price ultimately depends upon the details of the technology and how it is implemented.

How much capacity can be built, and how fast? It is expected that capacity can be built to meet the Renewable Fuels Standard of 5.5 billion gallons of cellulosic ethanol in 2017 and 16 billion gallons in 2022. In order for these goals to be met, cellulosic ethanol capacity will have to expand rapidly from 2012 to 2022. This could lead to a boom in the ethanol industry. One expert has predicted that growth in cellulose-based ethanol capacity may resemble growth in corn-based ethanol capacity, in this regard: that it will be difficult and require technological breakthroughs to reach 2 billion gallons capacity, but it will be much easier to go from 2 to 6, and from 6 to 12. Some companies already have viable technologies that only need to be tested in demonstration plants to be ready, while others are still in the process of research and development. Most companies plan to follow a path of first building a pilot plant, then a demonstration plant, and then a commercial plant. Most of the companies are now building or planning their pilot plants, while some are working on demonstration plants. A few have, or are close to, operational

demonstration plants. Some estimates claim that a typical commercial bio-refinery should have a capacity of 15,330,000 to 21,900,000 gallons per year.

A source that we spoke with has confirmed that there are several demonstration plants currently in operation, and predicted that many large-scale commercial bio-refineries may appear in 2010 to 2011. But this source cautioned us not to be overly optimistic. Regarding the price of ethanol, it must be noted that the two variables, the technology used and the cost of the feedstock, will have a dramatic effect on the price of the ethanol. This source was skeptical of estimates of \$1/gallon, saying that there are too many unknown variables to make such a prediction. But he did say that cellulosic ethanol will have to be at or lower than the price of corn-based ethanol in order to be competitive, and so corn-based ethanol may have an unforeseen impact on cellulosic ethanol prices. The price of gasoline and corn-based ethanol will determine the price of cellulosic ethanol. We at Altenews would say that \$1/gallon is an optimistic view, but nonetheless some analysts have made that prediction, and only time will tell how the technology develops.

Next we must look at a very important question: How much cellulosic ethanol can be made, given the supply of biomass in the United States? Is there enough biomass to meet the mandated goals? Is there enough biomass to one day completely replace gasoline with cellulosic ethanol?

First we must ask: How much ethanol per ton of biomass is made? The estimates vary based on which company and which technology are looked at. The low estimate is 70 gallons per ton, and the high estimate is 125 gallons per ton. There are estimates of 120 and 84. We may take as an average the estimate of 100 gallons of ethanol made from one ton of biomass.

Next, we must ask how many tons of biomass are available to be used as a feedstock for cellulosic ethanol production? To get this data there are two sources that we will consider. There was a popular and influential study of this matter done by the USDA and DOE in 2005, which contains a wide array of data relating to biomass. But before we look at that we can look at some USDA estimates regarding cropland.

Assuming that 1.25 tons of biomass per acre can be collected, how much agricultural waste will each crop yield? How much ethanol can be made from corn

stover? In 2006 the USDA reports 93.6 million acres were planted. That could have yielded 117 million tons biomass. How much from wheat straw? 60.4 million acres were planted in 2006, which could have yielded 75.5 tons biomass. How much from rice straw? 2.7 million acres were planted in 2006, potentially creating 3.3 tons of biomass. And how much from sugarcane bagasse? 2006 saw 883,000 acres planted, potentially creating 1.1 million tons biomass.

This leaves us with a total of 196.9 million tons of biomass from agricultural waste. This could make 19.69 billion gallons of ethanol without any land use changes (or 24.61 billion if technology enables 125 gallons per ton). This raises a serious objection to the criticism that land use changes will negate the environmental benefits of cellulosic ethanol. In the short term, up to about 20 billion gallons annual capacity, no land use changes will be required. We could also potentially get biomass from garbage and landfills, and from forest waste and paper mills, creating potentially much more capacity without land use change. One estimate claims that a full 40 billion gallons/year of ethanol could be created using only garbage in landfills as feedstock.

Now let us look at the USDA/DOE 2005 report (“Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply,” April 2005). The study found that 1.3 billion tons of biomass can be collected annually from forests and farms with few changes by 2030. That would enable from 130 billion to 162.5 billion gallons of cellulosic ethanol to be produced, which would put America one giant step closer to saving the environment and replacing gasoline. However, before we get optimistic, we must look at the details of the study, which contain some very questionable assumptions.

The study claims that 368 million dry tons can come from forestland, and 998 million dry tons from farmland, for a total of 1.366 billion tons. The study says that the United States of America has 2,263 million acres, 33% of which (749 million acres, of which 77 million is protected) is forest, and 20% of which (455 million acres, of which 342 is active, 39 is idle, and 67 is pasture) is cropland.

In the forestland, 52 million tons will come from fuel wood from forests, 145 million of waste from wood processing mills and pulp and paper plants (or much less, maybe 10 million), and 47 million from construction and demolition debris (This number

also includes wood in municipal solid waste, i.e. garbage.) 64 million will come from logging and site clearing residues (wood chips), and 60 million dry tons will come from treatment to reduce fire hazards (removing small or rotting trees from forests to reduce the risk of forest fires).

The assumptions used in this part of the study are that for foresting, only forests with roads and without environmental protections were considered. Recovery of wood chips in forests of 50% to 65% was assumed. This assumes that a portion of wood was left on site for soil protection, and that most wood collected went to consumer products. It also assumes forest growth of 89 million tons biomass by 2030.

The study includes 8 million tons of forest products industry waste, 20 million from construction and demolition (8.6 from construction, 11.7 from demolition), and 8 million from wood in consumer garbage (6 million from wood, 1.7 million from yard and tree trimmings).

That gives us 368 total. But it is only 308 without fire hazard treatment, 256 without wood gathered for fuel, and 121 if the more conservative estimate of waste from mills and plants is used. These assumptions are questionable, but nonetheless it may be reasonable to use 368 as a feasible number. This is especially the case because it seems to Altenews that 8 million of biomass from consumer garbage (i.e. municipal solid waste) is too low to be reasonable. It might be the case that garbage in municipal solid waste and landfills could provide upwards of 20 million tons of biomass, or more. This is especially attractive because garbage has no financial value in itself.

In farmland, the study claims the availability of 428 million tons of biomass from annual crop residue (corn stover, rice straw, sugarcane bagasse, etc.), 377 million tons from perennial energy crops (switchgrass, etc.), 87 million tons of grains used for biofuels (i.e. corn-based ethanol), and 106 million tons of animal manure and miscellaneous biomass. This gives us 998 total. But there is only 892 without manure (which cannot be readily turned into ethanol), 805 without counting corn-based ethanol or manure, and only 428 if only plant waste is considered and no energy crops are assumed.

The assumptions of the study are that yields will double by 2030, collection of residue (that is, plant waste from harvests such as corn stover) will be raised, and 55 million acres of cropland were converted to use by energy crops.

The study considers three different scenarios in making its predictions. In Farm Scenario One, 194 million dry tons are possible without technology changes to increase plant waste collection and energy crops, 75 million tons of which is from corn stover, 11 million tons of which is from wheat straw. In Farm Scenario Two there are no energy crops but more technological improvements, producing 600 million tons. And in Farm Scenario Three there may be 998 million dry tons, due to soybeans bred to yield more residue, and energy crops such as switchgrass and poplar trees. 35 to 55 million acres will be used for energy crops, yielding 5 to 8 tons of biomass per acre, with 93% of the harvest being used for biomass. The study notes that biomass will vary widely from year to year, due to annually fluctuating factors affecting farm biomass such as weather, soil cultivation, yield per acre, and residue per harvest. Biomass from agricultural sources will also vary because different breeds of plants produce different amounts of residue, so that plant breeding may increase residue.

Regarding energy crops it is estimated that farmers would need to be paid \$40 per ton (for an input price of \$0.40/gallon), and in the near term farmers could plant 42 million acres and get 4.2 dry tons per acre. The study assumes 8 tons per acre in 2030, made possible by technological advances.

Based on the study, if we are to consider conservative estimates, we should not count on the numbers that the study comes up with. But in spite of the fact that some of the assumptions are questionable, by 2030 we can expect significant and numerous changes in technology, both in agriculture and forestry and in the production of cellulosic ethanol. Based upon this we would feel justified in claiming approximately 1 billion tons of biomass available in 2030, which could produce 100 billion to 125 billion gallons of cellulose-based ethanol in 2030. If we assume 263.7 of transportation fuel consumed in 2030, that could displace approximately 38% to 48% of gasoline usage. It could also be blended to produce 117 to 147 billion gallons of E85. And if the cellulosic ethanol can be made for \$1/gallon and sold for \$2/gallon, it could blossom into a \$100 billion dollar industry.

Beyond 2030, say for example in 2050, factors such as new technologies might push production even higher. These numbers also may be too low because some cellulosic technologies can supposedly make ethanol from a more diverse range of feedstocks, such as rubber and plastics, enabling more garbage in municipal solid waste and landfills to be turned into ethanol. It can also be assumed that if ethanol becomes more valuable, farmers may convert more acres to energy crops, and more wood from forests might be switched from lumber and paper products to ethanol production.

To conclude our analysis of cellulosic ethanol, we must look at its environmental impact. What is the environmental benefit of cellulosic ethanol? It promises an 80% reduction in GHG (greenhouse gases), compared with approximately 30% for corn-based ethanol. How much oil does the process use? How much does it replace? This varies based on which technology is used, but some general idea can be reached. Critics say it takes 7 barrels of oil to make 8 barrels of corn-based ethanol, and the ethanol has less energy than gasoline, so there is no reduction in oil use from using ethanol. Cellulosic ethanol promises to displace much more gasoline, in part because lignin instead of oil can be burned to power the plants. Other estimates say 1 barrel of oil makes 1.3 barrels of corn-based ethanol, but makes 6 barrels cellulosic ethanol. Thus, cellulosic ethanol promises to be six times better for the environment than corn-based ethanol, which is itself an improvement over gasoline.

What is the net energy content in cellulosic ethanol? E85 gets 12 mpg compared to gasoline at 16 mpg, according to one estimate. That is 75%. However, there is some debate on this, with some advocates of ethanol claiming that E10 drives like gasoline, and that flex-fuel motors can be modified to get better mileage from E85. If that is true, then the net energy different may not be significant.

How much pollution will cellulosic ethanol eliminate? One estimate claims that biofuels could reduce greenhouse gas emissions by 1.7 billion tons per year by 2050. We can arrive at a different estimate based on the data. Transportation fuels create about 2 billion tons of GHG annually. Therefore, replacing 30% with ethanol that is 80% less polluting would eliminate 480 million tons of GHG. Replacing 50% would eliminate 800 million tons of GHG. This could be done by 2030, and it would go a long way towards protecting the environment and stopping global warming.

Does carbon release from land-clearing eliminate the environmental benefit from energy crops? The science seems to indicate that while it reduces the benefit for energy crops, it is not completely eliminated, and this is not true at all for biomass made from plant waste matter, which does not create land use changes, and from which a huge amount of ethanol can be made. Land cleared for energy crops will release some carbon into the atmosphere. However, the plants that are raised will absorb some of the carbon back as they mature. There is still an active debate about the environmental impact of ethanol made from energy crops. However, a huge portion of cellulose-based ethanol can be made from forest waste, agricultural waste, and garbage, none of which release carbon due to land clearing.

## Section Two: A Who's Who of Cellulosic Ethanol

This section features a series of profiles on the most interesting companies involved in cellulosic ethanol. The profiles are given in alphabetical order, and it is noted whether the company is public or private.

Abengoa Bioenergy is a public company (Symbol: ABGOF, Pink Sheets). It operates in Europe, U.S., and South America. It currently operates several current ethanol plants in the U.S., and is developing a cellulosic ethanol pilot plant in the U.S. and a demonstration plant in Spain. Abengoa uses enzymes for hydrolysis, but is also researching a thermo-chemical/syngas process.

Alico is a public company (Symbol: ALCO, Nasdaq). Alico is planning a 13.9 million gallon/year plant in Florida, using yard and vegetable waste as feedstock. Alico has received DOE and Florida State grants. They use BRI's gasification technology. Alico is primarily an agricultural company based in Florida, and ethanol is not its primary focus.

Arkenol is a private company. Its goal is to build bio-refineries and make cellulosic ethanol using a concentrated acid hydrolysis method. They are in the process of

building a 4 million gallon a year plant in California. Their technology has been licensed by BlueFire.

BlueFire Ethanol, based in California, is a public company (Symbol: BFRE, OTC:BB). It has a technology for concentrated acid hydrolysis, created partially by Arkenol, that is supposedly commercially ready. BlueFire is running demonstration plants, and plans a commercial plant in California, near a landfill, that will convert green waste into ethanol. BlueFire was given a DOE grant in 2007. The company wants to own and operate cellulosic ethanol plants, and claims that it can make ethanol from straw, wood chips and vegetable matter in garbage. Once its two plants in California are operating, it will produce 22 million gallons/year.

Colusa Biomass Energy Corporation is a public company (Symbol: CLME, Pink Sheets). It has a proprietary biomass to ethanol process, and is seeking funding. Based in California, they plan to build a facility that will make cellulosic ethanol using rice straw as a feedstock. They claim that their plant, when completed, will consume 130,000 tons of biomass and produce 12.5 million gallons of ethanol per year.

Coskata is a private company. It has partnered with GM, and one of its investors is the famous venture capitalist Khosla (who has invested in numerous cellulosic ethanol start-ups). They claim to have made a breakthrough in cellulosic ethanol technology, using a thermo-chemical process. They use heat and pressure to turn biomass into synthetic gas, and then uses microorganisms to make the gas into ethanol. This process uses only 1 gallon of water per gallon of ethanol, and their process can use anything dry and carbon-based, not just plant matter. They claim that garbage including tires and plastic can be used as feedstock, which would dramatically increase the potential for capacity growth. They estimate their ethanol can be made at or under \$1/gallon. They plan a 40,000 gallon demonstration plant to be operational in 2009, and a commercial plant built by ICM will be operational in 2010, and will produce 100 million gallons/year. They plan to supply ethanol to GM.

Dyadic is a public company (Symbol: DYAI, Pink Sheets). Dyadic is a company that uses genetic engineering on fungus to produce enzymes, for clothing and more recently for cellulosic ethanol. A short time ago the CEO was replaced after fraud was discovered in the company's Asian sales division. The dismissed CEO subsequently accused the company of owing him \$2.4 million. The company failed to file because of its accounting scandal and was de-listed from the AMEX. The stock reacted badly to all the bad news, and the company is seeking to be bought or to sell its assets.

Genencor International is a private company, but it is owned by Danisco of Copenhagen, Denmark, which trades on the Copenhagen stock exchange (symbol: DCO.CO). Genencor is an enzyme company that is making enzymes for cellulosic ethanol. Danisco is a large European sugar and ingredients company for whom Genencor's cellulosic ethanol is only a small segment. Genencor is building a \$3 million plant in Iowa for cellulosic ethanol enzymes.

Green Star Products is a public company (Symbol: GSPI, Pink Sheets). They have developed a technology to make biodiesel and ethanol using algae as feedstock. They have also bought two ethanol plants in Kentucky with the goal of making "super" high-octane ethanol.

Gulf Ethanol is a public company (Symbol: GFET, Pink Sheets). Gulf ethanol takes sugarcane-based ethanol from CAFTA/CBI countries in the Caribbean and South America and sells it in the United States. Rather than making their own ethanol they merely take it and resell it. They are also seeking to take advantage of cellulosic ethanol by finding someone who can make it for them and then reselling it.

Iogen Corp., based in Ottawa, Canada, is a private company. Their investors include Royal Dutch/Shell, Goldman Sachs, and Petro-Canada. Long considered to be the leader in cellulosic ethanol technology, they operates the world's only currently operational scale-sized cellulosic ethanol demonstration plant. Their demonstration plant

uses wheat straw, as a feedstock, and the ethanol that they make is currently in use in cars and trucks in Canada.

Lignol Energy Corp. is a public company (Symbol: LECFF, Pink Sheets). Based in Vancouver, British Columbia, Lignol has acquired cellulosic ethanol technology and plans to make ethanol using wood from Canadian forests as a feedstock. It currently runs a pilot plant and wants to build a scale demonstration plant, and then a commercial bio-refinery. They have received a DOE grant to build a demonstration plant in Colorado, to be run by Suncor.

Mascoma is a private company. It is backed by venture capitalists including Khosla and Kleiner Perkins Caufield & Byers. Mascoma is a science R&D company that develops biological methods for making cellulosic ethanol. They are building a 5 million gallon per year bio-refinery in Tennessee, which will use switchgrass as feedstock. Partnered with University of Tennessee, they plan to be operational in 2009. They also have plans for a wood-based plant in Michigan.

Novozymes is a public company that trades on the Copenhagen stock exchange (Symbol: NZYM.CO). Based in Europe, Novozymes is an enzyme company for which a small segment is supplying enzymes for use in making cellulosic ethanol. Novozymes recently failed to meet analysts' earnings expectations and predicted lower than expected future growth in 2008.

Pacific Ethanol is a public company (Symbol: PEIX, NASDAQ). Pacific Ethanol, a longtime leader in corn-based ethanol production, has partnered with BioGasol on a cellulosic ethanol project. BioGasol is an ethanol technology company based in Denmark. Pacific Ethanol received a DOE grant of \$24 million to build a cellulosic ethanol demonstration plant, using BioGasol technology, in Oregon, using wheat straw, wood chips and corn stover as feedstock. The plant, scheduled to be completed in 2009, will produce 2.7 million gallons annually.

Poet, formerly known as Broin, is a private company. A corn-based ethanol maker since 1987, Poet is using technology from DuPont and Novozymes and building a 125 million gallon per year cellulosic ethanol plant in Iowa, using corn stover as feedstock. The plant is due to be completed in 2009.

Range Fuels is a private company. Founded and funded by venture capitalist Vinod Khosla and his Khosla Ventures, Range Fuels uses gasification technology instead of enzymes. Range Fuels is building a plant in Georgia to use wood as feedstock, which it is claimed will have capacity of 1 billion gallons/year. Their thermo-chemical process turns biomass in syngas, then turns syngas into ethanol using a “catalyst,” without using enzymes.

Stora Enso North America is a public company (Symbol: SEOLF, Pink Sheets). Stora Enso is a European paper and forest products company. Their North American division recently received a grant to build a demonstration plant for making cellulosic ethanol.

SunOpta is a public company (Symbol: STKL, Nasdaq). A Canadian company, SunOpta is primarily a food company and only 1% of revenue comes from cellulosic ethanol operations. They are planning a 10 million gallon per year demonstration plant. SunOpta in January 2008 made a large accounting error regarding earnings and is being sued by investors in several class action lawsuits. SunOpta is also suing Abengoa, a former partner in cellulosic ethanol.

Syntec Biofuel Inc. is a public company (Symbol: SYBF.OB, OTC BB). Syntec uses a thermo-chemical process to make ethanol from syngas made from biomass. They have a catalyst that turns biogas into ethanol. They have expressed interest in building a bio-refinery.

Verenium Corp. is a public company (Symbol: VRNM, Nasdaq): Verenium makes enzymes, and has a cellulosic ethanol demonstration plant. Verenium was made

from the merger of Diversa and Celunol. Their process uses enzymes that can produce ethanol from both cellulose containing glucose and hemi-cellulose containing non-glucose sugar. It plans to build a plant in 2009 with capacity of 30 million gallons/year.

Xethanol is a public company (Symbol: XNL, Amex). Once a leader in corn-based ethanol, Xethanol now also has plans regarding cellulosic ethanol. Xethanol plans a cellulosic ethanol demonstration plant in Florida using citrus peel waste as feedstock, and it received a \$500,000 grant from the Florida state government for this purpose.

Conclusion:

It is still very early for cellulose-based ethanol. The technology has not yet been tried on a commercial level, some technologies are still in development, and there are many factors and variables relating to the economics of cellulosic ethanol that are as yet unknown. But if one is to take estimates that are optimistic, but reasonable, and which conform to Federally mandated expectations, one can expect a boom in cellulosic ethanol in the decade from 2012 to 2022. Beyond that, it may be feasible to replace 20% to 30% of gasoline in 2030, and to one day, possibly by 2050, make a bid to replace American gasoline usage with cellulosic ethanol.

Cellulosic ethanol promises all the things that corn-based ethanol promised but failed to deliver: energy efficiency, significant environmental benefits, domestic energy independence and freedom from Middle East political instabilities, and a very real prospect for displacing a substantial amount of petroleum usage. Furthermore the economics seem to indicate that there will be room for many different companies, in different regions and using different technologies, to profit from cellulosic ethanol. For these reasons we at Altenews.com are optimistic about cellulosic ethanol, and we believe that now is the right time to seriously consider cellulosic ethanol investments.