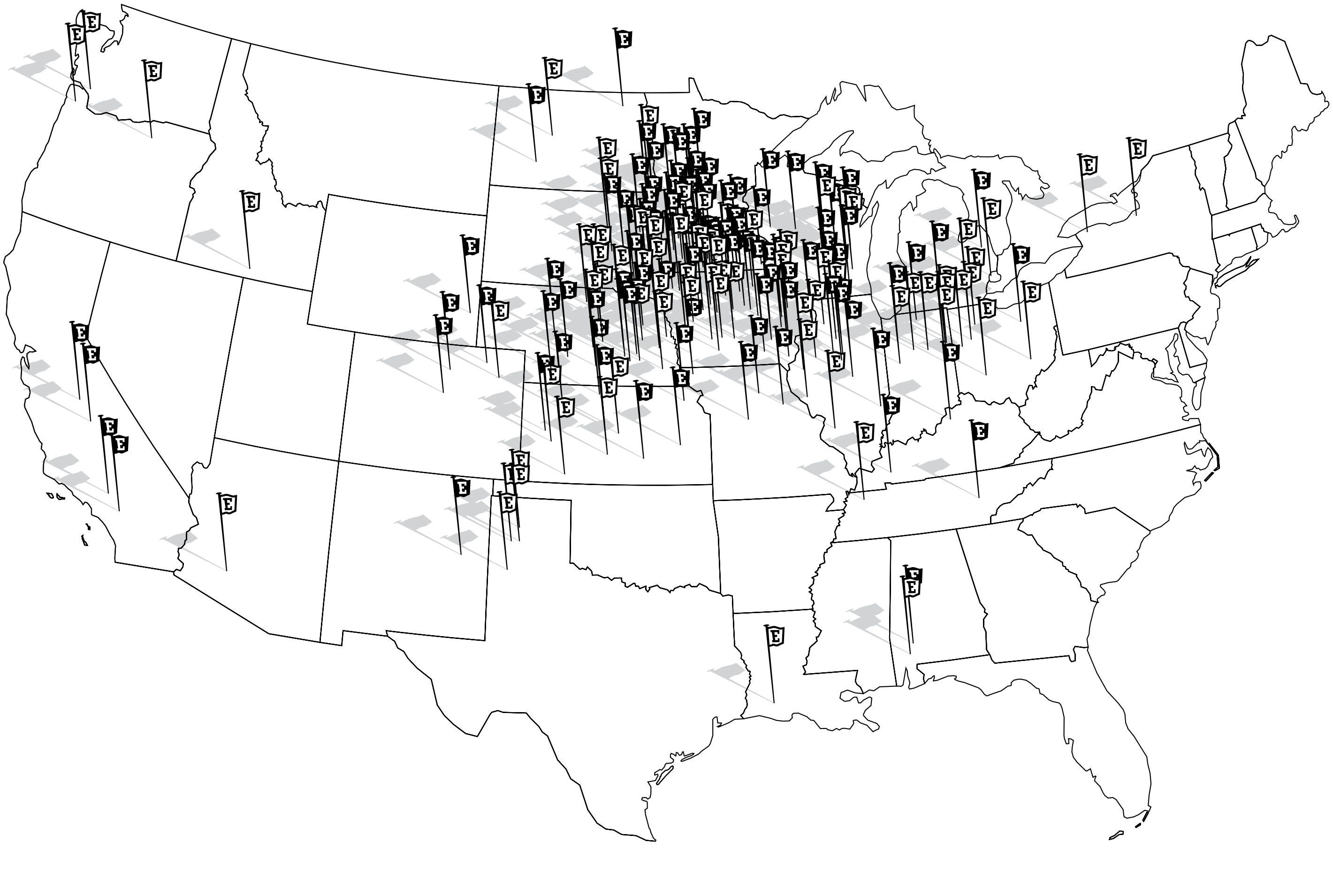
A Special Management Report From

Ag Equipment Intelligence

BIOFUELS:

POSSIBILITIES AND POTENTIAL FOR AG EQUIPMENT



An *Ag Equipment Intelligence* Staff Report

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I. Energy Use and Production: America Under Stress

History reports that in 1776 it took Thomas Jefferson 17 days to draft America's Declaration of Independence. Less than 7 days later on July 4, the U.S. Congress officially adopted the document thereby resolving: "That these United Colonies are, and of right ought to be, free and independent States."

More than 200 years later, it's become clearly evident that it will take "these free and independent states" significantly longer to become free and independent of foreign petroleum.

Since the energy crisis of the early 1970s, America has talked of reducing its dependence on foreign sources of oil and the use of alternative fuels, but it took the country another three decades to get serious. It took $3.00 a gallon gasoline for the American public to notice we may be in another, more serious energy crunch. But this time, someone's doing something about it.

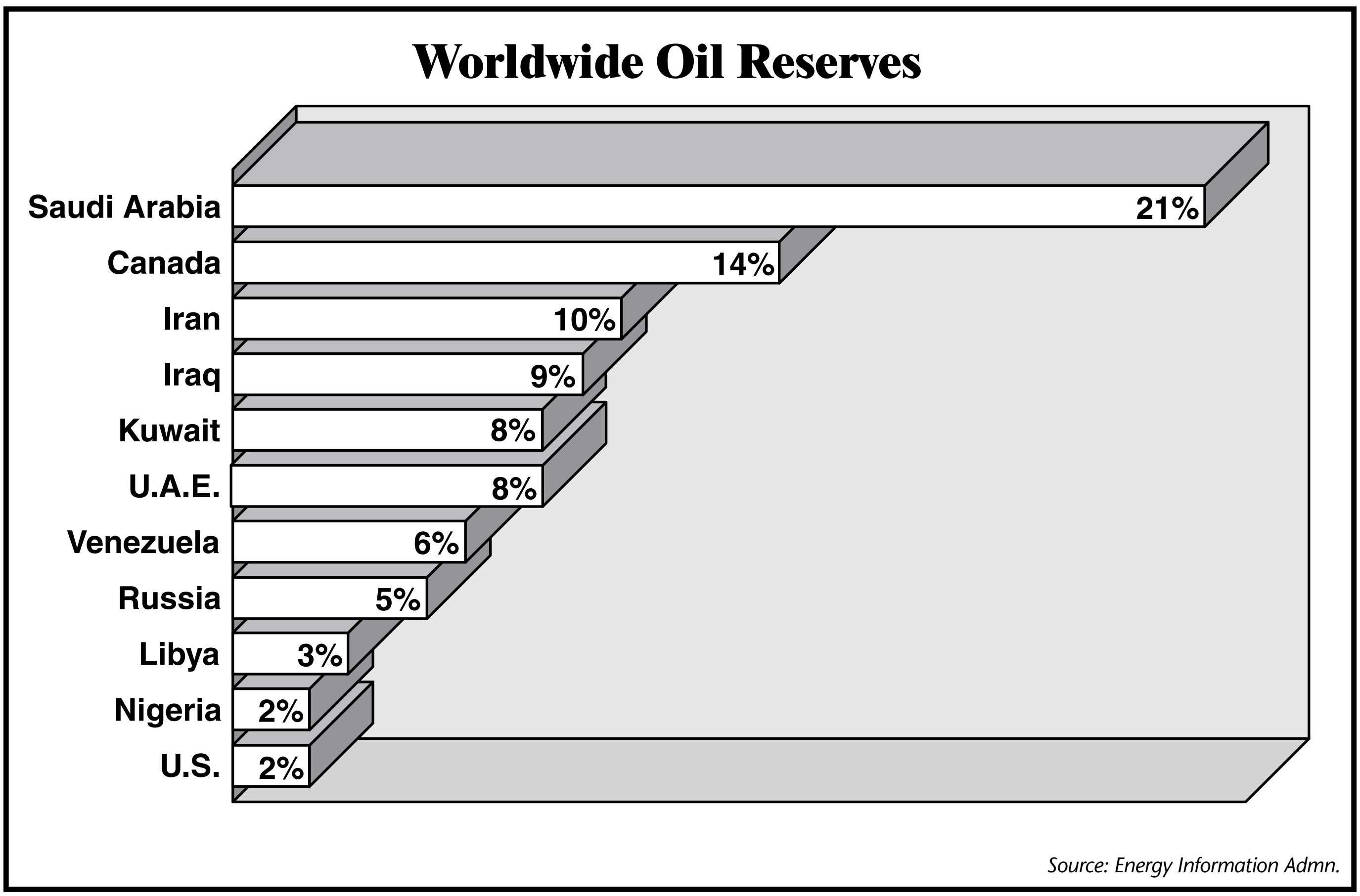
In his 2006 State-of-the-Union address, President George W. Bush made the pronouncement that the United States needs to "move beyond a petroleum-based economy," and then lent his support to the further development of energy from biomass and the increased production of fuels from renewable resources such as corn, soybeans and cellulosic material.

Considering this analysis and the fact that biofuel plants have been the only new refinery capacity the U.S. has added in the past 25 years, the call for increased production of renewable energy didn't come a decade too soon.

Don Borgman, John Deere's director of agricultural industry relations for North America, in his white paper presented on January 4, 2007 —*Agriculture, Biofuels and Striving for Greater Energy Independence* — summed up the impact of the President's comment in a sentence: "While these statements alone did not accelerate the recent increase in production of biobased fuels, they certainly cast the spotlight on renewable fuels and the agricultural sector that plays such a vital role in sustaining this burgeoning industry."

Addressing a Volatile Situation

Today, energy independence for the U.S. has become a matter of national security, economic well-being and



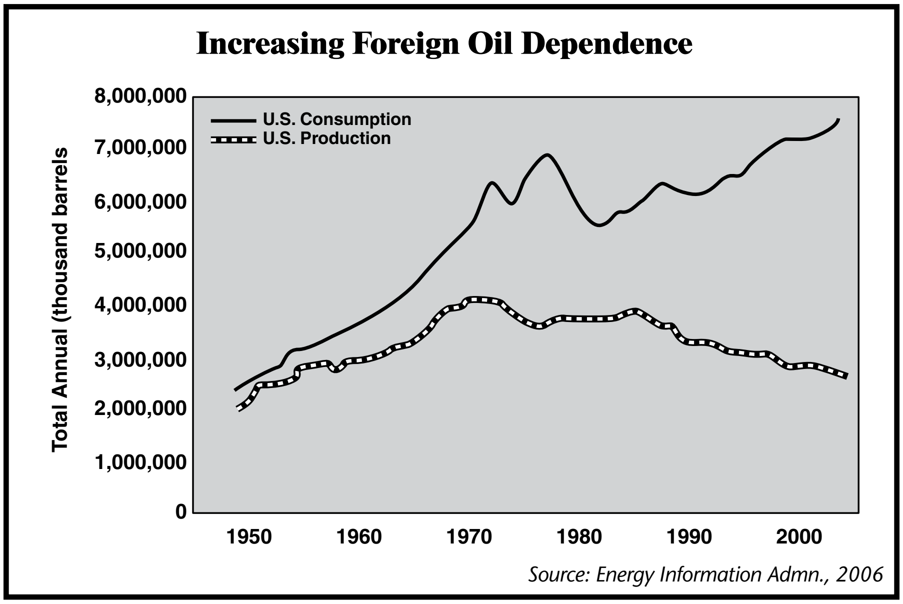
While the U.S. holds less than 3% of worldwide oil reserves, it accounts for 25% of global consumption. Nearly 60% of the world's reserves of oil are found in unstable regions, which is a major concern for U.S. national security.

environmental sustainability. America accounts for 25% of all global oil consumption, but has only 3% of known oil reserves. Some 60% of global oil reserves come from unstable regions in the world. Oil prices have become increasingly volatile and petroleum supplies unpredictable.

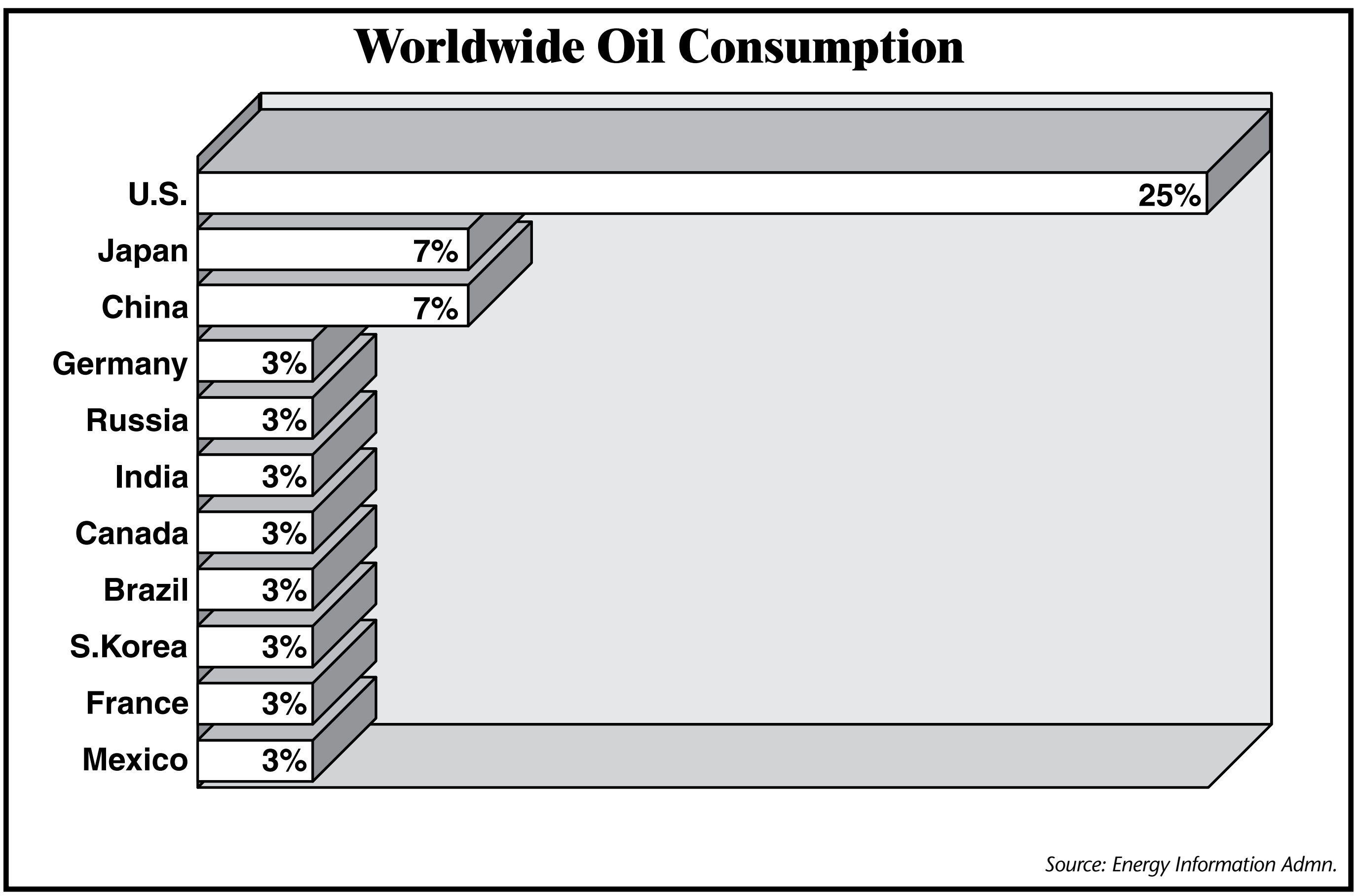
According to the Deere white paper, the U.S. Department of Energy forecasts that by 2030, energy consumption in the U.S. will increase by more than 30% from 2006 levels. The growth in energy to meet the transportation sector alone is forecast to increase by more than 40%. Projections for global energy growth show requirements outside the U.S. increasing at an even faster pace.

Considering this analysis and the fact that biofuel plants have been the only new refinery capacity the U.S. has added in the past 25 years, the call for increased production of renewable energy didn't come a decade too soon.

It's no secret that world oil prices have increased sharply since 1999



While U.S. oil production has decreased during the past 60 years, its consumption has grown dramatically, compounding its dependence on foreign sources of oil.



The most dramatic illustration of the precarious position of the U.S. when it comes to energy dependence is the fact that it consumes as much oil as does the next 6 highest consuming nations combined.

when the annual average nominal price of West Texas Intermediate (WTI) oil jumped from $19.25 per barrel in 1999 to $30.29 in 2000. From 2000 to 2003, the average WTI price ranged from $26 to $31 per barrel. Starting in 2004, WTI prices surged from $41 per barrel to over $56 per barrel in 2005.

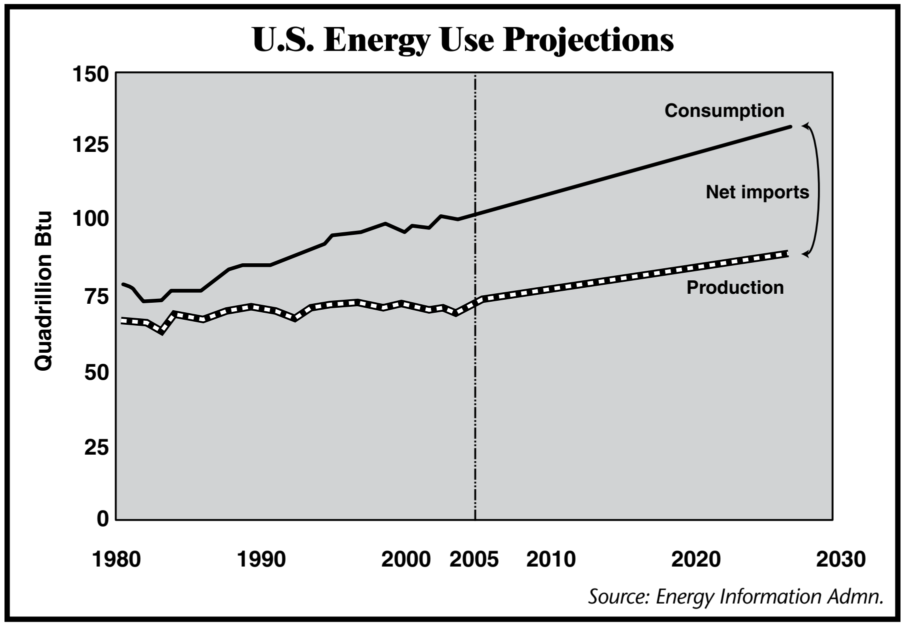
Short-term projections from the U.S. Department of Energy, Energy Information Administration (EIA) indicate the average WTI price for a barrel of crude oil will continue at current levels through at least the rest of this year.

EIA's long-term forecast is for world oil supplies to remain tight as demand for oil stays strong, keeping pressure on oil prices through 2030. According to Borgman, if future oil prices reflect EIA projections, demand for ethanol-based fuels will continue to grow. With corn as the main source, U.S. ethanol production will exceed 4.5 billion gallons in 2006. Some experts maintain the industry holds the potential to expand to 16 billion gallons by 2015 based on reasonable predictions for:

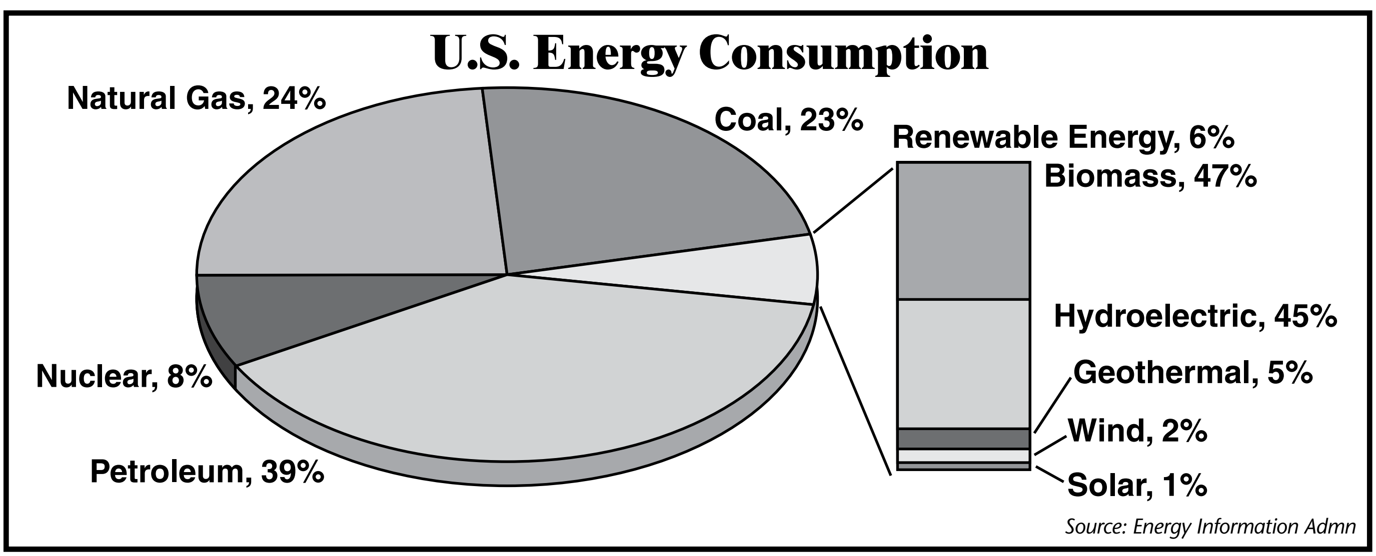
- ✔ Growth in corn yields (bushels per acre).
- ✔ Growth in ethanol yield (gallons per bushel).
- ✔ Probable expansion of corn acres.

Most energy experts agree that it will take more than ethanol made from corn and soybean-based biodiesel to make a significant dent in America's dependence on foreign oil. In addition to starch-based plants, crop residues, cellulosic plants like switchgrass and miscanthus, along with other biomass materials will all play key, long-term roles in tackling America's energy issues.

In 2006, U.S. refineries produced 136 billion gallons of gasoline (mainly from imported oil) and consumers used 143 billion gallons. The rest was made up by imports. U.S. production of ethanol last year amounted to about 5 billion gallons. With biomass materials accounting for only 6% of total U.S. energy consumption last year, it's evident that there's plenty of room to grow for American farmers. These, indeed, will be intriguing days for every sector of America's agricultural industry.



The gap between total U.S. energy consumption and production since 1980 has continued to grow and is expected to widen even more through 2030. This graph is measured in quadrillion BTUs.



In 2006, 86% of U.S. energy consumption came from petroleum, natural gas and coal, with only 6% derived from renewable energy sources. Of this, 47% came from biomass materials.

II. Corn Ethanol Ushers in Era of Biofuels

The age of biofuels is here and terms like corn ethanol, switchgrass and biodiesel are quickly becoming part of America's everyday vernacular.

No industry is feeling the shift toward renewable fuels more acutely than agriculture. The impact of the changes confronting every aspect of agriculture — from new cropping strategies to the development of innovative equipment — is intriguing, to say the least.

Not since Cyrus McCormick revolutionized farming with the invention of his mechanical reaper for harvesting small grains in 1834 has the potential for this magnitude of change confronted agriculture.

Not only did McCormick's time-saving invention address agriculture's biggest need at the time — increased productivity — but it spurred innovations in machinery that not only changed American farming, but the entire world of agriculture.

The emergence of biofuels, which it's hoped will address one of the most pressing issues confronting industry today — energy production — could produce the same level of change in agriculture in the future.

In total, renewable energy sources comprised only 6% of the energy consumed in the U.S. in 2006. Biomass made up 47% of this. So, the industry has barely scratched the surface when it comes to the potential of biofuels. The bigger question is: what surface should we be scratching.

A Boost for Biofuels

On June 21, 2007, the U.S. Congress passed an energy bill that increased average fuel economy by 40% to 35 miles per gallon that will be required for cars, SUVs and pickup trucks by 2020. It is the first increase in vehicle fuel efficiency since the current 22.7-mpg for cars was put in place in 1989 and the first time Congress has imposed a new auto efficiency mandate in 32 years.

While Republicans blocked Democratic efforts to pass a $32 billion package of tax incentives for renewable energy and clean fuels, the new legislation is considered a victory for farmers and the ethanol industry. The bill requires ethanol output to grow to at least 36 billion gallons a

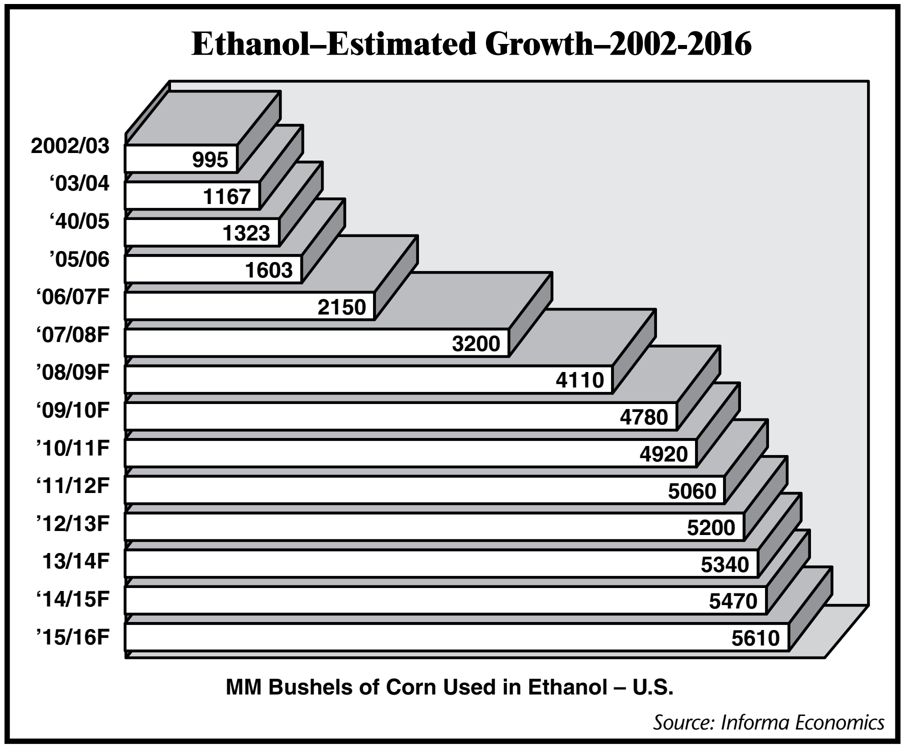
Photo courtesy of Case IH

Ethanol derived from corn represents the country's first significant step toward energy independence.

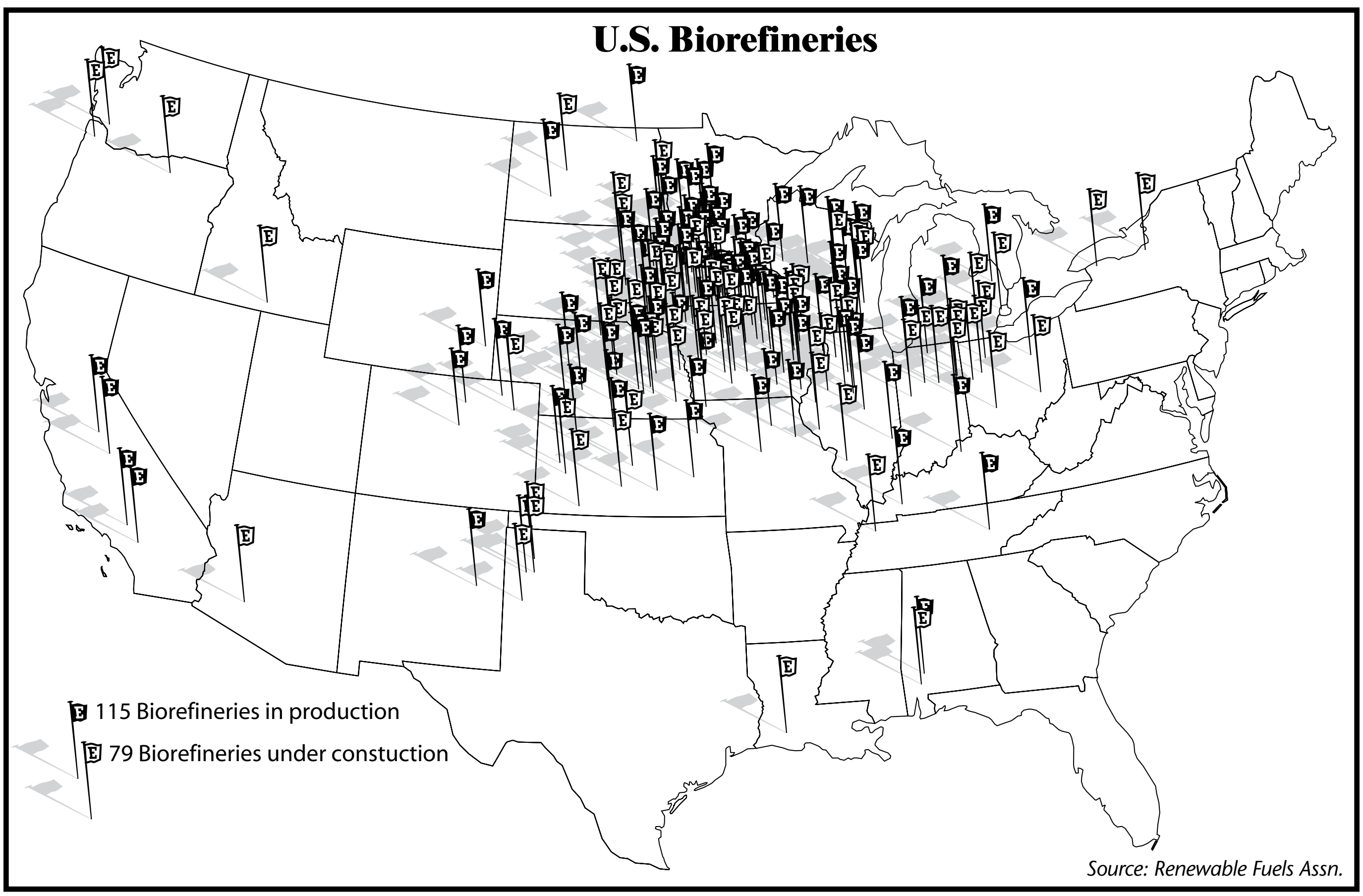
year by 2022, a sevenfold increase from the amount processed last year. Democrats also were unable to include in the bill a requirement for electric utilities to produce at least 15% of their electricity from renewable fuels such as wind and biomass.

Thanks to government subsidies (51 cents-a-gallon) and high oil prices, making ethanol is so profitable that the challenge now is to produce enough corn to meet the growing demand. There are 115 biorefineries already in production and 79 currently under construction, according to the Renewable Fuels Assn. Iowa, the nation's top corn-producing state, is projected to have so many ethanol plants by 2008 it could find itself importing corn in order to keep them producing at full capacity.

And the vision of energy independence doesn't end there. According to Kevin Shinners, professor in the Department of Biological



In its First Quarter 2007 Earnings Conference Call, John Deere issued its estimates of bushels of corn for ethanol production.

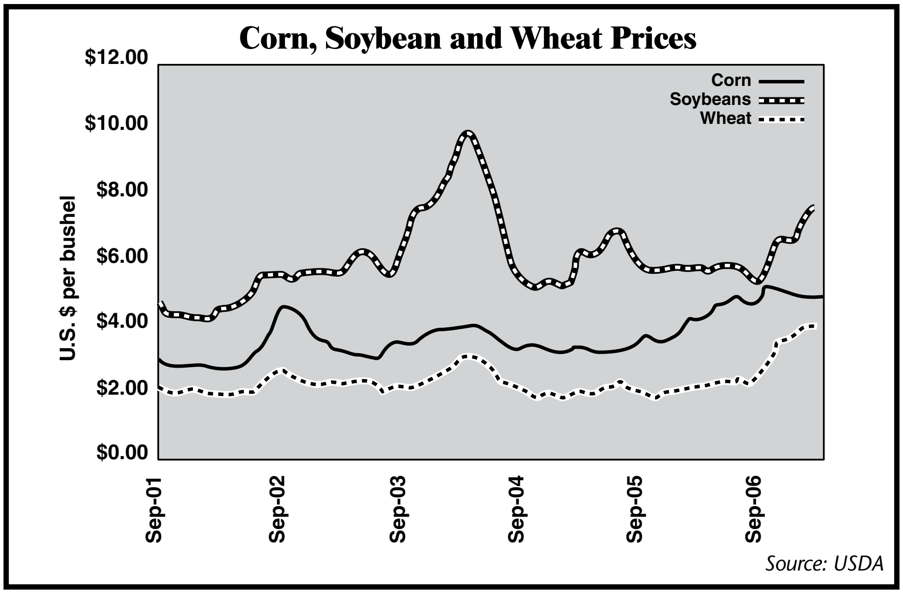


Map shows 115 ethanol biorefineries in production (5.6 bgy capacity); 79 biorefineries (6.9 bgy capacity) under construction; and another 7 under expansion as of January 2007.

Systems Engineering at the University of Wisconsin-Madison, the U.S. Department of Energy is promoting the "Billion Ton Study," which is pushing for 60 billion gallons of ethanol per year by 2035.

"If you have faith that this will occur, essentially what's going to have to happen," says Shinners, "is we'll need to just about double the current level of ag productivity in this country. If you add up the mass of all the things we are harvesting right now, including the machinery for processing as well as the transportation involved, in order to get to there, we're going to have to double total production to get to the 600 or 700 million tons of biomass that we'll need to harvest to get to 60 billion gallons of ethanol."

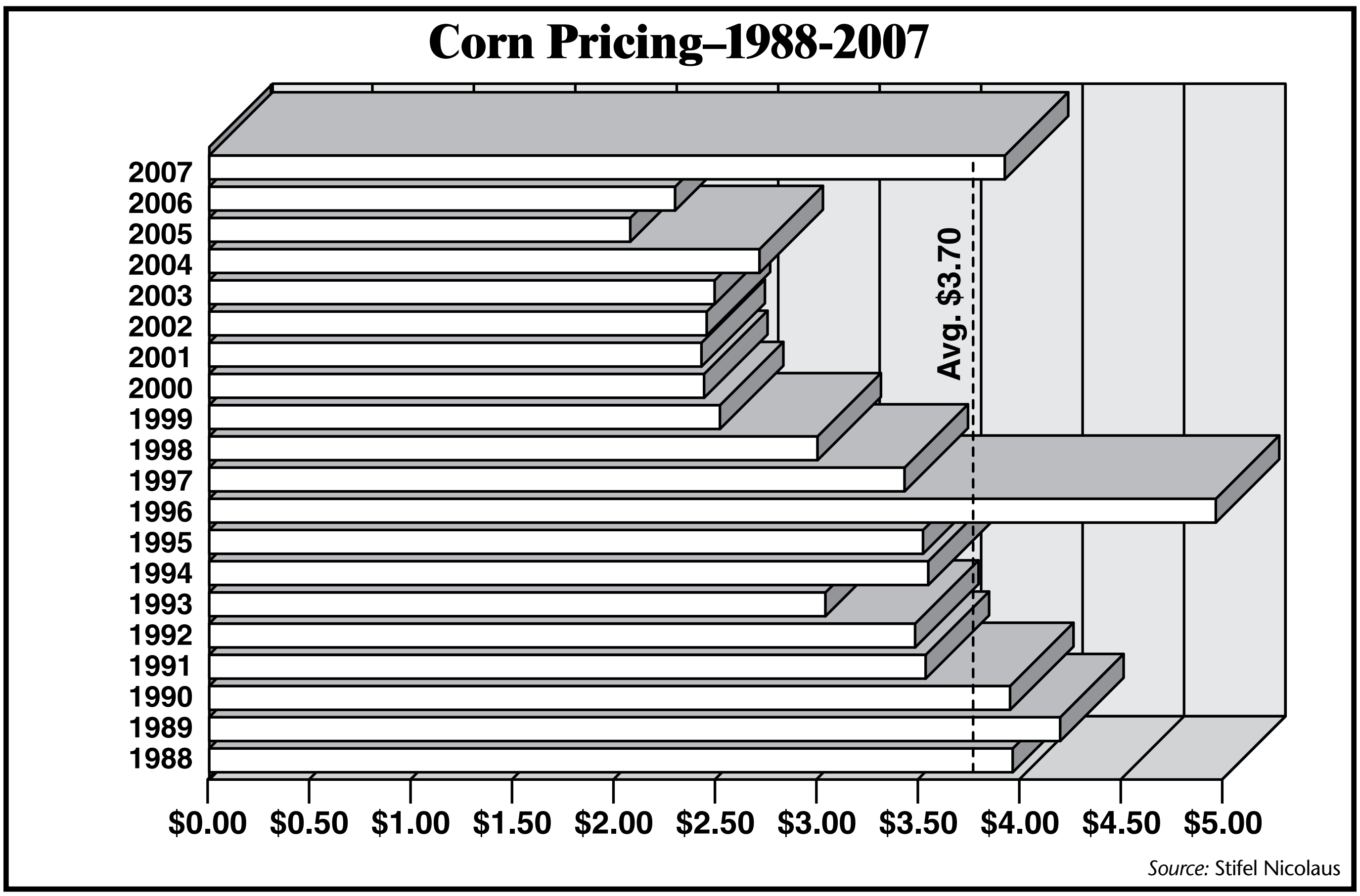
It's a tremendous opportunity, he says. "If that vision comes true, it will have a profound effect on ag production. We're going to need a heck of a lot more equipment, including different types of equipment, to handle the amount and the new kinds of material."



Prices of North American agricultural commodities — including corn, soybeans and wheat — have surged with the increased ethanol production.

Taking the 'Ethanol Plunge'

When it comes to producing energy today, the first word on the



Inflation-adjusted U.S. corn prices (dollars per bushel, seasonal average) are only now returning to the 1988-97 average.

street — both Main Street and Wall Street — is "corn ethanol." But most energy experts agree that it won't be the last word. In fact, most agree that the plunge into corn ethanol during the last year only signals that the industry has barely stuck its toe into the deep waters of alternative fuels.

Nonetheless, early reports are that the industry's "ethanol plunge" went even deeper than many observers expected and its ramifications are already being felt.

On June 29, 2007, the National Agricultural Statistics Service (NASS) of the USDA released its first acreage report since growers finished up their 2007 plantings. It estimates corn planted for all purposes increased to 92.88 million acres, up 19% from 2006 and 14% higher than 2005. Farmers increased corn planting 3% from their March intentions, as well, resulting in the highest planted area since 1944 when 95.5 million acres were planted.

The increase in corn acres has impacted the number of acres planted to other crops, too. The USDA report showed that soybean acres fell by 15% from last year's record high to 64.1 million acres. This was the lowest planted acreage since 1995. Cotton acres for 2007 are estimated at 11.1 million, 28% below last year and the lowest since 1989.

Along with the rising demand for corn for ethanol, speculation is also fueling a volatile pricing situation that isn't expected to let up soon. "This market is very sensitive to new information. We're going to see more volatility in a week's trading than you'd see in years past in a whole season," Bob Thompson, a farmer and ag analyst told *USA Today*.

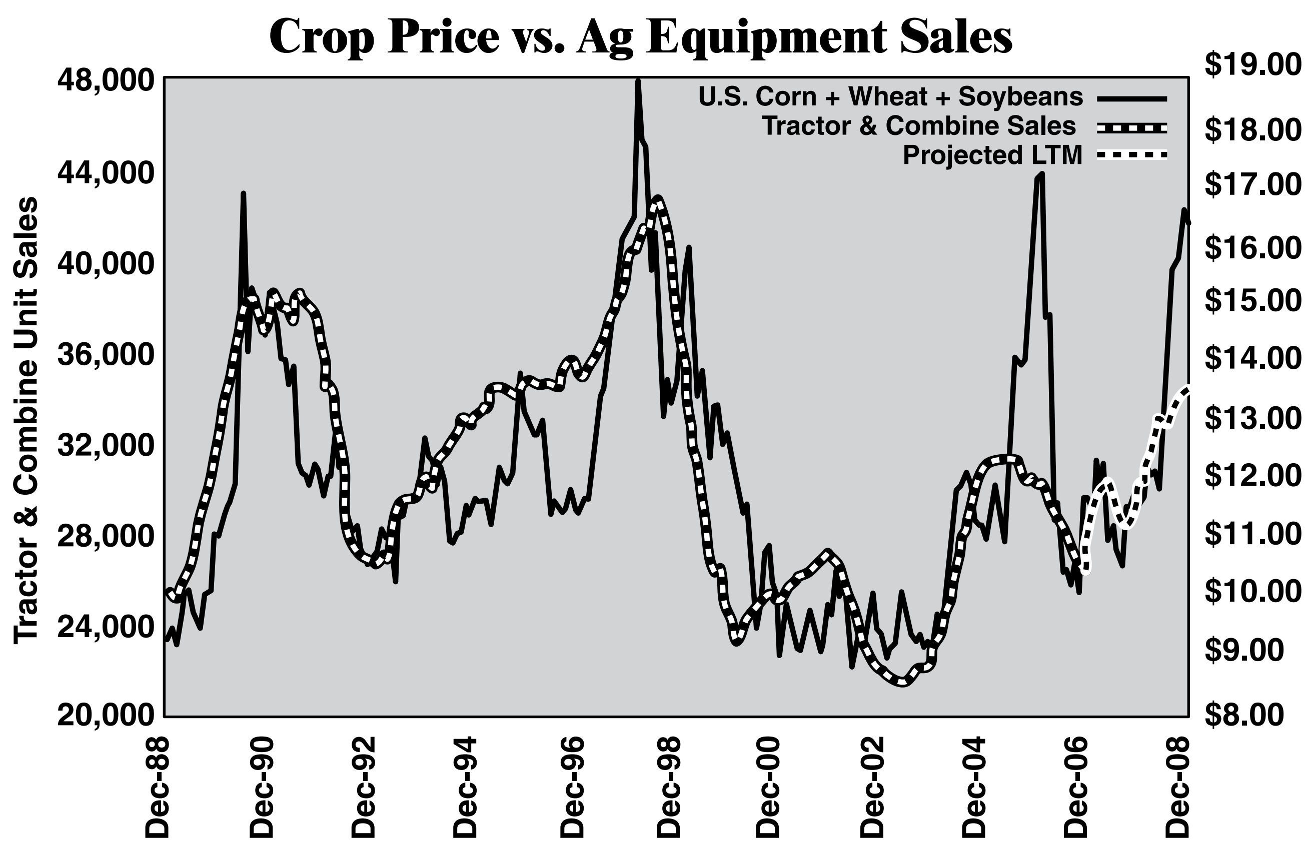
When the USDA issued its preseason planting intentions report on March 30, it projected that 90.5 million acres of corn would be planted in 2007 and the price of corn dropped immediately by 20 cents a bushel to $3.83. The following Monday the price fell even further to $3.54, down 21% from a high of $4.50 per bushel on February 26.

With the U.S. ending stock estimate for 2006-07 increasing to 877 million bushels, up 125 million bushels from March, this pushed the average corn price projection from $3.00 to $3.20 vs.$3.00 to $3.40 in February.

A 'Super Cycle' in the Making?

In his April 19, 2007, newsletter to Buhler Industries investors, Ben Cherniavsky, analyst for Raymond James, speculated that the North American ag industry may be on the brink of a "super cycle."

"North American agricultural prices — including corn, soybeans and wheat — have surged dramati-



Source: AEM, Factset prices, Stifel Nicolaus estimates for unit sales FY07 to FY08.

Trends in crop prices tend to lead equipment sales by 2 years. Graph shows crop price moved ahead by 24 months to demonstrate the impact on equipment sales.

cally in recent months, spurred largely by ethanol-induced supply concerns. Albeit less of an immediate factor, but certainly not one to be understated, demand from emerging markets is also putting increasing upward pressure on grain prices," says Cherniavsky.

"Taken together, these two structural trends foretell a significant, long-term tightening in the agricultural supply chain, and an associated long-term escalation in commodity prices. The corollary of this bullish outlook is a forecasted cash windfall for farmers that we expect will spur robust demand for new farm equipment and related services."

After a lackluster start for equipment sales in 2007, April retail sales of big tractors saw their first significant jump that continued into May, lending additional credence to earlier forecasts of strong 2007 sales for ag machinery makers and dealers, according to Baird analyst Robert McCarthy.

North American retail tractor sales comparisons remained strong in May amid strengthening of field crop futures prices. Row-crop and 4WD tractor sales were both up year-to-year by double-digit percentages (second consecutive month), and combine sales (+6%) rebounded to positive territory in May, McCarthy said, in reporting on the latest retail sales figures from the Assn. of Equipment Manufacturers.

Compared with May 2006, North American retail sales of row-crop tractors (2WD; >100 hp) increased 13% in May 2007, after increasing 14% in April. Sales also improved by 12% during the 3-month period.

Retail sales of 4WD tractors were also up sharply year-to-year in May, increasing 32% year-to-year after increasing 40% in April. Through the first 5 months of 2007, 4WD tractor sales increased 24% during the last 3-month period.

Despite improved sales levels in recent months, Cherniavsky warns that history suggests there is typically a significant lag of about 2 years between rising commodity prices and a "meaningful up-tick" in equipment orders.

The Downside of Ethanol

Not everyone is feeling giddy about the prospects for the corn ethanol boom on potential equipment sales. For one, Barry Bannister, analyst for Stifel Nicolaus, says that even at its current elevated levels, the price of corn in 2007 is only now crawling back to its 1988-97 average.

Conversion Factors for Biofuels

- ✔ A bushel of soybeans (60 lb or 27 kg) yields about 11 lb (5 kg) of soybean oil, making 1.5 U.S. gallons (5.7 liters) of biodiesel.
- ✔ A bushel of corn (56 lb or 25 kg) yields about 2.5 U.S. gallons (9.5 liters) of ethanol.
- ✔ A ton (2,000 lb or 980 kg) of corn stover will yield about 80-90 U.S. gallons (300-340 liters) of ethanol, and a ton of switchgrass will yield in the range of 75-100 U.S. gallons (285-380 liters)

Source: U.S. Department of Energy's National Biofuels Program

Nearly Half of Livestock Producers See Value in Feeding Ethanol Byproducts

Roughly half of the cattle and hog operations in a 12-state region either fed ethanol co-products or considered feeding them to their livestock last year, according to a report released on July 2 by the U.S. Department of Agriculture's National Agricultural Statistics Service (NASS) with the support and funding of the Nebraska Corn Board.

Among dairy operations, 38% indicated that they fed co-products during 2006 and another 22% considered doing so. In cattle feedlots, 36% fed co-products and 34% more considered it. Among beef cattle operations, 13% reported that they fed co-products and 30% considered it. For hog operation owners, 12% fed co-products and another 35% considered it.

NASS contacted approximately 9,400 livestock operations in Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota and Wisconsin to determine whether they used co-products — including distillers grains and corn gluten feed — in their rations in 2006. NASS collected information regarding the types and amounts of co-products fed, how the co-products were procured and used, and what concerns and barriers may have prevented operations from feeding co-products.

Among the various co-products available to operations for feeding, corn gluten feed was used by 46% of beef cow operations and 38% of cattle on feedlots, while distillers dried grains were used by 45% of dairy cattle operations and 44% of hog operations. Other co-products that the survey looked at included distillers dried grains with solubles, condensed distillers solubles, brewers grains and distillers wet grains.

According to the survey results, most dairy cattle, beef cattle and hog producers purchase co-products through feed companies or local suppliers, while a majority of cattle feedlots purchase them directly from ethanol and other processing plants.

Livestock operations that are not currently using ethanol co-products indicated availability is the primary impediment. Infrastructure and handling issues are also a barrier as, to a lesser extent, is cost.

From an economic standpoint, Bannister adds, "The inflation adjusted natural gas, a proxy for nitrogen fertilizer, cost of $7.04 per Mcf is among the highest prices of the past 20 years, a period in which the real natural gas price has averaged $4.05."

In addition to the energy required to distill ethanol from corn, according to Bannister, corn uses almost 70% of the combined nitrogen, phosphate and potash applied in the U.S., making it "an expensive crop" to grow.

Another who is less-than thrilled with the prospects of using corn ethanol for reducing America's dependence on foreign oil is Charlie Rentschler, machinery and agribusiness analyst for Wall Street Access.

In the April 3, 2007 WSA newsletter, he maintains that, "While doubling corn prices and triggering happy-times for U.S. agriculture, federal ethanol policy is going to lead to disastrous results, in our opinion, that could collapse the boom like a house of cards, among other dire consequences.

"If we are right, the outcome is not good for companies making farm machinery, fertilizer, seeds, etc.," he says.

Rentschler's argument against too much reliance on corn-produced ethanol for replacing petroleum fuels has its basis in, what he calls, humanitarian and practical grounds, as well as conservation principles.

"Truth is," says Rentschler, "America does not have enough land to grow all of the corn needed to come anywhere near to making E-85 a reality. To be sure, we could see a big surge in output this year, given a dramatic shift of soybeans to corn, but, afterwards, output has to taper off."

In WSA's "optimistic scenario" (see table below), projected increases in corn production over the next 3 years, after approximately doubling ethanol output, involve holding exports flat and keeping ending-inventories modest.

In its "pessimistic scenario," which involves a modest drought in the second year, he shows that, after feeding those ethanol refineries, we run our ending inventory down to almost nothing and have zero to export.

Rentschler says the real numbers ought to fall somewhere in between — and there's the rub.

The U.S. is easily the largest producer of corn in the world. "With per-capita income rising and tastes changing from starch to protein, other people, particularly Asians, want to emulate our dietary ways. Feedlots are springing up all over China," he says. "Why do we think that we have the right to use corn to fill up our SUVs and deny people in China meals of red-meat? We are, in essence, using food — or lack thereof — in our diplomacy.

"We can visualize a scenario 2 or 3 years out where the then-president of China visits the then-president of the U.S., wags a finger in his (or her) face, and insists that exports of corn resume. Wars have been started over far less trifling matters," says Rentschler.

The 'SUV' of the Plant World

On practical grounds, the WSA analyst adds that while ethanol is a perfect substitute as an oxygenate for MTBE, which has been banned, its negatives outweigh it positives. Among its downsides, Rentschler lists:

- ✔ Ethanol production is uneconomic without the $0.51 per gallon tax-credit to the blender and the $0.53 per gallon tariff on Brazilian ethanol.
- ✔ Corn-ethanol produces lower miles-per-gallon than gasoline to power U.S. cars and trucks.
- ✔ Other renewable fuels — namely sugar-cane ethanol and soybean-based biodiesel — require less BTU's per acre of output.
- ✔ The U.S. could become totally independent of OPEC if we emulated the Europeans and drove small (often diesel-powered) cars and trucks.

In terms of farming, the WSA analyst points out that corn is not environmentally friendly due to its need for massive amounts of nitrogen fertilizer and horsepower.

"We refer to it as the 'SUV of the

U.S. Corn Outlook — Two Scenarios

	Optimistic Scenario				Pessimistic Scenario			
Crop Year	2006	2007	2008	2009	2006	2007	2008	2009
Beginning stocks (bil. bushels)	2.0	0.8	1.0	1.0	2.0	0.8	0.7	0.5
Production	10.5	12.4(a)	13.0(b)	13.7(c)	10.5	11.5(a)	11.1(b)	11.5(c)
Available	12.5	13.2	14.0	14.7	12.5	12.3	11.8	12.0
Ethanol production (bil. gal.)	5.4	8.5	10.0	11.6	5.4	8.5	10.0	11.6
Corn for ethanol	2.0	3.1	3.6	4.2	2.0	3.1	3.6	4.2
Other domestic use	7.5	7.7	7.9	8.1	7.5	7.7	7.9	8.1
Exports	2.2	2.2	2.5	2.4	2.2	0.8	0.5	0.0
Needed	11.7	13.0	14.0	14.7	11.7	11.3	12.0	12.3
End stocks	0.8	1.0	1.0	1.0	0.8	0.7	0.5	0.2
Ethanol as % of production	19%	25%	28%	31%	19%	27%	32%	37%

Optimistic: (a) 89 mil. acres x 153 bu./acre x 91% acres harvested
(b) 5% y/y growth (more land, same yield)

Pessimistic: (a) 87 mil. acres x 145 bu./acre x 91% acres harvested
(b) 90 mil. acres x 135 bu./acre x 91%
(c) 90 mil. acres x 140 bu./acre x 91%

Source: Historic data: USDA; Forward estimates: Wall Street Access

Membrane Technology Aims for More Energy-Efficient Ethanol Production

An invention by researchers at the Agricultural Research Service (ARS) of the USDA, called a spiral-wound liquid membrane module, could potentially replace the widely used process of distilling ethanol from fermentation broths. The module offers ethanol producers the important advantage of combining two separation processes — extraction and membrane permeation — in one piece of equipment.

Chemical engineers Richard D. Offeman and George H. Robertson at the ARS Western Regional Research Center in Albany, Calif., think it may be possible to cut energy costs by using a series of specially designed permeable plastic sheets or membranes to produce ethanol from fermented broths of corn or straw and other kinds of biomass feedstocks.

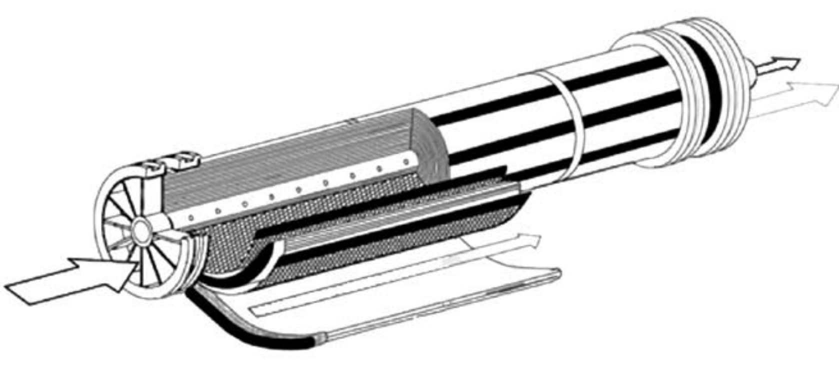
The technology will help address the concerns regarding the energy efficiency of bioethanol production, according to Robert L. Fireovid, ARS national program leader for process engineering and chemistry, Beltsville, Md.

With further research and development, the module would require less energy than distillation. Today, energy costs are ethanol producers' second largest expense; feedstocks are first.

In brief, the fermentation broth — typically containing 5 to 12% ethanol — would travel through a sandwich-like configuration of membranes and mesh sheets, called spacers, that separate the membranes from each other. One membrane has a solvent in its pores that extracts the ethanol from the broth. A second membrane, with the help of a vacuum, pulls ethanol out of the solvent. The ethanol-and-water vapor that results is then condensed into an ethanol-rich liquid.

The scientists have applied for a patent. They now plan to build and fine-tune a prototype, then turn it over to a membrane manufacturer for further development before commercialization.

Already, some ethanol producers have expressed interest in the invention. The device has other potential uses, such as cleaning up wastewater or treating natural gas for home use.



Bioethanol is taken out of an incoming fermentation broth using this spiral-wound liquid membrane module. The broth flows across the surface of specially designed permeable plastic membranes that are wrapped around the module's perforated collection tube. Ethanol in the broth is separated by the membranes using a vacuum and then sent to other equipment to be condensed into liquid. The leftover broth could be processed into byproducts.

plant world,' because, relative to other things American farmers grow, corn is energy-intensive," says Rentschler.

Conservation: Taking a Step Back?

What Rentschler finds even more troubling is the potential for growers "in their lust for $4 per bushel corn," to take a step back when it comes to conservation practices.

For example, moving toward corn-on-corn "is bad business for the environment," he says.

"A corn-on-corn protocol, in many cases, reverses years of practicing no-tillage." (Last year, Illinois — number one in soybean production and number two in corn — reported more no-till acres than acres tilled.)

"To prepare the field for a second year of corn, farmers are commonly reverting back to the 'old ways,' chiseling, deep-ripping or mold-board plowing these acres, which has adverse consequences," explains Rentschler.

"Soil quality is a function of organic matter — earthworms, fresh residue, decomposing trash — and organic matter is 60% carbon.

Tillage releases carbon by exposing it to sunlight. It then rises up into the air as carbon dioxide, adding to greenhouse gases or is washed by rainstorms down tributaries to the Mississippi River," he adds.

"In a colossal irony, many American farmers are turning away from no-till principles of minimizing soil disturbance and maximizing residue retention. We're forgetting Mother Nature's lesson that cultivation doesn't occur in nature because it is a catastrophic event," says Rentschler.

In addition, he says, tillage digs up old, dormant weed seeds, thus putting more pressure on herbicide programs. And there are already many places stretched as more species of weeds are becoming resistant to glyphosate.

"Now, you can see why we're calling this move toward corn ethanol Mad Corn Disease," he says.

III. The 3 Silos of Cellulosic Ethanol Production

If America is to reduce its dependence on foreign sources of oil, it needs to start somewhere. Today, the most expedient, though costly, route is corn ethanol. In the longer term, most energy experts agree that it will be ethanol production from a combination of non-food plants that will ultimately wean America away from its need for overseas petroleum. Most intensive ethanol research today is focusing on cellulose from a wide variety of plants, including crop residues and grasses, as well as willow and poplar trees.

Kevin Shinners, professor of Biological Systems Engineering at the University of Wisconsin-Madison, believes that it will be a combination of cellulosic-based fuels that will ultimately provide the longer-term answers to America's energy situation.

"Most people will agree that the amount of the corn that we can pull from the market place is going to start to dwindle. We're already hearing that we're reaching saturation of our corn shed. Much more and it will start affecting the price of food and export markets dramatically. The real emphasis will be to look at non-starch based ethanol production. If we're going to power things by ethanol, in all likelihood, starch-based ethanol is going to be a small fraction in the future."

Shinners likens this longer-term approach to cellulosic ethanol production to filling 3 silos. These include crop residues, perennial grasses and hybrid poplar and willow materials.

Silo 1: Crop Residues–The Best Long-Term Prospects?

Crop residue, the stuff that's left over after harvesting grain, is probably the prime example of using something that has little or no direct economic value, and turning it into a valuable energy commodity. "Corn stover is a great example of this," says Shinners.

Stover is all the non-grain fraction of corn — stalks, leaves and cobs. "We're going to have more than 90 million acres of corn growing this year in the U.S.," says Shinners. "This is going to create a lot of stover that can be fermented into ethanol with reasonable conversion efficiency. It's readily available and you have the grain to support the cost of production."

Wheat straw is another example, he says, though the yields from wheat straw are relatively low, making it a lower-rung candidate for large-scale use for ethanol production.

Considering the volume of corn stover available, it's no surprise that it's receiving considerable attention as a potential source for ethanol production. According to Jim Hettenhaus, at 250 million dry-weight tons of corn stover produced annually, it is the largest quantity of biomass residue in the U.S., with 30 to 60% available for processing.

"Stover has the potential of supplying 6 to 14 billion gallons of fuel ethanol to the U.S. transportation market, which is enough to cover about 10% of total gasoline needs," says Hettenhaus, president of cea, Inc., a consulting firm specializing in commercializing emerging applications of biotechnology in Charlotte, N.C..

Of all the cellulosic ag residues available as a feedstock, estimates indicate that 75% is corn stover

The Potential of Corn Stover

Corn stover is the largest underutilized ag resource in the United States, says Hettenhaus, "It has an inherent cost advantage over crops grown for industrial uses since those have higher production costs. Stover requires no more land because the material is already in the field. Today, more than 80% of the U.S. corn acreage is tilled.

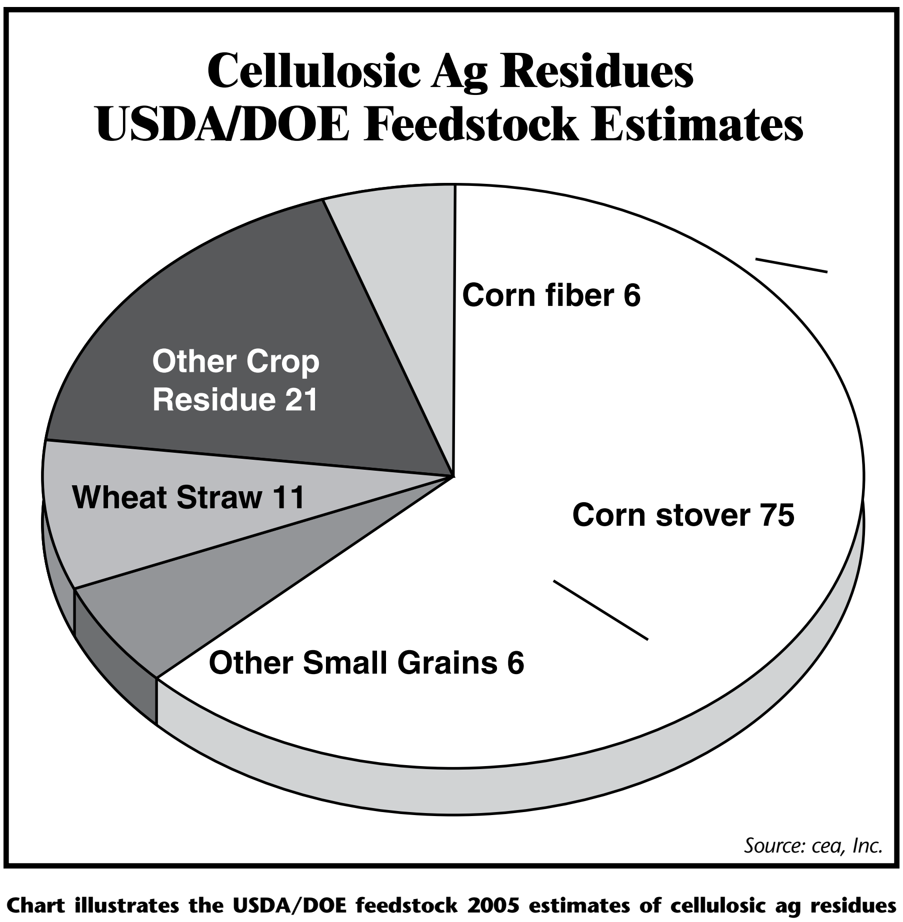


Chart illustrates the USDA/DOE feedstock 2005 estimates of cellulosic ag residues available for ethanol production.

If removing the excess stover encourages conservation and no-till farming practices, it would dramatically reduce the CO_2 generated from the decay of this residue on the soil and reduce soil erosion even further."

According to Hettenhaus, who has pushed for the use of corn residue for cellulosic ethanol for more than a decade, stover is approximately 50% stalks, 22% leaves, 15% cobs and 13% husks. Stover does not include the plant crown or its surface roots. Currently, most of this residue ends up back in the soil because most corn growers have no other alternative. Less than 5% is baled for animal bedding or feed. The remainder is left on the surface to retain soil moisture and control soil erosion.

About 1 ton of corn stover is produced for every 1 ton of grain. Corn yields per acre have increased 60% from the early 1970s, from about 85 bushels per acre nationwide to about 135 bushels today. Corn stover yields have increased proportionately and about 250 million dry tons of stover is produced each year.

Yet for all of its promise, stover remains a work in progress as research continues to determine the ultimate environmental and economic impacts of its use for ethanol. One of the big challenges confronting those who are aiming to utilize corn residue as an energy source is to determine exactly how much stover can be removed in a sustainable manner. Not only does residue contain valuable nutrients, but also plays a key role in controlling erosion.

How Corn Stover Value was Established

The use of corn stover as the basis for producing ethanol was established more than a decade ago — almost by accident.

According to Jim Hettenhaus, president of cea, Inc., for many years, Great Lakes Chemicals (GLC) had been converting oat hulls into furfural alcohol in their Omaha plant. In 1995, when oat hull prices soared to more than $100 per ton, GLC searched for an alternate, more economic source for their alcohol products.

GLC contracted with 440 corn farmers around Harlan, Iowa. In 1997, stover from 50,000 acres was successfully harvested using contract harvesters. In 1998, GLC was bought by Penn Specialty Chemicals which suffered financial problems. That led to the closing of the Omaha plant. Nevertheless, despite its shortlived operation, the Harlan enterprise established the viability of large-scale stover harvesting and generated concrete cost figures.

Environmental Benefits

Ag residues, in fact, provide a key role in maintaining soil quality. Surface cover is needed to prevent wind and water erosion, retain soil moisture, recycle nutrients from the plant back to the soil and support assorted life. When residue is removed, reduced inputs from the residue to the soil can result in a negative flux from the soil and a loss of soil organic matter (SOM) and other nutrients leading to a breakdown of soil structure.

"The amount of excess residue is a complex question," say Hettenhaus. "It depends on local factors like soil type, cropping practice, weather and topography. For example, in some dry areas surface cover is required to retain moisture, mostly in western areas of the grain belt. Further east, surface cover is given as a major reason for tilling, as the cover prevents the cold, wet soils from warming in the spring, delaying planting and reducing yield.

"Recycling nutrients from the plant, especially phosphorus (P) and potassium (K), back to the soil reduces the need for replacement," he explains. "Conversely, in areas where manure is used, the P contained in the soil may already be too high, resulting in excessive run-off that contributes to algae formation in ponds and streams."

When residue is removed, P and K content in straw and stover will eventually need to be replaced, according to Hettenhaus. The composition is typically 0.1% P and 1% K, valued at $3.50 per dry ton. The nitrogen (N) fertilizer value is more complex, and depends on crop rotation and local conditions. Reduced field operations are estimated to reduce inputs $24 per hectare for preparation of the seed bed.

"Removing the stover may also be a key to expanding no-till acres. . ."

He also adds that carbon credits would likely add additional economic incentive for U.S. farmers. "Reducing tillage or no-till sequesters about 0.3 to 0.5 metric tons carbon (C) equivalent per hectare. The increased soil carbon improves yields and this benefit continues with each crop year. Eventually, over decades, soil carbon equilibrium is achieved. In the European Union, carbon is currently trading for about $35 per ton C equivalent. In the U.S., a small, voluntary greenhouse gas trading market has been established — the Chicago Climate Exchange — for agricultural carbon sequestration as part of the Chicago Board of Trade. Recent efforts to move U.S. policy in this direction call for a $26 per ton of C-equivalent credit that would fund renewable fuels research and development," says Hettenhaus.

Reducing N use is also possible, depending on crop rotation, he explains. Microbes desire a 10/1 ratio of C/N for breaking down residue. Since the C/N ratio of straw and sto-

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Other Effects of Harvesting Corn Stover

Photo courtesy of Case IH.

In addition to controlling soil erosion, crop residues also play a vital role in soil composition and fertility.

A major challenge is to determine exactly how much stover can be removed in a sustainable manner.

In addition to controlling soil erosion, crop residues also play a vital role in soil composition and fertility, according to Jim Hettenhaus, president of cea, Inc., in Charlotte, N.C.

Soil composition is just one of many factors that affect how much stover can be removed from the soil. Hettenhaus explains that the USDA's National Resources Conservation Service has models that determine the required amount of cover to prevent both water and wind erosion.

"While surface cover primarily controls erosion and retains moisture, most of the soil fertility comes from the roots," Hettenhaus explains. "Studies done by the National Soil Tilth Lab in Ames, Iowa, showed that after a year, 75% of the new carbon moving into the soil came from roots and only 25% from surface residue. They also observed that two-thirds of the carbon contained in the surface residue had been released into the atmosphere as CO^2."

Removing corn stover can also affect the fertility of soils because it removes vital nutrients that will necessarily need to be replaced.

According to Hettenhaus, the value of the lost nutrients in corn is as follows:

- ✔ Potash, with a content of 0.1%, has a value of 83 cents per dry ton of corn stover removed.
- ✔ For potassium, with a content of 1.0% it is about $3.42 a ton.
- ✔ The nitrogen value computation is more complex. Corn stover nitrogen content varies from 0.5% to 6%, or 10 to 120 pounds per ton, dropping rapidly after harvest. If all of that nitrogen were available, the value of lost nitrogen would be $3.25-$39.02 per ton. However, adding additional nitrogen fertilizer when plowing under stover is common with continuous corn and varies with a soybean and corn rotation. Some use a starter fertilizer with the nitrogen costing $3.20 per ton buried. This calculation is highly dependent on crop rotation methods. "I use a cost of $3.20 to make up for the lost phosphorus and potassium nutrients," says Hettenhaus.

He also points out that, in some case, corn stover can actually enhance soil fertility.

"After the surface cover required for erosion control is met, removing the excess stover can actually aid soil fertility by eliminating the need to plow," he says. "Many studies by the USDA and others show that plowing results in a burst of CO^2 as the soil organic material (SOM) is oxidized when the surface is ripped open, exposing the material to air. Plowing depletes the SOM."

Soil researchers at the University of Minnesota found that about 6 tons of stover must be buried just to keep the SOM steady, if the field is plowed — the residue equivalent of a 200+ bushels per acre yield.

"Mulch tilling can reduce this loss, but still causes a major disruption to the habitat below the soil surface and some loss of SOM," Hettenhaus explains. "This is why no-till is a key to generating large amounts of available stover. Interestingly, removing the stover may also be a key to expanding no-till cultivation."

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ver is 40 to 70/1, 10 kg N fertilizer addition per ton of residue is typically recommended to avoid denitrification of the next crop. For 250 hectares of 9 dry tons per hectare corn (170 bushels per acre), 30 to 40 tons of N fertilizer may be avoided. In addition to the out-of-pocket costs, environmental benefits include reducing N run-off to streams and groundwater, and reducing greenhouse gas — 0.17 to 3.5 tons of N_2O/100 metric ton applied — 5 to 100 metric tons C equivalent per hectare.

Some surface residue — a minimum of 30% coverage — is required by USDA guidelines for erosion protection, says Hettenhaus. "Relating mass to soil cover is guesswork. The actual amount of stover that must remain to prevent soil erosion varies greatly, depending on local conditions such as soil type, slope of the field, length of slope, tillage practice and crop rotation."

To further evaluate residue requirements, Colorado State University is currently conducting a multi-year research program to determine the long-term affects on soil productivity. (See adjacent sidebar.)

No-Till is Best Approach

Hettenhaus maintains that no-till is the best approach to harvesting corn stover while retaining adequate residue. "With no-till, about 150 million dry tons could be taken off the land," he says. "For no-till fields with slopes less than 4%, the required cover varies from 0.5 to 1.5 tons per acre. So if the yield is 180 bushels per acre, which is about 5 tons an acre, 3.5 to 4.5 tons of residue can be removed while complying with Best Management Practices (BMPs) for residue set down by the USDA.

"For mulch till, the required cover amount is about doubled to 1 to 3 tons per acre, leaving 1 or 2 to 3 tons per acre available for removal. Generally, no stover can be removed from conventional tilled fields and still comply with BMPs."

It is estimated by the Conservation Technology Information Center, that nearly 23% of all acres farmed in the U.S. in 2004 were no-tilled. Hettenhaus believes that as the viability of harvesting corn stover for ethanol production becomes more apparent, a growing number of growers will adopt reduced tillage practices.

"In northern states, the cold, wet soil in the spring slows seed germination. The residue cover acts as insulation, retarding soil-warming," says Hettenhaus. "Farmers plow under the excess stover, to enable the soil to warm earlier and allow earlier spring planting. By removing the excess stover plowing could be avoided, encouraging more no-till."

This, he says, will further encourage stewardship of the land and play an important role in the environmental aspects of farming by reducing trips across the field, which saves fuel.

Hettenhaus adds that reduced tilling or no-till sequesters more carbon in the soil, increasing its fertility. "Soil erosion is reduced, wildlife habitat is improved and using the stover as a feedstock in lieu of fossil fuels can offset greenhouse gas emissions," he says. "Chemicals and nitrogen fertilizer application can be reduced, decreasing their leaching into groundwater and runoff into streams."

Turning Corncobs into Ethanol

Jeff Brown, CEO of Poet, the Sioux Falls-based ethanol producer formerly known as Brown Cos., is gearing up to make cellulosic ethanol exclusively from corncobs and kernels at its plant in Emmetsburg, Iowa, according to the *Argus Leader* newspaper.

Poet is one of six producers that won federal grants to make ethanol from cellulose. Brown expects the new process to produce fuel 30 months after Poet receives the grant money.

Although the new ethanol process is not yet cost-competitive with corn ethanol today, Poet and other companies are trying to be the first to make it commercially viable.

"With all of the interest surrounding cellulosic ethanol — and so many people saying it will be switchgrass woodchips or whatever — I think a lot of us in the industry recognize that the most logical step was to take the fiber or cellulose surrounding the corn plant," says Brian Jennings of the American Coalition for Ethanol in Sioux Falls.

Poet has been investigating the use of parts of the corn plant other than the kernel for producing ethanol for more than 5 years. But this is the first time it will use only cobs and the fiber from the kernel. With this approach, farmers will not need to collect and bale leaves and stalks.

Corn cobs have several advantages over other parts of the corn plant for ethanol production, according to Mark Stowers, a Poet vice president. They have a higher energy content and are more dense and thus easier to transport. Removing them will still leave enough plant material behind to maintain soil quality.

Brown says his company is working with farm equipment manufacturers to offer a range of options for cob harvest. He expects the Emmetsburg plant to expand from producing 50 million gallons of ethanol a year to 125 million. Of that, 25 million gallons will be produced from cellulose. The plant will use 83% less fossil fuel than a conventional plant. It will produce 11% more ethanol per bushel of corn and, because of the cobs, it will produce 27% more ethanol per acre of corn, Brown says.

"I don't think there is anyone else in the industry that is looking at the same feedstock we are, so certainly the corncobs make it unique," Brown says.

The Challenges of Stover for Ethanol

In addition to adapting no-till, the biggest economic and logistical challenges for growers and ethanol processors is dealing with competing markets as well as in the harvesting and transporting of the stover. Up to harvest, the process that farmers use to grow corn today remains pretty much the same.

According to George Michaels, vice president of engineering for Oxbo Corp., Byron, N.Y., which has a 3-year grant from the Department of Energy to develop a one-pass crop residue harvester, the absolute biggest challenge is getting the material away from the field.

"Coming up with a single-pass harvester is not that difficult. Making it as efficient as possible is more tricky," he says.

First, it has to be worthwhile for the grower to harvest the stover and the practice has to be environmentally sound.

"We've been working with various universities for almost 2 years to determine how much stover we can take off and not affect the carbon content of the soil. The really hard part, though, is making sure you don't extend the harvest time. Farmers want to get their harvesting done in the same amount of time they do now — or less. They want to harvest their corn with the same quality or better, so it doesn't interfere with the cash flow that they're currently getting from their corn. So the challenge is to not interfere with harvest and be able to get them the extra dollars per acre for stover in order to make it worthwhile," says Michaels.

He also points out that other markets are competing for corn stover, so it is critical that the entire process for harvesting it for ethanol is as efficient as possible.

"We found in Nebraska that in some cases they can put up electric fences around the stacked stover or the corn field and rent it out to feed cattle for $10 an acre. And then there's a possibility that the cob could have more value for producing other products, like abrasives and cosmetics, than it does for ethanol," says Michaels.

One-Pass Harvesting

Michaels says they've looked at various scenarios for harvesting corn stover that are both efficient and make sense economically.

One scenario is to cut the entire corn plant, including the ears, placing it on the ground for later collection. This isn't practical, he says, because it adds another handling task, which adds costs. Collecting the cut plants lying on the ground usually involves picking up soil from the field. "You don't want it on the ground because dirt can affect the enzymes used in the process. You need clean stover," Michaels explains.

Another option may be to cut the entire plant and transport it, corn kernels and all, to the processing plant. This would make the plant infrastructure more complex and because the farmers aren't getting the grain off of their land when they're harvesting it, they're not comfortable with this approach, says Michaels.

They've also looked at converting the stover into a slurry and pumping it to the processing plants within a 50-mile radius. But again, the infrastructure cost would be enormous. Besides, says Michaels, "People don't like windmills, so what are they going to do with pipelines?"

Ultimately, he says, they're aiming for a one-pass harvester. "We're working to develop a system that produces two product streams from one machine," he explains. "The best way to get clean stover is while it's standing in the corn field. We'll probably end up separating the corn from the stover in the field to reduce the number of handling operations.

"As soon as we get corn here in New York, we'll be testing the new unit we've come up with. Then we'll go to Imperial, Neb. and do some testing there."

Photo courtesy of CEA, Inc.

Various one-pass harvesters are under development with the ultimate goal of developing a system that produces two product streams from one machine.

Hettenhaus adds, "With no-till you want to avoid soil compaction, so we need a one-pass harvester that can accumulate both the grain and stover in one operation. But then we'll need more trucks to keep the combine running."

Hettenhaus and Michaels agree the chokepoint in the whole system is transporting this "bulky stuff" from field to processing plant.

The Transportation Challenge

While Oxbo's part of the research project only calls for the company to develop the one-pass harvester, Michaels says that there's no value in coming up with an innovative combine if they're unable to move the residue out of the field. As a result, the company has extended its investigation to address the transport issues.

The only practical way to do it currently is with trucks, he says. Unfortunately, it's not as simple as hauling corn. "For every truck of corn grain you haul, you need 8 to 10 trucks of the same volume to transport the stover you'll get from the same land area," explains Michaels.

The trucks aren't weight limited, but are volume limited and with that much traffic, soil compaction is bound to be an issue.

CSU Studying Crop Residue Removal Rates

Colorado State University (CSU) is playing a role in the intensive research being carried out across the nation to determine the economic and environmental viability of using crop residues as a source for ethanol production. Specifically, researchers are studying the effects of removing residue from the field.

The CSU program is part of the larger "Imperial Young Farmers and Ranchers Project: Biomass Opportunity for Imperial." Funded by the USDA, the project's goal is to determine the viability of cellulosic ethanol production in and around Imperial, Neb.

"We're looking at how much residue can be removed without affecting the long-term productivity of the soils," says Amy Swan, one of the project researchers. She says the researchers are also looking at erosion control, but the focus of the work revolves around longer-term soil fertility and carbon losses." While these things may be good ideas in terms of energy production and good revenue for farmers, we don't want to do anything that would threaten long-term productivity," she says.

A big part of her work is to study soil organic matter. "We've been sampling the soils on 3 farms with 2 of the 3 taking off approximately 60% of the residue left on the field. In a couple of years, we'll go back and sample again to determine changes in the organic matter in these fields."

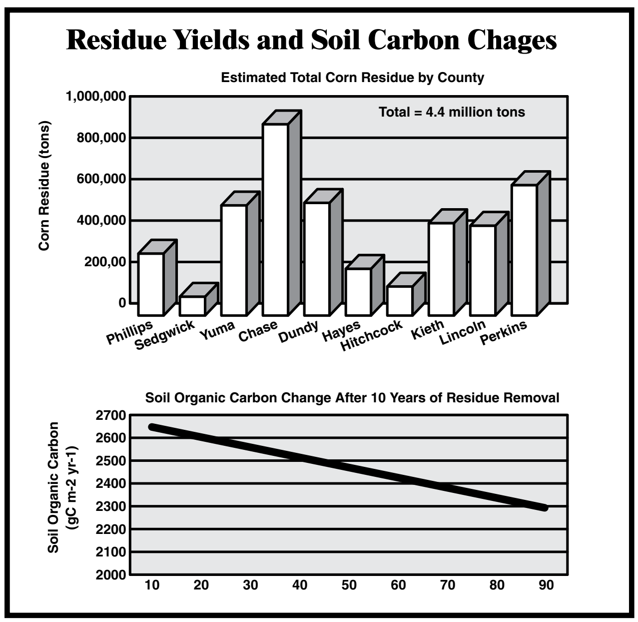
The research also utilizes the Century Model that was developed at CSU to simulate biochemical cycles in soils. "With this, we can come up with different scenarios involving different crop rotations along with various tillage practices and different soil management methods and look at varying levels of residue removal to determine the long-term implications," says Swan.

Part of the project is to determine if it is economically feasible to construct an ethanol plant in Imperial. To improve the overall efficiency of a plant, the idea is to produce all of its feedstock within a 50-mile radius. The purpose of the modeling is to regionalize the area to determine how much residue can be supplied to the ethanol plant.

"We've also talked about potential for using other types of plants, like switchgrass," says Swan. "They talking about planting this crop in the corners of the field because farmers don't like planting in the corners anyway. In this case, it would require some modification to the ethanol processing plant, basically they would need to run two different streams of materials and enzymes."

Based on the work they've conducted so far, Swan says that it appears that residue removal rates of 40% or more will likely result in soil carbon losses using conventional tillage practices. "Changes in management, such as adopting of no-till, will allow residue removal without compromising soil quality," she says.

Regarding the possibility of constructing a plant for the Imperial, Neb. area, Swan adds that, "Biomass production potentials are high in this region, making it a good



Based on preliminary results of Colorado State Univ.'s work on corn residue, it appears that removal rates of 40% or more will result in soil carbon losses using conventional tillage practices. Changes in land management, such as adopting no-till, may allow residue removal without compromising soil quality and productivity.

"And it all takes energy. If the energy formula going in and coming out aren't right, you're wasting your time," he says.

In terms of transport costs, Hettenhaus says, "For delivery within a 50-mile radius, $50 to $60 per dry ton delivered is a good number. The major cost is baling. With $4 per bushel corn, a farmer has little or no interest in messing with stover unless he nets $50 to $60 per acre minimum.

That puts the delivered cost closer to $60 per dry ton. Some are looking at tying the price of the stover to a barrel of oil or to natural gas, if it is used in a gasifier.

"For many farmers, there are too many unknowns to deal with to commit much more than a trial amount of acreage for residue sales — the impact of removing the residue on the soil and on the yield of future crops is of particular concern," says Hettenhaus.

Impact on Farm Equipment

While new one-pass harvesting machinery and transport equipment will provide manufacturers and dealers with new opportunities, Hettenhaus says that as more growers adopt no-till, the sale of some traditional farm equipment could decline as hours of use are reduced, and the need for some equipment could be totally eliminated.

On the other hand, he believes that the new high-tech systems (GPS auto-steer, etc.) coming to market will play a major role in improving the entire corn harvesting process.

"These systems will allow the farmers to do more with 'what ifs,'" says Hettenhaus. "Right now the farmer is looking at economics more than he is at the impact new practices have on his soils and we need to couple both of these needs. He needs to not only have knowledge of his yields ,but also of what's being removed and what he's adding to that field as you move across it."

In that way, he can adjust his fer-

Ethanol Byproducts Pelletized for Cattle Feed

One hundred percent of distillers dried grains with solubles (DDGS), a byproduct of ethanol production, can be pelletized without adding a binding agent or anything else, according to Agricultural Research Service (ARS) scientists and cooperators.

ARS agricultural engineer Kurt Rosentrater has turned DDGS from corn-based ethanol production into high-quality pellets using processing equipment at a commercial feed mill. The heating used in pelletizing did not harm the high-protein, low-starch nutrient content. Rosentrater is at the ARS North Central Agricultural Research Laboratory, Brookings, S.D.

Cattle feed is currently the primary outlet for distillers grain, but swine and poultry also eat it. To date, there are no commercial DDGS pellets available for livestock, which limits the byproduct's use in rangeland settings. DDGS is the protein, fat, fiber, unconverted starch and ash left over after ethanol production.

Fish raised for food in the growing aquaculture industry eat pelletized feed, but those pellets contain commercial fish meal as a protein source, rather than the less-expensive distillers grain.

Rosentrater is experimenting with adding soy and corn flour to distillers grain to produce pelletized feeds, to reduce the fish meal needs — or eliminate it entirely.

This pelletizing work also promises to solve a growing problem of product deterioration as well as hardening and caking problems during shipping and storage, which can clog chutes and bins used to transport DDGS. With an increasing supply of the byproduct, ethanol plants have to ship it greater distances to reach markets.

How Growers Benefit by Harvesting Corn Stover

Determining the value of stover can be complex and highly dependent on the efficiency of the baler-operator and local field conditions. The following baling cost from an Iowa State extension site can be used as a general guide, but should be adjusted further to reflect current fuel costs.

Assume the following:

Custom chopping	=	$6.50/acre
Custom raking	=	$3.80/acre
Custom raking	=	$8.25/acre
Three bales per acre (about 2 tons)		
Baled cornstalk price	=	$21.47/bales
$6.50 chopping + 3.80 raking	=	$10.30/acre
$10.30/acre/3 bales/acre	=	$3.43/bale
$3.43 + 8.25 baling	=	$11.68/bale total harvesting cost
$21.47 – 11.68	=	$9.79/bale standing price

Cost per acre for 3 tons removed, ignoring N and carbon sequestration, on no-tilled field that was previously tilled:

P and K	$4.25*3*0.85	$10.80
Chopping, raking, baling		$39.40
Less tillage savings		(10)
Net margin/acre desired		$50-$60

~ $38 to $40/dry ton baled in the field

tilizer and other inputs. For these reasons alone, I see much more high-tech and information technology moving into the corn field.

"It's a matter of coupling these technologies with practices like zone tillage. They'll make greater use of sensors to gather more information because we need some way to manage by exception. We also know that the grower will need help in processing this information so he doesn't have to spend all of his off time figuring it out."

Photo courtesy fob S. Long, U of I

Similar to typical haying operations, miscanthus is collected and bailed at the Univ. of Illinois research plot at its Urbana campus.

Emily Heaton, who is 5'4" tall, stands next to the miscanthus grass grown at the Univ. of Illinois to demonstrate its enormous size (April 2006).

Silo 2: Perennial Grasses: Ethanol's Next Frontier

When he uttered the words "switchgrass" in his 2006 state-of-the-union address, President Bush introduced the concept of using perennial grasses as feedstock for the production of ethanol to mainstream America.

It's the grasses that Kevin Shinners of the University of Wisconsin says will fill the second silo in the evolution of biofuels.

Switchgrass falls into this category, he says, but many other grasses could also come into play. Among these are reed canary grass, which is suited for the northern climates, and miscanthus that's prolific and grows well in southern climes. Giant reed is another candidate for producing cellulosic ethanol.

"Almost any high-yielding grass can be considered for cellulosic ethanol production, including alfalfa," he says. "There is work going on now to breed alfalfa as a biomass crop. It has a tremendous upside by virtue of its nitrogen fixing capability. In general, perennial grasses are very attractive vs. growing corn and other starches," he says.

For the grower, the prospect of raising perennial grasses is intriguing. "We've all heard about the Illinois row-crop farmer who spends his winters in Florida. If he switched from growing corn and beans and started growing a perennial grass, he could live in Florida for 9 or 10 months of the year," says Shinners. "He'd only have to come back to do some fertilizing and for harvesting.

"It's extremely intriguing. If you can get $50 a ton for miscanthus — this is what they're talking about in

Illinois — and you can get 15 tons of dry matter per acre, the farmer could make more money per acre than with $3 per bushel corn. So why wouldn't you do it?" asks Shinners.

Equipment Needs: A Mixed Bag

As for the equipment requirements, he says, this could be challenging for machinery manufacturers and dealers.

"When you think about all the equipment used for growing corn — tillage equipment, big tractors for planting — if you raise a perennial crop, you only plant maybe once or so every 10 years. This could have a negative effect on some equipment sales. On the other hand, with equipment used for harvesting — balers, rakes, choppers — we could see a resurgence in the sale of this type of equipment," he explains.

Fertilizing and weed control are also required for growing perennials because all grasses require nitrogen, according to Shinners. For example, switchgrass will need anywhere from 60-100 pounds of nitrogen per acre. "This isn't insignificant," he says. "This is the one negative you're going to have with most of the grasses. That's why some people are looking at alternative crops that are capable of nitrogen fixation in place of some of the perennial grasses."

Weed control isn't a slam-dunk, either. "Most of the grasses for ethanol will need some chemical weed control," says Shinners.

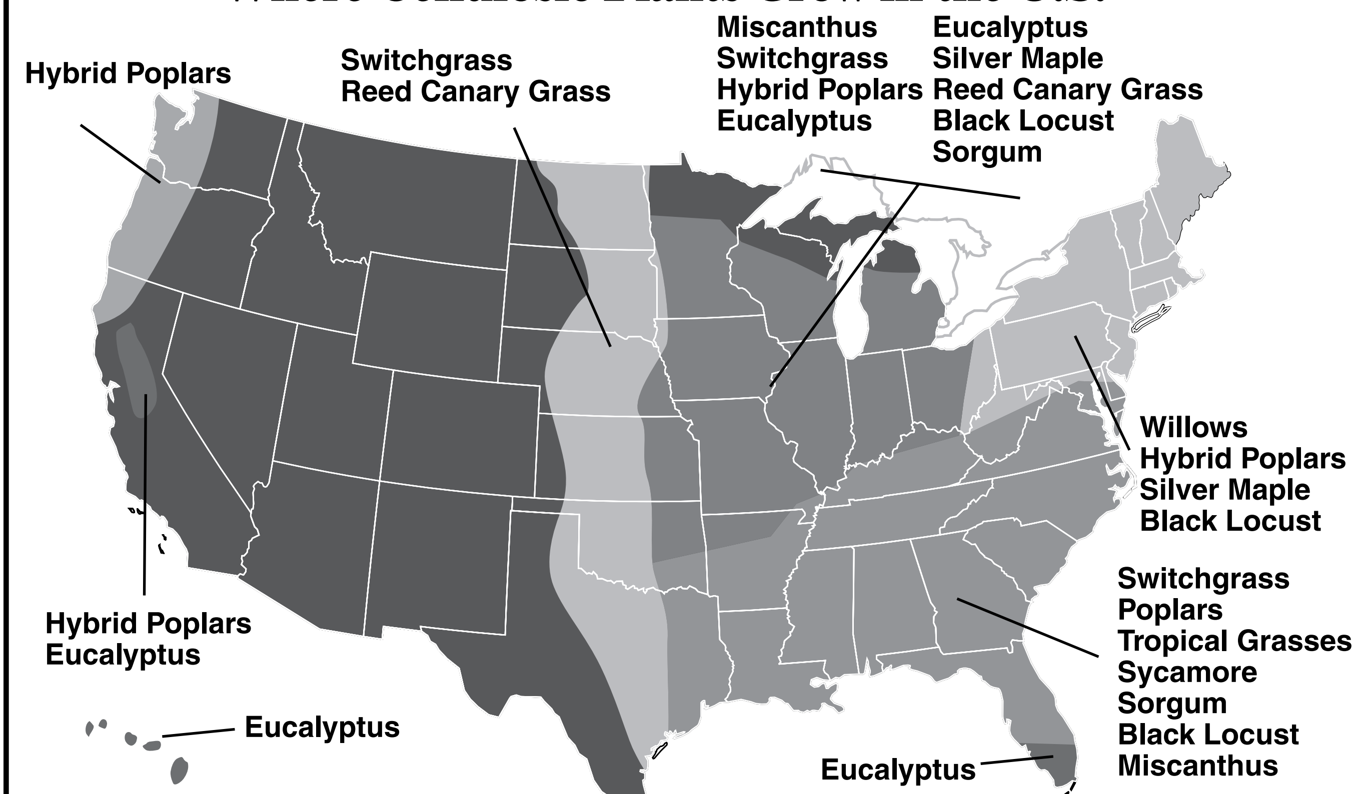
Another challenge he's found in his work with switchgrass is "critters," says the University of Wisconsin professor. "Most of these grasses provide fantastic wildlife habitat. This is both a blessing and a curse. On our switchgrass bales, maybe one out of 10 will have a critter in it. There are lots of skunks, coons and rabbits in these fields. Pheasants will take off while you're harvesting, but getting the others out of the field presents an engineering challenge."

Switchgrass: The Rising Star

Of all the grasses under scrutiny for producing cellulosic ethanol, switchgrass has received the most attention. It's a warm season grass and one of the dominant species of the central North American tallgrass prairie. Other names for it include tall panic grass, Wobsqua grass, lowland switchgrass, blackbent, tall prairiegrass, wild redtop and thatchgrass. Because it is capable of carbon fixation, it has an advantage with drought and high temperatures. Planting in the spring, at the same time corn is planted, is recommended.

Switchgrass is considered a good candidate for biofuel — especially ethanol production — due to its hardiness in poor soil and climate conditions, its rapid growth and low fertilization and herbicide requirements.

Where Cellulosic Plants Grow in the U.S.



Almost any high-yielding grass can be considered for cellulosic ethanol production, including alfalfa, according to Prof. Kevin Shinners of the Univ. of Wisconsin-Madison.

Because it is a perennial, unlike corn and sugar beets, and has a huge biomass output, the raw plant material used to make biofuel, can produce 6-10 tons per acre.

Growing 8 or 9 feet tall with a root system just as deep, switchgrass has the potential to produce the biomass required for production of up to 100 gallons of ethanol per metric ton. This gives switchgrass the potential to produce 1,000 gallons of ethanol per acre, compared to 665 gallons for sugar cane and 400 gallons for corn.

But there are two sides to the switchgrass-for-ethanol debate.

University of California-Berkeley professor Tad Patzek maintains that switchgrass has a negative ethanol fuel energy balance, requiring 45% more fossil energy than the fuel that it can produce.

On the other side, David Bransby, professor of energy crops at Auburn University, has found that for every unit of energy input, switchgrass yields four units. It is Bransby's work that was the source for President Bush's comments in the 2006 State-of-the-Union address.

According to the Department of Energy's Office of Transportation Technologies report, "Biofuels from Switchgrass: Greener Energy Pastures," many farmers already grow switchgrass, either as forage for livestock or as a ground cover, to control erosion. Producing switchgrass as an energy crop would require only minor changes in how it's managed and when it's harvested.

Switchgrass can be cut and baled with conventional mowers and balers. And it's a hardy, adaptable perennial, so once it's established in a field it can be harvested annually or semi-annually as a cash crop, for 10 years or more before replanting is needed.

Because it has multiple uses — as an ethanol feedstock, forage or ground cover — a farmer who plants switchgrass can be confident in knowing that it will be put to good use.

While most switchgrass research has been centered in the Midwest and Canada's prairie provinces, Canada is well ahead of the U.S. in developing switchgrass as a biofuel.

Iowa State University Researcher Dan Burden cites the work of Roger Samson of McGill University in pushing the Canadian government's proposal to replant 35 million acres of tallgrass prairie to mostly switchgrass for ethanol production.

Called "Solar Battery for the Prairies," this project could replace all of Canada's gasoline requirements; reduce government subsidies to both the agriculture and energy sectors; save farms, create rural employment opportunities; prevent Canada from becoming a net oil importing nation; rehabilitate prairie soils and wildlife populations; and reduce Canadian CO_2 emissions by 15%.

Exploring the Potential of Miscanthus

In early 2007, British Petroleum announced a $500 million research program to study the benefits of producing biofuels using corn residue, switchgrass and miscanthus. Under the new program, researchers at the University of Illinois in Champaign-Urbana joined the University of California at Berkeley and the Lawrence Berkeley National Laboratory in forming the new Energy Biosciences Institute (EBI).

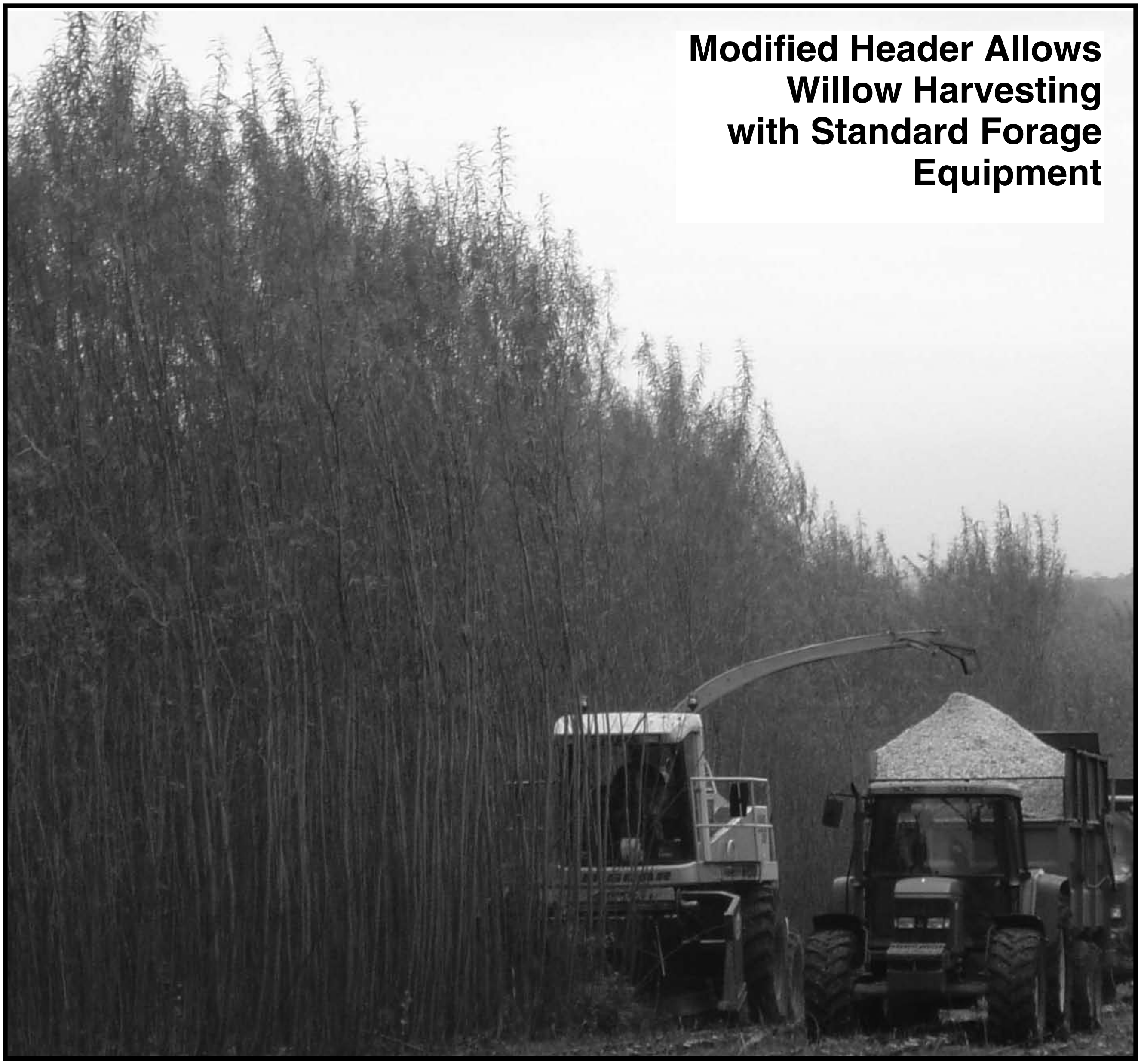
While research on using crop residues and switchgrass to produce cellulosic ethanol have been making headlines, miscanthus is the relative newcomer in the battle to lessen U.S. dependence on overseas petroleum products. New to most except for the University of Illinois, which has already done pioneering research on miscanthus as a bioenergy crop with support from the Illinois Council for Food and Agricultural Research.

Miscanthus — or more specifically miscanthus x gigantus — is a hybrid grass that can grow 13 feet tall. Under the EBI program, U of I is devoting 340 acres of farmland at its Urbana campus to the research. Based on previous work, researchers say this hardy perennial grass is more than twice as productive as switchgrass. Stephen P. Long, the rofessor of crop and plant biology is leading the EBI initiative for Illinois.

Continued on page 25

Tons of distiller's dried grains being held in storage at an ethanol plant.

Modified Header Allows Willow Harvesting with Standard Forage Equipment



Photos courtesy of Coppice Resources, Ltd., UK

A Claas Jaguar 860 equipped with a harvesting attachment developed by Coppice Resources in the U.K. works its way through a crop of willow. Coppice Resources is a wood chip procurement business that supplies planting, maintenance and harvesting services to growers.

According to the firm, the main requirements in terms of modifying standard forage harvesting equipment are some underbelly guards to protect the fuel tank and other components. The chopping mechanism, or harvest header, is key because it must produce a coarse but clean cut (inset) to produce a flowable fuel that can be reliably fed into power-generating boilers. The header was was developed by Coppice Resources.

Because the willow is soft, with about a 50% moisture content, it's not abrasive. Coppice Resources reports no problems with excessive wear and tear on the harvesting equipment.

Using Marginal Acres for Switchgrass

Currently, switchgrass production represents an important opportunity in the Midwest, especially where land is not well-suited to row-crop production, according to Dan Burden, of Iowa State University (ISU). Farmers currently enrolled in the USDA's Conservation Reserve Program (CRP), which pays landowners not to farm marginal land, may in the future, also profit from growing switchgrass as an energy crop.

"If CRP is discontinued or altered, in Iowa for example, up to 1.4-million acres of switchgrass currently held in CRP could be converted to energy production. This land has the potential to supply 530 million gallons of ethanol, or the equivalent of more than 3 million tons of coal capable of generating the amount of electricity used by 800,000 homes annually," says Burden.

Researchers at ISU determined that 1 pound of switchgrass contains 7,500 BTUs of energy. They further estimated that 1,500 acres of switchgrass per year would be required per megawatt of electrical-generation capacity.

Photo by David Tilman

The Minnesota biodiversity and bioenergy experiment contains numerous plots that were planted in various combinations ranging from 1 to 16 plant species.

Photo courtesy of USDA Agricultural Research Service

Technicians Calvin Vick (l) and John Massey measure switchgrass stem and density and geometry at the upstream end of a riparian gully at Little Topashaw Creek in Mississippi.

Continued from page 22

Before coming to Illinois, Long was involved with the European Union's renewable energy projects. "Miscanthus emerged there as a front-runner because it is very productive, yet requires very few inputs," he says. "For example, it appears to require almost no nitrogen fertilizer. In many areas of Europe, nitrogen pollution in the water is an issue. And so this was a particular environmental benefit of using the plant."

While some species of miscanthus are known to be invasive, Long says the type being studied is not. "We are currently using miscanthus x gigantus," he says. "This is a hybrid between two species, but a special type called a triploid. Triploids have three sets of chromosomes instead of the normal two. This prevents the formation of viable pollen and ovules. Triploids are known to be highly sterile. Triploid technology has been in use for over 100 years in the U.S. and elsewhere. Bananas sold commercially in the U.S. are triploids."

Miscanthus in Illinois starts growing in early April and carries on until almost the end of October. "This is why it reaches 13 feet. In 2004 we had 26 tons of dry matter per acre." This compares with about 10 tons per acre for switchgrass," says Long.

Long and graduate student, Emily Heaton, have been studying this grass since 2002, in which they conducted side-by-side comparisons of North American switchgrass with the European miscanthus.

In the 2004 trials, miscanthus production more than doubled the switchgrass output and tripled the yield in the 2005 trials, according to Long. "Our results show that with miscanthus, President Bush's goal of replacing 30% of foreign oil with ethanol, derived from agricultural wastes and switchgrass by 2030, could be achieved sooner and with less land," he says.

Because of the high yields with minimal inputs, Heaton says, farmers would make a profit if they received about $20 per ton. "The closer the field is to the processing plant, the cheaper it gets," she says.

According to Long, Europe currently has thousands of acres of miscanthus in production.

Silo 3: Hybrid Poplar and Willow Plantations Move Beyond Biofuels

Filling Kevin Shinner's third silo of cellulosic ethanol production are woody biomass materials from hybrid willow and poplar plants. This silo, says the University of Wisconsin researcher, will contribute a smaller fraction of the entire renewable supply, "but in certain locations, it may be very viable."

These biomass materials have, in fact, been under development in the U.S. for several decades, but their development lag woody biomass use in Europe, particularly in the U.K.

Perhaps the best known work on willow biomass has been at the State University of New York College of Environmental Science and Forestry (SUNY ESF). The Willow Biomass Project is a collaborative effort by members of the Salix Consortium to grow willow and other sustainable woody crops including poplar in upstate New York. The project, funded through the U.S. Department of Energy's Biomass Power for Rural Development Program, seeks to commercialize willow bioenergy crops as a renewable source of biofuel.

The program is supported by more than 20 organizations to facilitate the commercialization of willow crops and other woody biomass for bioenergy and bioproducts in the Northeast and Midwest United States. Project leaders say they are reconnecting the historic willow cultivation industry to central New York.

They say that willow — also called coppice — and other similar woody species like poplar are viable biomass material for the production of energy because:

- ✔ Willows are easily propagated from unrooted cuttings.
- ✔ High yields can be obtained in a few years.
- ✔ Willow's genetic diversity and short breeding cycle can be utilized to produce improved varieties.
- ✔ Willows vigorously resprout after each harvest.
- ✔ The amount of heat produced from a dry ton of willow is similar to other hardwoods.

Producing Willow Biomass

Willow biomass crops increase habitat diversity. They are planted on open, agricultural land and not on cleared forest land.

A crop can be harvested 6 to 7 times before replanting is required. Willow production uses significantly fewer pesticides than traditional agriculture.

DFSS Crops: Established Like Corn, Managed Like Hay

The Willow Dedicated Feedstock System (DFSS) is an agri-forestry system of production, using agricultural practices and equipment to produce wood biomass. By analogy, the willow biomass crop system is established like a corn crop, but managed like a hay crop with multiple harvests from a single planting.

In addition to the use of agricultural-type site preparation techniques and equipment, planting and harvesting machines and operations are more similar to agriculture than traditional forestry. Commercial planting equipment developed in Sweden for willow biomass crops includes an automated tractor-drawn and powered two- and four-row planters.

The researchers also assert that willow biomass products reduce the need for fossil fuels and petroleum products. Willow can be converted into a variety of sustainable environmentally-friendly resources, including:

- ✔ heat and electricity by direct combustion, co-firing with coal and gasification,
- ✔ biodegradable plastics and other polymers and
- ✔ biofuels.

"Removing the stover may also be a key to expanding no-till acres. . ."

Willow biomass grown in a dedicated feedstock supply system (DFSS) in the Northeastern U.S. was found to be a feasible means of augmenting current coal resources for power generation.

Beyond Bioenergy

In addition to bioenergy, proponents of willow plantations say they are ideal for a wide range of applications besides bioenergy and bioproducts and have other desirable environmental characteristics.These include:

- ✔ Riparian buffers — natural barriers that prevent chemicals from entering streams, ponds, and lakes.
- ✔ Phytoremediation — willows clean up toxins from contaminated sites.
- ✔ Living snowfences — strategically planted willows trap drifting snow.
- ✔ Wastewater management — willows filter contaminants from wastewater.
- ✔ Willow crops are carbon dioxide neutral, which helps reduce global warming.
- ✔ They reduce the need for fossil fuels for energy, chemicals, products and fuels.
- ✔ Combustion of willow biomass releases fewer acid-rain producing compounds into the atmosphere.
- ✔ Willow crops reduce soil erosion and nonpoint source pollution.
- ✔ Willow crops generate income for local landowners and create jobs within the local community.

Willow/Poplar Biomass Cropping

The willow biomass cropping system utilized by the Salix Consortium project has its basis in many traditional agricultural and conservation tillage practices. Trees are mechanically planted in the spring at 6,200 seedlings per acre using the Swedish double-row system. Cuttings are planted 2 feet apart, with the double rows being 5 feet apart, managed on coppice cycles of 3 to 4 years. Weed control is extremely important during the year of establishment. Nutrients (chemical fertilizers and/or organic sources) are applied in the spring and/or early summer after cutback and each coppice harvest. The willows are harvested in their dormant stage with modified agricultural machines.

Approximately seven coppice harvests over 21 to 28 years are expected following establishment. The willow crop can be reestablished whenever tree vigor-health-survival declines substantially and reduces productivity or new-improved clones become available and it is economically justified to replant. The crop can also be abandoned or the land be converted back to other uses.

Harvesting is done during the dormant (winter) season. This maximizes tree nutrient and carbohydrate allocation to roots during the autumn, promoting vigorous coppice re-growth the following spring and ensures that the leaves have fallen and will enter the site's nutrient cycle. In addition, leaves with their relatively high nutrient contents may be problematic in some conversion processes. Winter harvesting ensures that the ground is hard and trafficable, and does not interfere with normal farm harvesting operations in the summer and autumn.

Winter harvested material, which is immediately chipped, is stockpiled during harvest months (November to March) for use throughout the year, creating inventory management challenges, or stored as a "cold-season-only fuel" (6 months). In this case, during the "warm-season" (April to November) alternative fuels would be required since chipped material can only be stored for 1 to 4 months with proper management.

If willow biomass harvesting is done with a whole-stem harvester, cut stems can be stored for several years, drying while in storage, and then used as fuel during cold or warm-season months. In co-firing, coal-only fuel can be used as required. In advanced biopower conversion systems, 100% dependent on biomass, alternative biomass resources in addition to willow biomass crops may have to be used. These could include biomass from forests and wood processing industries, as well as seasonally available agricultural residues. Warm-season harvested DFSS crops, such as the alfalfa stem biofuel project in Minnesota, might also be attractive options.

Willow Harvesting Equipment

Automated willow DFSS harvesting machines have been developed in Europe and are commercially available in the U.S. Two basic types of machines have been developed: the harvester-chipper and the whole-stem harvester. Harvester-chippers are modified corn (Claas Jaguar 695 by Claas Corp.) or sugar cane (Austoft 7700 from Austoft, Inc.) harvesters, which cut, chip and blow the chips into a dump wagon following alongside or pulled by the harvester.

Two Swedish companies, Rosenhalls gard Energi AB and Froebbesta, Inc. have developed whole-stem harvester machines. These units cut whole stems and pile them in the field, which are moved by grappling equipment for on-site storage, direct transport or chipping and transport.

IV. Biofuel Production: A Billion-Ton Vision

Few would disagree that America has barely scratched the surface of its biomass-for-energy potential, but we're on our way.

When the U.S. Departments of Energy and Agriculture released the landmark study, *Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply* in April 2005, it signaled the country's first serious, significant steps toward energy independence and improving the environment. If anything is clear, it is that agriculture will play a critical role in achieving their "billion-ton vision."

The report estimates that, the U.S. can produce nearly 1 billion tons annually and still continue to meet food, feed and export demands. This projection includes 428 million dry tons of annual crop residues, 377 million dry tons of perennial crops, 87 million dry tons of grains used for biofuels, and 106 million dry tons of animal manures, process residues and other miscellaneous feedstocks. Assumptions that were made include:

- ✔ Yields of corn, wheat and other small grains were increased by 50%.
- ✔ The residue-to-grain ratio for soybeans was increased to 2:1.
- ✔ Harvest technology was capable of removing 75% of annual crop residues (when removal is sustainable).
- ✔ All cropland was managed with no-till.
- ✔ 55 million acres of cropland, idle cropland and cropland pasture were dedicated to the production of perennial bioenergy crops.
- ✔ All manure in excess of that which can be applied on-farm for soil improvement under anticipated EPA restrictions was used for biofuel.
- ✔ All other available residues were utilized.

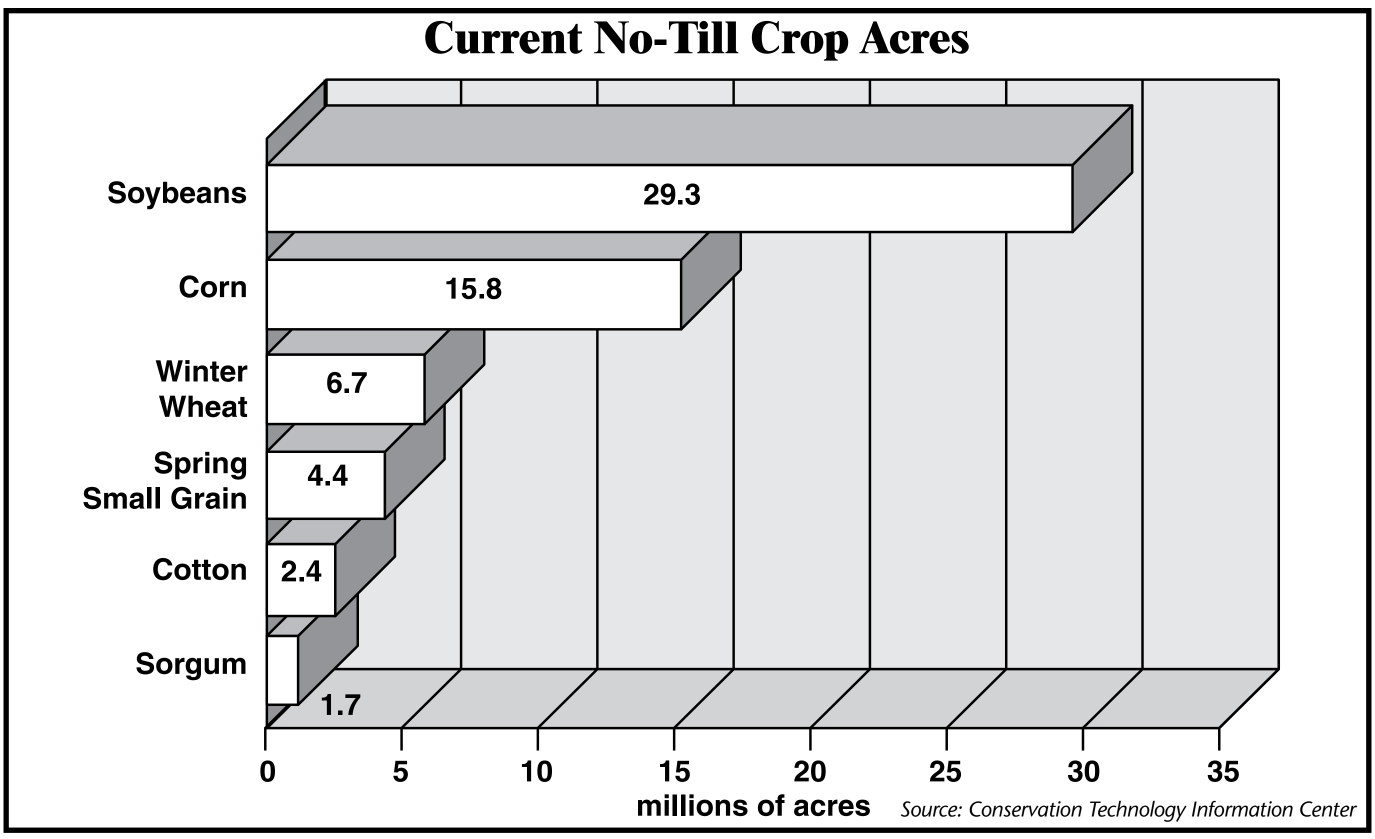
In a nutshell, agriculture will need to further improve its productivity by mechanizing and automating its operations, and by increasing the use of conservation tillage practices. Inevitably, seed and fertilizer suppliers, equipment manufacturers and farmers, themselves, will need to play their part.

On the Road, In the Field

Getting America on the road to energy independence will come from the fields of America's farmers. The technology for distilling and producing ethanol is still growing up. "It is in its infancy," says Shinners of the University of Wisconsin-Madison.

Whereas the production of corn ethanol has a three-decade head start on the science for producing cellulosic fuels, the resources needed to get it to where it needs to be as viable alternative fuel are in place.

"I envision it to be somewhere similar to where corn grain ethanol was at the same stage of development in the 1970s," says Shinners. "Thirty years ago we had an energy crisis and we looked at corn grain as a way to ease the emergency. It was



No-till planting now accounts for more than 60 million acres in the U.S. It is anticipated that no-till acres will grow significantly in the future.

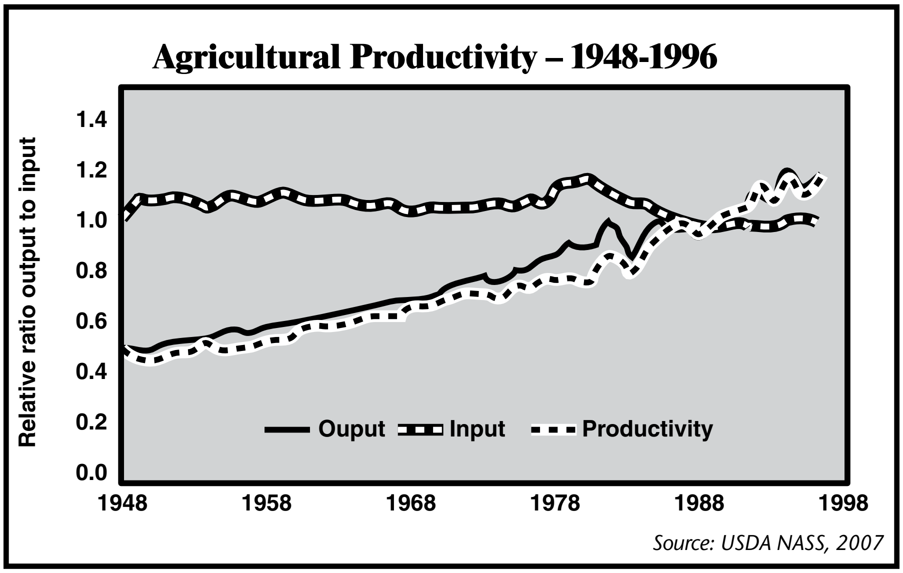
not particularly profitable at the time, but as more development work took place and the market came into place, it exploded. That's pretty much the same place where we are now with cellulosic fuels.

"There are more resources being invested into cellulosic ethanol development right now, so the total development time to maturity is going to be much, much shorter than it was with corn ethanol. The urgency is pushing it," he says.

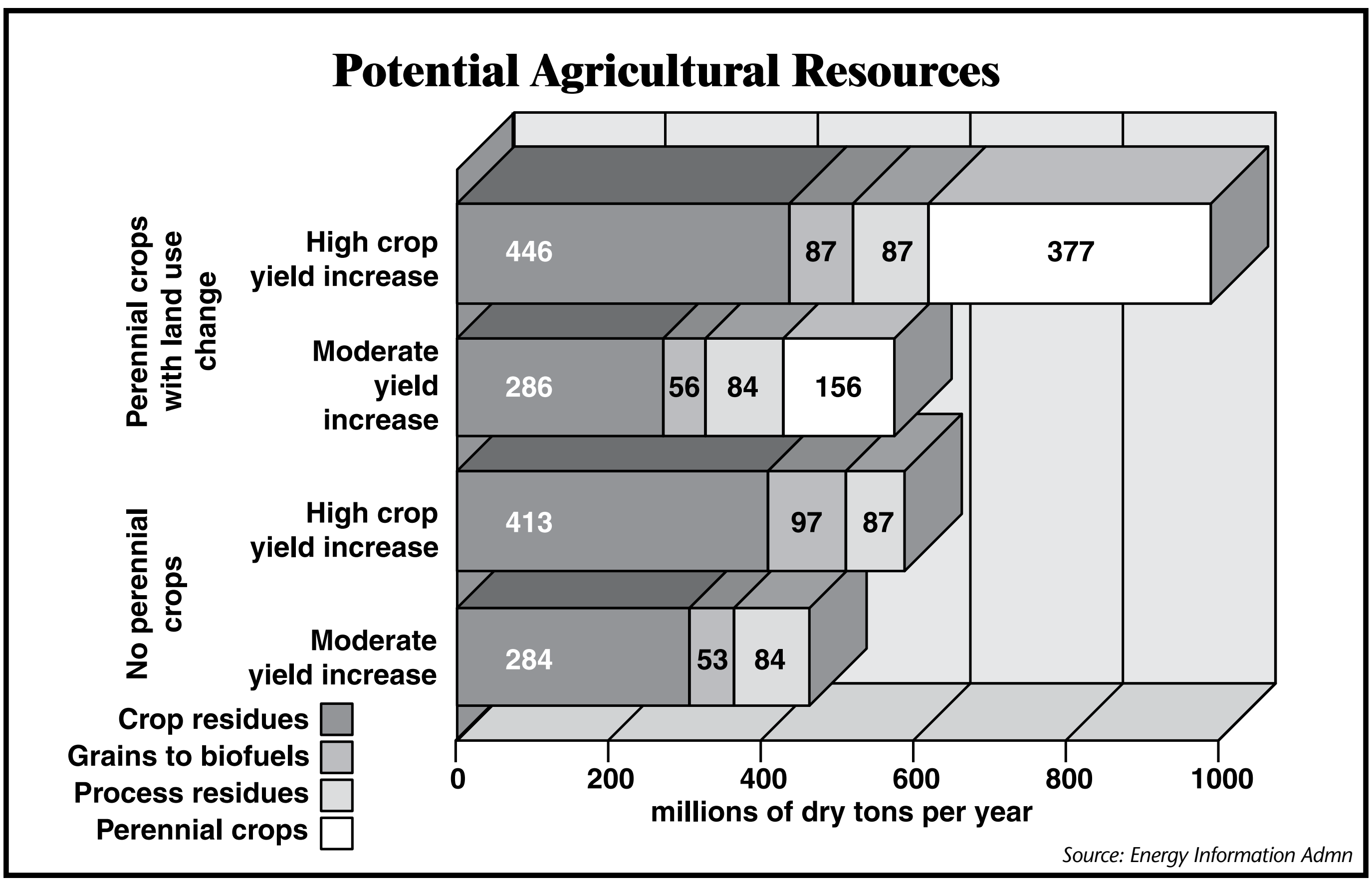
According to Shinners, the DOE has released about $380 million in 6 contracts to build cellulosic ethanol facilities across the U.S. All the way from Florida to California, they've started breaking ground on these. Later in this decade they'll be on line producing about 130 million gallons a year in total ethanol. These are relatively small plants, but they're big enough that you can learn something from them. There is going to be a tremendous learning curve as these 6 plants go up as they use everything from yard waste to corn stover to make ethanol."

It's Shinners' view that that the road to ethanol-based fuels will require both corn and cellulosic materials. "If you're really going to make 60 billion gallons by the year 2035, you're still going to need starch-based facilities.

"We'll be using cellulosic material side-by-side with corn grain and we'll have a very efficient, sustainable pro-



Agricultural productivity — a measure of output to input — has increased steadily during the last half of the century.



Summary of potentially available agricultural resource for production of ethanol.

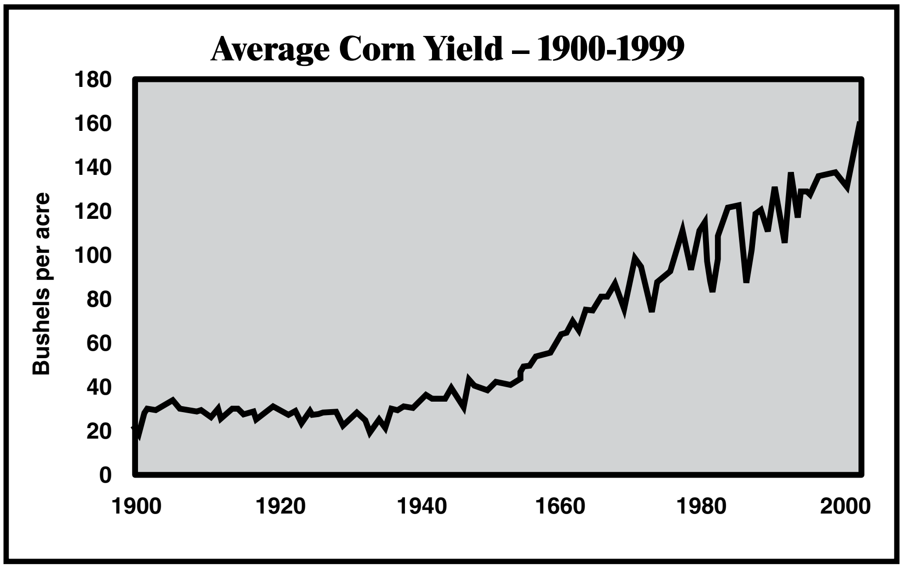
cess by doing this."

On the other hand, Don Borgman, in presenting John Deere's position on ethanol production, believes that through improving technology and development, corn will remain the primary source for agriculturally based fuels.

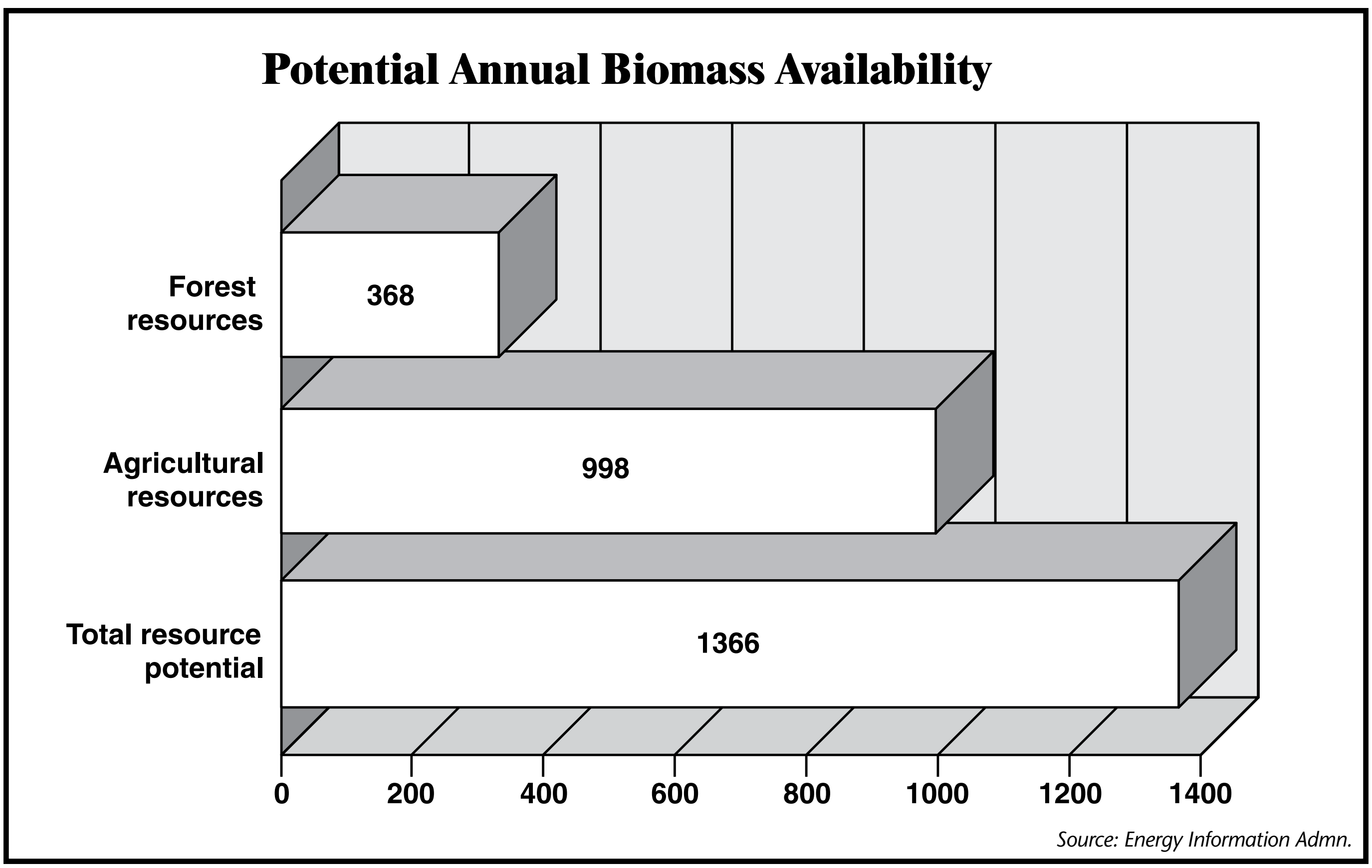
"With corn as the feedstock, U.S. ethanol production exceeded 4.5 billion gallons in 2006," says Borgman. "Some experts maintain the industry holds the potential to expand to 16 billion gallons by 2015 based on reasonable predictions for growth in corn yields, growth in ethanol yield and the probable expansion of corn acres.

"Meeting the long-term expansion potential of 60 to 80 billion gallons by 2030 may require the production of ethanol from cellulosic material such as crop and forest residues and dedicated energy crops. However, some believe the development of new generations of hybrid seed corn and improved production techniques could increase the U.S. corn crop to 25 billion bushels and beyond, lessening the need for development of cellulosic sources," he says.

"One thing, however, is certain: no matter the feedstock, deriving energy from renewable resources is positive for the environment, rural economies, and energy security for nations around the globe."



The per acre yield of U.S. corn crops has risen dramatically during the past century, but if corn is to continue playing a prominent role in the growing use of ethanol, cropping productivity will have to continue rising. A major assumption of the "Billion-Ton Vision" has corn yields increasing by 50% during the next 3 decades.



Annual biomass resources potential from forest and agricultural resources is estimated to surpass 1 billion tons.

IV. Biodiesel: New Kid on the 'Alternative-Fuels' Block

When Rudolf Diesel developed the diesel engine in 1912, he believed his new engine would be fueled by crop-based materials. Diesel was a man ahead of his time — way ahead of his time.

In a speech delivered in 1912, the German inventor of the diesel engine said, "The use of vegetable oils for engine fuels may seem insignificant today, but such oils may become — in the course of time — as important as petroleum and the coal-tar products of the present time."

Today, biodiesel is finally making its presence known, but compared to the headline-stealing move toward ethanol-based gasoline, it remains the new kid on the block. At the same time, the expectations for biodiesel's role in reducing the nation's reliance on petroleum for powering trucks, tractors and other diesel engines is as significant as ethanol is to gasoline-fueled vehicles.

Produced from domestic, renewable resources such as soybeans — biodiesel is a clean-burning alternative to petroleum-based diesel fuel. Pure biodiesel contains no petroleum, but it can be blended at any level with petroleum diesel to create a biodiesel blend. At lower blend levels, it can be used in compression-ignition (diesel) engines with little or no modifications. Pure biodiesel is biodegradable, nontoxic, and essentially free of sulfur and aromatics.

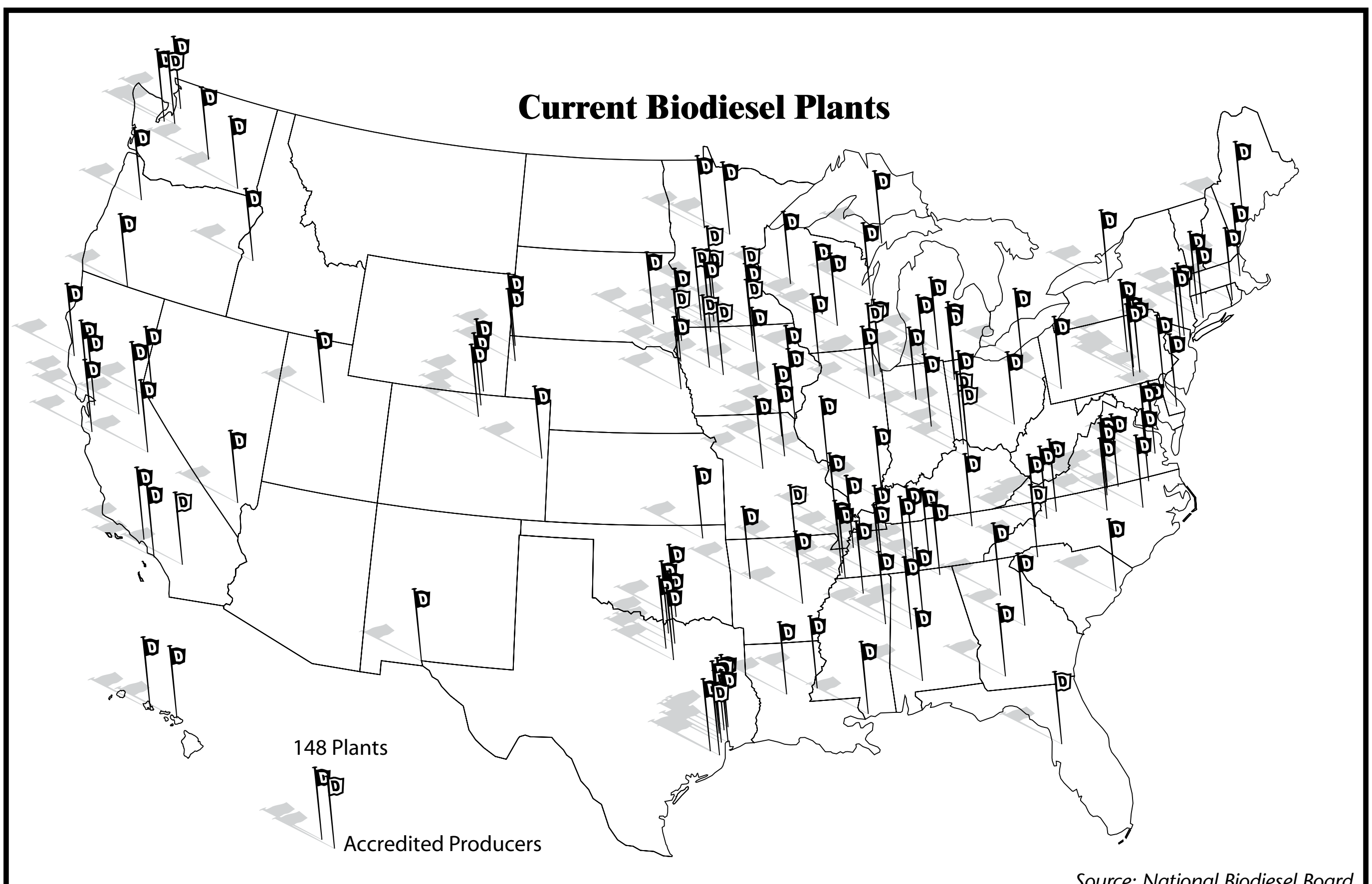
Biodiesel is made through a process called transesterification whereby the glycerin is separated from the fat or vegetable oil. The process leaves behind two products — methylesters (the chemical name for biodiesel) and glycerin (a byproduct usually sold for use in soaps and other products).

Room to Grow

Available to the marketplace since the 1970s, in terms of current production, biodiesel is in its infancy. As Don Borgman of John Deere puts it, "Biodiesel currently represents the proverbial drop in the bucket of total U.S. diesel fuel consumption." The 75 million gallons out of a total diesel fuel consumption of 58 billion gallons in 2005 equates to less than two-tenths of one percent.

Along with ethanol for gasoline, biodiesel is experiencing skyrocketing growth and has enormous potential for making a significant impact in reducing petroleum use. According to the National Biodiesel Board, in 2000 there were fewer than 10 biodiesel plants in the U.S. Production facilities had increased to 65 plants with the capacity for producing 395 million gallons by 2006.

Another 58 plants are currently under construction or in the process of expanding, adding another 318 million gallons of capacity when completed. While ethanol production increased 120% percent between 2001 and 2005, biodiesel production increased 900% over the same period.



Commercial Biodiesel Production Plants as of June 7, 2007.

Issues Confronting Biodiesel

As is the case with ethanol, the Energy Policy Act will encourage near-term growth for biodiesel, and is a major reason capacity is projected to reach 1.7 billion gallons by mid-2008. Over the long term, projections relating to crude oil prices and tightening supplies that are fueling the growth of ethanol-based fuels also will contribute to the growth of biodiesel.

In his white paper, Borgman outlined three broad challenges that he believes will ultimately affect the potential of biodiesel fuels in the U.S. These include the development of production and distribution systems that are intensely focused on consistent, high quality supplies of biodiesel.

Quality: Quality issues in the early days of Gasohol — more than 25 years ago — soured a significant portion of the population on the product, according to Borgman. "In fact, a recent survey indicates that 19% of Americans

Biodiesel vs. Renewable Diesel: Two Different Things

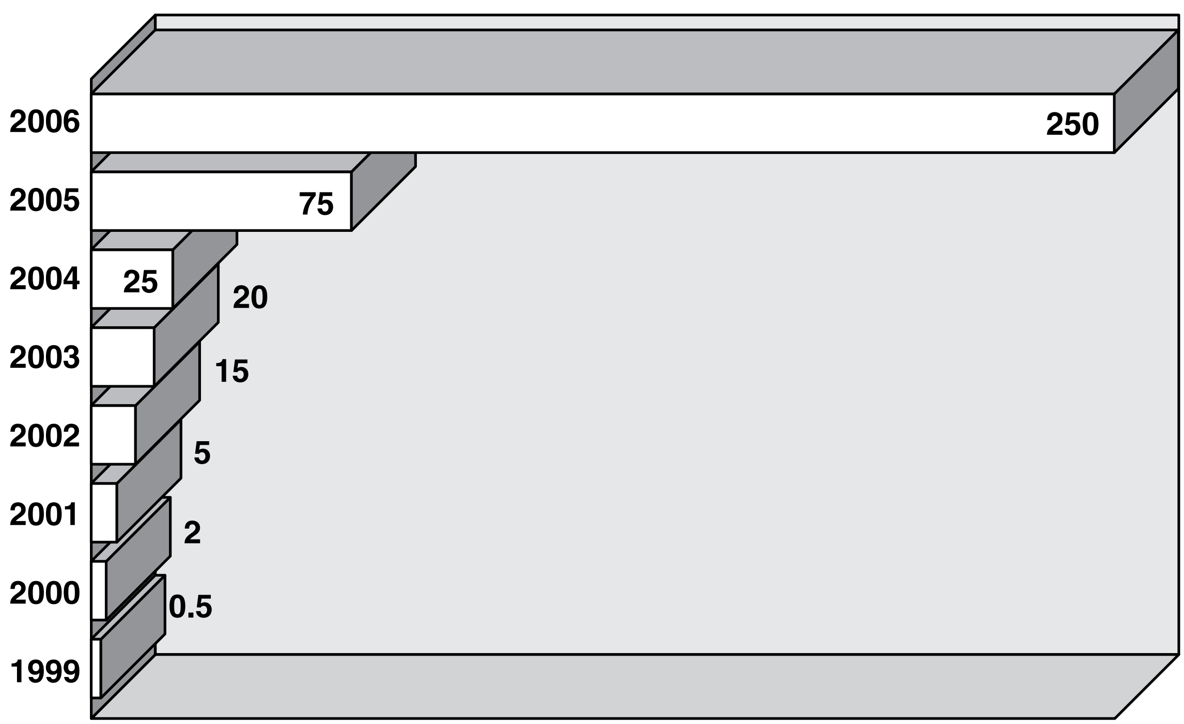
The majority of the 75 million gallons of biodiesel produced in 2005 came from soybean oil, although it can also be made from other oilseed crops, animal fats, waste oil and grease. It is important to note that biodiesel is not the same thing as raw vegetable oil.

Fuel-grade biodiesel must be produced to strict industry specifications (ASTM D6751) in order to ensure proper performance. Biodiesel that meets ASTM D6751 and is legally registered with the Environmental Protection Agency is a legal motor fuel approved for sale and distribution. Raw vegetable oil cannot meet biodiesel fuel specifications, is not registered with EPA and is not a legal motor fuel.

Another thing to keep in mind is that renewable diesel and biodiesel are two different things. Renewable diesel is chemically equivalent to conventional diesel and can be shipped through a conventional pipeline. And while renewable diesel and biodiesel use similar feedstocks such as animal fats and vegetable oils, they each have different processing methods and create chemically different products.

The National Biodiesel Board points out that biodiesel offers many benefits that renewable doesn't, such as adding to refining capacity, improving certain performance characteristics, reducing emissions like particulate matter when burned in a diesel engine and adding jobs to the economy.

U.S. Biodiesel Production – 1999-2006



Source: National Biodiesel Board

Production of biodiesel fuels reached 250 million gallons in 2006.

don't want to use ethanol today due to concerns over fuel-system or engine problems. It took more than 2 decades and significant upgrades in quality and industry standards — not to mention a name change from Gasohol to ethanol — before the industry was able to overcome these negative consumer perceptions.

"It is essential that the biodiesel industry avoid these problems and learn the lessons from the early days of ethanol," says Borgman. "In an effort to increase biodiesel production and acceptance, the industry has moved very rapidly, and the risk of quality issues and negative public perception is high."

Supply: The availability of adequate feedstocks is another factor affecting the near-term viability of B20 as an industry-wide standard. Current biodiesel production equates to an industry-wide blend rate of B13 (less than two-tenths of one percent). A B2 blend is an attainable goal, as it would require 1.1 billion gallons of pure biodiesel. Still, that would consume all the soybean oil from 18 million acres, or about one-fourth of current U.S. soybean production. Even meeting the supply needs of B5 would prove to be an aggressive goal as it would require 2.9 billion gallons of pure biodiesel or the oil from 46 million acres of soybeans.

Distribution: While the industry has made significant headway in expanding production facilities for biodiesel, distribution channels are still limited due to an extremely tight product supply. A distribution infrastructure needs to be developed that helps facilitate the growth of the biodiesel industry. As with any industry, it is difficult to develop all needed elements at once. Until adequate supplies of high-quality biodiesel are available, it is difficult to attract investment in broad scale distribution. And until distribution outlets are available, it's difficult to justify broad-scale investment in higher production. That's why public policy incentives and broader industry efforts are needed to develop the distribution infrastructure more rapidly.

What the Biodiesel Industry Needs to Avoid

A number of companies and organizations that are attempting to show their support of agriculture have advocated blends as high as B20, according to Don Borgman of John Deere. "Unfortunately, when operators use blend rates higher than B5, they run a greater risk of experiencing several difficulties," he says. These include:

- ✔ Water in the fuel due to storage problems.
- ✔ Foreign material plugging filters due to the solvent characteristics of biodiesel that "clean up" storage and fuel systems.
- ✔ Fuel system seal and gasket failure.
- ✔ Fuel gelling in cold weather.
- ✔ Crankcase dilution.
- ✔ Injection pump failure due to water ingestion.
- ✔ Power loss and, in some instances, power growth that is detrimental to long engine life.

"This is not to imply that an operator will experience any or all of these problems, but their risk of occurrence increases as the level of biodiesel blend increases," says Borgman. "Recent findings of quality problems with biodiesel blends in many regions of the country underscore the immediate need for intense industry focus on quality improvement.

The majority of the 75 million gallons of biodiesel produced in 2005 came from soybean oil. This rose to 250 million gallons in 2006. Soybean growers are expected to benefit from the increased use of biodiesel in the future as well.