Next generation biofuels - cellulosic ethanol

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Executive brief

Next-generation biofuels refer to those made using advanced technologies that greatly expand the potential to use widely available biomass, including woody biomass and wood waste; crop residues; dedicated energy crops such as switchgrass, energy cane, and biomass sorghum; municipal solid waste; and algae.

Preamble

The first commercial next-generation biofuel plants should be operational in 2010 in the United States. It will use pine-tree waste as the feedstock. Initial output will be methanol. The ethanol production is expected to commence at a later stage of development.

Another U.S. plant is expected to start commercial operations in the second half of 2010, using **animal fat as the feedstock** and producing a bio based diesel fuel.

A number of U.S. companies are currently experimenting with different approaches to producing **algae-based** fuels. Their interest in algae as a feedstock is driven by algae's **high potential yield per acre**. Some companies grow algae in photo-bioreactors and others in open ponds, with yields potentially greater than **5,000 gallons* per acre**, by far the greatest potential of any feedstock for conversion to biofuels. Algae can be cultivated on marginal land that is unsuitable for growing crops or raising livestock, but also can compete with food-producing resources (for example, converting catfish ponds to algae propagation). Although the majority of algae-to-biofuel companies are focusing on producing algae oil for traditional biodiesel production, some companies are using **algae to produce ethanol (Algenol**), or petroleum-equivalent fuels (UOP and Sapphire).

Development prospects

The U.S. Environmental Protection Agency (EPA) announced in early 2010 that the cellulosic biofuel mandate for 2010 would be reduced from 100 million gallons to 6.5 million gallons. There were no changes to mandated levels for subsequent years. The ERS (Economic Research Service - USDA) estimates that production capacity may be about about 10 million gallons, with capacity expanding to over 200 million gallons by 2012. Production is likely to be less than capacity, particularly with the short-term prevalence of pilot and demonstration facilities that are not operated on a continuous basis. Total production capacity for next-generation biofuels, including cellulosic biofuel, biobutanol, and biobased petroleum equivalents, is expected to be about 88 million gallons per year (primarily one company) by the end of 2010, less than the average capacity of a single new corn ethanol plant. Total sector capacity is expected to surpass 350 million gallons by 2012.

Poet Inc., which has a pilot plant operational in Scotland, South Dakota, may have the **first commercial plant to produce cellulosic ethanol**. The facility will be co-located with one of their existing corn ethanol plants in Emmetsburg, Iowa, and is scheduled to be **operational in late 2011 or early 2012**, using corn cobs as the feedstock. Most other 'bio-refineries' have pilot or demonstration plants, with average estimated production capacity of less than 1 million gallons, in 2010 but with future plans to expand.

In the short term, production of next-generation biofuels will be limited and thus will have a minor impact on feedstock demand. Furthermore, some companies will exploit already existing streams of forestry waste and municipal solid waste while supply arrangements for agricultural biomass (crop residues and energy crops) are developed. However, if production of next-generation biofuels gets on an expansionary path, agriculture could eventually play a large role. Biomass inventory and other analyses by the U.S. Department of Energy (DOE), USDA, and EPA conclude that of all potential sources of biomass, U.S. agricultural sources **(crop residues and energy crops)** are the most significant.

Cellulosic ethanol production process

As with grains, processing cellulosic biomass aims to extract fermentable sugars from the feedstock. But the sugars in cellulose and hemicellulose are locked in complex carbohydrates called polysaccharides (long chains of monosaccharides or simple sugars). Separating these complex polymeric structures into fermentable sugars is essential to the efficient and economic production of cellulosic ethanol.

There are two basic process options:

Option 1 – Using acid hydrolysis to break down the complex carbohydrates into simple sugars.

Option 2 - Enzymatic hydrolysis uses a pre-treatment process to first reduce the size of the material to make it more accessible to hydrolysis. Once pre-treated, enzymes are employed to convert the cellulosic biomass to fermentable sugars.

In both cases the final step involves microbial fermentation yielding ethanol and carbon dioxide.

Maize derived ethanol utilises fossil fuels to produce heat during the conversion process, generating substantial greenhouse gas emissions, whereas cellulosic ethanol production substitutes biomass for fossil fuels, changing the emissions calculations.

The calculations for cellulosic ethanol production showed greenhouse gas emission reductions of about 80% over petrol production but corn ethanol only showed a 20 to

30% reduction. Cellulosic ethanol's ‘cleaner’ profile stems from using lignin, a biomass by-product of the conversion operation, to fuel the process. Lignin is a renewable fuel with **no net greenhouse** gas emissions. Greenhouse gases produced by the combustion of biomass are offset by the CO_2 absorbed by the biomass as it grows.

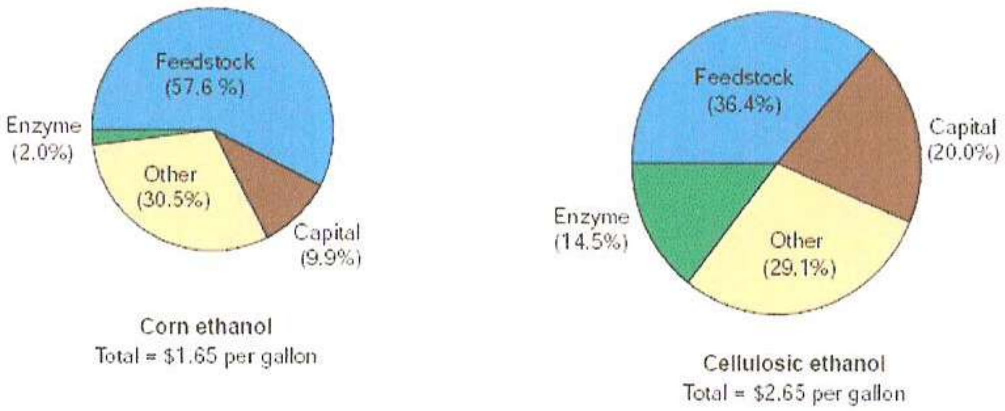
Economics of cellulosic ethanol

Production cost estimates (net of capital costs) for growing and converting algae to fuel are significantly higher than for first- and next-generation biofuels, ranging from $9 per gallon to $35 per gallon, depending on the production technology. This compares with less than $3 per gallon for cellulosic ethanol. **Except for subsidised military uses, the market for algae-based fuels will be limited until production costs are greatly reduced.**

Some companies will exploit already **existing streams of forestry waste** and **municipal solid waste**. Other companies are in the process of developing supply arrangements for agricultural biomass (**particularly crop residues and energy crops**). Eventually agriculture could play a significant role as next-generation biofuel production expands. Biomass inventory studies show that of all potential sources of biomass in the United States, agricultural biomass is the most significant. This is reflected by a number of companies planning significant biofuel production in 2011-12 from agricultural biomass: Poet Inc. plans to produce 25 million gallons from corn cobs starting in 2011 or 2012; Abengoa Inc., 11.6 million gallons from corn stover, wheat straw, and switchgrass in 2012; and Verenium Inc., 36 million gallons from energy grasses in 2012. Capital-investment costs for cellulosic ethanol should be significantly more than those for corn ethanol plants, although it must be kept in mind that this is an assumption, as there are no actual cost data for commercial operations since **none are yet operational**. So in the pie chart below the capital element for cellulosic production is an estimate.

The pie charts below shows the incremental costs associated with manufacturing cellulosic ethanol versus maize ethanol: a key element of which is enzyme use. The companies manufacturing the enzyme are forecasting a reduction in the cost of the enzyme element to the value of $0.50 per U.S. gallon of ethanol. This produces an estimate of **£1.0 per US gallon** for total cost in plants producing during the course of 2010, versus the current prediction (2009) of **$2.65 per U.S. gallon**.

Comparing corn and cellulosic ethanol production costs



Source: Keith Collins, Chief Economist, USDA. *The New World of Biofuels: Implications for Agriculture*. Presentation at Energy Information Administration (EIA) Energy Outlook, Modeling, and Data Conference. March 28, 2007.

In 2007, USDA estimated cellulosic ethanol production costs at $2.65 per gallon, compared with $1.65 for maize-based ethanol ($2.88 compared with $1.8 inflating by CPI). Capital and conversion costs are expected to decline as companies increase production and have greater access to low-cost biomass.

According to a 2008 report by the Biomass Research and Development Board, farmers would need to receive $40 to $60 per dry ton** to produce sufficient feedstock for 12 billion to 20 billion gallons of cellulosic ethanol from agricultural biomass—agricultural residues and energy crops. These prices are consistent with the $40 to $60 per ton that Poet Inc. plans to pay suppliers of corn cobs for delivery at its commercial cellulosic ethanol plant when it opens in 2011.

For farmers to shift to production of dedicated energy crops such as switchgrass, however, farm prices would need to compete with the lowest value crops such as hay, whose price has exceeded $100 per ton since 2007.

The number of gallons of ethanol produced per dry ton of biomass is forecast to improve from 50 gallons per dry ton to 117 gallons per dry ton. 117 gallons of ethanol per dry ton equates to 77- 82 gallons of petrol equivalent per dry ton (one gallon of ethanol contains about 66%-70% of the energy content of petrol). The bulk of the increase is expected to come from R&D driven advances in biological processing.

It is believed that bio-refineries will be producing cellulosic ethanol at a cost leaving the plant of $0.59 to $0.91 per gallon by 2015. The price range is dependent upon plant scale and efficiency factors. At these prices, biofuels would be competitive with the wholesale price of petrol.

Cellulosic ethanol subsidy

The new Biomass Crop Assistance Program in the Food, Conservation, and Energy Act of 2008 (Farm Act) will help to boost farmer incentives and lower feedstock costs for bio-refineries. This program provides assistance up to $45 per dry ton to producers of eligible biomass. The assistance is directed at the establishment and production of new feedstock for biofuels. The subsidy significantly increases incentives to produce, harvest, collect, and deliver bulky low-value biomass products to bio-refineries and other conversion facilities.

This subsidy to the farmer equates to over 30% of the cellulosic ethanol production costs and it is difficult to see how this level of subsidy can be sustainable.

The 2008 Farm Act provides funding for research on and development of conversion technologies and biomass; **a tax credit of $1.01 per gallon for cellulosic ethanol for 2009-12.**

The USDA **provides loan guarantees** to support development of innovative conversion technologies for next-generation biofuels. It is also proposing a program to encourage bio-refineries to use renewable biomass energy instead of fossil fuels and a payment system to support production. **EISA provides a 50-percent depreciation deduction for eligible cellulosic biofuel plants in the first year of operation through 2012.**

In several U.S. research centres, public funds target efforts to lower the costs of production of next-generation biofuels through increasing biomass yields (tons per acre), conversion yields (gallons per ton), and speed of conversion; finding new uses for co-products; improving the understanding of optimal removal rates for agricultural residues; and addressing economic and environmental issues.

Source data from the United States Department of Agriculture - May 2010

Conclusion

By 2011 to 2012 technology, particularly the improvement of the process to produce ethanol from plant material could overtake the bio fuel from maize process but vested interest in newly commissioned maize using plants may well delay the construction of new plants. However the drive by the U.S. to rid itself of reliance on imported fuel and reduce the burden on the food chain may well spark new initiatives to compensate companies willing to convert to cellulosic production prior to their old maize ethanol plants being fully amortised.

Notes

**1 US gallon = 0.833 Imperial gallons*

***1 US ton = 2000 lbs*

References:

William T Coyle Next Generation Biofuels - USDA
http://www.ers.usda.gov/AmberWaves/june10/Features/NGBiofuels.htm

Greer and Wang - Creating cellulosic ethanol: Spinning Straw into Fuel
http://www.harvestcleanenergy.org/enews/enews_0505/enews_0505_Cellulosic_Ethanol.htm

Purdue University - West Lafayette, Indiana,U.S.
http://www.ces.purdue.edu/extmedia/ID/ID-339.pdf