Energy

Woodstock revisited

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Could new techniques for producing ethanol make old-fashioned trees the biofuel of the future?

MANKIND has used trees as a source of fuel for thousands of years. But now the notion of exploiting trees for fuel is being updated with a high-tech twist. The idea is to make ethanol, a biofuel that usually comes from maize (corn) or sugar cane, from trees instead. Politicians and environmentalists are embracing ethanol for a number of reasons. Unlike oil, ethanol is renewable: to make more of it, you grow more crops. And blending ethanol into ordinary petrol, or burning it directly in special “flex-fuel” engines, reduces greenhouse-gas emissions.

Why use trees, rather than maize or sugar cane, as a feedstock for ethanol? Because “treethanol” has the potential to be much more energy efficient. The ratio of the energy yielded by a given amount of ethanol to the energy needed to produce it is called the “energy balance”. The energy balance for ethanol made from maize is the subject of much controversy, but America's energy department puts it at 1.3; in other words, the ethanol yields 30% more energy than was needed to produce it. For ethanol made from sugar cane in Brazil, the energy balance is 8.3, according to the International Energy Agency.

But for ethanol made from trees, grasses and other types of biomass which contain a lot of cellulose, the energy balance can be as high as 16, at least in theory. In practice the problem is that producing such “cellulosic” ethanol is much more difficult and expensive than producing it from other crops. But the science, technology and economics of treethanol are changing fast. Researchers are racing to develop ways to chip, ferment, distil and refine wood quickly and cheaply.

Interest in cellulosic ethanol is growing as the drawbacks of making ethanol from maize and sugar become apparent. Both are important food crops, and as ethanol production is stepped up around the world, greater demand is driving up the prices of everything from animal feed to cola and biscuits. The price of a bushel of corn rose by 70% between September 2006 and January 2007 to reach its highest level in a decade. Mexico's president, Felipe Calderón, even capped the price of corn tortillas in January as America's fast-growing ethanol industry caused prices to rocket. There are clear signs of a backlash against ethanol made from food crops. Supply is struggling to keep up, and as more governments introduce schemes to promote biofuels and cut greenhouse-gas emissions, the tension between food and fuel will only intensify.

Growing maize requires a lot of land, water and agrichemicals, so environmental groups such as America's Natural Resources Defence Council argue that it is merely a short-term, first-generation approach to making ethanol. Most energy experts reckon that using maize-based ethanol as a substitute for petrol can reduce America's demand for petrol by 10-15% at best. As for sugar, its growing value as a biofuel feedstock means that in Brazil, which is now one of the world's largest producers and exporters of ethanol, there is pressure to flatten rainforests to make more room for sugar production. One green objective (reducing dependency on fossil fuels) thus conflicts with another (preserving the environment).

Trees to the rescue

Cellulosic ethanol would address many of these problems. Writing in the *Wall Street Journal* recently, Vinod Khosla—a Silicon Valley venture capitalist who has made a fortune by spotting opportunities in fields from biotechnology to software—argued that America needs "cellulosic biofuels to win the war on oil...we must encourage research on biomass feedstocks, tomorrow's energy crops."

Trees are a particularly promising feedstock because they grow all year round, require vastly less fertiliser and water and contain far more carbohydrates (the chemical precursors of ethanol) than food crops do. Ethanol is the result of the fermentation of sugars, which is why it can be so simply and efficiently made from sugar cane. Making ethanol from maize is a bit more complicated: the kernels are ground into flour and mixed with water, and enzymes are added to break the carbohydrates from the maize down into sugars, which can then be fermented into ethanol. Making ethanol from cellulosic feedstocks is harder still, however, since it involves breaking down the tough, winding chains of cellulose and hemicellulose from the walls of plant cells to liberate the sugars. This can be done using a cocktail of five or six enzymes, says Edward Shonsey, the boss of Diversa, a biotech firm based in San Diego. The problem is that although such enzymes exist, they are expensive. It is no use being able to produce ethanol from trees if it costs $5 a gallon.

The lure of bioprospecting

So if cellulosic ethanol is to live up to its promise, researchers will have to find cheaper and more efficient enzymes. Grass, trees and other biomass feedstocks consist of a mixture of cellulose, hemicellulose and lignin, a tough material that helps plants keep their shape. Two large producers of industrial enzymes—Genencor, an American firm, and Novozymes, from Denmark—are working to reduce the cost of cellulase enzymes, which can break down cellulose, to below $0.10 per gallon of ethanol. For its part, Diversa is developing enzymes capable of breaking down hemicellulose. One approach, says Mr Shonsey, is to tweak the structure of existing enzymes to try to make them work better. Another approach is "bio-prospecting"—looking for natural enzymes in unusual places, such as in the stomachs of wood-eating termites.

Treethanol has particular appeal in countries that have a lot of trees and import a lot of fossil fuel. Top of the list is New Zealand: in 2005 the country exported lumber worth NZ$411m ($290m) and imported fossil fuel costing NZ$4.5 billion. In January two of New Zealand's Crown Research Institutes, Scion and AgResearch, announced a research partnership with Diversa. The aim is to investigate the feasibility of producing enough ethanol from trees to fuel all the vehicles on New Zealand's roads without fossil-fuel imports—in other words, to make the country self-sufficient in energy.

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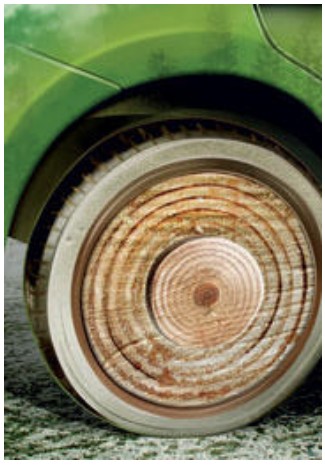

BioJoule, a start-up based in Auckland, New Zealand, is planning to build a pilot plant to produce ethanol from a type of willow. The idea, says James Watson, BioJoule's co-founder, is that farmers would grow coppiced willow trees which could be processed into wood chips and then transported to a conversion plant to be turned into ethanol. The process would produce two useful by-products: unsulphonated lignin, a commercially valuable polymer, and xylose, a type of wood sugar used in dyeing and in foods for diabetics. Selling these by-products, Mr Watson calculates, means his plant should be able to produce ethanol for a direct cost of $1.13 per gallon, which compares favourably with ethanol from American maize ($1.44) and is not much more than Brazilian sugar-cane ($0.95).

Because willows are fast-growing and can thrive even on nutrient-poor soils, BioJoule's technology could also be used in other parts of the world where there is strong demand for energy, but the soil is not suitable for food crops. Mr Watson thinks China and India look promising.

Another country keen on cellulosic ethanol is Sweden, which is relying heavily upon wood-based solid and liquid biofuels as part of its plan to wean itself off oil by 2020. But where New Zealanders favour willows, the Swedes prefer poplars, since they are abundant and their biology is well understood, says Mats Johnson of SweTree

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Technologies, based in Umea in northern Sweden.

New Zealand and Sweden.”

Even if the right cocktails of enzymes can be found, sceptics say treethanol will still have several problems to overcome. In particular, trees take much longer to grow than grass or food crops—so it might make more sense to make cellulosic ethanol from fast-growing grasses, or the leftover biomass from food crops. Some environmentalists worry that having struggled for years to protect forests from overexploitation, demand for biofuels could undermine their efforts.

And now for Frankentreethanol

One idea is to create new, fast-growing trees to address this problem, either through careful breeding or genetic modification. A team led by Vincent Chiang, a biologist at North Carolina State University, is investigating the production of ethanol from genetically modified trees, with funding from America's Department of Agriculture. “Our preliminary results clearly point out that transgenic wood can drastically improve ethanol-production economics,” says Dr Chiang.

A tree's rate of growth is limited by its lignin structure, which is what determines the tree's strength and form. Trees containing less lignin and more cellulose would both grow faster and also produce more ethanol. Some transgenic trees of this kind are being tested in America. Dr Chiang and his colleagues are also looking at ways to modulate the genes that determine the structure of a tree's sugar-containing hemicelluloses in order to make the breakdown and fermentation processes more efficient.

But Steven Strauss, a forest biologist at Oregon State University, says that because of the great genetic variation in willows and poplars, genetic modification may not be necessary. By screening existing varieties it ought to be possible to identify those well suited to ethanol production. Conventional breeding and cloning are very efficient when there is such a variety of species and hybrids to choose from, he says, and the tight regulation of genetically modified organisms makes using the technology expensive and time consuming.

Hundreds of thousands of years ago, when man first gained mastery over fire, wood was his primary fuel. In the past few centuries fossil fuels have risen to prominence, with calamitous consequences for the world's climate. A diversity of new fuels and energy sources seems the most likely future. It would be fitting if humanity's portfolio of new energy technologies had a place for wood, the oldest of them all.